## Chapter 24
MOBILITY MEASURES

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24.1 INTRODUCTION

The purpose of this chapter is to provide design guidelines for improved Transportation Systems Management through the use of high-occupancy vehicle (HOV) facilities, including HOV lanes on freeways and arterials, commuter transfer facilities, and other mobility measures. These measures focus on moving people and goods efficiently, not just vehicles. Further information on planning, design and operation of these facilities may be found in the publications listed in Section 24.7 References and Section 24.8 Other Sources at the end of the chapter. Guidance on temporary mobility measures during construction is being developed for release at a later date, either as a chapter in this Manual, or as a separate manual.

24.1.1 Background

New Yorkers pay a high price for congestion as a result of traffic tie-ups which reduce economic efficiency, increase the cost of products, exacerbate health risks from increased vehicle emissions and added mental and emotional stress, and expose travelers to greater accident risk.

Strategies to reduce predicted levels of congestion and vehicular pollutants at a reasonable cost have been identified in the Scoping Procedure Manual as:

1. Reduce the proportion of single occupant vehicles in urbanized areas (with a population) of over 200,000 during the peak travel periods,
2. Increase ridership on traditional transit (line haul fixed route) and non-traditional transit (demand responsive and paratransit),
3. Incorporate Transportation Systems Management (TSM) and Intelligent Transportation System (ITS) strategies to improve the operational efficiency of the existing transportation network with special emphasis on moving people and goods, and
4. Incorporate Travel Demand Management (TDM) strategies in the design of all new and expanded arterials.

These strategies are described in detail in Mobility in New York State, Issues and Opportunities, which outlines a strategy for combating congestion in New York's most populated areas.

The Regional Planning and Program Management Group, along with other functional units in the Region, should work through the development of the project to assure, among other things, that it is in conformance with applicable policies, procedures and guidelines, that it meets the project objectives, and that it is a socially, economically and environmentally compatible solution. A genuine consensus should be established among the Region's functional units about the nature of the proposed project and what it is supposed to accomplish and include before it is turned over to the designer. For a detailed description of the project scoping process, refer to the NYSDOT Scoping Procedure Manual.
24.1.2 HOV Lanes

The HOV lane concept is applicable only to corridors that serve urban and dense suburban areas, and that are, or forecast to be, subject to traffic congestion. There should generally be a high level of HOV use, transit use and ridesharing. The effectiveness of HOV facilities is enhanced when combined with a number of other TDM measures to encourage use, such as rideshare matching services, employer incentives, supporting facilities that help to collect and distribute passengers, and public information and education programs. Section 24.2 describes different physical and operational aspects of HOV facilities on freeways, and presents design criteria, cross sections, examples of access treatments, enforcement considerations, and signing and pavement markings for HOV lanes on freeways.

Most HOV lanes on arterials are bus-only lanes in downtown areas. The increasing congestion in urban areas makes it clear that arterial HOV lanes should continue to be actively considered. Section 24.4 presents guidelines for high-occupancy vehicle lanes on arterials, including passenger loading and unloading areas, signing and pavement markings, enforcement, access to abutting properties and provisions for bicycles.

24.1.3 Commuter Transfer Facilities

Commuter transfer facilities, including park-and-ride and park-and-pool lots, and transfer stations located on or near HOV lanes, permit commuters to transfer from single-occupant to high-occupancy vehicles to take advantage of HOV facilities. Access to transfer facilities can be made available for all travel modes. By using transfer facilities, commuters maximize the efficiency of the local transportation system. Section 24.3 presents guidelines for commuter transfer facilities.

24.1.4 Additional Treatments

Ramp metering is a common method of dealing with freeway congestion and improving merging operation safety at entrance ramps. Section 24.5.1 discusses the various types of ramp metering in use on freeway systems.

Metering of freeway-to-freeway connectors is a technique that has proven to be a successful and useful complement to ramp metering when high volume connectors are significant contributors to operational bottlenecks. Section 24.5.2 discusses freeway-to-freeway connectors.

Queue bypasses can be used at entrance ramps on freeway facilities with HOV lanes, or at bottlenecks created by lane reductions, freeway convergences, or toll plazas. Refer to Section 24.5.3 for further discussion.

The use of freeway shoulders as peak hour travel lanes and guidelines for their use are presented in Section 24.5.4.

Access management is applicable to all roadway types and is of particular importance along uncontrolled access facilities. The Department's driveway policy is found in the Policy and
Standards for Entrances to State Highways and a variety of access management treatments are covered in the Department's Best Practices in Arterial Management. Section 24.5.5 provides more detail.

Incident management is applicable to general-use freeway and HOV freeway lanes, and is discussed in Section 24.5.6.

Traffic calming, initially developed to mitigate the impact of traffic in residential areas and around schools, may now have limited application in certain situations, in urban areas. The Department is developing interim policy and guidelines for the use of traffic calming on State highways. It will be released as guidance separate from this Manual.
24.2 HIGH-OCCUPANCY VEHICLE LANES ON FREEWAYS

High-Occupancy Vehicle Facilities: A Planning, Design, and Operation Manual contains a list of the objectives of HOV priority treatments.

- Induce mode shift,
- Increase person-carrying capacity of highway corridors,
- Reduce travel time,
- Reduce or defer the need to increase highway vehicle-carrying capacity,
- Improve the efficiency and economy of public transit operations, and
- Reduce fuel consumption.

AASHTO's Guide for the Design of High-Occupancy Vehicle Facilities contains a list of general conditions which should, or be projected to, exist before serious consideration is given to an HOV alternative.

- There should be compatibility with other activities and plans.
- The HOV facility should be a part of an overall transportation plan.
- Support should be obtained from the community and various local agencies for developing HOV facilities.
- Intense, recurring congestion must exist on the freeway general-use lanes.
- Peak period traffic per lane on the freeway should be approaching capacity (1700 to 2000 vehicles per hour [vph]).
- During the peak hour, average speeds on the freeway mainlanes during non-incident conditions should be less than 50 km/h over a distance of 8 km or more.
- Relative to using the freeway general purpose lanes, the HOV facility should offer a travel time savings during the peak hour of approximately 1 minute per 1.6 km of facility length. An overall time savings of 8 minutes is desirable, and 5 minutes is minimum.

- The travel patterns on the freeway should be conducive to being served by rideshare - either bus or carpool.
- Desirably, a significant volume of peak-period trips (perhaps more than 6000 home-based work trips during the peak hour) on the freeway should be destined to major activity centers or employment areas in or along the corridor.
- Of the peak-period trips on the freeway destined to major activity centers, at least 65 percent to 75 percent should be longer than 8 km in length.
- The resulting rideshare demand should be sufficient to generate HOV volumes that are high enough to make the facility appear to be adequately utilized. The specific volume needed may vary by type of facility and location.

- The HOV facility design that can be provided should allow for safe, efficient, and enforceable operation.
Alternatives for freeway facilities in need of capacity improvements, especially those with six or more lanes, should include an HOV alternative, along with conventional alternatives.

The AASHTO Guide for the Design of High-Occupancy Vehicle Facilities also points out that the travel time savings must be maintained for the facility to remain viable. When a congested area is bypassed by a new HOV lane, speeds on the partially vacated general-use lanes will increase, reducing the HOV travel time savings. For the HOV lane to have an effective future, upstream traffic constraints must be such as to cause the general-use lanes to become congested again. This is important to induce drivers of single-occupant vehicles to switch to HOV travel. An operational analysis is necessary to verify that this condition will occur for the location under consideration.

Another element, just as important as the technical issues, is the need for acceptance and support of HOV facility implementation by the local, regional and state agencies involved, and the local, county, and state politicians and their constituents who live and work in the area and travel the corridor. Every effort should be made to solicit their involvement, input, and support through public awareness programs, advertising, public meetings, and focus groups.

A more comprehensive list of guidelines, provided in High Occupancy Vehicle Facilities: Current Planning, Operation, and Design Practices, Nomograph 5, is too extensive to be included here. The guidelines are divided into primary and secondary. Primary guidelines are described as those that should be met before a candidate freeway or region is considered valid for HOV priority treatment. Secondary guidelines are described as desirable criteria that are generally more qualitative in nature, and provide some assurance of the relative success that an HOV project can provide.

The length of prospective HOV lanes can be determined by estimating the extent of freeway speeds below 50 km/h during the peak period. The length should be extended sufficiently beyond the estimated limits to provide for future expanded congestion patterns.

The design guidelines contained in this section are for HOV lanes on freeways. They may be applied to projects that involve construction or reconstruction of HOV lanes on new alignment or adjacent to existing general-use lanes. They may also be applied to projects in which the HOV cross section is "retrofitted" into existing freeway cross sections by resurfacing, restriping, narrowing of lanes, and additional signing.
24.2.1 **HOV Types**

HOV lanes on freeways may be a single lane or multiple lanes separated from the general-use lanes by barriers, a buffer area, or a single stripe. They may operate as 1) reversible, 2) two-way flow (HOVs travel adjacent to and in the same direction as the general-use traffic), or 3) contraflow (HOVs travel adjacent to and in the opposite direction as the general-use traffic) lanes. They may be restricted to use by buses only or they may be available to all HOVs. HOV lanes may be constructed in separate rights of way, but they are usually incorporated into existing highway rights of way where width and lateral clearances may be limited. The following subsections cover the physical types of HOV lanes and what operational alternatives and methods of access are available.

### 24.2.1.1 Physical Types

HOV line-haul (that portion of a trip that is express [nonstop] between two points) treatments in freeway corridors are categorized in *High-Occupancy Vehicle Facilities: A Planning, Design, and Operation Manual* into the following physical types. Barrier-separated, buffer-separated, and nonseparated refer to the type of separation between the HOV lane and the adjacent general-use lane.

1. **Barrier-separated HOV lanes, freeway right of way**: A roadway or lane(s) built within the freeway right of way (commonly within the median) that is physically separated by barriers from adjacent general-use lanes and is designated for the exclusive use of high-occupancy vehicles during at least portions of the day. Opposing directions within a barrier-separated facility are separated by either a barrier or buffer.

2. a. **Busway HOV lanes, separate right of way**: A preferential roadway or lane(s) developed in a separate right of way and designated for the exclusive use of buses only. Barrier separation is not generally needed for busways in separate rights-of-way. High-speed bus lanes should be separated from each other by barrier. Bus lanes without separation may be considered for low-speed operation.

   b. **Busway HOV lanes, freeway right of way**: A preferential roadway or lane(s) developed in a freeway right of way and designated for the exclusive use of buses only. Barrier separation between HOV and general-use lanes is generally needed for busways in freeway rights-of-way. High-speed bus lanes should be separated from each other by barrier. Bus lanes without separation may be considered for low-speed operation.

3. **Buffer-separated HOV lanes, freeway right of way**: A roadway or lane built within the freeway right of way (commonly the median) that is separated from adjacent general-use lanes with a designated buffer width of 0.3 m or more. The lanes are commonly the inside lane(s) of the freeway cross section, adjacent to the median barrier, and are designated for the exclusive use of high-occupancy vehicles during at least portions of the day.
4. Nonseparated HOV lanes, freeway right of way: A designated lane containing no buffer separation with adjacent freeway lanes. The lanes are normally located adjacent to the median barrier as an inside lane, or may be an outside lane (either adjacent to or on the outside shoulder).

5. Contraflow HOV lanes, freeway right of way: A designated freeway lane or lanes, commonly the inside lane of a minimum 6-lane freeway, in the off-peak direction of general-use travel. Low-speed contraflow lanes are usually separated from the off-peak direction general-use lanes by insertable tubular markers. Movable concrete barriers should be used for high-speed contraflow lanes. The low-speed lane should be designated for exclusive use by occupancy vehicles (usually buses only). Carpools and vanpools may be included on barrier-separated lanes.

6. HOV queue bypass facility: A short, often nonseparated lane, designed to operate in the same direction as the adjacent general-use traffic lanes through an isolated traffic bottleneck, a toll plaza, or a metered location. The lane is designated for the exclusive use of high-occupancy vehicles and provides a "head of the line" advantage in bypassing queued traffic.

Typical cross section elements of the barrier-separated, the buffer-separated, and the contraflow lanes are shown in Figure 24-1. Detailed cross sections for each type of HOV facility are provided in Sections 24.2.4 through 24.2.9.

There should be adequate space for traffic moving at the posted speed to pass a disabled vehicle (e.g., a bus unloading passengers), on both the HOV lanes and the general-use lanes. Consequently, more width is required to provide the space on both sides of barrier-separated lanes than for the other types.

When right of way constraints allow only a narrow buffer (see Section 24.2.3.4 B), the breakdown shoulder (adjacent to the median) of a buffer-separated HOV lane may be for common use by both the HOV traffic and the general-use traffic. Advantages of a common breakdown shoulder are that it requires less right of way and provides more time and space for an HOV to take evasive action should it be necessary. Disadvantages are that disabled vehicles in the left general-use lane must cross the HOV lane to get to the shoulder, and it is difficult to enforce against drivers who violate the buffer to enter the HOV lane. In any case, this is an operational feature that should be negotiated with local enforcement agencies responsible for the facility. For example, on the Long Island Expressway, all general-use vehicles must use the right shoulder for breakdowns.
24.2.1.2 Operational Types

Three basic types of HOV operation are described in *High-Occupancy Vehicle Facilities: A Planning, Design and Operation Manual*, and are adapted for use in this chapter as follows:

**Reversible-flow:** One or more barrier-separated lanes usually operating in one direction in the morning and the opposite direction in the evening. Reversible-flow operation must be barrier-separated from general-use lanes to avoid confusion and to operate safely. In many areas, morning rush hour traffic is typified by a heavy flow in-bound and low flow out-bound at the same time, followed by a reversal of flows in the evening rush hour. Freeways which operate under these conditions are candidates for reversible-flow HOV lanes. This usually occurs on freeways which
serve as the major carrier of traffic between suburban residential areas and the central business district in large urban areas. The AASHTO Guide for the Design of High Occupancy Vehicle Facilities advises that a traffic demand split of 60% peak to 40% off-peak or higher should be forecast for the design year, and an absence of anticipated severe freeway congestion in the off-peak travel direction, will usually justify consideration of reversible lanes. The generally recognized range is 400 - 800 vph per reversible-flow HOV lane. Care should be taken in estimating the design year traffic to assure that the off-peak flows will not exceed the available capacity.

**Two-way flow:** Two or more lanes operating in opposite directions of travel during at least portions of the day. Two-way operation can be used with four physical types of HOV lane -- barrier-separated, busway, buffer-separated, or nonseparated lanes. Two-way buffer-separated lanes are also known as concurrent lanes. Two-way nonseparated lanes are also known as contiguous lanes. Congested corridors in which the design year demand is relatively even, generally less than 60% peak demand to 40% off-peak demand, may be candidates for two-way operation. That level of demand is typical of most suburban areas. The initial year of operation should be forecast to have a minimum HOV demand in the range of 400 - 800 vph per direction for the lanes to appear effective. The minimum design year one-way peak hour demand for busways should be 40 - 60 buses. As a type of two-way operation, contiguous flow HOV lanes may be appropriate when HOV operation is needed only during peak periods. During off-peak periods the HOV lane can be used as a general-use lane.

**Contraflow:** Usually one lane that is borrowed from the off-peak direction general-use lanes and modified to serve buses and possibly other select HOVs (e.g., vanpools) in the peak direction during at least portions of the day. Successful contraflow operation depends on a demand that exceeds capacity in one direction while the demand in the opposite direction is so low as to permit the borrowing of a lane from the off-peak direction to satisfy the peak period demand. The demand should be at least 60% peak to 40% off-peak and there should be a minimum of approximately 200 vph forecast to use the contraflow lane the first year. Further, it should only be used if it does not adversely affect the general-use traffic speeds and level of service.

Not all types of HOV operations are useable with all the physical types of HOV lanes. The references in Table 24-1 show which operational types can be used with which physical types of freeway HOV lanes. The numbers indicate the sections in which they are described.
### Table 24-1 Typical Freeway HOV Lane Alternatives

<table>
<thead>
<tr>
<th>Physical Type of HOV Lane</th>
<th>Operational Concept</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Reversible-Flow</td>
</tr>
<tr>
<td>Barrier-Separated, Freeway R.O.W.</td>
<td>Refer to 24.2.4</td>
</tr>
<tr>
<td>Busway, Separate or Freeway R.O.W.</td>
<td>Refer to 24.2.4</td>
</tr>
<tr>
<td>Buffer-Separated, Freeway R.O.W.</td>
<td>NA</td>
</tr>
<tr>
<td>Nonseparated, Freeway R.O.W.</td>
<td>NA</td>
</tr>
<tr>
<td>Contraflow, Freeway R.O.W.</td>
<td>NA</td>
</tr>
<tr>
<td>Queue Bypass, Freeway R.O.W.</td>
<td>Refer to 24.5.3</td>
</tr>
</tbody>
</table>

NA = Not Applicable

Source: Adapted from PBOD Manual

#### 24.2.1.3 HOV Facility Cross Section

The total cross section width of HOV facilities includes all elements between outside barriers, including buffers and median barriers, as illustrated in Figure 24-1. The dimensions shown in Table 24-2 are presented in the cross sections in Sections 24.4 through 24.9. The widths in the table compare favorably to those for HOV lanes in operation throughout the country and are consistent with AASHTO guidelines.

The standard widths are adequate for passing a disabled vehicle at speeds near the design speed of the facility. Special needs, such as enforcement or snow removal may also be accommodated with the wider dimensions. The acceptable cross section dimensions are not standard (i.e., they are nonstandard; refer to Section 24.2.3). They provide enough space to permit passing a disabled vehicle, and afford minimum separation from the median barrier and the adjacent general-use lane. The low-speed contraflow cross section width is adequate for the use of insertable tubular markers between the contraflow lane and the general-use lane. It is not wide enough for movable barrier.

The cross section widths shown in Table 24-2 may not provide sufficient horizontal SSD in all cases. HOV lanes to be constructed within the medians of existing freeways and separated by median barriers, should be examined to ensure that the minimum horizontal SSD is provided. This is especially true on curves to the left from the lane closest to the median barrier, and may also apply to curves to the right.
Table 24-2 Summary of Freeway HOV Facility Cross Section Widths

<table>
<thead>
<tr>
<th>HOV Facility Type</th>
<th>Cross Section Width</th>
<th>Standard</th>
<th>Acceptable¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barrier-Separated, One-Lane Reversible</td>
<td></td>
<td>7.8 m to 8.4 m</td>
<td>6.3 m</td>
</tr>
<tr>
<td>Barrier-Separated, Two-Way</td>
<td></td>
<td>16.2 m to 18.6 m</td>
<td>13.2 m</td>
</tr>
<tr>
<td>Two-Way Busway</td>
<td></td>
<td>13.2 m to 18.8 m</td>
<td>9.6 m</td>
</tr>
<tr>
<td>Buffer-Separated, Concurrent, Two-Way</td>
<td></td>
<td>16.2 m to 18.6 m</td>
<td>9.6 m</td>
</tr>
<tr>
<td>Nonseparated, Contiguous, Two-Way</td>
<td></td>
<td>13.8 m</td>
<td>8.4 m</td>
</tr>
<tr>
<td>Contraflow, One Lane</td>
<td></td>
<td>6.6 m to 8.4 m</td>
<td>6.6 m</td>
</tr>
</tbody>
</table>

Refer to Section 24.2.3

24.2.1.4 Access Treatments

Access to and from HOV lanes is gained through origin, termination and intermediate access treatments.

Origins and terminations should be designed similar to standard freeway entrance and exit ramps, with provision for merging if demand volumes warrant and with special consideration for the type of HOV operational concept to be used. Acceleration and deceleration lanes should be provided in accordance with Chapter X of AASHTO's *A Policy on Geometric Design of Highways and Streets*, 1994.

In certain situations, HOVs must enter general-use lanes from the left. If capacity is exceeded, traffic friction will result in less travel time savings for HOVs. Remedies might include replacing at-grade access with dedicated ramps, or providing a parallel weaving lane at at-grade ramps for acceleration and deceleration movements, as was done on the Long Island Expressway.

The designer should carefully evaluate the impacts of the volume of HOVs entering the adjacent general-use freeway and where impacts are forecast to cause serious disruption to the operation of the general-use lanes, the HOV volumes should be distributed to maintain a balanced level of service. This may be done by locating access points upstream of bottleneck locations, where possible, or by extending the ingress or egress zone over a longer distance so the weaving movements are smoother and the HOVs are allowed to enter or leave the freeway downstream or upstream of the potential disruption.

When an HOV facility is retrofitted into an existing freeway, generally it will not be necessary to provide ingress/egress connections at all freeway interchanges. Access connections for all HOV facilities should be located in accordance with the results of a traffic demand analysis, conducted during project scoping. Locations for ingress and egress are determined by modeling the traffic based on trip origins and destinations. Locations that provide easy access by HOVs to and from park-and-ride lots, transit transfer centers, large multiple activity centers, major freeways and arterials, and the central business district street system should be included.
MOBILITY MEASURES

Although there are several procedures available, procedures for estimating demand and modeling traffic have not been standardized. However, research continues in those areas to improve the capabilities for planning ingress/egress locations. AASHTO's *A Policy on Geometric Design of Highways and Streets*, 1994 contains warrants for interchanges and grade separations, which should be considered when planning and designing ingress/egress connections.

Ramps should be designed in accordance with Chapter 2 of this Manual, the New York State *Manual of Uniform Traffic Control Devices* (NYSMUTCD), and AASHTO's *A Policy on Geometric Design of Highways and Streets*, 1994. HOV mainline facilities should be considered controlled access facilities and ramps should be designed in accordance with appropriate geometric criteria for entrance and exit ramps. The desirable cross section for ramps should equal the cross section for the respective mainline HOV treatment. A fixed median barrier or wide buffer area and a separate breakdown shoulder for each direction of traffic being served, should be provided on ramps that serve two-way traffic. The guidelines below are adapted from guidelines and considerations in *High-Occupancy Vehicle Facilities: A Planning, Design, and Operation Manual* and NCHRP Synthesis 185, *Preferential Lane Treatments for High-Occupancy Vehicles*.

1. HOV ramps usually carry lower volumes which may allow prudent consideration of reduced ramp geometrics, if necessitated by physical constraints, and if it can be done without compromising safety.
2. Horizontal SSD on ramps for barrier-separated lanes may be obstructed if the barriers are located too close to the lane, or if glare screens are mounted on the barriers.
3. HOV ramps are generally amenable to, and should be considered for enforcement provisions, where possible.
4. Direct access ramps to and from HOV lanes should not be located on the same streets as the ramps to and from freeway lanes, to allow better distribution of traffic and prevent congestion at intersections.
5. Freeway ramps for general-use traffic may be metered. HOV ramps are normally bypasses at, or adjacent to, general-use ramps, and are generally not metered. For additional discussion of metering of HOVs, refer to AASHTO's *Guidelines for the Design of High-Occupancy Vehicle Facilities*.
6. Left- or right-hand exits from a one-lane HOV facility are equally valid and equally safe.

There are three basic types of access that may be applied to HOV lanes. They are at-grade slip ramps, flyover ramps and drop ramps.

A. At-Grade Slip Ramps

At-grade slip ramps are at-grade connections between HOV lanes and general-use lanes on adjacent freeways. Refer to Figures 24-4, 24-8, and 24-14. They are the most frequently used form of access to and from HOV lanes and the most economical and easiest to implement within the existing cross section of almost any type of facility. Other advantages are that pavement markings and signing are easily modified, and adjustments in barrier alignment and
location are the only modifications needed for barrier-separated lanes. Access location adjustments are also easily accommodated. At-grade slip ramps are best suited to lower HOV volumes that will not disrupt the operation of the general-use lanes and the freeway entrance and exit ramps. Weave lanes (Figure 24-8) should be provided between the general-use lanes and the HOV lane to allow for safe transition of HOV traffic. Some facilities have no designated access points, allowing HOVs continuous ingress and egress.

Among the disadvantages of at-grade slip ramps are that they depend on the existing freeway ramps to complete the need for local access, and the freeway operator lacks the ability to regulate HOV demand, compromising person-moving capacity should the facility's design capacity be exceeded. The HOV's dependence on the freeway ramps to access the local street system requires weave movements that result in reduced time savings compared to exclusive dedicated HOV ramps (flyover ramps or drop ramps). Enforcement of HOV regulations is also much more difficult.

HOVs leaving the HOV lane to exit to the local streets must exit by crossing the general-use lanes far enough in advance to reach the ramp safely and without disruption to the freeway traffic. The distance from the start of the weave move to the point where the exit ramp leaves the mainline may vary from location to location, depending on the demand volumes and freeway capacity, and should be designed on the basis of a weave analysis in accordance with TRB Special Report 209, *Highway Capacity Manual*.

When terminating HOV lane operation, that lane should be continued as a general-use lane to enable HOV traffic to continue without a merge, and to allow general-use traffic to merge into that lane. If traffic volumes decrease beyond the termination of HOV lane operation, requiring fewer lanes, it is preferable to drop the outside general-use lane a distance of no less than 1 km beyond the end of the HOV lane, as illustrated in Figure 24-2a.

If the HOV lane must be merged into the freeway traffic, a minimum 1 km of dashed white line should be provided beyond the termination of HOV lane operation before the HOV lane taper begins, as shown in Figure 24-2b. The HOV lane merge may result in a bottleneck condition at the merge and should be carefully analyzed.

Dropping an outside general-use lane as a mandatory exit to a ramp may be possible. A careful analysis must be made to ensure that a bottleneck condition does not occur, or that multiple weave areas are not created between the end of the HOV lane and the lane drop.
Figure 24-2 Terminating HOV Lane Operation at At-Grade Slip Ramps

a. Terminate Into Continuing Lane

b. Merge Into General-Use Lane
B. Flyover Ramps

Flyover ramps are high-speed, high-volume, grade-separated connections between HOV lanes and local streets, freeways, or other HOV lanes via elevated structures. Refer to Figures 24-5 and 24-9. The minimum threshold volume of HOVs needed to justify a flyover ramp is 400 vehicles or 1000 persons per hour. The width of the ramp cross section should match the width of the HOV mainline cross sections.

Flyover ramps can be used for terminal connections and intermediate connections as well. By connecting directly to local streets and, in the case of line-haul transit, to on-line or off-line transit transfer stations, savings in travel time can result. However, flyover ramps usually require additional right of way and extensive use of structures and retaining walls, making them very expensive and difficult to retrofit into an existing facility, which tends to limit their use to high-capacity locations.

C. Local Access Drop Ramps

Drop ramps are grade-separated connections of HOV lanes to local streets. Refer to Figures 24-6 and 24-10. The local street can be above or below the HOV lanes, and can serve either the termini or intermediate connections. Drop ramps are normally low-speed (60 km/h or less) ramps designed for low peak hourly volumes of less than 400 vph. Drop ramp structures should be wide enough for both entering and exiting traffic, to minimize costs.

Drop ramps can be designed for either left- or right-hand merge and diverge movements. Left-hand maneuvers are opposite to normal driver expectations when used on HOV lanes that have right-hand entrances and exits. These conditions should be made known to drivers, with appropriate use of signs and by providing adequate decision sight distance.

The specific roles for each type of ingress/egress treatment are listed in Table 24-3.
### Table 24-3 Roles for Various Ingress/Egress Concepts

<table>
<thead>
<tr>
<th><strong>At-Grade Slip Ramp at Project Termination</strong></th>
<th><strong>At-Grade Slip Ramp as an Intermediate Access</strong></th>
<th><strong>Drop Ramp with a Street</strong></th>
<th><strong>Drop Ramp with a Park-and-Ride Lot or Off-Line Bus Transit Station</strong></th>
<th><strong>Flyover Ramp</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>! An effective way of feeding and distributing high lane volumes with the adjacent freeway.</td>
<td>! Lowest-cost intermediate access approach; can be easily modified (relocated or removed).</td>
<td>! Effective way of collecting and distributing all mixes of HOVs, as well as serving off-line support facilities.</td>
<td>! Very effective way of extending preferential treatment into an off-line support facility, thereby increasing travel time savings.</td>
<td>! Highest-speed design intended for high interfacing volumes; most closely approximates any other freeway ramp in design speed.</td>
</tr>
<tr>
<td>! Requires left-hand entry/exit with the freeway.</td>
<td>! Most compatible with restricted envelopes, requires little widening.</td>
<td>! Provides opportunities to control or enforce entering volumes.</td>
<td>! Not recommended for serving other HOV users that have no need for the support facility; poses circulation conflicts within the support facility.</td>
<td>! Serves all HOVs well.</td>
</tr>
<tr>
<td>! Can be designed as a safe and enforceable treatment.</td>
<td>! Not safe for high accessing volumes without inclusion of a parallel weave lane.</td>
<td>! Works for reversible-flow or two-way configurations.</td>
<td>! Generally requires high transit and/or rideshare volumes to be cost effective.</td>
<td>! Can be applicable as an intermediate access or termination treatment.</td>
</tr>
<tr>
<td>! Low cost; easily modified if HOV facility is extended.</td>
<td>! Not the best traffic operation under high-volume conditions; can disrupt the adjacent freeway or HOV level of service.</td>
<td>! Cannot be safely enforced.</td>
<td>! Works best for two-way operations, although can be workable for reversible-flow if ramps are reversed as well.</td>
<td>! Least flexible treatment; sometimes deferred on an interim HOV operation and added later as demand warrants.</td>
</tr>
<tr>
<td>! Used as a &quot;standard&quot; termination treatment on most projects.</td>
<td>! Location is critical; if too close to nearby freeway intersections, weaving problems across the freeway increase.</td>
<td><strong>Source:</strong> PBQD Manual</td>
<td><strong>Source:</strong> PBQD Manual</td>
<td><strong>Source:</strong> PBQD Manual</td>
</tr>
</tbody>
</table>
24.2.1.5 Enforcement Areas

Enforcement of regulations is vital to the proper operation of HOV lanes and to maximize their vehicle carrying capacity. To be sure that the facility will be safe, familiar to, and useable by police officers, they should be involved in the project design early-on in the process.

Enforcement activities on HOV lanes can be greatly influenced by the physical and operational aspects considered in the design. The absence or presence of certain roadway features can adversely affect the enforcement process as well as the safety and operational features of the facility. Physical problems may include lack of safe and easily accessible enforcement areas, absence of vantage points, lack of physical separation, and lack of passing capability for enforcement vehicles.

Operational problems may include the visibility (or lack thereof) of police vehicles used for speed control. Enforcement areas should be located away from curves to reduce the risk of out-of-control vehicles sliding into a parked police vehicle. Speed differentials between the HOV lane and the general-use lanes during apprehension of violators, and difficulty in determining the number of vehicle occupants are other problems to be considered. Refer to the enforcement sections later in this chapter for the geometric and traffic control design considerations for each HOV treatment.
24.2.2 **HOV Operation**

The usual highway project development process involves scoping, design, construction and operation of the roadway. However, experience has proven that when an HOV facility is included as an alternative, operational considerations must be factored in at the scoping phase. This is particularly true when the project is part of an area-wide or system plan. Such HOV operational issues as eligibility criteria, hours of operation, enforcement, and incident management should be considered. The first three are discussed below, while incident management is discussed in Section 24.5.6. When facility operations are not included in the scoping phase, the result may be an HOV facility that is under utilized or congested, is subject to excessive loss of service due to incidents, and is difficult to enforce.

After determining that an HOV alternative is possible, an estimate of HOV demand is made, and the process of assessing operating scenarios and the design treatments needed to satisfy them is carried out. This interaction between HOV facility operations and design requires early involvement by various local agencies to ensure that the facility is designed to meet the particular needs of the corridor and conforms to the policies of the operating and enforcement agencies.

The Federal Highway Administration’s Project #42-10-4172, *Predicting the Demand for High Occupancy Vehicle (HOV) Lanes* reports on the development of a methodology and micro-computer software model for quickly analyzing HOV lane demand and operations. The methodology is designed to be applied by planners and engineers with limited, or no, access to, or experience with regional travel demand modeling. It provides a set of ‘quick response’ procedures for predicting and evaluating the impacts of HOV lanes on person demand, vehicle demand, auto occupancy, congestion, delay, and air quality. The methodology is applicable to corridor, network, and system level HOV demand analysis.

24.2.2.1 Eligibility Criteria

Eligibility criteria provides a flexibility to HOV projects that is not available in normal highway design. It restricts use to certain specified vehicles and to vehicles with a specified minimum occupancy, thereby making it possible to tailor demand to preserve vehicle flow, while providing a perception of adequate use.

It is important that the eligibility criteria be selected so that the resulting demand volume is less than the design capacity of the facility. The relationship between the facility’s demand and capacity will establish the maximum number of HOVs it can handle. That number will usually fall in the range of 1200 vph - 1500 vph for level of service ‘C’.

The eligibility requirement must also provide a public perception of adequate use, without which the project may be short-lived. General guidelines based on limited data, indicate at least 400 vph to 800 vph are needed for an HOV lane to appear to be adequately used. This may present a problem during off-peak periods when demand, both HOV and general-use, is less. Perceived inadequate use may result in public pressure to roll back occupancy restrictions, curtail or shorten the hours of operation, or terminate the project.
A. Vehicle Eligibility

Determination of which vehicles will be allowed to use HOV facilities is based in part on the type of facility. Generally, carpools, vanpools, and buses are eligible for most HOV facilities, except on busways and, in some cases, contraflow lanes, on which use is often restricted to buses only. Other vehicles that may be considered for eligibility are motorcycles, taxis, commercial vehicles, deadheading vehicles, and emergency vehicles.

The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 requires that motorcycles be permitted to travel in the HOV lanes of federally funded HOV projects unless the State certifies that such use will create a safety hazard. *Effect on Congestion and Motorcycle Safety of Allowing Motorcycle Travel on HOV Facilities in Virginia*, a study of motorcycle travel on Interstate highways in northern Virginia and the Hamptons Roads area in 1992-94, found a low level of motorcycle traffic on HOV lanes. It concluded that "...there is no evidence to indicate that allowing motorcycle traffic on HOV lanes has an adverse impact on congestion or motorcycle safety." Prohibition of motorcycles requires approval by the U.S. Secretary of Transportation through the Federal Highway Administration (FHWA).

There are no guidelines that recommend either inclusion or exclusion of commercial vehicles on HOV facilities. A benefit to making them eligible is improved safety on the general-use freeway lanes during peak periods. However, the geometrics that result from retrofitting HOV facilities into an existing freeway corridor may not be suitable for truck movements. Conflicts at ingress and egress areas between autos and trucks moving across the general-use lanes create unsafe conditions. Since commercial vehicles do not contribute toward increasing person movement along a congested corridor, they should generally not be considered eligible to use HOV lanes.

Deadheading vehicles (empty buses or taxis returning to their routes) is another consideration for HOV eligibility. Allowing them to use the facility will improve the transit operation efficiency but may bring complaints from the public. If deadheading vehicles are allowed, care must be taken so the number of vehicles does not cause congestion in the HOV lane.

B. Vehicle Occupancy

The selection of a minimum vehicle occupancy must allow for growth in traffic volumes as the popularity of the HOV facility grows. Vehicle occupancy rates for HOVs are the minimum number of persons that must occupy a vehicle to legally use the HOV lane. The rates are usually described as 2+ (two or more), 3+ (three or more), or 4+ (four or more). To establish vehicle occupancy requirements for an HOV facility, one must first determine the average existing vehicle occupancy rates in the corridor. High existing occupancy rates in excess of 1.4 persons per car indicate an HOV occupancy rate of 3+ or 4+ may be suitable. Lower existing occupancy rates indicate that a 2+ rate is more appropriate. Studies of existing facilities show that on average, those with 2+ requirements actually move approximately 2.5 persons per vehicle.
Setting a 2+ occupancy rate makes it attractive to existing carpoolers and vanpoolers, as well as to potential users by making it easier to form car pools. It also shows a commitment to HOV, and allows for staging an occupancy rate increase, should it become necessary due to future recurring congestion demands. However, increasing the requirement will result in 2+ vehicles returning to the general-use lanes, adversely effecting their operation, and may not be a viable choice. In that situation, it may be necessary to look into TDM techniques to mitigate the increased demand, or other techniques such as restricting 3+ to just the peak hour.

The 3+ occupancy rate will increase the person-moving capacity, and lessen the chance the facility's vehicular capacity will be reached, resulting in a high level of service. However, formation and sustainment of 3+ carpools is more difficult, and may adversely effect the demand, creating a perception of inadequate use. Before setting a 3+ occupancy rate, or increasing from a 2+ rate, it may be necessary to conduct a public education and marketing program to gather public and political support. AASHTO's Guide for the Design of High-Occupancy Vehicle Facilities recommends changing from 2+ to 3+ occupancy when the level of service of the HOV lane is approaching LOS "D" (on a regular basis).

Table 24-4, taken from High-Occupancy Vehicle Facilities: A Planning, Design, and Operation Manual, summarizes the relative advantages and disadvantages of the alternative operation approaches described above.
### Table 24-4 Comparison of User/Eligibility Trade-Offs

<table>
<thead>
<tr>
<th>Primary User Definition¹</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bus Only</td>
<td>Controlled user group that is easily managed</td>
<td>Speeds hard to sustain when volumes are high (greater than 200 vph)</td>
</tr>
<tr>
<td></td>
<td>∘ Maximizes person-moving capacity</td>
<td>Offers no benefits to other HOVs; ignores a potentially large market of users</td>
</tr>
<tr>
<td></td>
<td>∘ Minimizes enforcement needs</td>
<td>Not practical for most corridors</td>
</tr>
<tr>
<td></td>
<td>∘ Works well in slower-speed busway environments on separate R.O.W. where public cannot perceive the facility as underutilized</td>
<td></td>
</tr>
<tr>
<td>Authorized vehicle only (usually buses, taxis, and possibly vanpools)</td>
<td>□ Potential to control use of HOV facilities that are not safe if opened to unfamiliar users (e.g., contraflow)</td>
<td>Increases administrative costs for authorization procedures and training</td>
</tr>
<tr>
<td></td>
<td>∘ More effective regulation of users, allowing for more precise design capacity management</td>
<td>More difficult to communicate definition to the public</td>
</tr>
<tr>
<td></td>
<td>∘ Minimizes enforcement needs</td>
<td>Not consistent with general terminology used throughout the U.S.</td>
</tr>
<tr>
<td></td>
<td>∘ Easier to modify definition without changing signs and rules</td>
<td>Limited experience</td>
</tr>
<tr>
<td>Two or more person (2+) vehicles</td>
<td>□ Most frequently applied definition for opening new projects</td>
<td>Can quickly overwhelm the facility’s design capacity</td>
</tr>
<tr>
<td></td>
<td>∘ Easily understood</td>
<td>Difficult to alter once established (easier to lower than raise requirements)</td>
</tr>
<tr>
<td></td>
<td>∘ Initial use generally meets minimum person throughput requirements</td>
<td>Limits the improvement in person-carrying capacities on most projects to no more than two equivalent general-use lanes</td>
</tr>
<tr>
<td></td>
<td>∘ Most flexible definition to encourage ridesharing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>∘ Most appropriate for corridors with low bus transit affinities</td>
<td></td>
</tr>
<tr>
<td></td>
<td>∘ Suitable for 24-hour operation</td>
<td></td>
</tr>
<tr>
<td>Three or more (3+) vehicles (or 4+)</td>
<td>□ Adequately preserves future person-moving capacity for most projects</td>
<td>Will not sustain an adequate initial perception of use on all projects</td>
</tr>
<tr>
<td></td>
<td>∘ Easily understood</td>
<td>Makes rideshare formation harder to achieve and sustain</td>
</tr>
<tr>
<td></td>
<td>∘ A more suitable long-term definition after an HOV market has been created with lower occupancy rules</td>
<td></td>
</tr>
<tr>
<td></td>
<td>∘ More suitable to peak periods only</td>
<td></td>
</tr>
</tbody>
</table>

¹ Assumes criteria for minimum use are satisfied

Source: PBQD Manual
### Table 24-4 Comparison of User/Eligibility Trade-Offs (continued)

<table>
<thead>
<tr>
<th>Primary User Definition(^1)</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
</table>
| Three or more (3+) during peak periods, two or more (2+) during off-peak periods | ☑ Allows for separate control of peak/off-peak period volumes once peak period exceeds design capacity  
☑ More flexible than strict 2+ or 3+ definitions  
☑ Easier to modify  
☑ Promotes a broader distribution of peak period demand over a longer period  
☑ Can be an intermediate step in gradually increasing overall occupancy requirements from 2+ to 3+ | ☑ Harder to understand  
☑ Harder to enforce, promotes violations in transition periods  
☑ May not be applicable from a corridor or regional perspective (justification for consideration may be a point-specific bottleneck)  
☑ Limited experience |
| HOVs (2+ or 3+) during peak periods, general-use operation during off-peak periods | ☑ Promotes a perception of more effective general-use operation during off-peak periods  
☑ Serves primary periods of HOV demand  
☑ Easy to tailor operation periods to demand  
☑ Enforcement requirements reduced | ☑ Does not promote rideshare benefits when not in effect  
☑ Does not address travel benefits accrued from nonrecurrent congestion outside the peak periods  
☑ Promotes violations during transition periods  
☑ Does not instill a sense of permanence for the HOV concept  
☑ No real level of service advantage to opening HOV facility to mixed flow |
| HOVs (2+ or 3+) during peak periods, breakdown shoulder during off-peak period | ☑ Provides an additional lane when needed | ☑ Can be confusing to commuters and those that stop in the shoulders; not generally recommended by HOV practitioners |

\(^1\) Assumes criteria for minimum use are satisfied  
Source: PBQD Manual
24.2.2.2 Operating Periods

Operating periods for HOV facilities are either during the peak periods only, and possibly for just certain days of the week (e.g., I-495 Long Island Expressway, Nassau and Suffolk Counties), or continuous operation, 24 hr. daily (I-84, Hartford, CT). Peak period operation allows non-HOVs to use the facility during off-peak hours, and can allay potential public criticism for perceived under use of the HOV lane. It can also be used to test the operation before extending the operating hours. Peak period operation can be applied to all HOV facility types including reversible-flow facilities.

Continuous operation is applicable where traffic congestion exceeds, or is forecast to exceed, the peak periods. It protects HOV benefits during non-recurring congestion (congestion resulting from special events, holidays and weekends, freeway incidents, etc.) and is the easiest to sign and enforce. Continuous operation can encourage off-peak ridesharing and can be applied to all types of HOV facilities, except reversible-flow facilities.

24.2.2.3 Enforcement

Enforcement is necessary to the proper operation of an HOV facility. Without it, travel time and reliability benefits cannot be achieved. Early involvement by law enforcement officials is recommended to ensure that the facility will be enforceable. The type of enforcement is contingent upon the type of HOV facility. Dedicated barrier-separated facilities are easily enforced at entrances and exits. Buffer-separated concurrent flow or non-separated contiguous flow facilities require either wide enforcement shoulders or enforcement areas, and provide more opportunities for escape, making them more difficult to enforce.

Design features are also used to assist in achieving compliance by motorists. Dedicated access ramps, signing and pavement markings, lighting, and closed-circuit television cameras all act as deterrents to HOV lane use violations.

Violation rates on HOV facilities are influenced by the level of enforcement and the enforcement strategy used. On-site enforcement by law enforcement officers is a widely used method. With a high level of enforcement, the violation rate can be expected to remain low. However, it can be expensive, so alternative strategies may be necessary. Some states impose a high fine for first time violation and post the information at all entrance ramps. Other locations use the "HERO" program, a self-enforcement program in which motorists are encouraged to report violators to the police.

Public education can also be beneficial to enforcement programs. By presenting the concept of HOV facilities to the prospective users and non-users, the facility operator stands a much better chance of gaining adequate public support and compliance with the facility regulations.

For further discussion of different strategies in HOV enforcement, refer to AASHTO's Guidance for the Design of High-Occupancy Vehicle Facilities, or High-Occupancy Vehicle Facilities: A Planning, Design, and Operation Manual, or NCHRP's Synthesis 185, Preferential Lane Treatments for High-Occupancy Vehicles.
24.2.3 Design Criteria

The design development of HOV lanes closely parallels that of interstates and other freeways. For that reason, the standard values for the 17 critical design elements for interstates and other freeways (refer to Chapter 2, Section 2.7.1 of this Manual), and the recommended values for the controlling design parameters (refer to Chapter 5 of this Manual), should be used for HOV freeway lanes. Those criteria are shown in the cross section figures in Sections 24.2.4 through 24.2.9 as STANDARD.

While it is Department policy to at least meet the standard values when designing projects, there may be some situations where less than standard values are appropriate for a particular situation, and may provide the most cost effective, quality design. Examples of when less than standard values may be appropriate are on retrofit projects, or when constraints are encountered at isolated locations, or as an interim solution for a programmed upgrade. In those cases, only after deliberate consideration of constructibility, maintainability, and most importantly safety issues, should less than standard values be considered. They should be no less than the values shown in the cross section figures as ACCEPTABLE.

When the STANDARD design criteria values for critical design elements will not be met, a formal justification must be prepared in accordance with Department policy for use of the non-standard feature as specified in Chapter 2, Section 2.8 of this Manual. When the recommended values and practices for the controlling design parameters can not be met, the reasons must be explained and documented in the scoping and design approval documents or, when identified after design approval, the documentation must be placed in the project files, in accordance with Chapter 5, Section 5.1 of this Manual.

24.2.3.1 Vehicle Criteria (Controlling Design Parameter)

Vehicles usually considered as candidates for HOVs are passenger cars, vans, and buses. Although other vehicles, such as emergency vehicles or motorcycles may be allowed to use the HOV lane, they do not generally influence the design.

HOV lanes on freeways should be designed in accordance with the critical design elements and controlling design parameters for the single unit bus, AASHTO BUS, except for stopping sight distance. Stopping sight distance is controlled by the passenger car (P) due to lower driver eye height. AASHTO's A Policy on Geometric Design of Highways and Streets illustrates the turning radii for a 12.1 m bus. Section 1, Paragraph © of subdivision 3, of Section 385 of the New York State Vehicle and Traffic Law was amended in 1996 to limit the length of buses having a carrying capacity of more than seven passengers to 45 ft (13.7 m). Articulated buses are limited to 62 ft (18.9 m). Currently, the highway coach is the only 13.7 m bus in use. Design of a 13.7 m transit bus is underway. The designer should contact the local transit provider to obtain the physical and operational characteristics of its buses prior to the start of design.
Tractor-semitrailer trucks should not be considered as HOVs, or allowed to use HOV lanes during the peak periods. Commercial trucks generally have different origins and destinations from commuters. To try to accommodate both may result in operational incompatibilities. Operational and safety conflicts arise when trucks must weave across several general-use lanes to enter and exit HOV lanes located in freeway medians. Retrofit of HOV lanes may present restricted geometrics that are detrimental to trucking movements.

When it is determined that a project will be developed to operate as part-time HOV lanes, it may be prudent to consider WB-20 tractor-semitrailer trucks so as not to preclude the possibility that the HOV lanes may be used to give priority to tractor-semitrailers to promote commercial goods movement during off-peak periods and for incident management situations.

Table 24-5 provides a recommended design vehicle envelope for full-time and part-time HOV lanes. The envelope for full-time lanes includes standard and articulated buses, vans, and autos. The envelope for part-time lanes includes those vehicles and WB-20 tractor trailer trucks.

<table>
<thead>
<tr>
<th>Vehicle Characteristics</th>
<th>Design Vehicle Envelope for Full-Time HOV Lanes</th>
<th>Design Vehicle Envelope for Part-Time HOV Lanes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>18.9 m</td>
<td>18.9 m</td>
</tr>
<tr>
<td>Width</td>
<td>2.6 m</td>
<td>2.6 m</td>
</tr>
<tr>
<td>Height</td>
<td>4.1 m</td>
<td>4.1 m</td>
</tr>
<tr>
<td>Turn Radius</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outside</td>
<td>15.8 m</td>
<td>16.8 m</td>
</tr>
<tr>
<td>Inside</td>
<td>10.1 m</td>
<td>10.1 m</td>
</tr>
<tr>
<td>Gross Weight</td>
<td>22 680 kg</td>
<td>36 360 kg</td>
</tr>
<tr>
<td>Gross Weight Per Axle</td>
<td>10 180 kg</td>
<td>10 180 kg</td>
</tr>
</tbody>
</table>

Adapted from PBQD Manual & NYS Vehicle & Traffic Law
24.2.3.2 Design Speed (Critical Design Element)

HOV lanes should be designed to provide travel time savings and reliability to attract users. In a retrofit project, the mainline design speed selected for the HOV lane should be comparable to that of the adjacent general-use lanes. This is especially important if the HOV lanes are to be used by non-HOVs during off-peak hours, either immediately or in the future. In any case, the design speed should be established in accordance with Chapter 2 in this Manual.

The design speeds for ramps vary according to the type of ramp and the design speed of the HOV lane and general-use lanes. They should be selected in accordance with the design guidance in Chapter 2, Section 2.7.5.2.

24.2.3.3 Level of Service (Critical Design Element - Interstates)  
(Controlling Design Parameter - Other Freeways)

The objectives of an HOV lane are to 1) move more people in fewer vehicles than the adjacent general-use lane, 2) avoid congestion, and 3) carry enough vehicles so as not to appear under used after the first year of operation. This can be accomplished by choosing eligibility criteria based on the demand and capacity relationships for the corridor and type of facility. The level of service (LOS) for the HOV lane should be higher than the operational level of service of the adjacent general-use lanes, but not be less than “C”. The operating capacity at LOS “C” is dependent on the location and type of HOV facility, but will usually exceed 1200 vph in passenger car equivalents. An acceptable level of service may even be preserved at flows approaching 1500 vph in passenger car equivalents, depending on the percentage of buses in the vehicle mix. The design year peak hour volume for busways on freeways should range from 40 vph to 60 vph. The TRB Special Report 209 *Highway Capacity Manual* should be consulted for guidance in capacity analysis procedures and how to determine the upper levels of HOV lane capacity.

For vehicle throughput in the peak direction, a minimum peak hour range of 400 vph to 800 vph is generally recognized as a lower threshold for HOV lane acceptance for HOV facilities. It varies according to facility type and location. The acceptance criterion for the Long Island Expressway HOV lane was 800 vph. The minimum flow for contraflow HOV facilities should be 200 vph. Busway facilities should have a minimum flow of 30 vph to 45 vph.

The off-peak HOV demand should also be calculated to determine whether the lane can be operated full-time or should revert to general-use operation between rush hours. Low demand can result in the public perception of an “empty lane”, which may result in pressure to lower eligibility requirements.

Person throughput in an established HOV lane during the peak period should exceed the average throughput in the adjacent general-use lane. When the HOV lane is initially opened, person throughput within 20% of the average general-use lane throughput is acceptable.
24.2.3.4 Geometric Design Elements

The standard values for the 17 critical design elements for interstates and other freeways in Chapter 2 of this Manual are the design criteria for HOV lanes on freeways. An explanation of the standard values for lane width is contained in Section A below. In addition, other controlling design parameters included in this Manual, must be considered by the designer during the design phase. Two additional geometric design elements not included in Chapters 2 and 5 are buffer area and enforcement area, both controlling design parameters. See Sections B and C below.

A. Lane Width (Critical Design Element)

The standard lane width for HOV facilities shall be 3.6 m. A reduced lane width of 3.3 m may be acceptable where right of way constraints exist, however, lane width reductions should be considered only after all other cross section element reductions have been considered and selected or eliminated. Lane widths less than 3.6 m must be justified as described in Section 24.2.3.

B. Buffer Area (Controlling Design Parameter)

A buffer separation or buffer strip is a roadway area that is used to physically separate an HOV lane from a general-use lane. It is used to discourage drivers from indiscriminately crossing from the general-use lane to the HOV lane, and vice versa. Painted striping and hatching are used to define the buffer. The width of a narrow buffer should be no greater than 1.2 m or less than 0.3 m. The width of a wide buffer should be no greater than 4.2 m or less than 3.0 m. Buffer widths greater than 1.2 m and less than 3.0 m are not acceptable, except where transitioning between narrow and wide buffer areas. Buffer widths within that range are not wide enough for safe parking and may mislead drivers into using them for refuge.

C. Enforcement Area (Controlling Design Parameter)

An enforcement area is a dedicated space in which enforcement activities can be performed. An enforcement area should be a continuous paved median or individual areas at specific locations. Refer to the cross sections in subsequent sections of this chapter for the recommended locations of enforcement areas. Enforcement areas should only be located where proper sight distance is available to vehicles that are pulled over into the enforcement shoulder. Enforcement areas located in high speed (80 km/h or greater) areas should be no less than 4.2 m wide. Enforcement areas located in low speed (60 km/h or less) areas should be no less than 3.6 m wide.
24.2.4 Barrier-Separated Reversible-Flow Lanes

24.2.4.1 Operations

Reversible flow lanes are separated from adjacent general-use lanes by barriers to provide safety and avoid confusion. Reversible-flow facilities operate only during peak periods; they are not full-time facilities, nor are they meant to carry traffic in the off-peak direction.

Access to reversible HOV lanes is controlled with the use of exclusive ramps or access points, along with gates, signs, overhead lane arrows, variable message signs, or other traffic control devices. Controlled access prevents drivers from traveling the wrong way on the facility, reduces the level of enforcement, and minimizes opportunities for violations. It also requires that entry gates be checked, either manually, or with remote cameras and monitors located at traffic operations centers, at each change of operation, to ensure they are open in the peak flow direction and closed in the off-peak direction. Prior to each change of operation, the HOV lanes must be checked to ensure there are no obstructions.

Reversible flow lanes are suitable for all HOVs or as exclusive busway lanes. Refer to Section 24.2.1.2 for the recommended minimum one-way peak hour volume of buses.

24.2.4.2 Cross Section

Reversible-flow lanes are well suited to new alignment projects, but are difficult to retrofit into existing freeway rights of way because of bridge piers and other possible interferences within the median.

The standard cross section for single-lane reversible flow lanes (Figure 24-3a) includes a 3.6 m lane, a shoulder/lateral clearance of 3.0 m on one side, and 1.2 m on the other side, for a total cross section width of 7.8 m. The width needed for a stalled bus to discharge passengers on the wide shoulder without encroaching on the HOV lane is 7.2 m.

The standard cross section for a two-lane facility consists of two 3.6 m HOV lanes with two 3.0 m shoulders. Where space is restricted, shoulder/lateral clearance widths as shown for the single-lane version should be provided.

The acceptable values (refer to Section 24.2.3) in Figure 24-3b include a lane width of 3.3 m, a 2.4 m shoulder/lateral clearance on one side, and a 0.6 m lateral clearance to the barrier on the other side, for a total envelope width of 6.3 m, which is the practical minimum width needed to pass a stalled bus parked on the shoulder. A minimum envelope width of 7.2 m is required to allow passengers to discharge while parked. A two-lane reversible-flow cross section would add a 3.3 m HOV lane to the single-lane section.
Figure 24-3 Cross Section Dimensions for Barrier-Separated Reversible-Flow HOV Lanes

**a. Standard**

*4.2 m for enforcement shoulders or pockets*

**b. Acceptable**

(Use of non-standard dimensions requires justification in accordance with Section 24.2.3.)

Notwithstanding the standard shoulder and lateral clearance dimensions described above, horizontal sight distance is of particular concern on the inside of curves. This is especially important where a reversible-flow facility is to be retrofitted into the median of an existing freeway. The cross section needed to achieve the required sight distance should be carried throughout the length of the facility.
24.2.4.3 Access

Refer to Section 24.2.1.4 Access Treatments. Ramp design for all ramp types shall be in accordance with Chapter 2 in this Manual and AASHTO's Policy on the Geometric Design of Highways and Streets. Lane tapers shall be designed in accordance with the NYSMUTCD and AASHTO's Policy on the Geometric Design of Highways and Streets.

A. At-Grade Slip Ramps

Figure 24-4a illustrates an example of an at-grade terminal treatment for exclusive single-lane reversible lanes. A typical at-grade intermediate treatment is shown in Figure 24-4b.

B. Flyover Ramp

Figure 24-5a shows an example of a terminal flyover ramp connection. Figure 24-5b shows an example of an intermediate flyover ramp connection.

C. Local Access Drop Ramp

Figure 24-6 shows an example of a drop ramp treatment for intermediate access to a local street from the HOV lane. The treatment for termination of a reversible HOV lane is similar to the intermediate access except that the mainline HOV lane would not carry through beyond the termination point. A breakdown shoulder should be provided for each direction of travel.

24.2.4.4 Enforcement Areas

Reversible-flow facilities are generally considered to be the easiest type to enforce. Access points to reversible-flow lanes usually have spaces or pockets available which are ideal locations for enforcement areas. Enforcement areas may also be provided along the mainline, for example, as 4.2 m wide continuous enforcement shoulders, or intermittent enforcement areas. High-speed enforcement areas can be located in the vacant lane of slip ramps for the opposite direction of flow, as shown in Figure 24-4.

Low-speed enforcement areas, where violators can be prevented from entering the HOV lanes, are suitable for drop ramps as shown in Figure 24-6. The typical low-speed enforcement area should have:

- a minimum length of 30 m. High-volume settings may require up to 60 m.
- a minimum width of 4.2 m
- approach taper 2:1 where applicable
- departure taper 10:1 where applicable

Where conditions permit, a violator removal ramp can provide a means to reroute non-HOVs back to the general-use lanes. Refer to Figure 24-6.
Flyover ramps may be adaptable to low-speed enforcement, if space allows. If not, mainline enforcement may be provided in the form of periodic or continuous full width, high-speed enforcement shoulders along the mainline. Periodic high-speed enforcement areas should typically be:

- 400 m long
- 4.2 m wide (minimum)
- located at 3 km to 5 km intervals
- designed with approach and departure tapers of 80:1 or greater where possible, or in accordance with AASHTO’s *A Policy on Geometric Design of Highways and Streets*, Chapter X, as may be required to fit the design.

*Enforcement Requirements for High-Occupancy Vehicle Facilities* and FHWA’s *High Occupancy Vehicle Facility Enforcement Guide* provide further guidance for enforcement of barrier-separated HOV lanes on freeways.
Figure 24-5 Flyover Ramps for Barrier-Separated Reversible-Flow HOV Lanes

a. Terminal Flyover Connection

b. Intermediate Flyover Connection
Figure 24-6 Drop Ramp for Barrier-Separated Reversible-Flow HOV Lanes
24.2.5 **Barrier-Separated Two-Way Flow Lanes**

24.2.5.1 Operations

The symmetrical cross section of a two-way facility makes it more adaptable for retrofitting into an existing freeway median, with little or no interference from bridge piers or other median hardware. In addition, separation from general-use lanes provides safety of operation, prevents interference between general-use traffic and HOV traffic, requires no directional control, and allows continuous use as HOV lanes. When dedicated access connections are provided, exclusive two-way flow lanes function as fully controlled lanes within a freeway and are considered the most desirable type of HOV treatment, albeit the most costly treatment.

24.2.5.2 Cross Section

The opposing lanes of two-way flow HOV lanes are separated by a barrier. The standard cross section includes a 3.6 m lane width, a 3.0 m right shoulder width and a 1.2 m shoulder/lateral clearance to the barrier on the left, in each direction as shown in Figure 24-7a.

The acceptable values (refer to Section 24.2.3) include a 3.3 m lane width, a 2.4 m right shoulder width and a 0.6 m lateral clearance to the barrier on the left in each direction, as shown in Figure 24-7b. The narrow lateral clearance may reduce the SSD below allowable design standards and may only be suitable for use at isolated locations for short distances.

Openings for emergency access should be provided in the median barrier. Refer to Section 24.2.11.1 for further guidance.

24.2.5.3 Access

Refer to Section 24.2.1.4 Access Treatments. For guidance on ramp design refer to Chapter 2 in this Manual, AASHTO's *A Policy on Geometric Design of Highways and Streets*, and the NYSMUTCD.

A. At-Grade Slip Ramp

As indicated in Figure 24-8, the HOV lane should originate from the left general-use lane with a short taper to full width. It should terminate as a continuous lane into a general-use lane without a lane drop, if possible. When a lane drop is necessary, it is preferred that the right general-use lane be dropped approximately 800 m beyond the end of the HOV lane. Refer to Chapter 5, Section 5.8.12 Lane Drops in this Manual. Where a right general-use lane drop can not be made, the HOV lane may be dropped. In those cases, the AASHTO *Guide for the Design of High Occupancy Vehicle Facilities* recommends a longer than standard merge area to reduce the effects on merging traffic. In some circumstances it may be possible to drop the general-use lane as a mandatory exit to a ramp, to minimize merges. Figure 24-8a illustrates...
an example of an at-grade slip ramp at an HOV lane origination and termination. If the HOV lane has to be merged back into the freeway traffic, a dashed white line, preferably 800 m long, and no less than 400 m long, should be provided before the end of the HOV lane taper begins.

When conditions permit, intermediate ingress and egress should be provided at separate barrier opening locations to prevent conflicts between the associated weaves. Egress from the HOV lane should always precede ingress to the HOV lane to avoid congestion on the HOV lane. In addition, HOV egress should not be considered at the first access point downstream from the origin, and HOV ingress should not be considered at the last barrier opening upstream from the HOV lane termination. Each barrier opening should provide adequate distance for HOVs to weave into or out of the HOV lane. Special consideration should be given to the acceleration and deceleration characteristics of loaded buses, particularly if access ramps have significant grades. The weave distance should be calculated in accordance with TRB's Special Report 209 Highway Capacity Manual.

When constraints prevent the installation of separate ingress and egress, they may be provided at the same location. If there is enough space available, a weave lane should be provided to allow the entering and leaving vehicles to make an orderly transition from one facility to the other. An example of an intermediate combined ingress/egress area is shown in Figure 24-8b.
The opening length should generally range between 300 m and 450 m, as determined by a weave analysis in accordance with TRB Special Report 209, *Highway Capacity Manual*. Shorter distances may create a safety hazard by not providing adequate weave distance. Longer distances provide so much distance that the weave lane could be used as a passing lane by HOVs.

**Figure 24-8** At-Grade Slip Ramps for Barrier-Separated Two-Way Flow HOV Lanes

<table>
<thead>
<tr>
<th>LANE DROP TAPER</th>
<th>MERGE AREA</th>
<th>BARRIER</th>
</tr>
</thead>
<tbody>
<tr>
<td>FREEWAY</td>
<td>EXIT TAPER</td>
<td>IMPACT ATTENUATOR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HOV LANES</td>
</tr>
</tbody>
</table>

**a. Lane Origin and Lane Terminus**

<table>
<thead>
<tr>
<th>ENTRANCE TAPER</th>
<th>WEAVE LANE</th>
<th>HOV LANE</th>
</tr>
</thead>
<tbody>
<tr>
<td>FREEWAY</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>BARRIER</td>
</tr>
</tbody>
</table>

**b. Intermediate Combined Ingress/Egress**

Source: Adapted from PBQD Manual & AASHTO Guide
B. Flyover Ramps

Figure 24-9 illustrates an example of an intermediate access flyover ramp. The width of the ramp cross section should match the mainline HOV lane cross section width. The same concept, without acceleration and deceleration lanes at the mainline may be used to terminate the facility. In situations where access is being provided from a single local street, rather than frontage roads as illustrated, a two-way flyover ramp could be provided. That type of ramp requires a barrier throughout its entire length to separate the opposing HOV lanes.

Figure 24-9 Flyover Ramps for Barrier-Separated Two-Way Flow HOV Lanes

Source: AASHTO Guide
C. Local Access Drop Ramp

HOV lanes can be adversely affected by the design of drop ramps. To maintain the safety and capacity of the lanes, along with the benefits gained from high-speed travel, short ramps with low design speeds should be connected to the HOV lanes by acceleration and deceleration lanes that will allow HOVs to safely move into and out of the HOV lane. Figure 24-10 illustrates an example of a local intermediate access drop ramp on two-way HOV lanes.

Drop ramps require merge and diverge movements with left (inside) lanes. Left-hand maneuvers are opposite to normal driver expectations when used on facilities that have right-hand entrances and exits. These conditions should be made known to drivers, with appropriate use of signs and by providing adequate decision sight distance.

The ramp design could be repeated on the opposite side of the street if access to and from the HOV lanes in the opposite direction is needed. With some modifications, the ramp design shown in the example in Figure 24-10 may also be used for origin and termination access.

Figure 24-10 Two-Way Drop Ramp for Two-Way Barrier-Separated HOV Lanes
24.2.5.4 Enforcement Areas

Enforcement of two-way barrier-separated HOV lanes is generally similar to that for reversible-flow lanes (Section 24.2.4.4). Low-speed enforcement may be provided at flyover ramp entrances and drop ramp entrances. The exception is at slip ramps where there is no unused space available for enforcement areas. Continuous enforcement shoulders or periodic enforcement pockets should be used in those situations.

Continuous enforcement shoulders 4.2 m wide are recommended where space is available. The right shoulder, being the widest, is used for enforcement. If constraints prevent the use of continuous enforcement shoulders, 4.2 m wide enforcement pockets are recommended. Pockets should be 400 m in length plus approach and departure tapers (refer to NYSMUTCD Table 262-2). Enforcement intervals of 3 km to 5 km is typical for most facilities.

*Enforcement Requirements for High-Occupancy Vehicle Facilities and FHWA's High Occupancy Vehicle Facility Enforcement Guide* provide further guidance for enforcement of barrier-separated HOV lanes on freeways.
24.2.6 Two-Way Busway Lanes

NCHRP 155, *Bus Use of Highways: Planning and Design Guidelines* groups busways by direction of flow and placement of shoulder. Normal-flow busways provide a standard two-lane road with optional outside breakdown lanes. They are well suited for most busway applications, because they employ conventional right-hand operations with optional breakdown lanes on the outside. This section presents the normal-flow busway on freeways.

Special-flow busways provide two one-lane roads and a central breakdown lane. Buses stay to the right of the centerline. They afford economy of width where breakdown lanes are required. Contraflow busways provide two one-lane roads and a central breakdown lane. Buses keep to the left of the center line. This design permits common island station platforms, which minimize station security, supervision, maintenance, and vertical transportation requirements.

A summary of illustrative planning guidelines for bus priority treatments can be found in the *Highway Capacity Manual, Special Report 209*. For further information on normal-flow, special-flow and contraflow busways, refer to NCHRP Report 155 *Bus Use of Highways: Planning and Design Guidelines*.

24.2.6.1 Operations

Busways may be used to provide: line-haul express transit service to the city center; feeder service to rail transit lines; and short bypasses of major congestion points. They should segregate buses from other types of traffic, and may include ancillary passenger-bus interchange and parking facilities. NCHRP Report 155 *Bus Use of Highways: Planning and Design Guidelines*, recommends busway development should be considered where one or more of the following conditions are met:

- Freeway flow cannot be restored to level of service D with mixed traffic by ramp metering, ramp closures, or other simple controls.
- Contraflow bus lanes are not feasible because traffic flow conditions and roadway geometry prevent their use.
- Bus bypass lanes or ramps to bypass congested interchanges, lane drops, or high-volume on-ramps, of less than 2 km in length, are neither feasible nor enforceable.
- Rail rapid transit along the corridor will be warranted within 20 years.
- Travel time benefits accruing to bus passengers will exceed the purchase and development costs of the busway on an annual basis.

Consideration be given to developing line-haul busways wherever the following basic conditions are met:

- Design-year urban population should exceed 750,000; central business district (CBD) employment should exceed 50,000; peak-hour person-volumes across the CBD cordon (boundary) should exceed 35,000.
- There should be the potential for a minimum one-way peak hour volume of 40 buses and 1600 passengers to use the busway in the design year.
Buses utilizing the busway should save at least 5 minutes over alternative bus routings. Current highway demands in the corridor exceed capacity; and environmental, social, and/or traffic conditions preclude providing additional road capacity.

Downtown busway development should be considered where peak-hour bus speeds are less than 8 km/h - 10 km/h, where the congested area extends for more than 2 km, and where surface-street priority options cannot be effectively developed.

24.2.6.2 Cross Section

Busways are preferential two-way roadways designed for, and dedicated to, use by buses only. For high-speed (80 km/h or more design speed) operation the opposing lanes should be separated by a barrier. Facilities without a barrier between the HOV lanes are appropriate for low-speed (60 km/h or less design speed) operation. The only users should be trained, experienced professional drivers.

Figure 24-11a shows the standard cross section consisting of a 3.6 m lane, a 3.0 m right shoulder and a 1.2 m offset in each direction. The cross section for low-speed lanes provides two 3.6 m lanes and two 3.0 m shoulders, as shown in Figure 24-11b. The lanes are distinguished by striping. The acceptable cross section in Figure 24-11c may find use where impediments or cost prevent the use of a wider cross section.

Busways located within freeway rights of way should be separated from the freeway general-use lanes by barriers. Barriers are not required at the back of shoulders for busways located in separate rights of way.

24.2.6.3 Access

Access to dedicated busways can be provided with at-grade slip ramps, flyover ramps, or drop ramps, similar to access to barrier-separated two-way lanes. Busway-to-freeway junctions should conform to freeway design criteria. Examples of at-grade busway ramps and arterial street intersections are shown in Figure 24-12.

Refer to Section 24.2.5.3 for access treatments. For further discussion of access to busways, refer to NCHRP Report 155, *Bus Use of Highways: Planning and Design Guidelines*.

24.2.6.4 Enforcement Areas

Dedicated entrance ramps to busways provide ideal locations at which to conduct enforcement activities. Properly signed entrance ramps should curtail accidental entries. However, enforcement areas should be provided for use by officers to monitor entering traffic, similar to barrier-separated two-way lanes. Refer to Section 24.2.5.4 for further information.
Figure 24-11 Cross Section Dimensions for Two-Way Busway in Freeway Right of Way

**a. High-Speed, Standard**

**b. Low-Speed, Standard**

**c. Low-Speed, Acceptable**

(Non-standard dimensions require justification in accordance with Section 24.2.3.)

NOTE: OUTSIDE BARRIERS NOT REQUIRED ON BUSWAYS IN SEPARATE RIGHTS OF WAY.
Figure 24-12 At-Grade Busway Ramp and Cross Street Intersection

Source: NCHRP Report 155
24.2.7 Buffer-Separated Two-Way Concurrent Flow Lanes

24.2.7.1 Operations

Buffer-separated lanes carry traffic in the same direction as the adjacent general-use lanes, similar to two-way, barrier-separated lanes, but are separated from them by a buffer. They are located in the median of a freeway and are symmetrical about the median centerline. Buffer separated lanes normally operate on a continuous (24 hr.) basis. However, there are some, e.g., the Long Island Expressway in Suffolk County, that operate as peak-period HOV facilities, and the lanes revert to general-use lanes during the off-peak period.

24.2.7.2 Cross Section

The standard cross section for continuous enforcement has a 3.6 m HOV lane between a 4.2 m enforcement shoulder at the median side and a 1.2 m buffer which separates it and the general-use traffic, as shown in the example in Figure 24-13a. The buffer should be flush with the pavements on either side. When periodic enforcement is appropriate, the median shoulder can be reduced to 3.0 m, with a 3.6 m HOV lane and a 1.2 m buffer, as shown in the example in Figure 24-13b. Typically, the full buffer width should be no less than 0.3 m and no greater than 1.2 m. If a wide buffer is needed, it should be no less than 3.0 m and no greater than 4.2 m. Wide buffers should not be used as enforcement areas or as breakdown lanes because of the potential hazard of high-speed traffic on both sides of the buffer. Buffer widths between 1.2 m and 3.0 m wide are not wide enough to be used as breakdown lanes or travel lanes and should not be provided. Buffer widths in that range should only be used to transition between narrow and wide buffers at ingress or egress areas.

An acceptable cross section includes a 0.6 m offset to the median barrier, a 3.3 m HOV lane and a 0.6 m buffer, as illustrated in Figure 24-13c. The restricted width of this cross section provides no enforcement or breakdown capability, and may reduce the SSD below allowable design standards. Therefore, acceptable cross section dimensions should only be used on an interim basis or at isolated locations for short distances.

Openings for emergency access should be provided in the median barrier. Refer to Section 24.2.11.1 for further guidance.
Figure 24-13 Cross Section Dimensions for Concurrent Flow HOV Lanes

a. Standard, with Enforcement Shoulder

b. Standard, without Enforcement Shoulder

* 4.2 m at enforcement areas

c. Acceptable
(Non-standard dimensions require justification in accordance with Section 24.2.3)
24.2.7.3 Access

Refer to Section 24.2.1.4 Access Treatments. For guidance on ramp design, refer to Chapter 2 in this Manual, AASHTO's *A Policy on Geometric Design of Highways and Streets*, and the NYSMUTCD.

Access to buffer-separated concurrent-flow lanes should be provided at designated ingress/egress locations. Examples of terminal and intermediate access with slip ramps are shown in Figure 24-14. These locations can be marked out with pavement markings which can be adjusted relatively easily, if necessary, to optimize the operation. Alternatively, drop ramp access can be provided if its use is more suitable to the operation of the HOV lanes and adjacent general-use lanes. The ramp would be similar to the drop ramp for barrier-separated lanes, as shown in the example in Figure 24-10.

The recommended method of terminating an HOV lane is to continue it as a general-use lane without forcing HOV users to shift lanes. Refer to Section 24.2.5.3 A. If the HOV lane must be merged back into the freeway traffic, a dashed white line, preferably 800 m long, and no less than 400 m long, should be provided before the end of the HOV lane taper begins.

Intermediate access may be provided either by separate ingress and egress areas, as shown in the example in Figure 24-14b, or as combined ingress/egress areas. (Figure 24-8b shows an example of a barrier-separated combined ingress/egress area.) Separate access areas need to consider a vehicle move in only one direction, but may require more locations. The combined areas may be fewer but must be designed for weaving moves and distances. In any case, the design of the weaves and merges must conform to the requirements of the most recent edition of the *Highway Capacity Manual, Special Report 209.*
Figure 24-14 Ingress/Egress Areas for Concurrent Flow HOV Lanes

a. Origin/Termination

b. Intermediate Access

Source: LIE Project, D254006
24.2.7.4 Enforcement Areas

Enforcement areas should be designed with adequate width and length to provide safety to the enforcement officer and the violator. Medians 9.0 m in width, or greater, are wide enough to allow continuous 4.2 m enforcement shoulders in both directions, separated by a median barrier.

Median enforcement areas can be designed as either directional (used to observe in one direction only), or bi-directional (used to observe in either direction). Both types use offset median barrier to protect the enforcement vehicle. At locations where it is appropriate to have directional enforcement, the barriers need only to be offset enough to provide space for the vehicle. The upstream barrier alignment is on the median centerline to within 50 m of the enforcement area. The downstream barrier is offset to provide the required enforcement shoulder length and width. Refer to the example in Figure 24-15a.

Bi-directional enforcement must provide a clear dimension of 3.0 m between the barriers, wide enough for an enforcement vehicle to pass between them. The minimum median width needed is 6.6 m. Refer to the example in Figure 24-15b.

When the available median width is less than 6.0 m, the existing freeway lanes and the new HOV lanes must be shifted apart to fit a 4.2 m enforcement area, a 0.6 m barrier width and 1.2 m minimum lateral clearance between. Refer to the example in Figure 24-16.

Enforcement area spacing of 3 km to 5 km is recommended.

*Enforcement Requirements for High-Occupancy Vehicle Facilities,* and FHWA’s *High Occupancy Vehicle Facility Enforcement Guide* provide further guidance for enforcement of concurrent flow HOV lanes on freeways.
Figure 24-15 Median Enforcement Area for Medians 6.0 m to 9.0 m Wide

a. Directional Enforcement Area

b. Bi-Directional Enforcement Areas

Source: Adapted from AASHTO Guide
Figure 24-16 Median Enforcement Area for Medians Less Than 6.0 m Wide

Directional Enforcement Area

Source: Adapted from AASHTO Guide
24.2.8 Nonseparated Two-Way Contiguous Flow Lanes

24.2.8.1 Operations

Similar to other two-way facilities, contiguous lanes carry traffic in the same direction as the adjacent general-use lanes, but are separated from the general-use lanes by a lane line. This provides HOVs with ease of entry and exit during peak operation and to all vehicles during off-peak operation. However, it makes enforcement very difficult. Contiguous lanes are located in the median of a freeway and symmetrical about the median centerline. They are appropriate for HOV operation during peak periods and general-use operation during off-peak periods. They may also be appropriate for consideration when right of way constraints prevent the use of other HOV lane configurations. The operation of contiguous lanes can be affected by the congestion on the adjacent general-use lane. Safety is also a consideration. The proximity of the lanes to each other without separation increases the risk for illegal entry of low-speed general-use vehicles into the higher speed HOV lane. This may increase the chance of accidents and reduce the speed of HOVs.

24.2.8.2 Cross Section

Contiguous lanes are separated from general-use lanes by a paint stripe. A 3.0 m left shoulder should be provided adjacent to a 3.6 m HOV lane. If continuous enforcement is to be provided, the shoulder should be at least 4.2 m wide. This is also beneficial for stopping sight distance.

The preferred and acceptable cross sections for contiguous lanes are shown in Figure 24-17. The restricted width of the acceptable cross section provides no enforcement or breakdown capability, and may reduce the SSD below allowable design standards. Therefore, acceptable cross section dimensions should only be used on an interim basis or at isolated locations for short distances.

24.2.8.3 Access

The origin and termination of contiguous HOV lanes should be designed as additional conventional general-use lanes. Intermediate access locations need not be designated since HOVs are allowed continuous access.

24.2.8.4 Enforcement Areas

Enforcement of two-way contiguous lanes is difficult since potential violators have continuous access to the HOV lanes. Guidelines for enforcement of two-way contiguous lanes are similar to those for buffer-separated concurrent flow lanes. Refer to Section 24.2.7.4 in this Manual.
Figure 24-17 Cross Section Dimensions for Two-Way Contiguous Flow HOV Lanes

13.8 m

Freeway 3.6 m | 3.0 m | 3.0 m | 3.6 m | Freeway
HOV Lane Shoulder Shoulder HOV Lane

8.4 m

Freeway 3.3 m | 0.6 m Lateral Clearance | 3.3 m | Freeway
HOV Lane HOV Lane

a. Standard

b. Acceptable
(Non-standard dimensions require justification in accordance with Section 24.2.3)
24.2.9 Contraflow Lanes

24.2.9.1 Operations

Safety must be a top consideration with contraflow traffic operating on the same side of the freeway as the opposing general-use traffic. Tubular markers (Item 619.2001M; NYSMUTCD §292.6) can be installed along the lane line in flush-mounted sockets, to channel traffic in the contraflow lane and the adjacent general-use lane. Tubular markers are easily installed and removed for each operational change. However, they do not offer the safety and lateral separation between opposing lanes provided by movable barrier. Contraflow lanes with tubular markers should be reserved only for buses that are operated by trained, professional drivers, and speed limits should not exceed 60 km/h. Other restrictions may be desirable, such as the reduction of posted speed limits, the use of vehicle flashers and headlights, and maintaining headways, (e.g., 60 m headway).

Each day, barrier or tubular markers, signs, and other devices must be placed and removed with each change of operation. Ingress and egress gates or barriers must be opened or closed. The contraflow lane should be checked, either manually, or by surveillance equipment, to ensure that a stalled vehicle or some other blockage does not exist, before changing from general-use to HOV operation, or vice versa.

Alternatively, movable concrete barrier (MCB) may be appropriate to provide the needed protection, but additional width may be required to obtain the needed clearances and lane widths. The use of movable concrete barrier significantly improves the safety between the lanes by preventing errant vehicles from crossing into the opposing lane. The protection provided allows higher HOV speeds, and carpools and vanpools, as well as buses, can take advantage of travel time savings, thus increasing peak period person movement. However, movable barrier and barrier transfer machines(s) have a very high capital cost. The first contraflow HOV facility in the U.S. to use movable barrier, the East R.L. Thornton Freeway (IH30) movable contraflow lane in Dallas, TX. Operation details can be obtained from the Dallas Area Rapid Transit (see Section 24.7 References).

Movable barrier is also used on the Tappan Zee Bridge which spans the Hudson River between Rockland and Westchester Counties. Operation details can be obtained from the NYS Thruway Authority. Refer to Chapter 10, Section 10.2.4.9 B for information on MCB.

24.2.9.2 Cross Section

The contraflow lane cross sections in Figure 24-18 illustrate the minimum dimensions necessary for the use of tubular markers and MCB. The minimum cross section for tubular markers includes a 3.6 m lane and a 3.0 m breakdown shoulder. The tubular markers are approximately 64 mm in diameter and can be installed within the HOV lane width. If off-peak traffic volumes are low enough, it may be possible to take an additional general-use lane to increase the buffer between the HOV and general-use lanes. A buffer can be used as a refuge area for disabled vehicles, and for removing incidents from the contraflow lane. When space is not available for a buffer lane, median crossovers should be considered to provide emergency vehicles access to the contraflow lane when
approaching from the peak direction.

The cross section, when using MCB, includes a 3.6 m lane, a 1.2 m lateral clearance to the movable barrier, and a 3.0 m breakdown shoulder. Where space is restricted, a minimum 0.6 m lateral clearance should be provided to the barrier on the HOV side. If off-peak traffic volumes are low enough, it may be possible to take an additional general-use lane to increase the lateral clearance on both sides of the barrier.

**Figure 24-18 Cross Section Dimensions for Contraflow HOV Lanes**

- **a. Low-Speed Contraflow Lane**

- **b. High-Speed Contraflow Lane**
24.2.9.3 Access

Exclusive entrance and exit ramps are the preferred methods of access to and from contraflow lanes. The design of entrances and exits depends on the operating speed of traffic and the grades and curvature of connecting roadways. Access to contraflow lanes is normally provided by low-speed ramps across the freeway median. Crossovers should be located where traffic is slowed or stopped for a toll plaza, freeway entrance, or other reason, if possible. If this is not possible, a deceleration lane should be provided to give the HOVs the opportunity to slow to the proper speed before entering the contraflow lane. In other situations, high-speed access may be appropriate. The connectors should be located at level and tangent sites where visibility and sight distance are adequate. On freeways without a median, access is provided by a simple opening in the median barrier.

Ramps should diverge at an angle of 2° to 5° where space allows. The access ramp from contraflow lanes to general-use lanes should connect to a parallel-type acceleration lane to give the HOV the opportunity to safely move into the general-use traffic. Refer to the example in Figure 24-19.

24.2.9.4 Enforcement Areas

Typically, contraflow operations are limited to buses and violators are easily spotted by monitoring the entrances. Enforcing the lanes at the entrances also eliminates the need to monitor the lane for violators. Access points should be provided at low-speed entrances to furnish enforcement personnel a location to monitor entering traffic. Where medians are wide enough, a violator removal ramp may be provided. When enforcement can not be provided at entrances, the HOV lane should be monitored from enforcement areas or by roving patrol. Enforcement areas should be 4.2 m wide and 60 m long. Shorter lengths to 30 m are acceptable where constraints are encountered.

*Enforcement Requirements for High-Occupancy Vehicle Facilities,* and FHWA's *High Occupancy Vehicle Facility Enforcement Guide* provide further guidance for enforcement of contraflow HOV lanes on freeways.
Figure 24-19 Typical Terminal Treatments for Contraflow Lanes

**a. Entry**

- Freeway Off-Peak Traffic
- Tubular Markers (Optional)
- Movable Barrier or Tubular Markers
- Enforcement Area
- Contraflow Lane

**b. Exit**

- Freeway Peak Traffic
- Movable Barrier or Tubular Markers
- Taper (See Note)
- 50:1 Min.
- Contraflow Lane
- Taper

**Note:** Refer to NYS MUTCD Table 262-2 for standard taper lengths.

Source: Adapted from AASHTO Guide

§SEE 24.2.9.3 5/4/98
24.2.10 **Signing and Pavement Markings**

Users of HOV lanes must be provided with information to help them travel safely, smoothly and efficiently. Signs and pavement markings are the communication methods used to provide that information. Signs and pavement markings shall conform to the NYSMUTCD and Appendix A-19 in *Title 17 of the Official Compilation of Codes, Rules, and Regulations of New York State (NYCRR)*, to the fullest extent possible. Signs, signals, variable message signs (VMS), or lane-use control signals shall be used to convey lane use restrictions. Preferential lane markings should also be used to indicate that the lanes are restricted. The standard symbol for HOV lanes shall be the elongated diamond symbol which shall be used for all signs and pavement markings. All signs shall be reflectorized and illuminated as may be necessary. The Regional Traffic Engineer should be consulted on all signing and pavement marking design.

### 24.2.10.1 Signing, Lane Use Controls, and Other Devices

Access to and from HOV lanes is a major design element. Refer to Section 24.2.1.4 in this chapter for discussion of access treatments. The design of HOV lanes and access points necessitates providing information to the users regarding:

- **Entrances**
  - Advance notice of entrance point
  - Guidance to entrance
  - HOV lane entry requirements
  - Penalties for violations

- **Exits**
  - Advance notice of exit points
  - Correct lane for exiting
  - Maneuver needed to reach desired exit
  - End of HOV lane warning sign
  - Advisory exit speed on ramp
  - Advance notice of control devices at end of ramp

- **Other**
  - Speed limits
  - Advance notice of merge
  - Wrong way signs
  - Notice of atypical roadway conditions

Access to HOV lanes is provided at their termini and at intermediate locations along their length where HOV traffic can enter or exit the lanes via ramps. HOV lanes should be clearly signed with lane use restrictions, i.e., minimum person-per-vehicle occupancy requirements and vehicle type, and hours of operation. This information must be provided well in advance of the entrances to allow time for drivers to move into the proper lane. Lane use restrictions should also be provided periodically along HOV lanes to serve as a reminder to those in the lanes, and to alert new arrivals.
Information about approaching exits must be provided to the drivers well in advance for them to avoid missing the exit. Exit signing should use recognizable route numbers, street names or names of transfer facilities to identify nearby destinations. In recognition of efforts to improve the visual environment for the older driving population and drivers with vision impairments, signs that provide street and transfer facility names should be oversized to provide easiest recognition and to prevent erratic behavior in transition areas.

Signing requirements at intermediate access points are similar to those for terminal entrances and exits.

On the approaches to slip ramps, information must be provided to both the HOV lane user and the general-use lane user. Due to the proximity of the two facilities, the information may be visible to both drivers and may lead to some confusion. The signing must be designed so that the drivers on each facility are able to determine which signing applies to the HOV lanes and which applies to the general-use lanes.

Direct ramps (flyover and drop ramps) connect the HOV lanes directly to another type of facility, i.e., arterial street, frontage road, freeway, a transfer center or another HOV facility. The lack of control of access and the different directions from which traffic can approach the entrances may result in signs for the HOV lanes competing with signs for the other facility. The signing must be designed to inform the driver of the ramp location in sufficient time to make the correct maneuver.

Direct connector ramps from freeways to HOV lanes should have HOV lane guide signs, both advance and action signs (VMS or signs with flashing lights), as well as the normal HOV lane regulatory signs.

All signs should be sized in accordance with the NYSMUTCD. In some cases, it may be necessary to mount signs overhead to achieve the proper sign size. The diamond symbol should appear on all signs related to the HOV lane or HOVs. Ground-mounted signs should be located adjacent to the HOV lane to which they apply. Overhead signs should be mounted directly above the lane. Where signs are mounted on barriers, the sign panels may be skewed up to 30° to provide lateral clearance.

Signs, lane-use control signals, VMS, gates and other devices may be used at exclusive HOV lane entrances to inform drivers where access is located, when it is open for entry, and the proper direction of travel. Similar devices should also be installed at exclusive exits to prevent motorists from entering the lanes the wrong way.

The NYSMUTCD classifies signing into several categories. The categories discussed in Sections A through C below are regulatory signing, warning signing, and guide signing. Regulatory signs inform highway users of traffic regulations. Warning signs identify or emphasize particular conditions on, or adjacent to, the roadway. Guide signs provide a reasonable and realistic guidance communications system for safe and convenient highway travel.

Sections D through G discuss how signing should be applied to different types of HOV facilities.
A. Regulatory Signing

Regulatory signing should be used to inform all drivers of the restrictions and requirements of the HOV lanes, e.g., the minimum number of persons required per vehicle, the hours of operation (if appropriate), the penalty for violations, and the beginning and ending of the HOV lanes. Regulatory signing for HOV lanes should be black legend on white reflective background and rectangular in shape. The diamond symbol shall be a white reflective diamond on a black background. It should be incorporated into the sign format, at the upper left of the sign. Refer to the NYSMUTCD, §214.5 and NYCRR Title 17, Appendix A-19, Authorizations 94-1 and 94-2.

HOV occupancy should be defined in terms of "PERSON". Regulatory signing clarifying minimum person-per-vehicle occupancy requirements and vehicle type, hours of operation, direction of travel (if appropriate), and other operational restrictions should be provided at regular intervals. For HOV lanes that are not barrier-separated, regulatory signs should be located at intervals of 800 m to 1600 m. Regulatory signs on barrier-separated HOV lanes are needed at entrances and exits only. Regulatory signs located in advance of an HOV lane should be mounted adjacent to the approach roadway. Where VMS are used, the diamond symbol should be located on or above the VMS to the left.

B. Warning Signing

Warning signs alert drivers to highway conditions they should approach with caution, i.e., geometric changes or converging lanes. EXIT ONLY signs are used with EXIT signs to indicate a lane drop. Warning signs should be black legend on yellow reflective background. The diamond symbol shall be a white reflective diamond on a black background. It should be incorporated into the sign format, at the upper left of the sign. Refer to NYCRR Title 17, Appendix A-19, Authorization 94-3.

C. Guide Signing

Guide signing may be necessary to inform HOV drivers of the areas designated for access to and exit from the HOV lane. Guide signs should be white reflective legend on green opaque background. The diamond symbol shall be a white reflective diamond on a black background, incorporated into the sign format, at the upper left of the sign. Refer to NYCRR Title 17, Appendix A-19, Authorization 94-4.

HOV lanes with designated ingress/egress locations should provide guide signs on the approaches to, and at the locations themselves. Guide signing with an HOV message should be reinforced with a diamond symbol.
Drivers must be able to distinguish guidance for HOVs from guidance for general-use vehicles. If separate signs are used, the white diamond on black background shall be placed in the upper left corner of the HOV guide sign. When a single sign is used, the HOV diamond symbol shall be placed adjacent to the HOV guidance. Guide signs should be used to provide information on:

- transfer facilities destination(s) by name and distance to them
- HOV interchange destination and distance
- exit to street or freeway destination and distance

Signs should be sized in accordance with the NYSMUTCD. It may be necessary to mount signs over the lane to provide proper sizing. The diamond symbol should appear on all signs related to the HOV lane or HOVs. Ground-mounted signs should be located adjacent to the lane to which they apply. Overhead signs should be mounted over the lane. Where signs are mounted on barriers, the sign panels may be skewed up to 30° to provide lateral clearance.

D. Reversible-flow Signing

Entrances to reversible-flow lanes must be protected against wrong-way entry. Remote controlled VMS should be used to display the status (open or closed) of the lanes and gates or barriers should also be considered to provide positive control of ramp entrances. General HOV regulatory signing between terminals and access locations can often be mounted back to back, or located so that the signs for one direction of travel are not visible in the other direction. Refer to the NYSMUTCD §201.4.

E. Two-way Flow Signing

Two-way lanes should follow the general standards for preferential lane use signing specified in the NYSMUTCD. Areas of limited sight distance should be provided with VMS, lane-use control signals, or some other method of warning the motorists the HOV lane ahead is blocked. VMS should be considered for use to regulate the speed differential between the HOV lane (buffer-separated concurrent or nonseparated contiguous) and the general-use lane. Advance warning signs should be used approaching ingress and egress areas to encourage HOVs to weave into the HOV lane, and to give general-use vehicles adequate time and distance to exit the lane. Lane control signals, warning beacons or other electronic systems may be used to warn oncoming vehicles upstream of stoppages to reduce the danger of rear-end collisions.
F. Busway Signing

Busways should require little signing for the trained, professional drivers who will use them.

G. Contraflow Signing

Signing of contraflow facilities must make operational requirements clear to traffic traveling in the off-peak direction, such as the hours of operation, eligible vehicle type, which lane is the HOV lane, and direction of flow. Overhead lane control signs should be spaced to have at least one device in view of opposing traffic at all times, or at 300 m maximum intervals. Overhead lane control signals with changeable symbols or word messages should be considered. Supplemental side mounted signs should also be used wherever necessary. Where no buffer or barrier is provided, lane-use control signals should be displayed over the contraflow lane and the adjacent general-use lane.

Advance warning signs should be provided in both the peak and off-peak directions approaching the start of a contraflow lane. They should indicate the lane involved and the distance to its start. Arrows and flashers may be appropriate to move the off-peak traffic out of the borrowed lane. Signing at the end of the contraflow section should indicate the end of the HOV lane followed by lane-use control signals over each lane in the off-peak direction. VMS and side-mounted signs may also be appropriate for use, depending on the terminal treatment used.

Where space is restricted, reflectorized tubular markers should be used between the contraflow lane and the general-use lane. Movable barrier should be considered where sufficient space is available. Lowering speed limits should be considered to reduce speeds on contraflow lanes when tubular markers are used to separate HOVs from general-use traffic. Spacing of tubular markers should be close enough to discourage lane changes; 12 m maximum spacing is recommended.

24.2.10.2 Pavement Markings

All pavement markings shall conform to the NYSMUTCD and NYCRR, Title 17, Appendix A-19. The elongated diamond symbol illustrated in Figure 24-20 shall be used to designate all HOV lanes, except contraflow lanes, which should have no symbol. The symbol should be located on the centerline of the HOV lane at intervals of 150 m to 300 m.
Recommended pavement markings for HOV facilities are given in *High-Occupancy Vehicle Facilities: A Planning, Design, and Operations Manual.*

- Standard freeway lane delineation, consisting of a solid white stripe at the right edge of the HOV lane, and a solid yellow stripe at the left edge of the HOV lane, should apply to exclusive two-way flow and exclusive single lane busway HOV facilities.
- Bus lanes on exclusive two lane, one-way busways should be separated by a single broken white stripe.
- Two-way buffer-separated (concurrent) flow lanes should be delineated by a solid yellow stripe at the left edge of the HOV lane, and separated from the general-use lane by a buffer of 2 solid white lines parallel to the direction of travel. The parallel lines should be connected by solid white hatch lines for buffers less than 1.2 m wide, and by solid white chevrons for buffer widths of 1.2 m or wider. Refer to Figure 24-20.
- Nonseparated (contiguous) lanes that allow continuous ingress/egress and become general-use lanes during at least part of the day should apply standard freeway lane delineation.
- Contraflow lanes should be separated from general-use lanes by double broken yellow stripes. The edge line will be the existing edge line of the borrowed lane.
- Queue bypasses should apply the same pavement markings as are routinely applied along ramps.
Figure 24-20 HOV Lane Pavement Markings

a. HOV Lane Symbol

b. Painted Buffer Layout

c. Buffer at Ingress/Egress Transition
24.2.11 Provisions for Incident Handling and Maintenance

HOV lanes should be designed to accommodate the handling of incidents. Maintenance activities should also be considered to ensure that they can be carried out safely and with as little interruption to traffic flow as possible.

24.2.11.1 Incident Handling

Full width continuous shoulders should be provided wherever possible. Refer to the standard cross sections in Sections 24.2.4 through 24.2.9. There should be enough space for a stalled bus to discharge passengers on the wide shoulder without encroaching on the HOV lane and for other buses to pass the stalled vehicle. If the shoulder is to be used for enforcement, it should be 4.2 m wide.

If barrier-mounted glare screens are being considered, the need for them should be compared to the benefit of emergency/enforcement personnel having access across the barrier. Additionally, enforcement is enhanced by better visibility over barriers with no glare screens. On the other hand, glare screens can help prevent incidents, which may reduce the need for emergency access.

Median emergency crossovers should be located and designed in accordance with Chapter 5, Section 5.8.13 of this Manual. Prior to selection of the crossover locations, the designer should consult with the Regional Highway Maintenance Engineer as prescribed in Chapter 5. Discussions should also be held with local emergency services and law enforcement agencies, and the NYS Police, when appropriate.

Timely detection of incidents is vital to minimizing disruption to the operation of the lanes. Closed-circuit television and vehicle flow detectors are two examples of methods that may prove useful to facility operators to improve incident detection. Further, the information they provide could be relayed to upstream traffic by way of VMS and highway advisory radio to notify drivers of the downstream conditions and give them the opportunity to take an alternate route.

Surveillance and communications systems can be considered the forerunners of intelligent transportation systems technology improvements. Even if surveillance and communications are not required on a project immediately, provisions for future installation of surveillance and communications equipment should be considered in urban project designs. The following actions, adapted from High-Occupancy Vehicle Facilities: A Planning, Design, and Operation Manual, are typical of the provisions that should be considered:

- Installation of 3 NPS conduits; normally two are sufficient. They should be placed under or adjacent to the right shoulder in both directions. They should not be placed under barrier or buffers.
- Installation of conduit vault openings within longitudinal box beam bridge structures and abutments.
- Installation of induction loops in Portland cement concrete pavement at intervals of 450 m to 900 m. Up to three loops in a series should be applied, even if all are not ultimately used.
These provisions are not recommended for projects located in rural areas.

For further information on incident management, refer to Section 24.5.6.

24.2.11.2 Maintenance

The maintenance needs of HOV lanes are generally no different than those of any general-use facility. By taking certain factors into consideration, maintenance activities and their effect on the HOV facility’s operation may be reduced. The following factors, adapted from *High-Occupancy Vehicle Facilities: A Planning, Design, and Operation Manual*, are among those that should be considered:

- Median crossovers for maintenance and emergency use should be provided in accordance with Chapter 5, Section 5.8.13 in this Manual.
- Drainage inlets should not be located in a travel lane or under barriers.
- Gaining access to VMS, lighting, and surveillance equipment should not block a travel lane.
- Adequate width should be provided for snow storage and removal. Refer to Chapters 3 and 5 in this Manual for more information.
- Maintenance of enforcement areas should be provided on a routine basis to minimize debris accumulation, which might otherwise result in damage to HOVs and enforcement vehicles.

The appropriateness of these factors should be determined on a project-by-project basis.

24.2.12 Highway Drainage

Highway drainage is an important consideration in the design of HOV facilities. Highway drainage features should protect the HOV facility, adjacent roadway(s), adjacent landowners, and the traveling public while maintaining water quality and protecting other environmental resources. The physical type of HOV facility proposed will influence how the pre-project drainage patterns will be altered, and the extent of the drainage analysis necessary to accommodate these altered drainage patterns. Refer to Chapter 8 in this Manual for drainage design criteria and other considerations specific to highway drainage.

The location and placement of inlets is dependent upon the physical type of facility to be provided, the horizontal and vertical alignment of the existing freeway, and the cross sections of the new HOV facility and the existing general-use lanes. When the median is limited in width, it may be necessary to construct a retaining wall between opposing HOV lanes on superelevated horizontal curves. Roadway runoff can be collected as shown in Figure 24-21a. Another alternative is to construct standard crown HOV lanes which drain to the right shoulder where a closed drainage system can be installed to collect the runoff at the barriers on each side, from both the HOV lanes and the freeway lanes, as shown in Figure 24-21b. When the cross slope of the existing general-use lanes is continued across, and to the center of the HOV lanes, drainage can be collected at the center, as shown in Figure 24-21c. It will be necessary to provide inlet structures along the barrier between
Figure 24-21 Alternative Drainage Treatments for Barrier-Separated Two-Way HOV Lanes

a. Drainage on Banked Curves

b. Drainage from Single Crown

c. Drainage Into Median

Source: Adapted from PBQD Manual
the freeway and HOV lanes in areas where the freeway pavement drains toward the center.

Drainage structures, interconnected with storm drain, can be located beneath the median barrier. Inlets should be placed at the edges of the barrier to collect runoff, but not be located in a travel lane or under barriers.

24.2.13 **Lighting**

Lighting of HOV lanes, including the mainline, the origin, terminal and intermediate access ramps, ingress/egress weave lanes, enforcement areas, and emergency median crossovers, should be in accordance with the NYS *Policy on Highway Lighting* and Chapter 12 of this Manual. Consideration should be given to providing appropriate lighting levels in areas adjacent to concrete median barriers.

24.2.14 **Lane Conversions**

Three alternatives for adding HOV lanes are 1) constructing a new lane, 2) restriping an existing roadway for reduced lane and/or shoulder widths, and 3) taking an existing general-use lane and converting it to HOV use. Constructing a new HOV lane is usually the most costly method and may not be achievable due to right of way constraints. Restriping, while less costly, may compromise safety and restrict access by emergency vehicles. The lane conversion method has the capability of producing considerable construction cost savings, but has proven, in many cases, to be an unpopular alternative in the eyes of the general public. Several lane conversions have ultimately been revoked, and the lane returned to general use due to negative public opinion.

Converting general-use lanes to HOV lanes should not be considered on freeways with less than 6 lanes and is, therefore, not an acceptable alternative for many NYSDOT facilities since they do not have the excess capacity and the volume of multiple occupancy vehicles necessary for a successful lane conversion. Conversion of general-use lanes to HOV lanes on these facilities would severely impact the operation of the remaining general-use lanes. Lane conversion should be evaluated in corridor studies and/or major investment studies for facilities with 6 or more lanes.

Surveys of freeway users' opinions of HOV lanes and lane conversions have found that public involvement and support are critical to the success of lane conversion projects. Considerable marketing will be required to convince users to consider HOV lane conversions as an acceptable alternative. For further information on lane conversion survey results, refer to *Statistical Assessment of Public Opinion Toward Conversion of General-Purpose Lanes to High-Occupancy Vehicle Lanes; Public Attitudes Toward Conversion of Mixed-Use Freeway Lanes to High-Occupancy-Vehicle Lanes; I-90 Lane Conversion Evaluation*; and *Converting a General Purpose Lane to an HOV Lane: The Interstate 90 Project.*
24.3 COMMUTER TRANSFER FACILITIES

The AASHTO Guide for the Design of Park-and-Ride Facilities defines transfer facilities as those parking facilities where individuals rendezvous to utilize carpoools, vanpools, buses and/or public transit for group travel to their destinations. Park-and-ride (P&R) lots, park-and-pool (P&P) lots, employment center parking lots, on-line (located within the HOV facility right of way), and off-line (located off, but near the HOV facility right of way) transit stations, and bus stops are examples of transfer facilities.

During the scoping process, the HOV corridor under consideration should be identified as one of two basic types: radial or suburban systems. The type of corridor may influence the collection and distribution facilities needed to complement the mainline HOV lanes. The characteristics of corridors described below are found in High-Occupancy Vehicle Facilities: A Planning, Design and Operation Manual.

Radially oriented treatments serve a traditional central business district, or multiple activity centers, clustered in a hub surrounded by outer residential regions. There is usually some pronounced directionality for demand, and a peak direction is distinguishable. These HOV treatments typically (but not always) enhance conventional bus transit, since collection and distribution can be more effectively served and the productivity of the transit vehicle improved. Trips can be more easily aggregated between common trip origins and destinations. Radially oriented HOV lane facilities include such support facilities as:

- convenient bus stops and bus lanes on arterials leading to and within the central business district,
- P&R lots for bus transit users,
- P&P lots for vanpoolers and carpoolers,
- preferential ramps accessing HOV lanes and support facilities, and
- locally sponsored rideshare programs.

In a suburban orientation, trips are not as focused on a single activity center or closely concentrated area of employment. Trip characteristics are more dispersed, and there is no identifiable peak direction. Candidate freeways that exhibit this characteristic are circumferential loops, outlying segments of some radially oriented routes, and freeway networks that have no central urban focus. HOV treatments have been recognized as effective in addressing suburban congestion in this setting. A suburban orientation does not necessarily require conventional bus transit for success. Ridesharing (carpools and vanpools) can also succeed. HOV planning warrants in some states do not as yet recognize a suburban market orientation, but this characteristic is becoming increasingly common in congested corridors. System support facilities for suburban-oriented HOV lanes serving multiple activity centers include:

- greater reliance on P&P lots for carpooling and vanpooling near trip origins,
- ridesharing programs,
- preferential parking facilities near activity centers,
- convenient ingress/egress provisions with the HOV lane, and
- complementary zoning and building permit demand reduction policies and practices.
Where the need for transfer facilities is established, and construction is warranted, the market area should be defined and an analysis done to estimate the parking demand for the area. From that, the type of facility to be provided should be determined, the size estimated, and potential location sites evaluated. Following site selection, layout and design can begin. The design should be done with local agency and transit authority involvement and in compliance with all local standards, requirements and regulations. For general guidance on planning for transfer facilities, refer to High Occupancy Vehicle Facilities: A Planning, Design and Operation Manual; National Cooperative Highway Research Program (NCHRP) Report 155 Bus Use of Highways: Planning and Design Guidelines; and the Transportation Research Board (TRB) Special Report 209 Highway Capacity Manual.

P&R lots generally serve residential commuters who choose to change from low- to high-occupancy travel modes to reach their final destinations. In most cases, that means transferring from an automobile to line-haul (the portion of a commute trip that is express [nonstop] between two points) transit or rail system. Commuters also travel to P&R lots by local bus, bicycles or motorcycles, or as pedestrians. In areas where bus or rail services are not available, P&P lots may be created for carpool and vanpool operations. There are also P&R lots served by bus and rail services that allow the use of part of the facility for carpool and vanpool formation.

Transit transfer stations may be located on or off HOV lanes, where passenger transfers occur from transit, express, local and community transportation services, as well as transfers from auto, bicycle, and pedestrian modes. They are the link between multiple origin points and multiple destination points which maximizes the number of opportunities available to passengers. Transfer stations may be located at major activity centers, at outlying points in residential areas, or in the CBD of a heavily urbanized area. The transfers are interruptions in the passenger’s journey, so the design should ensure that they are as efficient, dependable, safe, and convenient as possible. Properly designed transfer stations will complement the HOV system of which they are a part.

No universal design criteria have been established for transfer stations due to the variability in needs and functions from project to project. Design guidelines are available in various references, including High-Occupancy Vehicle Facilities: A Planning, Operation and Design Manual; Revised Manual for Planning, Designing, and Operating Transitway Facilities in Texas; NCHRP Report 155 Bus Use of Highways: Planning and Design Guidelines; and The Location and Design of Bus Transfer Facilities.

As with HOV lanes, the design of transfer facilities should be sensitive to the operational needs determined during the scoping phase of project development. Poorly designed transfer facilities can cause delays in operation resulting in reduced time savings and loss of users, which could ultimately affect the entire HOV system.

Access to transfer facilities must be provided to persons with disabilities and the elderly in accordance with Chapter 18 of this Manual, and the Americans with Disabilities Act Accessibility Guidelines for Buildings and Facilities (ADAAG).

This section provides guidelines for the design of the more common types of transfer facilities, including park-and-ride, park-and-pool, on-line and off-line transit stations, and bus stops.
24.3.1 Park-and-Ride Lots

The Department is empowered to obtain property for, and construct P&R lots, by Section 10-39 of the New York State Highway Law and by Title 23 of the United States Code, Highways, Sections 137 and 142. The Federal-Aid Policy Guide, 23 CFR, Part 656 and Part 810 contains the federal guidelines for these facilities.

The New Jersey Transit Corporation has established guidance that recommends that P&R facilities, regardless of size, should achieve the following objectives:

- provide access to and encourage the use of mass transit,
- provide adequate parking capacity to meet existing and future needs,
- be recognized as an element of a park-and-ride network,
- provide an attractive, visible, high-quality environment that meets modern standards of comfort, safety, security, and access for persons with disabilities,
- be identified for ease of location,
- minimize the maintenance and operation burden on the responsible municipality or authority,
- provide an extensive display of transit system information, and
- be compatible with surrounding land uses and community needs and activities.

The High-Occupancy Facilities: A Planning, Design and Operation Manual maintains that P&R service for radially oriented facilities is justified when the central business district employment level reaches or exceeds 20,000, and/or commercial development exceeds 929,000 square meters (m²) in 2.6 square kilometers (km²). P&R lots should be provided at a minimum distance of 8 km and preferably 16 km from the central business district. New or expanded express bus service should be considered in conjunction with the opening of an HOV lane. Dedicated HOV ingress/egress ramps for high-volume passenger movements are strongly encouraged.

P&R facilities are generally categorized by their location relative to the activity center they serve, and the level of transit service provided, and the exclusive nature of the operation. Locations known as remote, local, and peripheral, and uses known as shared or exclusive are the common names given to P&R lots. The level of transit service provided to the P&R facilities is generally related to their location, as described below.

Remote P&R lots generally provide a location for travelers from communities outside major employment areas to change from their mode of travel to express transit. Their locations are rather distant from the final destination, from 7 km to 50 km, depending on the size of the community, but relatively close to the trip origin. This serves to make the travel time as short as possible. It is accomplished by being located adjacent to or near freeways or HOV lanes.

Local P&R lots are located along and at the ends of bus routes, closer to the final destination than remote lots. They serve various neighborhoods at those locations and are usually smaller than the remote P&R lots. They are served by local non-express transit.
Peripheral P&R lots are located at the edge of an activity center or central business district. They act as overflow lots by intercepting vehicles before they enter the area. In contrast to the other types of lots, the non-transit portion of the trip to peripheral lots is the longest, and the part by transit is the shortest. Transit service is normally provided by local or shuttle bus.

Exclusive lots are designed, built and operated specifically as P&R lots. They are generally medium to large in size, provide passenger amenities to attract users, and are served by frequent peak period transit service. Design effort should address all aspects of the facility, as described in this section. Shared-use lots are usually existing lots whose primary function is to serve local activity centers such as shopping malls, municipal buildings, sports arenas, etc. Generally, they are located along transit routes, and their P&R areas are usually smaller than exclusive P&R lots. Shared lots are normally on private property and require no design effort by the Department.

While shared-use lots should not be excluded from consideration by the designer, the main focus of this section will be on the design of exclusive lots. For additional information on shared-use lots, refer to Section 24.3.1.13.

### 24.3.1.1 Facility Demand

The size and type of P&R facility appropriate to a specific site is primarily determined by the level of P&R demand. According to *High-Occupancy Vehicle Facilities: A Planning, Design, and Operation Manual*, techniques for demand estimation for P&R facilities vary from extremely simple to relatively complex. The scale and complexity of the project should govern the level of effort expended on planning the facilities. The same manual overviews several relatively simple techniques which use commonly available data, including:

- Demand observation,
- Market area population,
- Mode split,
- Regression analysis, and
- The Institute of Transportation Engineers model.

NCHRP Synthesis 213 describes the factors that should be considered in estimating facility demand, as follows:

- daily demand fluctuation,
- maximum walking distance,
- transit service,
- ridesharing use,
- access, and
- land availability.

The projected average daily demand should be the starting point for sizing P&R lots, and should generally be expected to fluctuate very little, except during severe weather. However, the facility should be designed to accommodate additional vehicles. A 10% increase is suggested as a realistic factor to ensure that adequate parking is available.

The size of a lot may be constrained by the distances people must walk to and from their vehicles. It is best that the distance be kept within 120 m to 195 m. Factors influencing walking distances may include whether walkways are sheltered and the frequency of transit services.

Bus headways of 5 min to 10 min appear to be common from larger lots associated with HOV lanes or other dedicated facilities. Smaller lots served by one or two buses during each peak period are not normally governed by headways.

Walking distances in lots oriented only toward ridesharing activities, (carpooling and vanpooling), are less of a concern than with facilities served by buses. This is because carpoolers and vanpoolers will usually meet at a prearranged location, rather than walking to a central platform or waiting area. Lot size will depend on the demand projections, available space, and design constraints.

The capacity of roadways and intersections adjacent to the P&R site will also influence the size of the lot. To address potential concerns, a site-specific traffic impact analysis should be conducted as part of the lot selection and lot sizing process. This analysis should include a review of existing capacity and levels of service, as well as an estimate of the impact of the P&R lot. This analysis will identify whether there is a need to improve the roadway system to accommodate the projected demand.

A key consideration in the sizing of a P&R facility will be the amount of available land, the purchase or lease costs, and development costs.

In addition to the number of parking stalls, demand levels will also determine the extent and complexity of the internal circulation system, maintenance, security, and amenity requirements, and the need to insulate the facility from adjoining facilities.
24.3.1.2 Site Selection

P&R facilities improve transit service and operation performance by focusing demand near high-capacity roadway interchanges. Increased passenger loads collected over fewer boarding points can justify the levels of express service required to attract commuters, thereby making them willing to drive to reach the transit service. To intercept automobile trips and facilitate modal transfer with minimal delay, facilities must be properly located within the express bus commutershed, the regional highway system, and the transit network. In *High-Occupancy Vehicle Facilities: A Planning, Design, and Operation Manual*, the following guidelines are recommended for consideration in locating P&R facilities during the scoping and design phases:

- Lots will generate the greatest use in travel corridors that experience high levels of traffic congestion. As a general guide, as average traffic per freeway lane approaches about 20,000 vehicles per day, utilization increases significantly.
- Lots should be located in advance (upstream) of the more intense traffic congestion. Potential patrons should have the opportunity to select the alternative prior to encountering the more heavily congested peak-period traffic.
- The most successful lots tend to be located some distance from the user's ultimate destination. For P&R users this distance is at least 6 km to 8 km, and preferably 15 km. P&P demand is conducive to even longer trips of 15 km to 30 km. (Few successful lots have been located as far as 45 km from the destination.)
- Since relatively few patrons backtrack to use a lot, the lot should be located so that the area immediately upstream generates sufficient travel demand to the activity center intended to be served by transit.
- As the total population in the market area increases and as the patronage of the population working in the activity center served by the lot increases, so will use. The magnitude of development of the activity center is an important determinant of potential utilization.
- Both accessibility (a measure of the ease with which potential users can get to the general area of the lot) and access (a measure of how easily users can get into and out of the specific lot site) are associated with a parking facility's ability to attract potential users. Lots should be developed with both good access and good accessibility.
- If the current number of spaces available in an operating lot are sufficient to handle demand from a given area, other proposed lots in that same travel corridor should not overlap the market area (i.e., no closer spacing than 6 km to 8 km).
- To minimize development costs, the site should be flat and well drained. Compatibility with adjacent land uses should also be considered and environmentally sensitive areas avoided wherever possible.
- Space should be available for expansion. Initial demand may be underestimated and could increase over time.
- Preferably, a lot should be located on the right side of the roadway to conveniently intercept inbound traffic. However, successful lots have been developed that were not located in this manner. Local access conditions generally provide the greatest influence.
- To partially address security concerns, lots should not be located in high crime areas or have design features attractive to criminal activity. The lot should be clearly visible from the street, provide lighting and preferably security fencing, and have minimal line of sight obstructions. The possibility of jointly developing a lot with other services can contribute to security, and may be worth of consideration.
24.3.1.3 Interface with Local System

The traffic that will be generated by the P&R lot will have some effect on the local highway system. To assess the impacts, AASHTO’s Guide for the Design of Park-and-Ride Facilities recommends considering:

- easy maneuverability for the specific categories of vehicles allowed on the lot,
- minimizing potential increase in traffic congestion on local roadways, including expressways, and
- safety at access points and adjacent access roadways.

Current and projected design year traffic volumes, developed for the Expanded Project Proposal with the new P&R lot in place, should be used to determine the capacity of the existing highway and the improvement needs of the local highway and traffic signal systems.

Ingress and egress must be provided for automobiles and transit vehicles. In addition, access for bicycles and pedestrians should be considered. All users should be able to enter and exit safely and easily. Access points should be located in the vicinity of freeway or expressway interchanges, but not so close as to cause, add to, or be delayed by congestion on the local system, freeway or expressway. Exclusive bus-only entrance and exit connections may expedite the movement of transit vehicles. Access points on local collectors that intersect with arterials may be suitable for automobile traffic.

In situations where bus passenger loading/unloading areas may be located directly on the local streets, the proposed operation should be considered in the assessment of impacts on the local system.

24.3.1.4 Interior Lot Layout

A. Lot Capacity

The number of parking stalls should be based on the projected design year demand volumes from the Design Approval Document. A design load factor (the number of autos simultaneously parked [long term] divided by the total number of parking spaces) for P&R lots should not exceed 70% to 80%. That gives commuters a reasonable chance of finding a parking space. Where adequate overflow spaces exist on nearby local streets or lots, the design load factor can be increased to 80% to 90%.
B. Entrances and Exits

The number and type of entrances and exits for automobiles should be based on the projected design year lot capacity. There should be at least one entrance and one exit in lots with a capacity of up to 300 autos. For capacities exceeding 300 autos, two entrances and two exits should be provided. The demand should not exceed 300 vehicles per hour, per entrance or exit. Their locations are determined by the character of the adjacent streets, the lot shape and the desired interior lot circulation. It is preferable to have multiple entrances and exits to access different streets, if possible. Ideal circulation into the site would separate automobile traffic, bus traffic, bicycle traffic, and pedestrian traffic, thus easing the access for each.

Guidelines for the location of entrances and exits for automobiles and buses are contained in the AASHTO Guide for the Design of Park-and-Ride Facilities. Driveways should be designed in accordance with Chapter 5, Section 5.8.11 of this Manual. The design should emphasize safe access for both automobiles and transit vehicles. Entrances and exits used by buses should be designed for the AASHTO BUS design vehicle, or the local transit operator buses, whichever are larger.

Pedestrian access to P&R facilities should be provided by walkways from adjacent streets to passenger loading areas. Walkways should be as direct as possible to discourage pedestrians from using drives meant for vehicles, or to minimize the number of pedestrian crossings at circulation roads. Pedestrian walks should be adequately signed and marked. Pedestrians should have right of way over vehicles at all pedestrian/vehicle crossings. AASHTO’s Guide for the Design of Park-and-Ride Facilities recommends:

- Pedestrian crossings should have good visibility for both pedestrians and drivers. Curbs at all marked crossings between the parking facilities for persons with disabilities and loading zones should be ramped.
- Refuge or pedestrian islands should be provided where street widths or large volumes of pedestrians and vehicular traffic make it difficult for pedestrians to cross the street safely. Refer to Chapter 18, Section 18.6.6.3D for additional information on refuge islands.
- Midblock pedestrian crosswalks should be avoided; pedestrian crosswalks should be located at intersections. Drivers do not expect pedestrians at midblock, signals are not usually warranted, and visibility may be restricted due to parking or bus loading and unloading along the curbs.
- Ramps, pedestrian walkways, and facilities for persons with disabilities must conform to ADAAG requirements. Refer to Chapter 18 in this Manual for additional information on pedestrian facility design.
C. Parking Layout

Consideration should be given to including provisions for loading and unloading bus passengers, kiss-and-ride (K&R) passengers (commuters who are dropped off in the morning and picked up in the evening), taxi passengers, cyclists, and pedestrians, and to providing parking for buses, K&R, taxies, bicycles, motorcycles, and long term park-and-ride parking. These spaces should be located so the time required to transfer to the bus loading area is as short as possible.

The bus loading/unloading area is the focal point of the P&R lot. The internal parking areas should be oriented toward it, and their proximity to it should be prioritized as follows:

7. parking for persons with disabilities,
8. bicycle parking,
9. motorcycle parking,
10. K&R and taxi parking (short term parking), and
11. P&R parking (long term parking).

The number of parking spaces reserved for persons with disabilities shall be based on the total number of parking spaces in the lot. Refer to ADAAG Section 4.1.2 (5) (a). Accessible parking should be located adjacent to the bus shelter with direct access to the shelter and the bus loading/unloading area. Wheelchairs should not be required to cross internal traffic routes or behind parked cars. Accessible parking stalls shall be 2440 mm wide and 6096 mm long with a 2440 mm wide access aisle between spaces. Refer to Standard Sheet M608-4.

Bicycle parking demand should be estimated, and where necessary, provision should be made for parking and/or storage of bicycles. The area should be located as close as possible to the passenger loading/unloading area without disrupting pedestrian flow or facility operation. Refer to Chapter 18 of this Manual, the AASHTO Guide for the Design of Park-and-Ride Facilities, and the NYSDOT Pedestrian and Bicycle Facility Scoping Guide for information on the design of bicycle parking areas. Refer to Section 24.3.1.9 B for information on bicycle parking facilities.

Motorcycle parking demand should be estimated, and where necessary, provisions should be made for parking of motorcycles. The area should be as close as possible to passenger loading/unloading areas without disrupting pedestrian flow or facility operation. The area should be well lighted to reduce the risk of theft and vandalism. Motorcycle stalls should be a minimum 1000 mm wide and 2000 mm long measured at 90° to aisles that are a minimum 1500 mm wide.
K&R parking stalls should be close to the bus loading/unloading area and have easy access from the interior circulation routes. They should face the bus loading/unloading area if possible. K&R operates best with one-way drive through stalls at an angle to the aisle. The stalls should be 3.0 m wide, and laid out at a 45° angle between 4.6 m wide aisles spaced 6.1 m apart. Lots served by 12 buses per peak hour or less can normally operate satisfactorily with the K&R discharge and loading area at the bus loading/unloading area. For lots utilized by more than 12 buses per peak hour, the K&R discharge and loading area should be separate from the bus loading/unloading area. K&R parking stalls and discharge and loading areas may also be used by taxies.

The components of P&R parking include stalls, aisles, and combinations of the two, called modules. A complete module consists of one access aisle and the row of parking stalls that borders on each side of the aisle. A partial module is where the aisle serves only a single row of parking. The dimension of a complete module is obtained by adding the aisle width plus the stall depth on both sides. The dimension of a partial module is dependent upon the boundary condition of the module. Where car bumpers contact a wall or fence, the maximum partial module dimension is required. Where the boundary is a curb or wheel stop, the bumper overhang must be considered. For 90° pull-in (as opposed to back-in) parking, a minimum bumper overhang of 0.76 m should be provided.

The recommended arrangement is to interlock the stalls in a bumper-to-bumper layout as shown in Figure 24-22. The bumpers of cars in abutting stalls are next to one another but offset from those in the stalls on either side. This arrangement maximizes the use of available space and provides easier traffic circulation when the parking angle is less than 90°.

Aisle width varies according to stall width and parking angle. Aisles for 90° parking should be two-way and one-way aisles should be used for lesser angles. Minimum aisle widths for one-way operation shall be 4.6 m (45° parking), and 8.0 m for two-way operation, (90° parking). Figure 24-22 shows standard 2.7 m wide stalls (measured perpendicular to the side stall lines) for parking at 90°, 75°, 60° and 45° angle parking.

While the most appropriate parking layout is site dependent, rectangular sites are best for maximizing capacity, maneuverability, and circulation. By arranging access aisles parallel to the longer site dimension with parking spaces along both sides of the access aisles, the efficiency of space use is maximized. The 90° parking layout provides the most efficient use of space and allows two-way aisles. The wider aisles of 90° parking are more inviting than the narrower aisles of the lesser-angle layouts. The Traffic Engineering Handbook describes other advantages of 90° parking.

Angular parking provides easier maneuverability to and from the stall than 90° parking. The Traffic Engineering Handbook describes other advantages and disadvantages of parking layouts less than 90°:

The arrangement of parking stalls and the location of the bus loading/unloading area should be designed so that walking distances are minimized. A layout which limits walking from 120 m to 195 m is preferable. A distance no greater than 300 m is considered an acceptable maximum. Since aisles also serve as pedestrian walkways, the rows of parking stalls should
be generally parallel to the direction the pedestrian must travel between the parking stall and the bus loading/unloading area. With this arrangement, the pedestrian will not be forced to walk between parked cars and the number of vehicle travel aisles to be crossed will be minimized.

The use of bumpers and excessive use of islands should be avoided since they also hinder snow removal operations. Islands should accommodate needed channelization and placement of light poles and should be large enough to accommodate appropriate landscape plantings. Channelizing islands are suggested at the ends of rows of parking stalls to better define the row alignment and to maintain a clear sight distance area for drivers and pedestrians at the point where the aisles intersect circulation routes. They also limit parking encroachment into cross aisles, provide space for storage of limited quantities of snow, and protect directional signing.
Figure 24-22 Recommended Minimum Dimensions for 2.7 m Wide Parking Stalls

\[ X = \text{Stall not accessible in certain layouts} \]

<table>
<thead>
<tr>
<th>Dimension (meters)</th>
<th>On Diagram</th>
<th>Angle (a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stall width, parallel to aisle</td>
<td>A</td>
<td>3.9</td>
</tr>
<tr>
<td>Stall length of line</td>
<td>B</td>
<td>7.1</td>
</tr>
<tr>
<td>Stall depth to wall</td>
<td>C</td>
<td>5.0</td>
</tr>
<tr>
<td>Aisle width between stall line</td>
<td>D</td>
<td>4.6</td>
</tr>
<tr>
<td>Stall depth, interlock</td>
<td>E</td>
<td>4.4</td>
</tr>
<tr>
<td>Module, wall to interlock</td>
<td>F</td>
<td>14.0</td>
</tr>
<tr>
<td>Module, interlocking</td>
<td>G</td>
<td>13.4</td>
</tr>
<tr>
<td>Module, interlock to curb face</td>
<td>H</td>
<td>13.4</td>
</tr>
<tr>
<td>Bumper overhang (typical)</td>
<td>I</td>
<td>0.6</td>
</tr>
<tr>
<td>Offset</td>
<td>J</td>
<td>1.9</td>
</tr>
<tr>
<td>Setback</td>
<td>K</td>
<td>3.1</td>
</tr>
<tr>
<td>Cross aisle, one-way</td>
<td>L</td>
<td>4.3</td>
</tr>
<tr>
<td>Cross aisle, two-way</td>
<td>-</td>
<td>7.3</td>
</tr>
<tr>
<td>Interlock offset</td>
<td>M</td>
<td>2.7</td>
</tr>
</tbody>
</table>

Adapted from AASHTO P&R Guide

5/4/98 §24.3.1.4
D. Bus Loading and Unloading Area

The area of the P&R lot designated for passenger loading and unloading should provide convenience and security for the passenger and a minimal maintenance and operational burden on the responsible municipality, authority, or agency. The design of the area should be closely coordinated with the Regional Landscape Architect.

The bus loading/unloading area can be located at the perimeter of the lot, accessed directly from the street or the lot, or located at or near the center of the lot. Refer to Sections 24.3.5 and 24.3.6 for more information on curbside bus stops and bus turnouts. Street side bus loading/unloading areas may provide a time savings because the bus would not have to enter, circulate through and exit the lot, which may make it suitable for small lots. In a large lot, where the distance from the farthest parking stall to the Street side location would exceed 300 m, a layout with an interior bus loading/unloading area may be more appropriate.

It is recommended that the bus loading/unloading area be separated from other loading and discharge areas when bus volumes exceed twelve buses per peak hour. The area should provide for right side loading and unloading and be located so that pedestrian/vehicle conflicts are minimized or prevented altogether. A shelter over the bus loading/unloading area should be provided at P&R lots, based on consultation with local transit providers.

The number of bus bays will depend on the passenger demand, bus routing, the headways on the routes, and the number of bus companies using the lot. A reasonable minimum number is 2. As a guide in determining the capacity of a single bus bay, it is estimated to take 5 minutes to load and 3 minutes to unload a single-door 60 passenger bus. Consideration should be given to furnishing additional bus bay area to accommodate future increases in bus volumes.

The dimensions of the 12.1 m BUS design vehicle should be used to establish the turning radii unless the local buses are a larger size or different type. Refer to Figure II-3 in the AASHTO Policy on Geometric Design of Highways and Streets for turning radii. Bus parking stalls may be the parallel type or sawtooth type. The sawtooth type is appropriate for loading more than two buses at a time. Typical bus bay layouts can be found in the AASHTO Guide for the Design of Park-and-Ride Facilities, Figure II-8, and Figures 24-26 and 24-27 in this chapter.

E. Interior Traffic Movement

One-way bus circulation within the lot is more direct and avoids conflict. Bus routes within the lot should permit safe, convenient and fast circulation between entrances and exits and the bus loading/unloading area. Usually this will be provided by locating the bus loading/unloading area at the front of the lot. Generally, bus traffic and automobile traffic should be kept from using the same internal routes, if possible. Further, buses should not be forced to circulate through automobile parking aisles. For P&R lots located at the end of bus routes, consideration should be given to providing a bus layover area near the approach to the bus loading/unloading area.
The layout of interior automobile circulation routes and parking stalls will depend upon the shape and size of the lot, the entrance and exit locations and the location of the bus loading/unloading area. One-way circulation should be in a counterclockwise direction. Less space is required but signing is necessary to prevent traffic conflicts and confusion. Long term and short term parking aisles can be either one-way (angle parking) or two-way (90° parking). Two-way traffic flow eliminates the problem of signing, traffic conflicts and confusion but takes more space.

K&R parking should be one-way through stalls to accommodate passenger arrival and drop-off and passenger pick-up. Two-way bicycle paths should be provided separate from the automobile and bus routes. The Regional Traffic Engineer and the Regional Landscape Architect can provide valuable assistance regarding the interior layout and should be consulted early in the development of the project.

In all cases, an adequate length or queuing must be provided within the parking lot to prevent backup of entering vehicles onto the adjacent highway. Also, when feasible, an adequate queuing length should be provided within the lot at the approach to the exit to prevent blocking of parking stalls. A continuous interior circulation route is desirable so that a vehicle searching for a parking space can easily maneuver within the lot. Where space is available, this should be provided by a continuous circulation route around the periphery of the lot. Long, dead-end aisles should be avoided. Refer to the AASHTO Guide for the Design of Park-and-Ride Facilities for a list of further considerations on interior traffic movement.

F. Channelizing Islands

Islands in entrances and exits, and within the parking lot should be designed in accordance with Chapter 5, Section 5.10.4 of this Manual. Islands within the parking lot should have a 0.6 m offset from the edge of interior circulation routes. No offset should be provided from the edge of aisles and parking stalls.

Islands in the entrance and exit area shall be paved in accordance with Chapter 5, Section 5.10.4.9 of this Manual. Islands within the parking lot should either be planted consistent with landscaping needs or paved where no special treatment is required.

G. Walkways

Walkways leading to the bus loading/unloading area should be accessible to persons with disabilities, and as direct and safe as possible, with a minimal number of crossings of vehicle routes. Raised sidewalks should be provided at and on approaches to the bus loading/unloading area, and between rows of cars to aid pedestrian flow. However, the potential for problems associated with snow removal, drainage, and maintenance should be considered before installing raised sidewalks within the parking lot.
Sidewalks for use by the general public shall be a minimum of 1.525 m wide. At curbed exits and entrances and along the edge of curbed parking lots, the sidewalk width shall be measured from the back of the curb. Where significant pedestrian traffic is anticipated and where continuous pedestrian facilities are available, such as sidewalks on the adjacent streets, paved sidewalks should be placed along the exit and entrance roadways to provide access to the bus loading/unloading area. Sidewalk design must include sidewalk curb ramps for persons with disabilities.

The minimum width of the bus loading/unloading platform should be 3.66 m, or the width of the adjacent walk plus 2.1 m, whichever is greater.

For further details on sidewalk design see Chapter 18, Section 18.6 and Chapter 3, Section 3.2.11 in this Manual.

24.3.1.5 Pavement and Shoulders

Entrances and exits and interior roadways used by buses shall have minimum 3.6 m lane widths. Interior roadways with curves shall be widened in accordance with Chapter 2, Table 2-7, Lane Widths for Ramps and Turning Roadways. Widths shall be appropriate for passing a stalled vehicle.

For uncurbed entrances and exits, it is recommended that 1.2 m wide shoulders be provided at the same thickness as the adjacent pavement.

Where bicycle paths are provided, the width of two-way paths should be at least 3.0 m wide. Curves shall be in conformance with AASHTO's *Guide for the Development of Bicycle Facilities*, Table 1 Minimum Radii for Paved Bicycle Paths. For additional information, refer to Chapter 18, Section 18.7.8 of this Manual.

The pavement thickness design guidelines for P&R lots are as follows:

A. Hot-Mix Asphalt (HMA) Pavement

1. Automobile Areas

HMA pavement thickness should be 100 mm (40 mm top course over 60 mm binder course) over 300 mm select subbase (subbase thickness requirements may be modified by the Regional Geotechnical Engineer based on local conditions).

2. Bus Areas

HMA pavement thickness should be 155 mm (40 mm top course over 40 mm binder course and 75 mm base course) over 300 mm select subbase (subbase thickness requirements may be modified by the Regional Geotechnical Engineer based on local conditions). See note below.
B. Unreinforced Portland Cement Concrete (PCC) Pavement

1. Automobile Areas

PCC pavement thickness should be 125 mm over 150 mm select subbase (subbase thickness requirements may be modified by the Regional Geotechnical Engineer based on local conditions).

2. Bus Areas

PCC pavement thickness should be 150 mm over 150 mm select subbase (subbase thickness requirements may be modified by the Regional Geotechnical Engineer based on local conditions). See note below.

Note: In areas of a P&R lot that may be exposed to vehicle loading heavier than that for which it is intended, (e.g., snow removal or maintenance equipment) the pavement should be designed commensurate with the heavier loading. Assistance with determining the appropriate pavement thickness is available from the Geotechnical Engineering Bureau.

24.3.1.6 Drainage and Snow Removal

P&R lots should be designed to provide a well-drained surface and subsurface. Drainage system design should take into consideration the effect of overflow relief on features located on and/or adjacent to the site (e.g., buildings, parking lots, etc.). Where there are no features, or where overflow relief is available that will protect those features, drainage systems should be designed for a 10-year design storm frequency. Where no overflow relief is available, a 50-year design storm frequency should be used.

Stormwater inlets should be located in areas where pedestrians do not walk or stand, such as along parking stall interlocks (see Figure 24-22). Stormwater inlets should be located so that surface runoff will not travel more than 50 m to reach an inlet, and designed so that no ponding will occur at the inlet, under design storm conditions. Pavement and sidewalk elevations should be designed to provide drainage away from pedestrian areas. A minimum profile of 0.5% with a minimum cross slope of 2% is recommended to provide adequate runoff of the paved area and subsurface. The maximum grade should not exceed 5.0%.

Highway drainage facilities affected by P&R lot projects should be designed according to Chapter 8 of this Manual. The provisions for subsurface drainage should be thoroughly discussed with the Regional Geotechnical Engineer.

On-site snow storage is less costly than removal to off-site locations, and should be a design consideration. For curbed exit and entrance roadways with sidewalks, a 0.9 m to 1.2 m minimum snow storage area should be provided between the curb and sidewalk. Refer to Chapter 3, Section 3.2.11 in this Manual for further information on snow storage provisions. Within the P&R lot, consideration should be given to providing large obstacle-free areas to maximize snow removal efficiency.
24.3.1.7 Signing and Pavement Markings

Signing and pavement markings shall conform to the NYSMUTCD. Guide signing should be provided on all major access routes in the areas served by the P&R lot. Interior signing should be provided to direct the commuter to the appropriate area of the lot. Signing should be used to designate specific functional areas such as bicycle parking/storage, K&R and taxi parking, short-term and long-term parking, loading and discharge zones, and exits. Signs shall be provided for all parking stalls for persons with disabilities.

The travel routes within the P&R lot should be generally self-regulating to minimize the need for control devices. One-way entrances and exits and one-way circulation routes should be signed to prevent wrong-way movements. Self-regulation of these moves should be developed by placing curb radii and directional islands where they permit turns only in the desired one-way direction. The AASHTO Guide for the Design of Park-and-Ride Facilities provides guidance on locating external guide signs and interior lot signing.

Special display signing of information on bus routes and schedules, maps, and bus fares should also be provided.

Pavement markings aid the driver in complying with the P&R lot regulations when they are used to designate parking areas, direction of travel, restricted areas, crosswalks, stop lines, and other special uses. Crosswalks should be conspicuously marked to enhance the safety of pedestrian access to boarding areas. The type of markings used and what they designate is dependent on the type of pavement provided. Stone or gravel surfaces are not appropriate for painted markings and require stop blocks and curbs made of PCC, asphalt, or wood. PCC and HMA pavements offer the advantage of being suitable for pavement markings, minimizing or eliminating altogether the need for other types of markings. Accessible parking for persons with disabilities in lots with paved surfaces of HMA or PCC and shall be delineated by pavement markings and signs. Refer to ADAAG Section 4.1.2, the AASHTO Guide for the Design of Park-and-Ride Facilities, Figure II-19, and Standard Sheet M608-4 for details.

24.3.1.8 Lighting

Lighting is considered warranted at P&R lots in accordance with the Department’s Policy on Highway Lighting. Where lighting of P&R lots is provided, it should be of adequate level to enhance safety and security for commuters. Illuminance values shall be in accordance with Chapter 12, Section 12.8 of this Manual. The lighting layout should be closely coordinated with the parking lot and landscape design. Poles within the parking lot shall be non-breakaway type.

Illumination of automobile parking areas should be designed so that the motorist can distinguish features of the area, as well as pedestrians moving about. The area should be lighted so that the motorist can read information signs for directions to various areas. The level of illumination should be sufficient to discourage illegal activities by vandals, muggers, etc.
The illumination design shall be such that the vision of drivers in adjacent roadways is not impaired by luminaire brightness or light spillage. Also, for parking lots in residential areas, the light spillage at the perimeter of the lighted area should be minimal.

The lighting of the bus loading/unloading area should be given special consideration. This may consist of different source color illumination for improved color rendition or area designation, increased average level of illumination (not to exceed twice that of the general parking area), or variations on pole or fixture design or mounting height. Luminaires should be placed so as to prevent steps and curbs from being located in shadows.

24.3.1.9 Furnishings

A. Shelters

It is recommended that a sheltered waiting area be provided at all P&R lots. The type, size, and number of shelters should be coordinated with the local transit provider serving the lot, who may have a standard shelter design suitable for use.

Clear sided structures are recommended for security. The floor should be located slightly above grade. The placement of an appropriate number of suitable heavy duty benches is recommended. Permanently fixed litter containers shall be placed at appropriate locations to assist in maintenance of the area. Public telephones should also be considered. For larger shelters, other amenities might include heated waiting space and restrooms, vending machines and information displays. Factors such as the size of the P&R lot, the number of users, whether the lot is owned or leased, and whether local policies or conditions permit their use, all influence which amenities are appropriate for a particular P&R site.

Shelters should be located adjacent to bus loading/unloading areas, parking areas for persons with disabilities, and short-term (K&R and taxi) parking areas. The shelter's location should not interfere with the sight distances of drivers using the lot. Shelters must be accessible to persons with disabilities and shall be designed in accordance with the applicable provisions of ADAAG. Shelters should be oriented so the opening is away from the direction of the prevailing wind, if possible. The AASHTO Guide for the Design of Park-and-Ride Facilities recommends several other considerations in shelter design, such as site visibility, the width of doorways, the use of doors, and the use of optional features. It also provides guidelines on sizing the shelter to the lot capacity and on the use of construction materials and elements.
B. Bicycle Parking Facilities

P&R lots should be safe and secure to induce bicyclists to make use of them. Bicycle parking/storage facilities should be located near the bus loading/unloading area, protected by curbs or barriers. The area should be well lighted to reduce the risk of theft and vandalism, and protected from rain. It may be appropriate to coordinate the planning and design of the facilities with representatives of the local bicycle club.

Bicycle parking should be provided on well-drained hard surfaces with facilities for short term and long term users. The type of facility (e.g., bicycle rack or storage locker) to be used should be coordinated with the party responsible for operating the lot. Refer to Chapter 18, Section 18.7.9.1 for additional information.

24.3.1.10 Landscape Development

A well-landscaped P&R lot can improve the area in which it is located as well as enhance the visual appeal of the facility. The landscaping should be consistent with the surrounding land uses and take into consideration such things as safety, operation, degree of maintenance and snow removal, fiscal constraints, vandalism, loitering and where possible, the preservation of existing vegetation. It should be of sufficient quality to result in a beneficial visual impact. Landscaping should be designed so as not to compromise the safety and security of the users of the lot. The Regional Landscape Architect should be involved early in project development to ensure that pedestrian and vehicular circulation, lighting, landscaping and aesthetics are properly considered, developed, and coordinated. Further guidance is available in the AASHTO Guide for the Design of Park-and-Ride Facilities.

Peripheral landscaping should be considered for all P&R lots. Lots with a capacity of 130 parking stalls or more should also be considered for interior landscaping to provide relief from, and to reduce the scale of, expansive paved areas.

24.3.1.11 Security

Providing security to the users of P&R lots is a very important consideration. Adequate protection of people and their vehicles will serve to draw users to the facility. Some examples of security measures are fences and gates, lighting, 911 emergency/security call boxes, guards, and security cameras. Determining which security measures are necessary should be done on a case-by-case basis. It is recommended that P&R lots be fenced, in areas subject to vandalism or where access is to be prevented to adjacent areas such as railroad tracks. Vinyl-clad chain link fences, plantings, or other cost effective materials should be considered where aesthetics is important.
24.3.1.12 Maintenance and Operation

The Highway Law, Section 10, Subdivision 39 gives the Commissioner the authority to construct publicly owned parking facilities and appurtenances for use in conjunction with existing or planned public transportation systems or facilities. Prior to construction, the governing body of the municipality where the facility is to be located must give its approval. The law also allows the Commissioner, through the municipality, or other party, to operate and maintain the parking lot and enter into an agreement for those services. Usually, the Department arranges for maintenance and operation to be done by the local municipality, authority, etc. However, there may be situations when local municipalities cannot, or will not, provide all maintenance and operation. For example, in Region 10 the local government provides snow and ice removal. Region 10, by low bid contract, may provide maintenance and repair of fencing, signs, pavement markings, landscape development, litter removal, sweeping of the pavement, mowing of grass, etc., on an as needed basis.

The Region and the local government should agree, before P&R lot construction begins, who will be responsible for maintenance, repairs, and operation of the lot, or, if the responsibilities are to be shared, how they will be divided.

Proper upkeep of P&R lots is necessary to enhance the operation of the facility, to help attract users, and to provide the best return on investment to the State. An effective maintenance and repair program will include the following items:

- periodic inspection,
- pavement resurfacing and repair,
- shelter or station repair,
- traffic control devices (signs and pavement markings),
- lighting and telephone systems,
- mowing and care of trees and shrubs,
- sweeping and cleaning,
- litter and refuse collection and removal,
- landscape development,
- site furnishings,
- snow and ice control,
- removal and replacement of vandalized or damaged items, and
- security/gates.

Costs of P&R lots also include operation of the lighting system and telephone system.

The responsible agency or authority should provide for adequate safety of commuters and protection of personal property. Police surveillance should be provided in order to control illegal or improper parking and use of the lot. The extent of law enforcement effort and involvement should be coordinated with the local governing body and law enforcement agency.
MOBILITY MEASURES

24.3.1.13 Shared-Use Lots

A shared-use P&R lot may be selected over an exclusive lot because it is the least cost alternative to constructing a new lot, or it may be used to serve as a test location to help determine if an exclusive P&R lot is needed. Potential shared-use lots may be available at shopping centers, churches, and recreation or entertainment centers. Each potential site must meet ADAAG requirements and should be assessed in terms of lot size, delineation, bus accommodation, and amenities before concluding which site is to be selected. The AASHTO Guide for the Design of Park-and-Ride Facilities elaborates on these factors and how they affect the selection of a shared-use site. When a lot is selected, it is recommended that agreements addressing lease/rental arrangements, maintenance and repairs, number of spaces, seasonal use, etc., be formalized between the appropriate parties.

High-Occupancy Vehicle Facilities: A Planning, Design, and Operations Manual describes shared-use lots and exclusive lots as having certain advantages and disadvantages, with the advantages of shared-use lots being, in effect, the disadvantages of exclusive lots, and vice versa.

Advantages of Shared-Use Lots

- The parking facility is immediately available and, therefore, the lead time for opening the lot is significantly reduced. Provision of new exclusive facilities can greatly increase the lead time required for inaugurating transit service.
- The parking area and access roadways already exist, requiring less capital to implement.
- Due to the lower capital requirements, shared-use lots can be used as a means of testing demand. If demand proves inadequate, the transit service or lot designation for ridesharing can be quickly terminated. If the demand is more substantial, the desirability of serving that demand with more capital-intensive facilities can then be considered. Although the location and amenities at a shared-use lot may not be optimal, opening a lot at the location may still generate significant use.
- The shopping opportunities available at some shared-lot location may encourage ridership.

Disadvantages of Shared-Use Lots

- Transit services, if provided, must be worked into the existing lot layout. This may create difficulty in developing desirable access and circulation patterns. Pavement strength within the lot may dictate that all transit operations take place on the adjacent streets.
- Space may not be available for expansion. Expansion area will be needed if initial demand estimates are low or if demand increases over time. If demand at the shared-use lot location is greater than anticipated, problems may be created when the excess parking demand causes parking in areas not designated.
- It may be difficult to obtain assurance that a certain number of parking spaces will be available on a daily basis. Many shared facilities that have unused parking area during most of the year require the use of that parking area during peak times of the year. In essence, the transit operator or rideshare sponsor lacks control over the facility.
There is generally a lack of management control over a shared facility (i.e., safety and liability). This shortcoming may prevent the operator from obtaining adequate liability insurance.

Many of the amenities provided may be temporary in nature since large capital investment may be difficult to justify. The temporary appearance of the facility may discourage some potential riders.

During peak periods, especially the evening peaks, congestion within the lot and at the access points may be intensified due to traffic generated by the shared use. For example, evening shopping traffic may conflict with evening park-and-ride traffic.
24.3.2 Park-and-Pool Lots

Park-and-Pool (P&P) lots are locations where drivers of single occupant vehicles meet to switch modes to carpool and vanpool vehicles. P&P lots are not generally served by public transit, and as such, have no provision for access by bus, or for assigned passenger loading/unloading areas. In most other respects, P&P lots should be designed similar to P&R lots. They can be the exclusive-use type or the shared-use type, similar to P&R lots. Refer to Section 24.3.1 in this chapter for more information on usage types. P&P lots may start out as test locations for future P&R lots. In those cases, they must be designed to allow for incorporation of the P&R elements at a later date.

P&P lots should be designed to meet the same objectives as P&R lots, as listed in Section 24.3.1. Site selection guidelines are the same for P&P lots as for P&R lots. Refer to Section 24.3.1.2.

A traffic analysis similar to that for P&R lots should be done for P&P lots to determine what improvements will be needed to interface with the local street system without creating significant negative impacts. Refer to Section 24.3.1.3 in this chapter.

The standards that apply to the location and design of P&R lots also apply to P&P lots. P&P parking is generally designed as right angle (90°) parking. Refer to Figure 24-22 for parking stall layout dimensions.

If there is a likelihood that the P&P will become a P&R, provisions should be made in the design for subsequent accommodation of bus loading, turning radius, vertical clearances, and grades. Refer to Sections 24.3.1.4 through 24.3.1.10 for the design guidelines. Fewer amenities are needed for P&P lots than for P&R lots. Items for consideration might include a public telephone, trash receptacles, and lighting.
24.3.3 **On-Line Transfer Stations**

On-line transfer stations are located along the HOV facility within the right of way or adjacent to it. They function as collection and distribution points for passengers to transfer from bus to bus (both express and local), which improves travel time compared to off-line transfer stations. Their location within the right of way may make access for pedestrians difficult, but where there is demand, pedestrian access and P&R access should be provided, if possible.

On-line stations generally reduce travel time by providing through-routing in the station design, which is influenced by the orientation of the passenger platform areas. Figures 24-23 and 24-24 illustrate center loading platform and side loading platform arrangements, respectively. The center loading platform makes it easier for passengers to transfer but requires buses traveling in opposite directions to cross paths as they enter and leave the bus loading area to accommodate right-side loading and unloading. Side loading platforms do not require buses to cross paths but passenger safety may be jeopardized if someone tries to cross the through route rather than using the pedestrian access. Although this scheme requires more width than the center loading scheme, it may be preferable to crossing bus paths.

It is recommended that the following factors, taken from *High-Occupancy Vehicle Facilities: A Planning, Operation and Design Manual*, be considered when designing on-line transfer stations:

1. Maintain the capability of mainline traffic to bypass loading and unloading vehicles at the stations. If the station is located along a high-speed through lane used by other HOVs, some consideration should be made for a buffer or barrier separating the mainline lanes from the bus loading lane.
2. Provide good pedestrian access, via ramps and/or elevators. For side-loading platforms, pedestrian access should be possible from one platform to the other without having to cross the mainline through lane. This accommodation can be made by grade separating access via an elevated or depressed walkway or by use of an adjacent street grade separation.
3. Provide supporting improvements that can facilitate effective collection and distribution. These improvements may include park-and-ride lots, feeder bus loading/unloading platforms, passenger pick-up/drop off zones, pedestrian walkways and other features to integrate the station with the specific needs of the area.
4. Provide amenities comparable to most grade-separated rail stations. If the busway is considered to be convertible to rail technology at some future date, it may be desirable to orient the amenities to serve both technologies in order to maintain this flexibility.
5. Provide access for persons with disabilities in accordance with the requirements of ADAAG, Section 10.

On-line stations are best suited to two-way operation, and may be adapted to reversible-flow HOV operations. Through lanes should be provided at the stations to allow other HOVs to bypass stopped buses. The cross section of station through lanes should match the cross section of the HOV mainline lanes, if possible. Where constraints do not allow that, the through lane cross section may be reduced to the appropriate acceptable cross section. Refer to Section 24.2 of this chapter for HOV cross sections.
MOBILITY MEASURES

Figure 24-23 On-Line Center Platform Transfer Station

a. Plan

b. Preferred Section

Source: Adapted from PBQD Manual

§24.3.3  5/4/98
Figure 24-24 On-Line Side Platform Transfer Station

a. Plan

b. Preferred Section

Source: Adapted from PBQD Manual
24.3.3.1 Bus Berths

Bus berths are specific spaces in transfer facilities designated for loading and unloading passengers. Small transfer stations, such as simple one-route operations, may also allow the berths to serve as temporary layover points for buses between scheduled arrival and departure times. For larger operations, transfer stations should include separate unloading and loading berths, with separate holdover areas. The primary factors to be considered in the selection of berth type are available space, pedestrian access, bus operations policies, and to a lesser extent, snow removal requirements. The different types of bus berths are:

- parallel bus bay
- sawtooth bus bay
- linear bus bay
- head-in bus bay.

Linear bus bays and head-in bus bays are generally limited to major transfer stations in the central business district (CBD), and as such, are not included in this Manual. For further information refer to NCHRP Report 155, *Bus Use of Highways: Planning and Design Guidelines*.

The parallel design fits better into an existing right of way, reduces the turning movement the buses must make, and easily adapts to various bus lengths. In constrained areas, it allows buses to operate linearly where they queue up to unload and load passengers and leave the station. It also allows them to pull in and pull out around stopped buses along the platform, in stations where enough space is available for wider loading lanes and longer platforms. Figure 24-25 illustrates the layout dimensions for parallel bus bays.

Considerable linear space is necessary to permit a bus to overtake and pull into a platform ahead of a standing bus. Table 24-6 shows the required berth length dimensions to achieve various tailout dimensions, as illustrated in Figure 24-25. Shorter berth lengths result in the rear of the bus protruding further into the loading lane. Where road width is constrained, longer berth lengths may be required to provide adequate passing room. For any runaway where such maneuvers are permitted, the road width should also assure adequate safe clearance for vehicles in the adjacent lane.

Additional roadway width is required for swing-out maneuvers past other vehicles in close quarters. The roadway width and the amount of lineal space at a bus loading platform are directly related where designs allow departing buses to pull out from the platform around a standing bus. Table 24-7 shows the effect that pull-out distance has on loading lane width. The shorter the berth length allowed, the wider the roadway must be, and conversely.
Sawtooth bus bays optimize the number of bus loading areas that can be placed in a confined area of a given length. Buses are able to pull in to and pull out of each bus bay without interference from parked buses in other bays. The loading lane width shown in Figure 24-26 is the minimum width required. Compared to the parallel bus bays, they require greater station width but shorter station length. They may be preferred over the parallel type to prevent delays where more than two buses will be stopping at one time. Sawtooth bus bays should only be considered in an indoor or roofed facility where they are well protected from the weather, and snow removal is not required.

The layouts in Figures 24-25 and 24-26 are for the standard 12.1 m BUS vehicle. The bus berth lengths must be increased for articulated buses.

24.3.3.2 Passenger Platforms

The platform widths shown in the bus bay layouts are the minimum widths for single-sided platforms. The minimum width for double-sided platforms should be 3.6 m. Permanent passenger platforms should be raised 125 mm to 200 mm above the busway pavement. Passenger protection should be provided in the form of railing, fencing or wall around the sides where access to the buses is not needed. The bottom of the fence or railing should provide continuous protection against roadway splash and exhaust blast. Detectable warning devices conforming to the current requirements of ADAAG must be provided at platform edges where access to buses is provided. The design of the platform should be coordinated with the transit authority.

24.3.3.3 Platform Shelters

Canopy shelters should be provided over the passenger loading areas. The canopies should provide adequate vertical clearance to allow them to overhang the buses by at least 300 mm, and care should be taken not to place supports where they will interfere with the transfer operation. Refer to Table 24-5 for the desirable design vehicle height, and to ADAAG Section 10.2.1 for accessible design requirements.

24.3.3.4 Platform Access

Access to the passenger platforms should be provided by stairs and/or ramps. Multi-level stations will normally require escalators or elevators. Access should be provided at the end of the platforms to minimize interference during the loading/unloading process. Stairways and ramps should be designed in accordance with Chapter 18, Section 18.6.6 of this Manual, and Section 10 of ADAAG. The Regional Landscape Architect should be consulted for additional information regarding access for persons with disabilities.
Figure 24-25 Parallel Bus Bay Layout Dimensions

Table 24-6 Berth Length for Bus Pull-In

<table>
<thead>
<tr>
<th>Tail-Out Distance A (meters)</th>
<th>Berth Length B (meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.3</td>
<td>28.0</td>
</tr>
<tr>
<td>0.6</td>
<td>24.4</td>
</tr>
<tr>
<td>0.9</td>
<td>20.1</td>
</tr>
<tr>
<td>1.2</td>
<td>18.3</td>
</tr>
<tr>
<td>1.5</td>
<td>17.1</td>
</tr>
</tbody>
</table>

Source: NCHRP Report 155

NOTE: Berth Length "B" is based on a 12.1 m bus. Increase "B" for articulated buses or for standard buses longer than 12.1 m.

Table 24-7 Road Width for Bus Pull-Out

<table>
<thead>
<tr>
<th>Pull-Out Distance C (meters)</th>
<th>Lane Width W (meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.4</td>
<td>7.0</td>
</tr>
<tr>
<td>4.9</td>
<td>6.7</td>
</tr>
<tr>
<td>5.4</td>
<td>6.6</td>
</tr>
<tr>
<td>9.4</td>
<td>6.4</td>
</tr>
</tbody>
</table>

Source: NCHRP Report 155

NOTE: Pull-out Distance "C" may increase for 13.7 m bus. Check with transit operator.

Figure 24-26 Shallow Sawtooth Bus Bay Layout Dimensions

*Increase dimensions for 13.7 m single-unit bus and for 18.9 m articulated bus.

Source: NCHRP Report 155

§SEE 24.3.3.1

5/4/98
24.3.4 **Off-Line Transfer Stations**

Off-line transfer stations are located off the HOV lanes, outside the right of way. They can be P&R lots or they can be major terminals. They function as collection and distribution points for passengers to connect to express buses. Their location is less dependent on the HOV lane alignment than on-line transfer stations are, lending versatility to site selection. Connections to HOV lanes can be provided for vanpools and carpools, but they should be separate from those for buses. Locations that provide good connections to HOV lanes are generally well-suited to interfacing with local activity or employment centers.

There are a number of factors which should be taken into consideration when designing off-line stations. The following factors are taken from the NCHRP Report 155 *Bus Use of Highways: Planning and Design Guidelines*.

1. **Special bus areas.** Off-street bus loading areas or loops should be provided when there are more than 12 to 15 buses per peak hour terminating at a single stop and where the stop serves as a staging area for buses.

2. **Station capacity.** The number of bus berth positions should be based on the maximum number of buses to use the station at any given time. Berthing requirements depend on peak-hour passenger volumes and berth turnover. Current experience indicates 20 to 30 bus berths as an upper limit for most urban conditions.

3. **Berth capacity.** Bus layover times should be minimized during peak periods with 5-minute loading (dwell) times a desirable maximum. This allows a peak berth turnover of about 10 buses per hour.

4. **Berth design.** A specific loading area should be designated for each bus route. Heavily used bus routes may need two berths, whereas long-headway lines may double-up at a single berth. Bus platforms may be of either the parallel pull-through type or a modified sawtooth design, and must be sized according to the largest type of bus that will use them. A primary design requisite is the need for buses to load parallel to curbs or walkways. Refer to Figures 24-25 and 24-26 for typical bus berth layouts.

5. **Street access.** Bus access should be by ramp directly from arterial streets and the HOV lanes. Street widening, reserved bus lanes, special bus turn lanes and signals, or even bus grade separations, may be provided to expedite bus flow and minimize conflicts.
24.3.5 **Curb-Side Bus Stops**

This section provides guidance regarding the location of bus stops, and factors that should be considered in their design. Refer to Section 24.3.6 for guidance on bus turnouts. For further guidance in the design of bus stops, refer to the Transit Cooperative Research Program (TCRP) Report 19 *Guidelines for the Location and Design of Bus Stops*, NCHRP Report 155 *Bus Use of Highways: Planning and Design Guidelines*, and *Summary of Guidelines for Bus-Related Street Improvements*. Guidance on curb-side factors, including those that can affect the comfort, safety, and convenience of bus patrons, as well as discussion of shelter design and placement, amenities, and enhancing bus patron comfort at bus stops, can be found in the TCRP Report 19.

Guidance regarding access to bus stops for pedestrians and for persons with disabilities is found in Chapter 18, Section 18.6.6.9 of this Manual, and in ADAAG, Section 10.

Curb-side bus stops are designated areas where buses stop in the right curb lane to load and unload passengers at curb side. They are generally located where there is concentrated commercial, residential, office or industrial development, or at intersections of arterial or major collector streets. TCRP Report 19, *Guidelines for the Location and Design of Bus Stops*, describes several advantages and disadvantages of curb-side bus stops. Advantages are:

- they provide easy access for bus drivers and result in minimal delays to the bus,
- they are simple to design and easy and inexpensive for a transit agency to install,
- they are easy to relocate, and
- they provide easy access for passengers going to/from bus stops.

Disadvantages are:

- they can cause traffic to queue behind a stopped bus, thus causing traffic congestion,
- they may cause drivers to make unsafe maneuvers when changing lanes in order to avoid a stopped bus, and
- they can cause sidewalk congestion.

A variation of the curb-side bus stop is the nub, or curb extension bus stop. It is applicable to intersections where parking is permitted. The curb line is extended into the parking lane between the end of the curb radius and the end of the adjacent parking zone. Buses stop in the traffic lane to load and unload passengers. Refer to Figure 24-27. Nub-type bus stops are particularly suited to streets with low traffic speeds and volumes. Advantages of nub bus stops are:

- they remove fewer parking spaces for the bus stop,
- they decrease the walking distance (and time) for pedestrians crossing the street,
- they provide additional sidewalk area for bus patrons to wait,
- they result in minimal delay for the bus, and
- they provide additional space for persons with disabilities.

In addition to the same disadvantages as for curb-side bus stops, nub bus stops also cost more to install compared with curb-side stops.
The location pattern (near-side or far-side) of a community’s bus stops should be standardized to the extent that bus service requirements and traffic conditions permit. If conflicts seriously impede bus and vehicle flow, the stops should be relocated to an adjacent intersection or eliminated. When a large percentage of passengers using a stop are destined for a single trip generator (a school, office, shopping center or similar generator), the stop should be located to minimize pedestrian street crossings.

The design of bus stops should be coordinated with the local transit authority. Pedestrian crossing issues affecting bus passengers should be examined in the placement of bus stops for both the inbound and return trips. If pedestrians will be required to cross the road for either of these trips, the following design treatments should be considered:

- placing bus stops at cross streets, preferably signalized;
- placing bus stops to provide adequate sight distance for pedestrians and motorists;
- providing signage to alert drivers of pedestrian crossings;
- providing clearly marked crossing zones;
- locating bus stops to reduce pedestrian travel across intersections; and
- placing the bus stop within the trip generator.

### 24.3.5.1 Vehicle Criteria

The design vehicle for bus stops shall be the AASHTO BUS (refer to Section 24.2.3.1.). Where articulated buses are in use, or are planned for use, the design vehicle shall be the AASHTO A-BUS. Refer to Chapter II of AASHTO’s *A Policy on Geometric Design of Highways and Streets* for their turning templates.

### 24.3.5.2 Bus Stop Spacing

Bus stop spacing has a major impact on transit vehicle and system performance. Stop spacing also affects overall travel time, and therefore, demand for transit. Bus stops should be spaced to maximize passenger accessibility, convenience, and safety, while minimizing undue delay or traffic interruptions. Land use characteristics and population densities should be taken into consideration. The determination of bus stop spacing is primarily based on development type, such as residential area, commercial, and/or central business district. Typical bus stop spacings representing a composite of prevailing practices are shown in Table 24-8.

<table>
<thead>
<tr>
<th>Environment</th>
<th>Spacing Range</th>
<th>Typical Spacing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central Core Areas of CBDs</td>
<td>90 m - 300 m</td>
<td>180 m</td>
</tr>
<tr>
<td>Urban Areas</td>
<td>150 m - 370 m</td>
<td>230 m</td>
</tr>
<tr>
<td>Suburban Areas</td>
<td>180 m - 760 m</td>
<td>300 m</td>
</tr>
<tr>
<td>Rural Areas</td>
<td>200 m - 800 m</td>
<td>380 m</td>
</tr>
</tbody>
</table>
Special bus stop spacing considerations should be arranged to serve major employment or residential generators, and coordinated with the local transit authority.

24.3.5.3 Bus Stop Location

The location of bus stops is described by their position relative to intersections. Far-side bus stops are located immediately after passing through an intersection. Near-side bus stops are located immediately prior to an intersection. Midblock bus stops are located within the block. Nub-type bus stops are normally installed at the near-sides of intersections. Figure 24-27 illustrates the bus stop placements. The conditions that determine the suitability of the different bus stops are described in Sections 24.3.5.4 through 24.3.5.7. A comparison of the advantages and disadvantages of each bus stop location is found in Table 24-9.

TCRP Report 19, *Guidelines for the Location and Design of Bus Stops*, lists the following factors to be considered when selecting the location of bus stops:

- adjacent land use and activities,
- bus route (e.g., is bus turning at the intersection),
- bus signal priority (e.g., extended green suggests far side placement),
- impact on intersection operations,
- intersecting transit routes,
- intersection geometry,
- passenger origins and destinations,
- pedestrian access, including access for disabled persons,
- physical roadside constraints (trees, poles, driveways, etc.),
- potential patronage,
- presence of bus bypass lane, and
- traffic control devices.

24.3.5.4 Near-side Bus Stops

Near-side bus stops are normally preferred:

- where buses operate in median lanes,
- where signalized intersections are frequent,
- where curb parking is permitted through the day, and
- where the accumulation of buses at a far-side stop would exceed the length of the bus zone, and additional length is not available. This removes the potential for queuing buses to overflow the intersection.
Buses stopping on approaches to intersections can use the width of the cross street to re-enter the main traffic flow. However, near-side stops do have drawbacks in that the stopped bus:

- may block the view to the right, or the view of the signal head for through lane drivers, and
- creates a hazardous situation for motorists making right turns.

Near-side stops should not be used where the right-turning traffic exceeds 250 turns per peak hour.

When transfer activity between two lines exhibits a strong directional pairing (i.e., heavy volumes from eastbound to northbound), placing one stop near-side and one stop far-side can minimize pedestrian activity within the intersection.

24.3.5.5 Far-side Bus Stops

Far-side bus stops are normally preferred:

- where there is a high volume of right or left turns at an intersection;
- when the transit route alignment requires a left turn. Stops should be located one block before, and immediately after the left turn is completed;
- at complex intersections such as intersections with multi-phase signals or dual right or left turn lanes, because they remove the buses from the complicated activities occurring within and near the intersection;
- where sight distance or signal capacity problems exist; or
- where buses have use of curb lanes during peak periods.

24.3.5.6 Midblock Bus Stops

Midblock stops may be used when a stop is required in advance of a left turn, or when a long loading area is required where several routes come together, or where major passenger generators are located.

Midblock locations should be used when project conditions prevent the use of near-side or far-side stops.
## Table 24-9 Comparison of Bus Stop Locations

<table>
<thead>
<tr>
<th></th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Near-Side Stop</strong></td>
<td>CMinimizes interferences when traffic is heavy on the far side of the intersection.</td>
<td>CIncreases conflicts with right-turning vehicles.</td>
</tr>
<tr>
<td></td>
<td>CALLows passengers access to buses close to crosswalk.</td>
<td>CMay result in stopped buses obscuring curbside traffic control devices and crossing pedestrians.</td>
</tr>
<tr>
<td></td>
<td>CProvides the width of the intersection for the driver to pull away from curb.</td>
<td>CMay cause sight distance to be obscured for cross vehicles stopped to the right of the bus.</td>
</tr>
<tr>
<td></td>
<td>CEliminates the potential for stopping twice (once at the signal and again at the far side; see Far-Side Stop, Disadvantages).</td>
<td>CMay block the through lane during peak period with queuing buses.</td>
</tr>
<tr>
<td></td>
<td>CALLows loading/unloading of passengers while the bus is stopped at a red light.</td>
<td>CIncrease sight distance problems for crossing pedestrians.</td>
</tr>
<tr>
<td></td>
<td>CProvides driver with the opportunity to look for oncoming traffic, including connecting buses.</td>
<td>CMay cause additional delays due to traffic signal.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CMay limit bus priority signal strategies.</td>
</tr>
<tr>
<td><strong>Far-Side Stop</strong></td>
<td>CMinimizes conflicts between right turning vehicles and buses.</td>
<td>CStopping buses may block the intersections during peak periods.</td>
</tr>
<tr>
<td></td>
<td>CProvides additional right turn capacity by making curb lane available to traffic.</td>
<td>CStopped buses may obscure sight distance for crossing vehicles.</td>
</tr>
<tr>
<td></td>
<td>CReduces sight distance problems at approaches to intersections.</td>
<td>CStopped buses may increase sight distance problems for crossing pedestrians.</td>
</tr>
<tr>
<td></td>
<td>CEncourages pedestrians to cross behind the bus</td>
<td>CIncreases potential for a bus to stop twice (once at signal and again at far side) causing interference with bus operations and other traffic.</td>
</tr>
<tr>
<td></td>
<td>CBus can use the intersection to decelerate.</td>
<td>CIncreases potential for rear-end accidents by drivers not expecting buses to stop after passing through the intersection.</td>
</tr>
<tr>
<td></td>
<td>CBus drivers may take advantage of the gaps in traffic flow created at signalized intersections.</td>
<td>CIncreases potential to queue traffic into intersection when a bus is stopped.</td>
</tr>
<tr>
<td></td>
<td>CImproves potential for signal priority treatments.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CReduces potential for buses to block curbside signs approaching intersection.</td>
<td></td>
</tr>
<tr>
<td><strong>Mid-Block Stop</strong></td>
<td>CMinimizes sight distance problems for vehicles.</td>
<td>CRequires additional distance for no-parking restrictions.</td>
</tr>
<tr>
<td></td>
<td>CMay result in passenger waiting areas experiencing less pedestrian congestion.</td>
<td>CIncreases walking distance for patrons crossing at intersections.</td>
</tr>
<tr>
<td></td>
<td>CUsually provides adequate space for buses.</td>
<td>CLt may be difficult to merge back into the general traffic lane.</td>
</tr>
<tr>
<td></td>
<td>CEnhances potential for signal priority treatments.</td>
<td>CLess convenient for connecting with routes on cross streets.</td>
</tr>
<tr>
<td></td>
<td>CReduces potential for buses to block the intersection.</td>
<td>CMay cause congestion at midblock with buses merging back into traffic lane.</td>
</tr>
</tbody>
</table>

Sources: TCRP Report 19 and draft NCHRP HOV Systems Manual
24.3.5.7 Bus Stop Lengths

Bus stop lengths for single unit buses are shown in Figure 24-27. The dimensions will permit the use of a 13.7 m bus in the future (refer to Section 24.2.3.1). They are measured as follows:

1. Near-side stops are measured from the front of the stopped bus to the front of the preceding parking stall (Figure 24-27a).
2. Far-side stops are measured from the rear of the stopped bus to the end of the first parking stall (Figure 24-27c). Where buses enter a far-side stop after a right turn, increase the length by 17 m, measured from the face of curb of the intersecting street to the rear of the bus (Figure 24-27d).
3. Midblock stops are measured from the front of the preceding parking stall to the rear of the next parking stall (Figure 24-27e).
4. Nub-type stops (Figure 24-27b), (see Near-Side Stops above).

Where more than one single unit bus will be using the bus stop at a time, the bus stop length should be increased by 15 m for each bus. Where the bus stops will be used by articulated buses, the bus stop length should be 20 m for one bus. For each additional articulated bus, provide an additional 20 m.

24.3.5.8 Signing and Pavement Markings

Bus stops should be provided with signing in accordance with the requirements of the NYSMUTCD. They should delineated with the standard NO STOPPING EXCEPT BUSES signs (§221.5). Signs containing information on the bus routes and hours of operation (§253.4) should also be provided. Signs should be located in accordance with §221.5 and §253.4 respectively, and must conform with the requirements of ADAAG, Section 10.2.1(3).

A common marking is yellow painted curb at the bus stop. The bus stop should be separated from the adjacent traffic lanes by a solid white line, 150 mm to 200 mm wide.

Crosswalks should be provided at midblock bus stops.

24.3.5.9 Site Furnishings

Sidewalks and other appropriate facilities that provide access for persons with disabilities should be provided at all bus stops and placed at locations consistent with local accessible bus configurations. See Chapter 18, Section 18.6.6.9 in this Manual, and ADAAG, Section 10 for additional guidance.

Bus stops are frequently constructed or reconstructed and improved as part of Department projects. Existing bus stops that must be removed or relocated as part of a project are usually reconstructed at Department expense. However, this depends on the specifics of any existing agreement with the transit operator. The designer should refer to Chapter 18, Sections 18.6.6.9 and 18.6.6.11 for additional information.
Figure 24-27 Curb-Side Bus Stop Dimensions

a. Near-side Bus Stop

b. Nub-Type Near-side Bus Stop

Notes For All Figures:
1. BUS = single unit 12.1 m - 13.7 m length.
2. Increase dimensions for articulated buses.
3. X = 1.5 m from edge of crosswalk or end of sidewalk, whichever is further from the intersection.

c. Far-side Bus Stop
d. Far-side Bus Stop After Right Turn

e. Midblock Bus Stop

Source: Adapted from NCHRP Report 155 and TCRP Report 19
24.3.6 **Bus Turnouts**

Bus turnouts, also known as bus bays, are bus stops located in recessed curb areas out of the adjacent moving lanes of traffic. They should be considered on arterials and other major roadways that experience high auto traffic volumes, high over-all travel speeds, and where the bus dwell times are relatively long. With the use of bus turnouts, through traffic is allowed to flow freely without the obstruction of stopped buses.

Turnouts are preferred at the far sides of an intersection wherever possible. Far-side locations are less likely to be mistaken for turning lanes by general traffic. Near-side turnouts should be avoided, if possible, due to conflicts with right-turning vehicles. Midblock turnouts should be used where major activity centers attract large numbers of bus transit users. Queue-jumper bus bays should be used at congested intersections to enable buses to bypass traffic to reach the far-side bus turnout.

TCRP Report 19, *Guidelines for the Location and Design of Bus Stops* recommends bus turnouts be considered when the following conditions exist at a location:

- Traffic in the curb lane exceeds 250 vehicles during the peak hour,
- Traffic speed is greater than 70 km/h,
- Bus volumes are 10 or more per peak hour on the roadway,
- Passenger volumes exceed 20 to 40 boardings an hour,
- Average peak-period dwell time exceeds 30 seconds per bus,
- Buses are expected to lay-over at the end of a trip,
- Potential for auto/bus conflicts warrants separation of transit and passenger vehicles,
- History of repeated traffic and/or pedestrian accidents at stop location,
- Right of way width is adequate to construct the bay without adversely affecting sidewalk pedestrian movement,
- Sight distances (i.e., hills, curves) prevent traffic from stopping safely behind a stopped bus,
- A right-turn lane is used by buses as a queue jumper lane,
- Appropriate bus signal priority treatment exists at an intersection,
- Bus parking in the curb lane is prohibited, and
- Improvements, such as widening, are planned for a major roadway. (This provides the opportunity to include the bus turnout as part of the reconstruction, resulting in a better designed and less costly bus turnout.)

Bus turnouts should not be used where traffic volumes exceed 1000 vph per lane.

Bus turnouts should be designed to allow buses to safely exit from and merge into the general traffic lane within the length of the turnout, so that the traffic in the adjacent through lanes is not significantly affected.
Fully effective bus turnouts include:

- A deceleration lane and taper to permit safe exit from the general traffic lane and easy entrance to the loading area,
- A standing space sufficiently long to accommodate the maximum number of vehicles expected to occupy the space at one time, and
- An acceleration lane and an exit taper to enable safe and easy re-entry into the through-traffic lanes.

A deceleration lane allows the bus to slow down without slowing the traffic behind. An acceleration lane permits the bus to reach a suitable speed for merging into the adjacent lane.

While the use of bus turnouts is generally associated with concurrent curb HOV lanes, their use can also be extended to contraflow (one-way right curb, or two-way with median inside) and median or center lanes (two-way with median), where the median width is adequate. The median width should be a minimum of 1.6 m for passenger loading/unloading areas. The median width should be carried to the crosswalk to allow passengers to move safely. The use of fencing and splash guards is also recommended for the passengers' protection.

Various configurations of bus turnouts are available to accommodate bus service. Figure 24-28 illustrates far-side and midblock turnouts and queue-jumper bus bays. An exception is at signalized intersections where right turns exceed 250 in the peak hour, in which case the combination near-side right-turn lane and far-side bus turnout, known as a queue jumper bus bay, is preferred. The near-side right-turn lane serves as a right-turn lane for all traffic, and as a queue jumper lane for buses only to bypass the queue in the adjacent through lane to reach the far-side bus turnout. The far-side turnout is used for passenger unloading and loading.

The advantages and disadvantages of the various types of bus turnouts are listed in Table 24-10.

24.3.6.1 Vehicle Criteria

The design vehicle for bus turnouts shall be the AASHTO BUS (refer to Section 24.2.3.1). Where articulated buses are in use, or are planned for use, the design vehicle shall be the AASHTO A-BUS. Refer to Chapter II of AASHTO's *A Policy on Geometric Design of Highways and Streets* for their turning templates.

24.3.6.2 Bus Turnout Spacing

The spacing of bus turnouts is similar to the spacing of bus stops. Refer to Section 24.3.5.2 .
24.3.6.3 Bus Turnout Location

Bus turnouts should be located in accordance with the following guidelines, adapted from TCRP 19, *Guidelines for the Location and Design of Bus Stops*:

- Far-side intersection location is desirable (may vary with site conditions). Bus turnouts should be placed at signal-controlled intersections so that the signal can create gaps in traffic.
- Near-side turnouts should be avoided at intersections where right turns are allowed, due to conflicts with right-turning vehicles. They also cause delays to transit service as buses attempt to re-enter the travel lane, obstruct the view of traffic control devices and interfere with pedestrian activity.
- Midblock bus turnouts should be considered only when associated with pedestrian access to major activity centers.
- Queue-jumper bus bays begin at the near side of intersections to allow for right turns, and carry across to the far side.

A comparison of the advantages and disadvantages of each bus turnout location is found in Table 24-10.

**Table 24-10 Comparison of Bus Turnout Locations**

<table>
<thead>
<tr>
<th></th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Midblock Turnout</td>
<td>CAllows patrons to board and alight out of the travel lane. CProvides a protected area away from moving vehicles for both the stopped bus and the bus patrons. CMinimizes delay to through traffic. CBus drivers may be able to take advantage of gaps in traffic flow created at signalized intersections.</td>
<td>CWithout acceleration lane and exit taper, may be difficult to re-enter traffic, especially during periods of high roadway volumes. CSLs expensive to install compared with curbside bus stops. CSLs difficult and expensive to relocate. CMay significantly reduce sidewalk space at turnout. CMay increase the difficulty meeting ADAAG accessible design requirements at turnouts.</td>
</tr>
<tr>
<td>Far-Side Turnout</td>
<td>CAllows the bus to decelerate as it moves through the intersection. CSee Midblock Turnout advantages.</td>
<td>CPedestrian crossing distance is increased by the width of the turnout. CSee Midblock Turnout Disadvantages.</td>
</tr>
<tr>
<td>Queue-Jumper Bus Bay</td>
<td>CAllows buses to bypass queues at a traffic signal. CSee Far-Side Turnout advantages.</td>
<td>QMay cause delays to right-turning vehicles when a bus is at the start of the right turn lane. CSee Far-Side Turnout disadvantages.</td>
</tr>
</tbody>
</table>

Source: TCRP Report 19
24.3.6.4 Near-side Bus Turnouts

The preferences for the use of near-side bus turnouts are similar to those for near-side bus stops. Refer to Section 24.3.5.4.

24.3.6.5 Far-side Bus Turnouts

The preferences for the use of far-side bus turnouts are similar to those for far-side bus stops. Refer to Section 24.3.5.5.

24.3.6.6 Midblock Bus Turnouts

The preferences for the use of midblock bus turnouts are similar to those for midblock bus stops. Refer to Section 24.3.5.6.

24.3.6.7 Queue-jumper Bus Bays

TCRP 19 recommends that queue-jumper bus bays be considered for use when:

- high-frequency bus routes have an average headway of 15 minutes, or less,
- traffic volumes exceed 250 vph in the curb lane during the peak hour,
- the intersection operates at level of service “D”, or worse, and
- land acquisitions are feasible and costs are affordable.

An exclusive bus lane, in addition to a right-turn lane, should be considered when right turns exceed 400 vph during the peak hour.

24.3.6.8 Bus Turnout Lengths

The TCRP Report 19 Guidelines for the Location and Design of Bus Stops, advocates including enough space for entrance and exit tapers, deceleration and acceleration lanes, and the stop area, where feasible. The recommended deceleration, acceleration, and taper lengths for various entering speeds are given in TCRP Report 19, Chapter 3, Figure 5.
The layouts in Figure 24-28a, b, and c illustrate the more common practice of providing only the taper lengths and stopping area, leaving deceleration and acceleration to occur in the travel lane. The dimensions will permit the use of a 13.7 m bus in the future (refer to Section 24.2.3.1). They are measured as follows:

1. Near-side turnouts are measured from the front of the stopped bus to the beginning of the turnout entry transition (Figure 24-28a).

2. Far-side turnouts are measured from the rear of the stopped bus to the end of the turnout exit transition (Figure 24-28b). Where buses enter the turnout after a right turn, provide an additional 17 m measured from the face of the curb of the intersecting street to the rear of the bus.

3. Midblock turnouts are measured from the beginning of the turnout entry transition to the end of the turnout exit transition (Figure 24-28c).

The queue-jumper bus bay illustrated in Figure 24-28d includes an acceleration lane, and a deceleration lane that also provides the means for the bus to “jump” a queue at the intersection.

Where more than one single unit bus will be using the bus turnout at a time, the bus turnout length should be increased by 15 m for each additional bus. Where the bus turnouts will be used by articulated buses, the bus turnout length should be 20 m for the first bus. For each additional articulated bus, provide an additional 20 m.

24.3.6.9 Signing and Pavement Markings

Signing and pavement markings for bus turnouts are similar to the signing and pavement markings for bus stops. Refer to Section 24.3.5.8.

24.3.6.10 Site Furnishings

Sidewalks and other appropriate facilities that provide access for persons with disabilities should be provided at all bus turnouts and should be placed at locations consistent with local accessible bus configurations. See Chapter 18, Section 18.6.6.9, and ADAAG, Section 10 for additional information.

The site furnishings that should be provided at bus turnouts are similar to the site furnishings that should be provided for bus stops. Refer to Chapter 18, Sections 18.6.6.9 and 18.6.6.11.
MOBILITY MEASURES

Figure 24-28 Bus Turnout Dimensions

a. Near-side Turnout

Notes For All Figures:
1. BUS = single unit 12.1 m-13.7 m length.
2. Increase dimensions for articulated bus.
3. X = 1.5 m from edge of crosswalk or end of radius, whichever is further from the intersection.

b. Far-side Turnout

c. Midblock Turnout

d. Queue-Jumper Bus Bay

Source: Adapted from NCHRP Report 155 and TCRP Report 19
24.3.7 **Bus Turnarounds**

Bus turnarounds enable buses to return to the routes they serve without having to travel a circuitous route. They may be used at the termini of routes or they may be incorporated into the design of new developments for which transit service is to be provided.

Transit operations are most efficient when provided on through streets. However, developments that do not have internal roadway networks to return a bus efficiently to the arterial roadway may choose to use bus turnarounds. "Cul de sac" and "loop" designs are acceptable for the end of a bus route. A "jug-handle" bus turnaround design may be used at mid-block bus terminal locations. Examples of bus turnarounds that will accommodate 12.1 m buses are shown in Figure 24-29.

Bus turnarounds should be designed so that a bus can be turned in a counter-clockwise direction to improve the driver's visual capabilities. The roadway should be designed wide enough to allow adequate space for a bus to pass a standing vehicle. This facilitates service in the event of a breakdown and permits passing at terminals used by buses from several routes.
Figure 24-29 Bus Turnaround Dimensions

a. Cul de sac Turnaround

b. Loop Turnaround

c. Jug Handle Turnaround

Source: Pace Development Guidelines
MOBILITY MEASURES

24.4 HIGH-OCCUPANCY VEHICLE LANES ON ARTERIALS

Most congestion on urban/suburban arterial streets occurs at signalized intersections, causing delays to buses and other HOVs. By giving buses advantages over non-HOVs, person-hours of delay due to congestion can be reduced, and may help to increase bus ridership. This should, in turn, improve the arterial's person-moving efficiency, maintain mobility and provide reliability. Design treatments include designating exclusive busways or HOV lanes, providing queue bypasses at bottlenecks, intersection channelization improvements, bus stop improvements, bus turnouts, and bus shelters. Operational treatments include priority treatments at signals, priority turns at intersections, or turn controls that exempt buses. To determine the appropriate treatment, the designer should consider the function of the arterial in question, its geometric and operational characteristics, the source of the congestion, and the abutting land use.

Bus-only treatments make up virtually all existing urban arterial HOV lanes. Very few cities that have them allow carpools to use the lanes. As a result, there is very little information available on combined bus/carpool HOV lane treatments to help develop recommendations for typical cross section dimensions as has been done for freeway HOV lanes. The guidelines that are currently available are based on urban arterial bus-only lanes. Since most projects of this type are retrofit projects, they have the cross section elements of general-purpose urban arterials. The AASHTO Guide for the Design of High Occupancy Vehicle Facilities, and the National Cooperative Highway Research Program (NCHRP) Report 155 Bus Use of Highways: Planning and Design Guidelines provide detailed guidelines. The bibliography and list of references at the end of this chapter provide other design guideline sources.

24.4.1 Design Considerations

24.4.1.1 Design Criteria

The standard values for critical design elements for Urban Arterials in Chapter 2, Section 2.7.2.2, of this Manual are the design criteria for HOV lanes on urban arterials. In addition, other controlling design parameters, included in Chapter 5, must be considered by the designer during the design phase. Variances from standard values established for the critical design elements require a justification and approval as described in Chapter 2, Section 2.8 of this Manual. Variances from the recommended values and accepted practices for the controlling design parameters must be explained and documented as described in Chapter 5, Section 5.1.
24.4.1.2 Design Factors

Urban arterials that have limited access from abutting property and that permit, turning movements (right and left, onto and off the facility) under off-peak conditions, are generally used to provide priority treatment for buses. The NCTR&DP Synthesis of Transit Practice, *Enforcement of Priority Treatment for Buses on Urban Streets* recommends that project design should consider the possible conflicts between bus priority and other functions of the arterial, e.g., property access, vehicular traffic flow, on-street parking, etc. The following factors should be considered in evaluating alternatives for bus priority treatment and in designing projects:

- street widths and facility capacity,
- number of traffic lanes,
- the traffic volumes and speeds,
- anticipated changes in traffic flow as a result of project restrictions,
- cross streets and cross-traffic volumes,
- turning movements,
- median type and width,
- vehicle travel times and delays (including buses),
- curb-parking controls,
- bus passenger loading (curb or off-street),
- abutting land use, property access and future growth,
- the traffic generated by abutting properties,
- adjacent major parking facilities,
- bus routing and volume,
- conflicts with pedestrian traffic, and
- bicycle traffic, lanes, and routes.

It should be noted that many of the above factors can be modified or restricted to facilitate bus priority (e.g., number of traffic lanes, curb parking, turning movements); however, such restrictions must be enforced, making enforcement an important factor to be considered early in the project.
24.4.2 **Design Treatments**

As with HOV lanes on freeways, HOV lanes on arterials are categorized by their physical and operational attributes. There are one-way without barrier and two-way, with or without median or median barrier between the HOV lanes. They can operate as center lane, concurrent flow or contraflow lanes. They may be located in an exclusive right of way or use one or more lanes of an arterial. Figure 24-30 shows a matrix of various combinations of physical and operational types of HOV lanes. The physical types of arterial (across the top) and the types of operation (along the left side) are matched for arterial HOV treatments. As pointed out in AASHTO's *Guide for the Design of High Occupancy Vehicle Facilities*, not all HOV lane combinations diagrammed are necessarily amenable to local bus transit use because of the need to maintain safety of passengers during right side loading and off-loading. Table 24-11 lists various design issues to be considered for the HOV types.

These bus priority treatments differ according to the direction of flow, which lane is to be used, what the mix of vehicles will be, and what traffic controls will be used. Guidelines from *HOV Lanes on Arterial Streets*, adapted here for use in designing and operating arterial priority lanes and streets, are:

- ! Access to major parking garages should be maintained. This may require limited automobile circulation in the block adjacent to the garage.
- ! Design and operations must accommodate the service requirements of adjacent land uses. Deliveries should be prohibited from bus lanes only during the hours that the lanes are in operation. Alternatives would be to provide for deliveries from side streets, from off-street, or from a delivery bay adjacent to the HOV lane.
- ! Bus lane additions, ideally, should not reduce the lanes available to through traffic in the heavy direction of flow. Accommodation of both existing lanes and the bus lane addition may entail eliminating parking or reducing lane widths to provide additional travel lanes, eliminating left-turn lanes, and/or providing reversible lane operation.
- ! Median bus lanes should be physically separated from general traffic for maximum effectiveness.
- ! Taxi loading areas should be removed from the bus lane to prevent interference. On one-way streets, the loading areas should be placed on the opposite side of the street from the bus lane.
- ! Curb parking should be prohibited before bus lanes are established. This makes an additional lane available for moving traffic, thereby substantially increasing street capacity, reducing delays and marginal frictions resulting from parking maneuvers, and giving buses easier access to stops. Where that is not practical, the bus lane should be provided in the lane adjacent to the parking lane.
- ! Bus routes should be restructured (by the transit operator) to make full use of priority lanes and streets. Buses may be shifted from other streets to build up usage, provided that they do not exceed capacity, or inconvenience passengers. One-way volumes ranging from 60 to 80 buses per peak hour will help "enforce" the bus lanes without excessively bunching buses.
- ! Bus lanes may operate all day, or only during peak periods. On streets that pass through shopping areas, bus lanes should be limited to peak periods to allow curb access by shoppers during off-peak periods.
Cross street geometrics at their intersections with arterials can be affected by the HOV treatment selected for use. The turning radii for curb lanes or median lanes may need to be enlarged to permit buses to make the turn from the arterial to the cross street without encroaching into the adjacent lane. Turning radii from the cross street to the arterial may have to be reduced to prevent turns by general-use vehicles onto the arterial. Cross streets may also need upgrading where right turn ground loops (three consecutive right turns around a city block) are used in place of left turns.

The following sections provide guidelines for the types of bus priority treatments available for consideration. Additional guidance is available in *HOV Lanes on Arterial Streets, Operations and Design Guidelines for Facilities for High-Occupancy Vehicles*, and NCHRP Report 155 *Bus Use of Highways: Planning and Design Guidelines*, including detailed descriptions of the exclusive busway, the median bus lane, the concurrent bus lane and the contraflow bus lane. They also provide guidance as to the applicability of, and the factors to be considered in the design and operation of, these treatments on urban arterials. The AASHTO *Guide for the Design of High Occupancy Vehicle Facilities* contains design guidelines for geometric design and traffic control considerations for HOV lanes on arterial streets. Another good source of information is *Faster Than Walking? Street Congestion and New York City Transit Buses* prepared by MTA New York City Transit.
### Figure 24-30 Arterial Street HOV Lane Combinations

<table>
<thead>
<tr>
<th>HOV TREATMENT</th>
<th>ARTERIAL</th>
<th>TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ONE-WAY</td>
<td>TWO-WAY w/ MEDIAN (OR BARRIER)</td>
</tr>
<tr>
<td>EXCLUSIVE R.O.W.</td>
<td>![Diagram]</td>
<td>![Diagram]</td>
</tr>
<tr>
<td>MEDIAN OR CENTER LANE</td>
<td>![Diagram]</td>
<td>![Diagram]</td>
</tr>
<tr>
<td>RIGHT CURB</td>
<td>![Diagram]</td>
<td>![Diagram]</td>
</tr>
<tr>
<td>INSIDE OR INTERIOR</td>
<td>![Diagram]</td>
<td>![Diagram]</td>
</tr>
<tr>
<td>LEFT CURB</td>
<td>![Diagram]</td>
<td>![Diagram]</td>
</tr>
<tr>
<td>CONTRAFLOW</td>
<td>![Diagram]</td>
<td>![Diagram]</td>
</tr>
<tr>
<td>INSIDE OR INTERIOR</td>
<td>![Diagram]</td>
<td>![Diagram]</td>
</tr>
<tr>
<td>LEFT CURB</td>
<td>![Diagram]</td>
<td>![Diagram]</td>
</tr>
</tbody>
</table>

**NOTES:**
1. RIGHT AND LEFT CURBS ARE AS VIEWED FROM THE HOV LANE IN THE DIRECTION OF TRAVEL.
2. THE ARTERIAL TYPE REFERS TO THE PHYSICAL TYPE OF ARTERIAL, THE TREATMENT REFERS TO THE TYPE OF HOV OPERATIONAL TREATMENT APPLIED TO THE ARTERIAL.

**SOURCE:** Adapted from Operational Design Guidelines for High Occupancy Vehicle Lanes on Arterial Roadways

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5/4/98  §24.4.2
<table>
<thead>
<tr>
<th>HOV TREATMENT TYPES</th>
<th>ARTERIAL TYPE</th>
<th>ONE-WAY</th>
<th>TWO-WAY w/ MEDIAN (OR BARRIER)</th>
<th>TWO-WAY w/o MEDIAN (OR BARRIER)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXCLUSIVE R.O.W.</td>
<td></td>
<td>-Parking &amp; loading prohibited in both lanes</td>
<td>-Provide shoulder in each lane -Provide bus turnouts if used by local transit</td>
<td>-Provide passenger loading platforms at local transit bus stops</td>
</tr>
<tr>
<td>MEDIAN OR CENTER LANE</td>
<td></td>
<td>NOT APPLICABLE</td>
<td>-Provide a shoulder in HOV lane -Provide bus turnouts if used by local transit</td>
<td></td>
</tr>
<tr>
<td>RIGHT CURB CONCURRENT</td>
<td></td>
<td>-Provide bus turnouts if used by local transit</td>
<td>-Provide passenger loading platforms at local transit bus stops -Parking &amp; loading prohibited in HOV lane -Prohibit right turns from HOV lane</td>
<td>-Prohibit left turns from general-use lane</td>
</tr>
<tr>
<td>INSIDE OR INTERIOR</td>
<td></td>
<td>-Provide passenger loading platforms at local transit bus stops</td>
<td>-Lane separation by buffer or broken white line -Provide passenger loading platforms at local transit bus stops -Parking &amp; loading prohibited in right curb lane</td>
<td></td>
</tr>
<tr>
<td>LEFT CURB CONCURRENT</td>
<td></td>
<td>-Provide passenger loading platforms at local transit bus stops -Parking &amp; loading prohibited in left curb lane -Prohibit left turns from HOV lane</td>
<td></td>
<td>SEE CONCURRENT RIGHT CURB</td>
</tr>
</tbody>
</table>

SEE CONCURRENT RIGHT CURB
<table>
<thead>
<tr>
<th>HOV TREATMENT TYPES</th>
<th>A R T E R I A L</th>
<th>T Y P E</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>ONE-WAY</td>
<td>TWO-WAY w/ MEDIAN (OR BARRIER)</td>
</tr>
<tr>
<td>RIGHT CURB</td>
<td>-Provide bus turnouts if used by local transit&lt;sup&gt;1&lt;/sup&gt; -Parking &amp; loading prohibited in HOV lane -Prohibit right turns from HOV lane&lt;sup&gt;2&lt;/sup&gt; -Prohibit left turns from HOV lane&lt;sup&gt;3&lt;/sup&gt; -Specialized treatment of exit/entry points -May increase pedestrian accident rate</td>
<td>SEE CONTRAFLOW LEFT CURB</td>
</tr>
<tr>
<td>INSIDE OR INTERIOR</td>
<td>NOT RECOMMENDED</td>
<td>-Provide passenger loading platforms at local transit bus stops -Parking &amp; loading prohibited in left lanes -Prohibit right turns from left curb lane&lt;sup&gt;2, 5&lt;/sup&gt; -Prohibit left turns from left curb lane&lt;sup&gt;3, 4&lt;/sup&gt; -May increase pedestrian accident rate</td>
</tr>
<tr>
<td>LEFT CURB</td>
<td>-Provide passenger loading platforms at local transit bus stops -Parking &amp; loading prohibited in HOV lane -Prohibit left turns from HOV lane&lt;sup&gt;2&lt;/sup&gt; -Prohibit right turns from HOV lane&lt;sup&gt;3&lt;/sup&gt; -Specialized treatment of exit/entry points -May increase pedestrian accident rate</td>
<td>-Provide passenger loading platforms at local transit bus stops -Parking &amp; loading prohibited in left lanes -Prohibit left turns from right general-use lanes -Prohibit left turns from HOV lane&lt;sup&gt;2&lt;/sup&gt; -Prohibit left turns from left general-use lane&lt;sup&gt;3, 4&lt;/sup&gt; -Prohibit right turns from left general-use lane&lt;sup&gt;3, 5&lt;/sup&gt; -Specialized treatment of exit/entry points -May increase pedestrian accident rate</td>
</tr>
</tbody>
</table>

Source: Adapted from Operational Design Guidelines for High Occupancy Vehicle Lanes on Arterial Roadways
NOTES TO TABLE 24-11

GENERAL:

! Refer to Section 24.4.3.2 for lane separation and pavement markings guidelines.

! Prohibit right turns from right curb lanes, and left turns from left curb lanes when the volume of pedestrians crossing at the cross street exceeds 300 persons per hour.

SPECIFIC:

4. Prevents delays to HOV through traffic at passenger loading/unloading areas.
5. Prevents delays caused by heavy volumes of pedestrian crossings.
6. Prevents delays caused by oncoming traffic.
7. Permit general-use left turns by providing an interior general-use left-turn lane.
8. Permit general-use right turns by providing a general-use right-turn lane.

24.4.2.1 Exclusive Busways

Exclusive busways (bus streets) are located on arterial rights-of-way reserved exclusively for use by buses only. They are most often found in the central business district (CBD) where traffic is usually dense and internal circulation is poor. Bus service there is generally local and more consideration is given to movement of people and maintaining good traffic circulation than to reducing travel time. Typical applications for their use are:

! bus/pedestrian malls to provide direct access to major activity centers,
! bus loop at street terminus to allow a smooth return to the bus route,
! terminal approach to CBD transfer facilities, and
! connector links between arterials or from an arterial to a freeway.

Busways generally operate on a full-time (24 hr) basis and separate bus traffic from general-use traffic, to improve bus service. During night periods when traffic is light, however, general-use traffic may be allowed to use them. The selection of streets to be used for HOVs must be made so as not to have a significant negative impact on other traffic or access to abutting properties. Parallel routes with sufficient capacity to carry the diverted traffic should be available.

The safety of exclusive busways is increased, and their enforcement is made easier, when ingress and egress are gained only at the termini. Access should be restricted to the termini and prevented at cross-street intersections. Preventing access may be accomplished by restricting turning movements, or by eliminating the cross-street, where possible. Terminal treatments for exclusive busways are project specific and do not lend themselves to standard or typical layouts. Locations where busways begin and end must be designed to allow the smooth diversion of general-use traffic to other streets. The diversion of traffic should be direct and deliberate, preferably through the use of right turns.

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Busways that carry heavy volumes of more than 60 buses per hour and are more than 800 m long, should be wide enough to allow for passing stopped buses. An alternative, in areas where sufficient space is available, is to provide bus turnouts. Refer to Sections 24.3.5 and 24.3.6 for design guidelines for bus stops and bus turnouts.

Delivery zones should be provided to accommodate the service requirements of the abutting land use where off-street or side street access cannot be gained. On-street delivery zones may be provided for use during off-peak hours when traffic is minimal. Set back delivery areas should be considered for deliveries that must be made during peak hours.

Automobile access to or from parking garages should not be provided by way of a busway, if at all possible. In cases where it cannot be avoided, autos that must enter a busway to access a parking garage should be allowed to enter the busway, within the block in which the garage is located. Autos that must use the busway as egress from the garage should be required to exit the busway at the first downstream cross street.

24.4.2.2 Median or Center Bus Lane

Median or center bus lanes are applicable to two-way streets with five or more lanes, and are almost always reversible. Different methods of separating buses from general-use traffic include painted areas, raised medians abutted by curb (mountable or non-mountable), barriers, or flexible posts installed in holes drilled into the pavement, in which case they operate similarly to exclusive busways. Consideration should be given to snow removal operations, collection of surface runoff, and enforcement operations in selecting the method of separation to be used. In situations where there is no separation between the median lane and the general-use lanes, they operate similarly to two-way median or center lanes without median barrier.

Terminal point transition, points of access, and turning movements on median or center lanes are described in the AASHTO Guide for the Design of High Occupancy Vehicles.

The preferred width of passenger loading/unloading islands is 3.0 m and should extend to the nearest crosswalk serving the islands. The length of non-continuous islands should be determined by the number of buses to stop for passengers at one time, but no less than 15.0 m. The islands should be raised (150 mm mountable curbs) for easy access to buses. Fencing, or posts and chains may be used to designate waiting areas and channel passengers to crosswalks. Splash barriers should be provided to protect passengers. Pedestrian cross walks should be protected by traffic signals and provide access from the near side intersection.

To support a bus-only median bus lane, current guidelines call for the number of peak hour bus passengers to equal the average number of passengers carried by car in the adjacent general-use lanes. The recommended threshold range for minimum peak hour bus usage is from 20 to 40 buses per hour (AASHTO Guide for the Design of High Occupancy Vehicle Facilities).
24.4.2.3 Concurrent Flow Lane

HOVs in concurrent flow lanes travel in the same direction as the adjacent general-use traffic without physical separation between the lanes. They normally require only the addition of pavement markings and signing, and are the most common priority treatment used on arterials. They are usually located next to the curb or in the inside lane next to a median. The curb lane is well suited to local bus service. The inside lane is better suited to express service.

Pickups, deliveries, and parking must be prohibited in curb bus lanes when they are in operation. The lanes should be strictly enforced and parked vehicles must be removed quickly, if the lanes are to operate properly. Heavy use of the curb lane by delivery vehicles, particularly where no other means of goods delivery is possible, may dictate the use of interior lanes. The preferred lane width is 3.6 m and a lane width of 3.3 m is acceptable. Where the demand for curb access is high, and there is no other acceptable alternative but to allow it, the design should provide a 6.1 m wide continuous curb bus lane to permit a bus to pass vehicles that are loading/unloading, or set back delivery zones should be provided where needed.

Buses should not leave the bus lane during normal operation except to pass a stalled vehicle. At locations where right turns are necessary, right turning general-use vehicles should only be allowed to enter the HOV lane within one block of the intersection. Turning movements for concurrent flow lanes are described in the AASHTO Guide for the Design of High Occupancy Vehicle Facilities. An alternative method is to set the right curb back at certain signal-controlled intersections to provide storage for a right turn lane.

Left turning restrictions vary from prohibiting all left turns to the joint use of left turn bays by HOVs and non-HOVs. Where the blocks are small enough and local streets can carry diverted traffic, right turn ground loops can be used. Still another alternative is to use priority signal turn phases.

The NCHRP Report 155 Bus Use of Highways: Planning and Design Guidelines advocates the use of a concurrent flow bus lane when the number of peak hour bus passengers equals the average number of passengers carried by car in the adjacent general-use lanes. The guideline for minimum peak hour bus usage is 30 to 40 buses one way. HOV Lanes on Arterial Streets goes on to recommend that in situations where the peak bus volumes exceed 100 buses per hour, dual bus lanes should be considered to prevent congestion. This allows buses to pass each other at stops, but right turns by general-use traffic from the right are precluded.

Operations and Design Guidelines for Facilities for High-Occupancy Vehicles recommends posting speeds that limit the speed differential between the HOV lane and the general-use lane to a maximum 15 km/h, if necessary and possible, to minimize the number of accidents that result from large speed differentials. This can be accomplished with the use of variable message signs (VMS) installed above the lanes.
For curb lane HOV lanes, locations should be provided for enforcement areas that do not encroach on the street and impede traffic. The use of cross streets may be a viable option.

Pedestrian safety must also be considered. The following options, adapted from Operations and Design Guidelines for Facilities for High-Occupancy Vehicles, should be considered:

- strict enforcement of jay-walking ordinances.
- a special yellow stripe 300 mm to 600 mm wide with a warning message painted on the sidewalk adjacent to the curb.
- plantings to obstruct and channel the pedestrian traffic to particular locations equipped with pedestrian signals.
- buses operating with their headlights on at all times.

In selecting the curb lane as the HOV lane, there may be deficiencies which require correction to make the lane useable. Signs, poles and other obstacles located along the route should be a minimum of 500 mm from the curb. Drainage inlets may need to be relocated or leveled to provide a smooth ride.

24.4.2.4 Contraflow Lane

A contraflow bus lane is a lane borrowed from the off-peak direction to carry HOVs in the peak direction. To be successful, the directional traffic demand split should be 60% peak to 40% off-peak or greater. The contraflow lane can be the curb lane of a one-way street, or the curb lane or the inside lane of a two-way street. The center lane of a three lane one-way street should not be used as a contraflow lane.

Contraflow lanes operating in right curb lanes of one-way streets orient the bus passenger door to the right curb line, and are best suited to passenger loading/unloading. These lanes normally serve local bus stops. They may operate either during the peak period or on a 24 hour, full-time basis. Use of the contraflow lane by other types of HOVs (carpools and vanpools) should not be considered unless bus volumes are low.

Contraflow lanes operating in left curb lanes or inside lanes are normally used for express bus service. The inside lanes may be used as reversible lanes to provide reserved lanes in the peak direction at all times. They permit HOVs to bypass congestion in the general-use lanes and at signalized intersections. They generally operate during the peak period.

The preferred width of all lanes is 3.6 m; the acceptable lane width is 3.3 m. Where there are heavy pedestrian volumes and sufficient space is available, contraflow bus lanes next to curbs should be 3.9 m to 4.2 m wide, so buses can turn out around pedestrians who step off the curb.
The operation of contraflow lanes is contrary to basic driver expectancy. They are potentially one of the most hazardous priority treatments that can be implemented on an arterial street. The possibility that motorists and pedestrians may not recognize the opposing traffic flow, and what lane it is in, may lead to higher accident rates during the initial operation. To help mitigate that, contraflow bus lanes are usually limited to use by buses driven by trained professional bus drivers.

To further improve safety, when space is available, contraflow lanes should be separated from general-use lanes by physical separations. AASHTO’s *Guide for the Design of High Occupancy Vehicle Facilities* contends that for right curb contraflow lanes on one-way streets and inside contraflow lanes on two-way streets, this is not essential. However, left curb lanes should always be physically separated from opposing traffic. Median islands or barriers are the preferred separation; permanently installed flexible posts are acceptable where space is constrained; and pavement striping can be used for low speed areas.

*Operations and Design Guidelines for Facilities for High Occupancy Vehicles* recommends improving the safety of pedestrians and motorists by:

- strict enforcement of jay-walking ordinances
- signing that warns pedestrians to “LOOK BOTH WAYS” at designated cross-walks
- special visual or audible warning devices installed on contraflow lane buses
- a special yellow stripe 300 mm to 600 mm wide with a warning message painted on the sidewalk adjacent to the curb
- for median contraflow projects with a divided median, application of a combination of fencing and plantings in the median to obstruct and channel the pedestrian traffic to particular locations equipped with pedestrian signals
- buses operating with their headlights on at all times.

Left turns should be prohibited in both the contraflow lane and the off-peak direction when pedestrian traffic parallel to the bus lane is heavy, unless traffic signal phasing and separate storage lanes 3.9 m to 4.8 m wide are provided to protect the turning vehicles, allow the pedestrians to clear the crosswalk, and prevent delays in the bus lane.

Contraflow HOV lanes with high bus volumes and no passing lane should be provided with bus turnouts to allow for passing a stopped bus.

24.4.2.5 Transitions

The design of transitions from normal street cross sections to HOV priority lanes is a key factor in determining the effectiveness of the facility. Priority lanes should be terminated only at intersections. Various combinations of signing, pavement markings, signalization, movable barriers, and geometric changes can be used to provide the transition treatment needed for projects. Advance warning signs alerting motorists to the start of an HOV lane should be provided at least one block upstream of the start of the lane to give motorists time to move safely into the proper lanes. Signs should also be provided at the beginning of the priority lane. Refer to the NYSMUTCD, §214.5, R4-20 or R4-25 signs.
MOBILITY MEASURES

Signs warning motorists of the end of the HOV lane should be provided in advance of the transition, and at the end of the HOV lane where the parking lane resumes. Advance signs should be located so as to give the HOV driver sufficient time to move safely into the adjacent lane. The end of the priority lane should be a right-turn-only lane to prevent vehicles from crossing the intersection into the parking lane. Refer to the NYSMUTCD, §214.5, R4-22 or R4-27, and R3-24 signs. Curb lanes that transition to a general-use lane on the other side of the intersection need not be signed for a right-turn-only.

Pavement markings can also be used to aid HOV transitions on 24-hour HOV lanes. Permanent pavement markings should not be used on HOV lanes that operate only on a part-time basis, due to the confusion that may occur during the off-peak hours the lanes are not in operation.

HOV lanes generally begin at intersections. When an HOV lane begins on the near side of an intersection, care must be taken to prevent the development of a queue of non-HOVs that will block the intersection. An alternative would be to start the HOV lane on the far side of the intersection.

Concurrent HOV curb lanes can also be terminated upstream of the intersection at a pre-signal location where a priority green phase is provided to the HOV lane, allowing HOVs to move forward into any of the approach lanes. When the HOVs are in place, the pre-signal allows the non-HOVs to move into the approach lanes. Then the main signal is activated to clear the intersection. This operation allows maximum use of the intersection approach capacity, particularly when the HOV volumes are low. In addition, right curb setbacks or turning lanes can expedite turning movements by preventing blockages due to waiting vehicles.
24.4.3 **Signing and Pavement Markings**

When space allows, concurrent flow HOV lanes should be separated from general-use lanes by buffers, and contraflow lanes should be separated by barriers. When that is not possible, pavement striping must be used to provide the separation. Signs and pavement markings should follow standard signing principles and conform to the NYSMUTCD and Appendix A-19 to Title 17 of the New York State Official Codes, Rules, and Regulations (NYCRR) to the fullest extent possible. Signs and/or signals, including variable message signs, should be used to convey lane use restrictions. Preferential lane markings should also be used to designate the restricted lanes. The standard symbol for HOV lanes shall be the elongated diamond symbol which shall be used on all signs and as pavement markings. Refer to Figure 24-20.

### 24.4.3.1 Signing

Preferential lane signs should be located at regular intervals along the HOV lane and at exit and entry points. Signs may be ground-mounted for the curb lanes, but they may be less visible to the motorist than overhead signs, due to visual interference by other signs, buildings, etc. Overhead signs are the most visible, and should be used exclusively for interior lanes.

Implementing preferential lane use restrictions may require obtaining approval of signs not included in the NYSMUTCD and NYCRR, Title 17, Appendix 19. For example, lanes restricted to buses may be signed “BUSES ONLY” or “RIGHT LANE BUSES ONLY”. The sign should be similar to R4-21 or R4-26 signs in the NYSMUTCD, with appropriate wording changes, and conform to the requirements of §214.5. Lane restrictions can be emphasized by overhead signing placed over the appropriate lanes at intersections. Signing for HOV lanes not physically separated from the adjacent general-use lanes should be located at shorter intervals than on separate HOV lanes. AASHTO recommends spacing of 100 m minimum to 250 m maximum.

Reversible-flow lanes and contraflow lanes are good candidates for the use of overhead signs. The signing of contraflow lanes can be augmented with flashers to warn opposing traffic. The reversible lane signing can have signals installed for both directions to show drivers which direction of travel is in operation. Flashing lights along with a sign message, for example, "HOVs ONLY WHEN FLASHING", on HOV lanes, conveys to motorists when the lane is in operation and helps prevent confusion as to when the lanes are open to general-use traffic. Information giving time of operation and vehicle occupancy requirements can then be provided on roadside signs, when feasible.

Signs for control of exits and entrances to HOV lanes should be located far enough in advance to give the drivers time to move into the correct lane. Signing in the off-peak direction approaching a contraflow section should include advanced-warning and restricted-lane signing along the mainline. Signing in the peak direction would normally be the standard signing with emphasis on vehicle eligibility.
When right turns are permitted from right curb HOV lanes, the signing should state specifically where the right-turning general-use vehicles may enter the lane. NCHRP Report 155 *Bus Use of Highways: Planning and Design Guidelines* recommends right-turning general-use vehicles be allowed to enter the right curb lane 75 m upstream of the intersection. Signs with the wording “BUSES AND RIGHT TURNS ONLY” should be used, including the days and hours of operation. The sign should be similar to R4-21 or R4-26 signs with the appropriate wording changes, and conform to the requirements of the NYSMUTCD, §214.5.

Refer to Section 24.2.10 in this chapter for additional guidelines on signing.

### 24.4.3.2 Lane Separations and Pavement Markings

The preferred method of separating exclusive, median, or concurrent flow HOV lanes from adjacent general-use lanes and from adjacent HOV lanes is by 0.6 m wide buffers. Contraflow lanes should be separated from the adjacent general-use lanes by 0.6 m wide concrete barriers. When the cross section is restricted by lack of space, preventing the use of buffers or barriers, lane striping must be used.

Lane striping guidelines for the separation of HOV lanes from adjacent general-use lanes, and from adjacent HOV lanes, are found in AASHTO's *Guide for the Design of High-Occupancy Vehicle Facilities*.

All pavement markings for travel lane lines, edge lines, full barriers, reversible lane lines and HOV lane symbols shall conform to the NYSMUTCD and NYCRR, Title 17, Appendix A-19. The elongated diamond symbol illustrated in Figure 24-20 shall be used to designate all HOV lanes, except part-time lanes, to avoid confusion. The diamond symbol should be centered laterally in the HOV lane, and located at intervals of 25 m to 150 m depending on the block length and location of major access points. Pavement markings, combined with appropriate signs and lights, contribute to ensuring that motorists are aware that the lane is restricted and when it is in operation.
Additional recommended guidelines for the location of diamond symbols, based on work by the Ministry of Transportation of Ontario, and found in Operational Design Guidelines for High-Occupancy Vehicle Lanes on Arterial Roadways, are as follows:

- A diamond symbol should be centered laterally on the lane and located 10 m downstream from the beginning of the block or the cross walk. Additional diamond symbols may be used, depending on block length and the location of major access points.
- On concurrent flow lanes, additional diamond symbols may be used, if right turns are not permitted from the right curb HOV lane.
- On contraflow lanes, additional diamond symbols should be located 10 m upstream from each intersection.

At intersections where side street traffic is allowed to turn right across an HOV lane, an intersection line should be marked from the curb to the lane line, except where crosswalk markings are provided. In those cases, the intersection line should extend from the downstream crosswalk line to the lane line. The intersection line should be the same width and color as the lane line which adjoins it. Refer to Figure 24-31 for layout guidelines. Carrying the HOV lane markings through the intersection may also be helpful to guide turning drivers away from the HOV lane. Dotted pavement markings are appropriate for this use. Refer to NYSMUTCD §261.4.

Figure 24-31 Intersection Lines for Concurrent Flow Arterial HOV Lanes

Source: Operational Design Guidelines for High-Occupancy Vehicle Lanes on Arterial Roadways
24.4.4 Enforcement

The National Cooperative Transit Research & Development Program Synthesis of Transit Practice Number 2, Enforcement of Priority Treatment for Buses on Urban Streets provides information on bus priority design guidelines in which enforcement is considered to be a primary element in a project’s success. It makes the point that the lack of consideration of enforcement strategies during the design of a project may result in significant limitations on the enforcement effort. Improper project design for bus priority treatments on urban arterials may result in either expensive enforcement or an operation in which enforcement is difficult or impossible. Project design should be coordinated closely with the local enforcement agency.

FHWA’s High Occupancy Vehicle Enforcement Guide contains design considerations important to enforcement of surface street HOV lanes, which include various geometric and traffic control elements, summarized in Sections 24.4.4.1 through 24.4.4.3 below. Also refer to FHWA’s Enforcement Requirements for HOV Facilities for additional guidance.

24.4.4.1 Exclusive HOV Lanes

A. Geometric Considerations

Access and egress usually occurs at HOV lane terminal points. Unlawful access at intermediate intersections can be impeded by using small radius curbs that will not allow for an adequate turning path for a passenger car.

B. Traffic Control Considerations

1. Pedestrian indications at intersections and midblock locations.
2. Traffic signs and signals to restrict the turning movements between the busway and cross streets.
3. Use of NYSMUTCD signing and pavement markings for terminal areas and other access areas to channel the traffic appropriately.
24.4.4.2 Concurrent Flow Lanes

A. Geometric Considerations

1. Center medians of sufficient width, or containing numerous left turn lanes, closed off during peak period operation due to left turn restrictions, may provide vantage points (points from which enforcement officers can watch the HOV lanes) and violator detention areas.
2. Cross streets may be considered for violator detention areas for lanes with tight space restrictions.

B. Traffic Control Considerations

1. NYSMUTCD signing upstream of, and within, HOV lanes should be frequent enough to alert new arrivals and remind through traffic of lane use restrictions.
2. "RESTRICTED LANE ENDS" signing is necessary to establish the location where the HOV lane use restriction ceases, and the lane is available to all motorists.
3. Signing permitting right turns from curb HOV lanes should specifically state the point at which a right-turning general-use vehicle may enter the priority lane.
4. Possible need for signs restricting turns from HOV lanes.
5. Signs prohibiting parking in curb HOV lanes.
6. Wider striping used as lane lines.
7. Use diamond symbol, rather than word messages, for 24-hour operation restrictions. Diamond symbol should not be used for facilities that operate as restricted lanes only during the peak-period.

24.4.4.3 Contraflow Lanes

A. Geometric Considerations

1. Wide HOV curb lanes (6.0 m preferred) provide a violator detention/citation area during HOV operation, or space for loading/unloading when the HOV lane is not in operation, and a passing lane, that will allow traffic to safely pass.
2. Inside contraflow or reversible lanes with adjacent physical medians and mountable curbs, or with left turn lanes that are closed during peak period operation, provide areas for surveillance, apprehension and issuing citations.
B. Traffic Control Considerations

1. Special signal control devices might be required to guide traffic through the entrance points to and exit points from the contraflow lane.
2. Use overhead lane use signals (NYSMUTCD §275.3), especially at lane terminals and intermediate access locations.
3. Overhead lane designation signs are desirable.
4. Use advanced warning signs to advise drivers they are approaching the beginning or end of preferential lanes (NYSMUTCD §214.5).
5. Special crossover signs may be required at transitions points.
6. Marked buffers are desirable, where space allows.
7. Diamond symbols should only be used on 24-hour full-time HOV lanes to avoid confusion.
8. Stanchions (drums, cones, and tubular markers) are effective when used to facilitate transitions and limit intermediate access and egress.
9. Stanchions (drums, cones and tubular markers) may be used to separate right curb or median HOV lanes from opposing general-use lanes (AASHTO’s *Guide for the Design of High Occupancy Vehicle Facilities*).
10. Left-curb HOV lanes should always be physically separated from opposing general-use traffic (AASHTO’s *Guide for the Design of High Occupancy Vehicle Facilities*).
24.4.5 **Access to Abutting Properties**

It is just as important to consider the adverse impacts that converting a curb lane to HOV use can have on access to the abutting properties for service and deliveries, as it is to consider the impacts to the traffic patterns and street system capacities. Curb lane HOV treatments will likely result in conflicts between the need for access to the abutting properties and the objective of providing improved traffic conditions. Full-time curb lane HOV treatments require that curb parking be prohibited and property access be achieved by some other means such as from the rear, off a local street or alley, or via off-street access. If there is no alternative but to provide access from the arterial, it will be necessary to select specific locations for the turns. A part-time HOV curb lane restricts access only during the peak period, and reverts to normal use during the off-peak period. In either case, arrangements must be made with abutting property owners and the street should be signed to restrict the turns, as necessary.

24.4.6 **Provisions for Bicycles**

Arterials may be shared roadways, designated as bike routes (not a preferential use lane), or have designated bike lanes within their rights of way. This tends to make turning movements at intersections, bus stops and bus turnouts complicated. Where bike lanes are provided, a marked through lane should be provided to guide bicyclists along the outside of the bus stop or turnout. Refer to Chapter 18 in this Manual and AASHTO's *Guide for the Development of Bicycle Facilities* for further guidance on the design of bike lanes at intersections. Those details can be adapted for use at bus stops and bus turnouts, as shown in Figure 24-32.

Another means of providing for bicycles is for transit operators to implement an on-vehicle bus storage program to allow passengers to bring their bicycles onto the bus. An alternative is for operators to provide a carrying rack on the front of the bus.
Figure 24-32 Bicycle Lanes at Bus Stops and Bus Turnouts

a. Near-side Bus Stop

b. Far-side Bus Turnout

Source: Adapted from Guide for the Development of Bicycle Facilities
24.5 OTHER TREATMENTS

This section discusses other treatments that may improve mobility for highway users. Section 24.5.1 presents freeway entrance ramp control as a means of reducing congestion on the mainline and improving safety at the mainline/ramp merge point. Section 24.5.2 discusses the use of freeway-to-freeway connector metering to alleviate congestion on high volume connectors. Queue bypasses for HOVs at freeway entrance ramps and other queue bypass treatments are discussed in Section 24.5.3. The use of freeway shoulders as peak hour travel lanes is covered in Section 24.5.4. Section 24.5.5 summarizes the importance of access management to preserving safety and arterial capacity, and reducing congestion on streets and roads. The importance of incident management is summarized in Section 24.5.6. Section 24.5.7 briefly presents the relatively new topic of traffic calming. Work is ongoing to develop a formal policy on the use of traffic calming measures. A Department task force has developed a draft policy and interim guidance to assist the Regions. Special traffic controls, including signal priority systems, signal preemption systems, and signs and lane use control signals are covered in Section 24.5.8. A brief discussion of traveler information systems is presented in Section 24.5.9.

24.5.1 Freeway Entrance Ramp Control

Freeway entrance ramp control is the application of control devices such as traffic signals, signing, and gates to regulate the number of vehicles entering the freeway in order to achieve some operational goal, such as balancing demand and capacity or enhancing safety. The primary method of ramp control is ramp metering. Typically, the objective is to balance demand and capacity of the freeway in order to maintain optimum freeway operation and prevent operational breakdowns. Ramp metering may also be applied for safety considerations where certain geometric inadequacies or other constraints exist. Positive benefits of ramp control most commonly realized are reduced delay, travel time, and accident experience, and increased throughput and operating speeds.

By maintaining noncongested freeway flow, or at least reducing freeway congestion, ramp metering improves the efficiency and safety of freeway operation. It can also improve the safety of the merging operation, particularly at entrance ramps with inadequate sight distances. In addition, by making traffic wait, it makes using the freeway less attractive for some trips than using available alternate routes, or using the freeway at another time, or transferring to another mode of transportation.

Although individual ramps may be metered or closed for specific reasons, ramp control is most effective when ramps are metered in an integrated system manner. System control requires a central or distributed control system master with control algorithms and interconnection by some communications media.

The following sections present discussion on metering rates and strategies to reduce or eliminate congestion, and enhance the safety of merge operations, pretimed and traffic-responsive metering, and local and system control.
Entrance ramp closure is a seldom-used technique for ramp control. It is the most restrictive and least popular form of ramp control, and should not be considered comparable to ramp metering.

The following factors, adapted from NCHRP Report 155 *Bus Use of Highways: Planning and Design Guidelines*, are recommended for consideration in determining the applicability of ramp metering:

- Ramp metering should be considered wherever urban freeways operate below level of service "D". Freeway lane density generally should exceed 25 to 30 vehicles per kilometer.

- Adequate parallel surface routes must be available for the traffic diverted from the ramps, to improve overall network performance.

- Adequate ramp storage capacity must be available, to prevent queues of vehicles waiting to enter the freeway from blocking local street circulation.

- Ramp metering should not be applied where queues exist, e.g., at freeway lane-drops or convergence points, or at freeway-to-freeway connectors.

A report on the Connecticut Freeway Traffic Management System relates applicability of ramp metering to available ramp storage:

".........metering is considered feasible if the available ramp storage exceeds 10 percent of the premetered peak hour volume. If there is storage for 5 percent to 10 percent of the peak volume, metering may still be feasible; but additional analysis is required and possibly mitigating measures (e.g., additional ramp lane, queue detection, etc.). Ramp metering is not considered feasible if the storage is less than 5 percent of the premetered peak hour volume."


24.5.1.1 Ramp Metering

Metering rates are determined according to whether metering is to be used to reduce congestion, or to improve the safety of the merge operation. For examples of how to calculate metering rates, refer to FHWA's *Traffic Control Systems Handbook*.
A. Metering Rates for Congestion Reduction

To eliminate or reduce congestion, demand must be kept below capacity. The metering rate will depend on the relationship among upstream demand, downstream capacity, and the volume of traffic wishing to enter the freeway at the ramp. Downstream capacity is determined by the capacity of a downstream bottleneck or the merging capacity at the ramp. When the sum of upstream demand and ramp demand are less than or equal to downstream capacity, ramp metering is not required to prevent congestion.

When upstream demand is less than downstream capacity, but the sum of upstream demand and ramp demand exceeds downstream capacity, ramp metering is necessary to prevent congestion. The ramp metering rate is determined by the difference in hourly volumes between upstream demand and downstream capacity.

When upstream demand exceeds downstream capacity, a minimum metering rate of 3 vpm - 4 vpm should be used. It has generally been found that metering rates lower than 3 vpm are not effective because drivers waiting at the ramp will judge the ramp metering signal to be malfunctioning and proceed through on red resulting in increased congestion. Metering at the minimum rate may reduce the congestion that might otherwise result from violators ignoring the metering signal.

B. Metering Rates for Safer Merging Operations

When the purpose of ramp metering is to provide safer ramp merging operations, the metering rate should be selected to ensure that each vehicle has time to merge before the next metered vehicle approaches the merge area. When vehicles are released in a platoon from a traffic signal at a nearby intersection onto a ramp, they will compete for gaps in the mainline traffic stream, creating risks of rear-end and lane-change collisions. Ramp metering can break up the platoons and smooth out the merging operation. The Traffic Control Systems Handbook (1996) recommends that metering rates for single lane ramps be:

1. no less than the peak hour ramp volume, or 240 vph, whichever is greater, to prevent queues from forming on the ramp and encroaching into the local street, and
2. no greater than 900 vph, to prevent traffic from being released so close together that safety is compromised.

The Traffic Control Systems Handbook also recommends that a 2 lane meter use a minimum metering rate of 400 vph and a maximum rate of 1500 vph.
24.5.1.2 Pretimed Metering

Pretimed metering refers to a fixed metering rate that is not influenced by current mainline traffic conditions. The rate will normally be set on the basis of historical data. The time period over which a metering rate is in effect is the control interval, which is usually the length of the peak period. Several methods have been developed to establish metering rates for pretimed metering. Refer to FHWA's *Traffic Control Systems Handbook* (1985).

Metering cycles may be actuated and terminated by detectors on the ramps. The ramp metering signal intervals (red, green and yellow) are timed according to whether single-entry metering or platoon metering is used. Single-entry metering permits one vehicle to enter the freeway per green interval.

Platoon metering allows the release of two or more vehicles per green interval, either two abreast or in tandem. With two-abreast metering, two vehicles are released side-by-side per green interval. This method is used on the Long Island Expressway in Suffolk County. Requirements are two parallel lanes on the entrance ramp and sufficient distance beyond the ramp metering signal to achieve a tandem configuration before merging with freeway traffic. With tandem metering, the vehicles are released one after another.

The disadvantages of the platoon metering are driver confusion, greater probability of rear-end accidents, and greater likelihood of disrupting mainline freeway flow. Platoon metering should only be used when the required metering rates are higher (greater than 900 vph) than can be provided with single-entry metering.

Pretimed metering gives a condition to which the driver can easily adjust, and which can be depended upon. A primary disadvantage to pretimed metering is that it cannot adjust to significant changes in mainline demand or react to circumstances resulting from incidents. Therefore, the metering rate should be set to operate at volumes that, when added to the upstream volumes, will total slightly less than the downstream capacity.

Pretimed metering is the simplest form of entrance ramp metering. The essential components of a pretimed metering system include:

- **Ramp metering signal** - A standard 3-section (red-yellow-green), or 2-section (red-green) signal display which controls the ramp traffic. Refer to the NYSMUTCD §275.6 for design, location, and operation requirements.

- **Local controller** - A standard pretimed controller, with or without the logic to adjust metering rates by time of day and/or accept input from check-in and queue detectors.

- **Advance signal ahead sign with flashing beacon** - A sign which indicates to traffic approaching the ramp that the ramp metering signal is in operation when the beacon is flashing. Refer to the NYSMUTCD §275.6 for related devices.
Optional components that may be used to provide more capabilities to the metering system include:

- **Check-in detector**: A detector placed on the ramp approach to the metering signal upstream of the stop line. When the vehicle stops at the stop line and is detected, the signal changes from red to green. It is preferable to have a default minimum metering rate of 4 vehicles per minute (vpm) on the chance that the detector fails or that the vehicle is not detected. An alternative is to install two detectors in the ramp lane.

- **Check-out detector**: A detector placed on the ramp 2.4 m downstream of the stop line. When the vehicle is detected, the green signal is terminated. This limits the length of the green interval to the time needed to permit one vehicle to pass.

- **Queue detector**: A detector placed as far upstream on the ramp as possible, without detecting the frontage road traffic which desires to bypass the ramp. When a vehicle occupies the loop for a minimum length of time, indicating a queue that may interfere with the traffic on the access roadway, the metering rate changes to a higher rate to shorten the queue, or metering may be temporarily terminated to clear the queue. There may be situations where the ramp length is not adequate for the queue that will develop during the peak hour. In those cases, adding a storage lane and queue detector to the access roadway should be considered.

- **Merge detector**: A detector that senses stopped vehicles in the merge area of the ramp and freeway mainline. Actuation of the merge detector preempts subsequent green intervals until the vehicle merges.

The *Official Compilation of Codes, Rules, and Regulations of the State of New York* (NYCRR), Title 17, Appendix A-19, Authorization 89-3 authorizes the use of signs with the words ‘ONE VEHICLE PER GREEN’ in conjunction with ramp metering signals.

Refer to Figure 24-33 for a layout of a pretimed entrance ramp metering system.


### 24.5.1.3 Traffic-Responsive Metering

Traffic-responsive metering strategies are based on current or predicted demand-capacity conditions and real-time traffic measurements. The basic metering strategy is:

- obtain real-time measurements of traffic variables on the freeway and entry ramps,
- on the basis of these measurements, determine how the freeway section is operating with respect to capacity, and
- determine the maximum ramp metering rate at which vehicles can be permitted to enter the freeway to maintain uncongested operations.
A refinement which is often made to this strategy is to take into account the effects of traffic composition and weather conditions on the downstream capacity.

Flow rate (volume) and lane occupancy (defined as the percent of time that a point on a roadway is occupied by a vehicle) are the two traffic variables generally used to describe freeway traffic conditions for traffic-responsive metering. They are used because they can be measured in real time using vehicle detectors. While there are several variations on the basic strategy of metering which utilize different combinations of traffic variables, the principal metering strategies are

- demand-capacity control, and
- occupancy control.
A. Demand-Capacity Control

Demand-capacity control involves measuring the real-time upstream volume and comparing it to the downstream capacity. The downstream capacity is either:

- a preset value of downstream capacity determined from historical data, or
- a real-time value computed from downstream volume measurements.

The difference between the upstream volume and the downstream capacity then becomes the allowable entrance ramp volume. The ramp volume is expressed as a metering rate and is used during the next control interval (usually 1 minute).

The downstream capacity may be a fixed value estimated for the site. The disadvantage of a fixed value capacity is that variations in weather conditions, traffic composition, and incidents make it difficult to estimate. An alternative to a fixed value capacity is a real-time capacity measured by detectors located at the downstream site.

Refer to Table 24-12 for ranges of metering rates applicable to different demand-capacity metering arrangements. For further detail on the demand-capacity strategy, refer to the *Traffic Control Systems Handbook* (1985 and 1996 editions).

Since a low upstream volume could occur in congested as well as uncongested flow, volume alone does not indicate degree of congestion. Therefore, an occupancy measurement also is usually made to determine whether uncongested or congested flow prevails. If the occupancy measurement is above a preset value which is determined from historical data, congested flow will be assumed to exist and a minimum metering rate used.

B. Upstream Occupancy Strategy

Occupancy control uses real-time occupancy measurements generally taken upstream of the entrance ramp. One of a number of predetermined metering rates is selected for the next control interval (usually 1 minute) on the basis of occupancy measurements taken during the current control interval. For each level of occupancy measured, a metering rate can be computed that corresponds to the difference between the predetermined estimate of capacity and the real-time estimate of volume. If the measured occupancy exceeds or equals the preset capacity occupancy, a minimum metering rate is selected, for the same reasons as described in Section 24.5.1.1.

Refer to Table 24-13 for ranges of local actuated metering rates applicable to the upstream occupancy strategy. For further information on the upstream occupancy strategy, refer to the *Traffic Control Systems Handbook* (1985 and 1996 editions).
Table 24-12 Metering Rates for Demand-Capacity Metering

<table>
<thead>
<tr>
<th>Type of Metering</th>
<th>Number of Metered Lanes</th>
<th>Approximate Range of Metering Rates (vehicles/hour)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single vehicle entry per green interval</td>
<td>1</td>
<td>240 - 900</td>
<td>NA</td>
</tr>
<tr>
<td>Single vehicle entry per green interval per lane</td>
<td>2</td>
<td>400 - 1500</td>
<td>Applies when required metering rate exceeds 900 vph&lt;br&gt;Requires 2 lanes for vehicle storage&lt;br&gt;Vehicles may be released from each lane simultaneously or sequentially</td>
</tr>
<tr>
<td>Single lane multiple vehicle entry per green interval (platoon metering)</td>
<td>1</td>
<td>200 - 1100</td>
<td>Platoon lengths permit passage of 1 to 3 vehicles per green interval&lt;br&gt;Principally used to increase metered volumes when geometrics do not permit use of more than 1 metered lane&lt;br&gt;Requires changeable sign indicating permitted number of vehicles in green interval&lt;br&gt;MUTCD requires yellow interval after green</td>
</tr>
</tbody>
</table>


Table 24-13 Local Actuated Metering Rates as a Function of Mainline Occupancy

<table>
<thead>
<tr>
<th>Occupancy (%)</th>
<th>Metering Rate (Vehicles/Minute)</th>
</tr>
</thead>
<tbody>
<tr>
<td>#10</td>
<td>12</td>
</tr>
<tr>
<td>11 - 16</td>
<td>10</td>
</tr>
<tr>
<td>17 - 22</td>
<td>8</td>
</tr>
<tr>
<td>23 - 28</td>
<td>6</td>
</tr>
<tr>
<td>29 - 34</td>
<td>4</td>
</tr>
<tr>
<td>&gt; 34</td>
<td>3</td>
</tr>
</tbody>
</table>

Traffic-responsive systems contain the same components as described for pretimed systems, as described in Section 24.5.1.2. In addition, detectors are required on the mainline both upstream and downstream of the ramp. The controller must have the additional capability to monitor the detectors, select metering rates and respond to override conditions. It may also be desirable to include detectors that sense weather conditions and traffic composition to account for their effects on the traffic flow.

The principal advantage of traffic-responsive metering is that it automatically adapts to the ever changing traffic conditions, thus minimizing the adverse impacts of variations in demand and capacity.

Refer to the NYSMUTCD (§275.6) for metering signals and related devices, §261.12 for stop line markings, and NYCRR Title 17, Appendix A-19, Authorization 89-3 for signing requirements.

Refer to Figure 24-34 for a layout of a traffic-responsive entrance ramp metering system.


- Continued actuation of the queue detector - Indicates that the queue of vehicles waiting at the ramp metering signal is approaching the frontage road or surface street and is likely to interfere with traffic on either or both. Therefore, a higher metering rate should be used to shorten the queue length.

- Actuation of the merge detector - Indicates that a vehicle is still in the merge area. Therefore, in the case of single-entry metering, subsequent green intervals are preempted until the vehicle merges.

- No actuation of the checkout (passage) detector after a green interval - Indicates that a vehicle has missed the green signal. Therefore, the ramp metering signal is returned to or left in green.

- Continued actuation of the queue detector with no actuation of the check-in (demand) detector (in the case of systems in which the ramp metering signal rests in red) - Such a condition would indicate that a vehicle on the ramp has stopped short of the check-in detector. Therefore, the ramp metering signal is turned to green to allow this vehicle to proceed.
Figure 24-34 Layout of Traffic-Responsive Entrance Ramp Metering System

Legend

- Controller
- Stop line
- Ramp metering signal
- Advance ramp control warning sign with flashing beacon
- Check-in detector
- Queue detector (optional)
- Check-out detector (optional)
- Merge detector (optional)
- Control variable detector (see note)

Notes
Complete mainline coverage of all lanes is provided only in interconnected control systems, usually at 3 km - 5 km spacing.

For isolated traffic-responsive ramp meter control, a minimum of one CV detector is needed either upstream or downstream of the ramp, but not both.

24.5.1.4 Local Ramp Metering

Local ramp metering is used:

- to improve safety,
- to control one or a few ramps, where downstream freeway sections have experienced recurrent congestion, or
- where system-wide metering proves difficult because metering is not feasible at certain ramps.

24.5.1.5 System Ramp Control

System ramp control refers to the application of ramp control to a series of entrance ramps where a single ramp meter cannot address the excess freeway demand. The primary objective of system ramp control is to prevent or reduce the occurrence of congestion on the freeway. The control of each ramp in the control system is based on the demand-capacity considerations for the whole system rather than on the demand-capacity constraint at each individual ramp. System ramp control may be applied to both pretimed metering and traffic-responsive metering. Refer to the *Traffic Control Systems Handbook*, (1985 and 1996 editions) for more information on system pretimed and system traffic-responsive ramp metering.

A significant feature of system ramp control is the interconnection among local ramp controllers, which permits conditions at one location to affect the metering rate imposed at one or more other locations. Real-time metering plans are computed and updated by a central master computer which issues metering rates to the respective local ramp controllers on the basis of freeway traffic information obtained from vehicle detectors throughout the system.

Although the decision-making capabilities are centralized within the central computer system, the processing of control intelligence may be distributed among the individual entrance ramps. For economic reasons, there is a trend toward decentralized decision-making, distributed computation, and hierarchical control. For further details on system ramp control, refer to the *Traffic Control Systems Handbook*, (1985 and 1996 editions).

System control can also be used to coordinate traffic operations of freeways with street, parkway, or other systems to provide an integrated system. The INFORM system in Region 10 is an example of system control operation.

24.5.1.6 Ramp Design

A. Ramp Type

Single-lane metered entrance ramps should be provided when ramp volumes are less than 900 vph. Multi-lane metered entrance ramps should be used when entrance ramp volumes exceed 900 vph, and/or when an HOV bypass lane is required. Three-lane ramps should be considered only under the most advantageous conditions where the ramp will be on a tangent or a minimum 100 m radius curve approaching the ramp meters.

B. Design Criteria

Metered entrance ramps should be designed in accordance with the design criteria for ramps in Chapter 2, Section 2.7.5.2 of this Manual. Design features or elements which deviate from those standards must be justified and approved in accordance with Chapters 2 and 5.

C. Ramp Length

The length of metered ramps is affected by three design elements:

- the length of the frontage road from the cross street to the entrance ramp;
- the length of queue storage from the ramp entrance to the stop line; and
- the distance from the stop line to the freeway entrance gore point (the physical point where the ramp lane and the mainline lane meet).

Access to a ramp from a cross street is often provided by a frontage road or surface street. If the capacity of the ramp is exceeded, additional storage may be available on the frontage road.

The minimum required storage length is project dependent, based on traffic projections. The available queue storage length depends on the availability of space. Ideally, the available queue storage capacity of the ramp will exceed the difference between ramp demand and the metering rate. At ramps with volumes between 500 vph and 900 vph, where single lane storage capacity may be exceeded, and there is no storage capacity on the frontage road, a second bypass lane may have to be provided to double the vehicles that can be stored in the available storage length. An alternative is to install a queue detector near the beginning of the entrance ramp. When a queued vehicle stops on the detector, the ramp metering interval is adjusted to unload the ramp. See Sections 24.5.1.2 and 24.5.1.3 for detailed descriptions of the system operation. CALTRANS has developed ramp meter design guidelines that include storage requirements, as represented by the chart in Figure 24-35.
The distance from the stop line to the gore point should be enough to allow the vehicle to at least attain minimum speeds in accordance with Chapter 2, Section 2.7.5.2A of this Manual. The grade of the ramp and the percentage of trucks will affect the length and should be considered. Refer to AASHTO’s *A Policy on Geometric Design of Streets and Highways*, 1994, Chapter X for guidance on determining the additional length of acceleration lane needed for ramps on grades. Multiple lane ramps will require longer distances than one lane ramps, to allow vehicles to merge into a single lane before reaching the gore. The lanes should be reduced by taper in accordance with Table 262-2 of the NYSMUTCD.
24.5.2 Freeway-to-Freeway Connector Metering

Interchanges and ramps that connect urban freeways are potential locations for congestion. Even with metering at upstream ramps, high-volume freeway-to-freeway connectors can be bottlenecks. Metering of freeway-to-freeway connectors is a technique that has proven to be a successful and useful complement to ramp metering when high volume connectors are significant contributors to operational bottlenecks.

FHWA’s Control of Freeway and Freeway-Freeway Connectors for Bottleneck Alleviation describes traffic situations that lead to congestion on freeway connectors as being typified by:

- high volume connectors which, together with the mainline volumes, involve demands on merge areas in excess of capacity immediately downstream of the merge area;
- queuing on the connectors, which may back up to and interfere with traffic flow on the feeding freeway;
- queuing on the mainline, which may back up to interfere with upstream exit movements; and
- in some instances, additional mainline congestion at other interchanges in the freeway segment.

Metering of freeway connectors has been used successfully in several locations to alleviate congestion. Potential benefits of metering freeway connectors include:

- displacement of queuing from the mainline to connectors, providing a consistent, controlled traffic situation with better safety characteristics,
- improved flow through the bottleneck area on the mainline, with attendant increase in traffic volume,
- avoidance of less efficient metering of on-ramps upstream of the freeway-to-freeway interchange,
- improved equity amongst drivers along the corridor, and
- diversion of connector traffic to alternate routes to provide better utilization of the freeway corridor.

Operational bottlenecks associated with freeway-to-freeway interchanges can be relieved by metering high-volume connectors. Connector metering moves the congestion from the receptor freeway or upstream metered on-ramps to the connector. If appropriate advance warning is provided to the connector traffic and queues do not extend into through traffic on the crossing freeway, this can lead to safety improvements. HOV treatments can be applied at the metering location to provide passenger travel time benefits. By maintaining uninterrupted flow conditions on the mainline freeway, full geometric capacities are realized. Diversion of connector traffic may occur and lead to further travel time benefits.

Metering is typically accomplished by the use of a pair of traffic signals placed on either side of the connector. The options of one-at-a-time, two-at-a-time and platoon metering are available to yield the required range of metering rates.

The queues which are created by connector metering require particular attention. They can grow
to such length that they impede traffic on the crossing freeway. This could negate any travel time benefits otherwise obtained and may create a serious traffic hazard. This potential problem can be addressed by restriping and/or reconstruction to provide more storage, operational procedures (e.g., closing a nearby ramp) to reduce weaving through the queue, and by queue override techniques which have been used for on-ramp metering. The latter technique involves real-time measurement of the queue length, and a responsive metering implementation which can open up metering as necessary to avoid having undesirable queue growth.

Connector metering is generally a part of a larger metering system, including the metering of adjacent on-ramps. Thus, design of the metering plan for a connector should be integrated into a system metering plan.

For a detailed presentation of freeway-to-freeway connector metering, refer to FHWA's *Control of Freeway and Freeway-Freeway Connectors for Bottleneck Alleviation*. 
24.5.3 **Queue Bypasses**

Queue bypasses are treatments that can be used in conjunction with general-use freeways or with HOV lanes during peak periods. Queue bypasses usually possess characteristics typical of constrained environments and often exist as concurrent flow lanes without separation from the adjacent general-use lanes. No uniform designs prevail; consequently, design latitude is broad. HOV queue bypasses at metered freeway entrance ramps, as presented in Section 24.5.3.1 below, are the most commonly applied treatment.

Special treatments can be provided on arterials to allow HOVs to bypass bottlenecks or gain access to certain locations. In doing so, these HOVs may achieve travel time savings, enhanced travel time reliability, and improved access to specific activity centers, which may help to attract more users. Priority treatments can also be provided at signalized intersections, either as standalone treatments or in combination with other treatments. Some examples of treatments are presented in Section 24.5.3.2.

### 24.5.3.1 Freeway Entrance Ramp Meter Bypasses

Metered entrance ramps to freeways are designed to reduce or prevent congestion on the mainline by metering the vehicles onto the freeway (See Section 24.5.1). A disadvantage to metering is that it temporarily delays non-HOV traffic on the ramp. However, by providing entrance ramp meter bypasses, HOVs are rewarded by being given unimpeded entry to the freeway, or metered entry at a rate favorable to HOVs. This may be done by restriping or re-signing the existing ramp, or adding a new bypass lane by widening the existing ramp, or adding a separate ramp nearby for HOVs only.

Generally, it is best for a general-use lane ramp and an HOV lane ramp to be separated from each other by a barrier or by distance. Remote HOV bypass ramps should be located downstream of metered general-use ramps to avoid queues that may form at metered ramps. The width of bypass lanes and shoulders should conform to Chapter 2, Section 2.7.5.2 in this Manual. A 4.3 m wide right shoulder should be provided for enforcement purposes.

The hours of operation of the bypass lane should coincide with those of the entrance ramp metering operation, normally during the peak period only. During the off-peak period, both lanes of two-lane ramps should be made available for general-use traffic. Three-lane ramps should be limited to 2 lanes during the off-peak period to reduce potential merge operation conflicts.

Queue bypasses are also applicable to other freeway congestion problem areas such as bottlenecks created by lane reductions, freeway convergences, significant truck volumes, or toll plazas. The bypasses at these locations are generally standalone facilities that can be located on either line-haul HOV facilities or general-use facilities. Bypass roadways must be longer than the normal maximum upstream queues to be effective. Bypass lanes should generally begin 100 m to 150 m upstream of queues. The selected length should be determined by field measurement with provisions for future traffic growth. Bypass lanes should be physically separated from the adjacent general-use traffic. Bypass lanes at toll plazas should generally be the center lane(s). Bypass lanes should meet the standards for the functional class of the general-use lanes adjacent to them. Separate bypass roadways should meet the standards in Chapter 2, Section 2.7.5.2 of this Manual.

When long queues develop at intersections on line-haul arterials with no HOV lanes, HOVs can be given priority by allowing them to advance through an intersection from a right-turn-only lane, or by providing a queue bypass lane for their use only. This should include providing an advance green and a merge lane downstream of the intersection to allow the HOVs to re-enter the traffic flow. Queue bypasses are also applicable at other bottlenecks such as approaches to toll plazas, bridges and tunnels.
24.5.4 Freeway Shoulders as Peak Hour Travel Lanes

Shoulders are frequently used as a means of traffic congestion relief in many states. Some typical applications include auxiliary lanes, merge areas, recurring congestion (bottleneck areas), deceleration lanes, preferred treatment of HOVs, and maintenance of traffic in construction work zones. In many cases, the existing lanes are narrowed so the shoulder can be widened to carry traffic. A recent study of 52 project sites in 11 freeway corridors across the U.S. focused on the operational and safety performance of various shoulder-use applications. The research found that simply using the shoulder as a travel lane or reducing lane widths over an extended distance can have a negative effect on corridor safety performance. However, when these methods are used selectively to deal with lane balance, lane continuity, and bottlenecks, there is no significant change in accident rates. A reduction of lane width from 3.6 m to 3.3 m was also found to have no significant impact. For more information refer to NCHRP Report 369 *Use of Shoulders and Narrow Lanes to Increase Freeway Capacity*.

The use of shoulders, or the narrowing of lanes and shoulders, as described below, may result in nonstandard features. When nonstandard lane widths or shoulder widths are created, their use must be justified in accordance with the requirements of Chapter 2, Section 2.8 in this Manual.

The use of auxiliary lanes is a very common application of shoulder use and narrowed lanes. See Figure 24-36a. They can be used on urban freeways between closely spaced interchanges, for example, by changing the lane line between a 3.0 m shoulder and a 3.6 m right lane, to provide two 3.3 m lanes. This is often an inexpensive method, but traffic operations may be affected by the narrower lanes. The general rule is that converting shoulders to auxiliary travel lanes must have potential for reducing greater numbers of congestion related problems and accidents than will be produced by the resulting lack of full shoulders for normal use.

Merges of two facilities, where heavy traffic causes queuing on one or both of them, is another application for shoulder use and narrowed lanes. See Figure 24-36b. The added lane extends the merge area and can be dropped at a point downstream when it is no longer needed.

Locations of recurring congestion may be altered by using shoulders and narrow lanes. See Figure 24-36c. The shoulder lane is employed as a mainline lane and is carried through several interchanges.

The extension of deceleration lanes upstream of exit ramps, by the use of shoulders, may be resorted to at major facility connections, or at major ramps, to prevent ramp queues from backing up onto the mainline, or to allow ramp traffic to bypass a mainline queue. Refer to Figure 24-36d.

Providing HOV lanes is another common reason to narrow existing lanes and utilize shoulders as travel lanes. See Figure 24-36e. In most cases, the left mainline lane is designated as the HOV lane and the right shoulder becomes a replacement lane. Depending on the available shoulder width, it may or may not be necessary to narrow the general-use lanes.
Figure 24-36 Shoulder Use and Narrow Lane Applications

a. Auxiliary Lane

b. Merge Lane

c. Recurring Congestion Areas

d. Deceleration Lane

e. HOV Lane

Source: NCHRP Report 369
The use of these concepts to achieve additional width for travel lanes is not a normal alternative to traditional linear widening. Their use should, generally, be considered only as an interim measure, in instances where long-term solutions have been identified and will be programmed. These concepts should not be considered where there are nonstandard horizontal or vertical sight distances, or at non-standard horizontal curves and grades. Additionally, these concepts should not be considered at priority investigation locations (PILs), unless it can be shown that they are interim measures.

The following recommendations, adapted from NCHRP Report 369, *Use of Shoulders and Narrow Lanes to Increase Freeway Capacity*, should be considered when contemplating the use of shoulders as travel lanes:

- Providing additional lanes through the use of shoulders and narrow lanes should not be considered as an option to traditional widening projects for adding capacity to a freeway.

- Use of shoulder(s) and narrow lanes should be considered as one alternative to achieve smoother flow in those areas of limited length and turbulent flow conditions. Such use should be limited to lengths of 1.5 km or less, to maintain as much of the standard lane widths and emergency parking areas as possible, while achieving the desired improvements.

- Where heavy truck traffic is a significant proportion (5% or more) of peak period traffic, and the structure of the shoulder is not adequate to support heavy trucks, they should be restricted from using shoulder lanes.

- Consideration be given to restricting the use of the converted lanes to peak period or daylight hours only.

Generally, the left shoulder should be considered first, for use as a travel lane, because the right shoulder is the preferred refuge area. The right shoulder is also better for providing emergency response access. The advantages and disadvantages of each shoulder use alternative are summarized in Table 24-14.

For more information on the use of shoulders, refer to NCHRP Report 369 *Use of Shoulders and Narrow Lanes to Increase Freeway Capacity* for guidance in the application of AASHTO’s standards and policies and those in the Federal MUTCD. Additional guidance is contained in FHWA’s *Freeway Modifications to Increase Traffic Flow*.

Guidelines for geometrics, operations, signing, and incident response are presented in Sections 24.5.4.1 through 24.5.4.4.
<table>
<thead>
<tr>
<th>Alternative</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use of Left Shoulder</td>
<td>Left shoulder not used as much for emergency stop or emergency enforcement.</td>
<td>Usually requires restriping.</td>
</tr>
<tr>
<td></td>
<td>May be able to open for use with little or no modification if width is</td>
<td>Sight distance problem with some median treatments.</td>
</tr>
<tr>
<td></td>
<td>available.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No interference by trucks on highways where trucks are restricted from the</td>
<td></td>
</tr>
<tr>
<td></td>
<td>left lane.</td>
<td></td>
</tr>
<tr>
<td>Use of Right Shoulder</td>
<td>May only require re-striping the right lane line adjacent to shoulder.</td>
<td>Right shoulder is preferred area for emergency stops and enforcement activities, and maintenance staging areas.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Merge angle and length of acceleration lane changes at entrance ramps.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sight distance changes at merge and diverge areas of ramps.</td>
</tr>
<tr>
<td>Use of Both Shoulders</td>
<td>NOT PERMITTED.</td>
<td>Requires restriping.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Safety concerns (no refuge).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Enforcement is difficult.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Exacerbates incident management problems.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Maintenance too difficult and expensive.</td>
</tr>
</tbody>
</table>

Sources: Adapted from NCHRP 369 and Freeway Modifications to Increase Traffic Flow
24.5.4.1 Geometric Guidelines

Lane widths should conform to the standards in Chapter 2 for the functional classification of highway under consideration. If a narrower lane is used, a nonstandard feature justification must be prepared in accordance with Chapter 2, Section 2.8. An alignment transition from a standard lane to a shoulder may affect the operation of the freeway by causing traffic to slow down. It is desirable that any traffic slowdown at the beginning of a transition not affect freeway entrance ramps upstream. It is recommended that a minimum of 600 m be maintained between a transition and the next upstream ramp.

Use of shoulders at entrance and exit ramps may reduce sight distance, and acceleration and deceleration lane lengths. Those locations should be examined. Where minimum standards are not maintained, improvements should be made, such as widening the section. Horizontal sight distance should also be investigated at retaining walls, high barriers and glare screens.

Emergency stopping areas should be provided. This may require relocating guide rail and/or improving the edge treatments.

Vertical alignment and sight distance should also be reviewed, especially on freeways with overpasses and underpasses at interchanges.

24.5.4.2 Operations Guidelines

Conventional shoulders do not generally have the structural capability to support heavy truck traffic, in which case, trucks should not be allowed to use the right shoulder as a travel lane. Reinforcing or reconstructing the entire shoulder to support trucks may be too expensive. However, the right shoulder should be reinforced at entrances and exits to allow trucks to use the right shoulder lane to enter and leave the freeway. A minimum distance of 0.5 km should be provided beyond the end of the taper from entrance ramps and prior to the beginning of the taper for exit ramps.

Shoulders constructed in accordance with equivalent single axle load (ESAL)-based design are full-depth shoulders, i.e., shoulders having the same pavement section as the mainline pavement. Full-depth shoulders can support truck traffic and can be used by trucks as long as the shoulder width is adequate.

Turnouts and crossovers should be provided for emergency use. The turnouts should be large enough to accommodate a WB-20 tractor trailer and at least one piece of emergency equipment. The desirable turnout width is 4.9 m. Entrance and exit tapers should be 20:1. Generally, turnouts should be located at 0.5 km intervals.

Shoulder use lanes that are not restricted to daylight hour use should be improved with the lighting and delineation of shoulder areas where necessary. Lighting should be provided in accordance with the NYS Policy on Highway Lighting and Chapter 12 of this Manual.

Maintenance forces should inspect the shoulders each day for loose debris and disabled vehicles, prior to opening them to traffic.
24.5.4.3 Signing Guidelines

Signing for areas where driving on the shoulder is allowed shall conform to the NYCRR, Appendix A-19, Authorizations 92-1, 92-2, and 92-3. Advance warning should be provided at least 0.8 km upstream of where the shoulder use begins. Continued notice should be repeated at 1.5 km intervals.

Sections of highway beyond the limits of permitted shoulder use should be signed in accordance with the NYSMUTCD, Appendix A-19, Authorization 92-4. The signing should be located near the shoulder use lane termini.

Signs advising drivers of turnouts should be provided at the beginning of the shoulder use area. Advance signing for individual turnouts should be provided 300 m upstream of each turnout. Signing for emergency stopping only should be provided at turnouts in accordance with NYSMUTCD, §221.8.

24.5.4.4 Incident Response Guidelines

Corridors subject to significant incident-related congestion may not be improved with the use of shoulders as travel lanes. Elimination of the shoulder as access for emergency vehicles makes reaching the incident more difficult, resulting in delayed response time; longer periods of congestion; greater risk for secondary incidents; and increased difficulties in clearing incidents. The corridor should be carefully evaluated before proceeding to ensure that shoulder use applications are appropriate to the solution of the problem. There are actions that can be taken to mitigate the effects of no shoulder and narrow lanes, as discussed below.

Consideration should be given to implementing surveillance and service patrols to help eliminate the disadvantages of unfavorable geometrics to shoulder usage by emergency vehicles. In areas where there is a shoulder, emergency equipment usually approaches the incident along the shoulder. When there is no shoulder available, the approach must be made through the queue. A standard procedure should be developed and communicated to the public so they may respond safely in such situations.

Pre-established emergency response routes should be developed. Consideration should be given to selecting locations where all traffic can be stopped to allow emergency vehicles access to the incident site from downstream. These locations should be identified in advance so that decisions can be made rapidly.
Median crossovers should be provided more frequently in shoulder use areas than are normally provided in areas that do not permit use of shoulders as driving lanes.

Consideration should be given to installing reference markers with dual panel faces so they are visible from both directions to assist emergency vehicle drivers who may be required to approach the incident from downstream.

Numbered call boxes should be provided at emergency turnouts.

The use of closed circuit television (CCTV) for freeway surveillance can decrease the incident detection time and provide a precise location of the incident.

For information on incident management on freeways, refer to Section 24.5.6.

24.5.4.5 Conflicts With Bicyclists and Pedestrians

Bicyclists and pedestrians are prohibited, by law (NYS Vehicle and Traffic Law, §1229a), from traveling on expressways or interstate routes in New York State. Generally, that does not present a problem because virtually every expressway and interstate highway in the state has a roadway nearby that can be used by bicyclists and pedestrians. Therefore, converting shoulders to travel lanes on expressways and interstates should not result in conflicts between motor vehicles, bicyclists, and pedestrians. Where bicyclists and pedestrians are allowed, by exception, to use controlled access highways, provisions should be made for safe access to, and use by them.
24.5.5 Access Management

Access management is the process that manages access to land development while simultaneously preserving the flow of traffic on the surrounding public road system in terms of safety, capacity, and speed. Management of access to roadways may be the single most effective means of preserving safety and arterial capacity thereby reducing congestion and prolonging the functional life of existing capital investments. The primary goals of access management and the techniques used to achieve those goals are:

11. Limit the number of conflict points by decreasing the number of left turns, using right-turn-in and right-turn-out turns, restricting movements at median openings, and closing median openings. These techniques directly reduce the frequency of either basic conflicts, or encroachment conflicts, or reduce the area of conflict at some or all driveways on the highway by limiting or preventing certain kinds of maneuvers.

12. Separate conflict points by implementing spacing standards, corner clearance requirements, signal spacing requirements, and separation of access points requirements. These techniques either reduce the number of driveways or directly increase the spacing between driveways or between driveways and intersections. They indirectly reduce the frequency of conflicts by separating turning vehicles at adjacent access points and by increasing the decision-process time for the through driver between successive conflicts with driveway vehicles at successive driveways.

13. Separate turning traffic from through traffic through the use of left and right turn lanes, two-way left turn lanes, and acceleration/deceleration lanes. These techniques directly reduce both the frequency and severity of conflicts by providing separate paths and storage areas for turning vehicles and queues.

14. Reduce maximum deceleration requirements by regulating highway speed limits, installing traffic signals to slow speeds, improving sight distances, and increasing the effective approach width of driveways. These techniques reduce the severity of conflicts by reducing highway speeds, increasing driveway speeds, and/or increasing driver perception time.

For a comprehensive discussion of techniques to control conflicts at commercial driveways, refer to Technical Guidelines for the Control of Direct Access to Arterial Highways, Volumes I and II.

Identification and implementation of such techniques should be discussed and worked out with the local governmental agency having jurisdiction for the project area, as the techniques are best implemented as part of the local site plan approval.

For additional information, refer to the Department's Access Management Policy found in the Policy & Standards for Entrances to State Highways, and Best Practices in Arterial Management.
24.5.6 Incident Management

Incident management is the spectrum of activities involved in detecting, responding to and clearing roadway incidents. It is the coordinated pre-planned use of human and technological resources to restore full capacity after an incident occurs, and to provide motorists with information and direction until the incident is cleared.

Studies have shown that delay to motorists increases geometrically with the time it takes to clear an incident. The California Department of Transportation estimates that for each minute the time to clear blocked lanes is reduced, a motorist's delay is reduced by four or five minutes.

Incident management techniques involve many different agencies. The appropriate blend of solutions to incident management will require a high degree of coordination among the participating agencies.

An incident management program involves identifying the agencies and officials who will have a stake in the program, meeting as a group to establish needs and responsibilities, and ultimately identifying the incident management techniques most suitable for use.

Effective incident management generally requires that six major tasks be accomplished, defined in the *Freeway Incident Management Handbook* as:

- **Detection** - Determination that an incident of some nature has, indeed, occurred. This information needs to reach the location where response can be initiated.
- **Verification** - Determination of the precise location and nature of the incident as well as the display, recording, and communication of this information to the appropriate agencies.
- **Response** - The activation, coordination, and management of the appropriate personnel, equipment, and communication links and motorist information media as soon as there is reasonable certainty that an incident is present.
- **Traffic Management** - Application of traffic control measures in the area of the incident site including:
  - lane closures and openings,
  - establishing and operating alternate routes,
  - diversions,
  - parking of emergency vehicles, and
  - ensuring safety of incident victims, motorists, and emergency personnel.
- **Information to Motorists** - Activation of various means of communicating incident site traffic conditions to motorists.
- **Removal/Restoration of Capacity** - Removal of the wreckage, debris, spilled materials, etc., from the roadway and restoring the roadway capacity to its pre-incident condition.
For a comprehensive discussion of the steps involved in planning, developing, and operating an incident management program, refer to FHWA's *Freeway Incident Management Handbook*.

### 24.5.7 Traffic Calming

Traffic calming is the combination of mainly physical measures that reduce the negative effects of motor vehicle use, alter driver behavior, and improve conditions for non-motorized street users. The Department policy and guidance on traffic calming that creates a hierarchy of application for traffic calming techniques which strives to consider and balance the many conflicting needs between highway users and adjacent land owners, with safety being of paramount concern. Often both the State and local highway systems will be affected and coordination is needed during scoping and early design phases. It is essential that an evaluation be made in the scoping stage to determine if traffic calming measures are warranted and implementable, or if traditional approaches or strategies are more appropriate.

Policy and guidance on traffic calming will be issued as a new chapter in this Manual in the future.
24.5.8 Special Traffic Controls

Implementing HOV lanes on congested CBD arterial streets, in itself, may not solve the problem of improving mobility on urban arterials. It may be necessary to enhance the movement of HOV traffic so it can use the existing facility more efficiently, maintain its advantage over general-use traffic, or improve access for emergency vehicles. Special controls can be provided to accomplish these. Examples of special controls include signal priority systems, signal preemption systems, signal queue jumps, directional controls and lane use control signals, and prohibition of curbside parking or vehicle loading. For further guidance on special traffic controls, refer to the FHWA publication Traffic Control Systems Handbook (1985 and 1996 editions), AASHTO's Guide for the Design of High-Occupancy Vehicle Facilities, Alternatives for Providing Priority to High-Occupancy Vehicles in the Suburban Arterial Environment, and NCHRP Report 155 Bus Use of Highways Planning and Design Guidelines.

24.5.8.1 Signal Priority Systems

Signal priority systems provide priority to buses or emergency vehicles at signalized intersections by altering the operation of the traffic signal in their favor. With respect to buses, the purpose is to minimize total person delay, as compared to normal traffic signal systems, which attempt to minimize total vehicle delay. Signal priority systems identify priority vehicles, and modify the signal timing to the benefit of those vehicles.

Bus detection involves the use of a radio frequency transmitter, a receiving loop buried in the pavement, and a control cabinet located at curbside. When the bus is over the detector, a bus-mounted transponder sends out a radio signal to the detector in the pavement, and the position and direction of approach of the bus are established. The signal is transmitted to the traffic signal control cabinet which modifies the traffic signal timing to give the bus priority through the intersection. After a predetermined time, the signal returns to normal operation. Other technologies include microwave transmission, optical or infrared identification, and surface acoustical wave technology.

For information on other signal priority techniques, refer to the Traffic Control Systems Handbook, 1996.

24.5.8.2 Signal Preemption Systems

Signal preemption systems are used to preempt the normal cycling of traffic signals for emergency vehicles, to control intersections near railroad tracks, or to permit transit buses to pass through intersections in advance of other vehicles.

Emergency vehicles may use two preemption techniques. A local signal preemption system includes a transmitter located on emergency vehicles which emits an optical or radio signal detected by a receiver at the intersection. When the vehicle is detected approaching the intersection, a special signal control procedure assigns right of way to the vehicle. After a predetermined time, the signal returns to normal operation.
Route preemption is a system that provides a preplanned route for firefighting equipment. Green signal indications are displayed at signals along the appropriate route, often selected at a control panel in the central fire station. The signals are switched back to normal operation after the reported passage of the emergency vehicle(s), often at a pre-specified time.

Intersections that are located near railroad crossings and are affected by passing trains can be controlled by signals that stop traffic when they sense approaching trains. The signals can be programmed to display the appropriate colors for the direction in question, i.e., red on the street crossing the railroad tracks, and green on the street parallel to, and not crossing, the tracks. This should only be permitted if there are enough lanes to provide through traffic and turning traffic with their own lanes.

24.5.8.3 Signs and Lane Use Control Signals

Signs and/or lane use control signals are normally used to control reversible-flow and contraflow HOV lanes on arterials and freeways, tunnel and bridge traffic operations, peak hour shoulder use on streets and highways, toll booth lane use, and special event traffic.

Lane use control signals:

- permit or prohibit use of specific lanes of a street or highway;
- indicate impending prohibition of lane use;
- are commonly used for reversible-lane control to increase road capacity during periods of directional peak traffic flow;
- are used on freeways to keep traffic out of certain lanes at certain hours; and
- are used on freeways to indicate that a lane ends.

Signs are used to provide directional control. Static signs communicate a single message. The message is applicable at all times to a recurrent situation and the sign should be located in accordance with the NYSMUTCD.

Active signs communicate a message that is applicable only at certain times. Signs may have lights that flash when the message is in effect, or they may be VMS that operate only when it is necessary to convey the message.

24.5.8.4 Bicycle Sensitive Traffic Signal Loops

Normal large area signal loops (long loops designed to register the presence of a vehicle in the zone of detection as long as the detector is occupied) will not detect bicycles, and can leave cyclists who want to cross a busy road or street waiting for a motor vehicle to trip the signal for them. Large area detectors located on bicycle routes should be able to detect all vehicles, including bicycles, and hold the call until the display of the phase. Provision for bicycle detection should be considered on all urban arterials. Bicycle detection can be accomplished by winding the loop wire of a Quadrupole-loop configuration twice to give a double-layer design.
24.5.9 Traveler Information Systems

Safe and efficient operation of a highway system is dependent upon drivers being informed of the conditions they will encounter so they may act accordingly. The information is passed on to the traveler via traveler information systems (TIS), which include various visual and audio techniques. Among them are signs, signals, lane markings, public-address systems, telephones, and radio broadcasts. Static signs and lane markings are discussed in detail in Sections 24.2.10 and 24.4.3. This section discusses variable (or changeable) message signs (VMS or CMS), and highway advisory radio (HAR).

24.5.9.1 Variable Message Signs

The INFORM system on Long Island is an example of a visual TIS. VMS are used to display different messages to motorists as traffic conditions warrant. Computers measure and analyze impulses from sensors in the major highways within Long Island’s central corridor and determine the volume and speed of traffic on different sectors of the highways. With that information, the Traffic Operations Coordinators can transmit appropriate real-time motorist advisories to any of the VMS located at key points on the corridor highways and connecting routes.

VMS can be used to inform drivers of both general and specific real-time problems resulting from varying traffic, roadway, and environmental conditions, such as incidents, work zones, weather, and special events.

Unlike the standards established for static signing in the NYSMUTCD, there are no standards for VMS, mainly due to rapidly changing technological advancements. In fact, there is no widely accepted standard, state-wide or nation-wide, that addresses most aspects of VMS at the present time.

Refer to the Traffic Control Systems Handbook, 1996, Chapter 10, for a comprehensive list of applications of VMS, and a detailed discussion of VMS technologies, display types, and installation, operation, and maintenance issues.

24.5.9.2 Highway Advisory Radio

HAR is an example of an audio TIS. HAR provides information to travelers via the AM band in their vehicle radios. HAR can be either stationary or portable. Portable systems are mounted on trucks and moved from site to site to broadcast as needed.

The area of coverage allowed for an HAR broadcast is project specific, and is typically very small. Therefore, HAR messages are intentionally short so the message can be repeated at least once during a driver’s trip through the area.
The two methods of HAR broadcasting are vertical antenna systems and induction cable antenna systems. Vertical antenna systems are installed within the broadcast area to form an electronically interconnected array to transmit the broadcast. Induction cable antenna systems use buried roadside cable, normally located along the center of the broadcast area, and broadcasts cover an area 30 m to 45 m in width.

For more discussion on these and other types of audio TIS, refer to the *Traffic Control Systems Handbook* (1985 and 1996), and the *Freeway Management Handbook*. 
24.6 INTELLIGENT TRANSPORTATION SYSTEMS (ITS)

[This section will be prepared in the future and released at a later date.]
24.7 REFERENCES

The following is a list of the publications that were used in the preparation of this chapter. Those with an asterisk (*) are available from the Main Office Plan Sales Section.


Converting a General Purpose Lane to an HOV Lane, November 29, 1994, memorandum from Design Quality Assurance Bureau to Corridor Planning and Project Scoping Section, New York State Department of Transportation, 1220 Washington Avenue, Albany, NY, 12232.
24.7 REFERENCES (continued)


The Dallas Contraflow Lane and Movable Barrier, 1993, Poe, C. Transportation Research Circular 409. Transportation Research Board, National Research Council, 2101 Constitution Avenue, NW, Washington, DC, 20418.


The Effects of Environmental Design on the Amount and Type of Bicycling and Walking, 1993, National Bicycling and Walking Study, Case Study No. 20. Federal Highway Administration, 400 Seventh Street, SW, Washington, DC 20590.


5/4/98
24.7 REFERENCES (continued)


24.7 REFERENCES (continued)


24.7 REFERENCES (continued)


Operational Experience with Concurrent Flow Reserved Lanes, 1977, Fuhs, C., A.V. Fitzgerald, R.W. Holder. Texas Transportation Institute, Texas A&M University System, College Station, TX, 77843-3135.


Pace Development Guidelines, Revise June 1995. Pace, Suburban Bus Division of the Regional Transportation Authority, 550 West Algonquin Road, Arlington Heights, IL, 60005-4412.


24.7 REFERENCES (continued)


Transit Facility Design Guidelines, 1987. Regional Transportation District, Department of Planning, Division of Systems Planning, 1600 Blake Street, Denver, CO 80202-1399.
24.7 REFERENCES (continued)


24.8 OTHER SOURCES

The publications listed below are additional sources of information related to the topics presented in this chapter:


*Development of Arterial High-Occupancy Vehicle Enforcement Techniques*, 1994, Stoddard, A.M. Texas Transportation Institute, Texas A&M University System, College Station, TX 77843.


24.8 OTHER SOURCES (continued)


24.8 OTHER SOURCES (continued)


# MOBILITY MEASURES

## 24.9 ACRONYMS

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>AASHTO</td>
<td>American Association of State Highway and Transportation Officials</td>
</tr>
<tr>
<td>ADA</td>
<td>Americans with Disabilities Act</td>
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<tr>
<td>ADAAG</td>
<td>Americans with Disabilities Act Accessibility Guidelines</td>
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<tr>
<td>CBD</td>
<td>Central Business District</td>
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<tr>
<td>CCTV</td>
<td>Closed Circuit Television</td>
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<td>CMS</td>
<td>Changeable Message Sign</td>
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<tr>
<td>ESAL</td>
<td>Equivalent Single Axle Load</td>
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<td>FHWA</td>
<td>Federal Highway Administration</td>
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<td>HAR</td>
<td>Highway Advisory Radio</td>
</tr>
<tr>
<td>HCM</td>
<td>Highway Capacity Manual</td>
</tr>
<tr>
<td>HDM</td>
<td>Highway Design Manual</td>
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<td>HMA</td>
<td>Hot Mix Asphalt</td>
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<td>HOV</td>
<td>High Occupancy Vehicle</td>
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<td>ISTEA</td>
<td>Intermodal Surface Transportation Efficiency Act</td>
</tr>
<tr>
<td>ITE</td>
<td>Institute of Transportation Engineers</td>
</tr>
<tr>
<td>K&amp;R</td>
<td>Kiss-and-Ride</td>
</tr>
<tr>
<td>MCB</td>
<td>Movable Concrete Barrier</td>
</tr>
<tr>
<td>NA</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>NCHRP</td>
<td>National Cooperative Highway Research Program</td>
</tr>
<tr>
<td>NYCRR</td>
<td>New York State Compilation of Codes, Rules, and Regulations</td>
</tr>
<tr>
<td>NYSMUTCD</td>
<td>New York State Manual of Uniform Traffic Control Devices</td>
</tr>
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<td>PCC</td>
<td>Portland Cement Concrete</td>
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<td>P&amp;P</td>
<td>Park-and-Pool</td>
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<tr>
<td>P&amp;R</td>
<td>Park-and-Ride</td>
</tr>
<tr>
<td>PIL</td>
<td>Priority Investigation Location</td>
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<tr>
<td>ROW</td>
<td>Right of Way</td>
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<tr>
<td>SOV</td>
<td>Single Occupancy Vehicle</td>
</tr>
<tr>
<td>SSD</td>
<td>Stopping Sight Distance</td>
</tr>
<tr>
<td>TCRP</td>
<td>Transit Cooperative Research Program</td>
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<td>TDM</td>
<td>Transportation Demand Management</td>
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<tr>
<td>TIS</td>
<td>Traveler Information System</td>
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<td>Transportation Research Board</td>
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<td>Transportation Research Record</td>
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<td>Transportation Systems Management</td>
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<td>USDOT</td>
<td>United States Department of Transportation</td>
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<td>VMS</td>
<td>Variable Message Sign</td>
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<tr>
<td>VPH</td>
<td>Vehicles Per Hour</td>
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<tr>
<td>VPM</td>
<td>Vehicles Per Minute</td>
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</table>
24.10 GLOSSARY OF TERMS

This Glossary includes terms used in this chapter and in publications by the Institute of Transportation Engineers (ITE), American Association of State Highway and Transportation Officials (AASHTO) and the U.S. Department of Transportation (USDOT).

Add-a-lane. A general implementation approach whereby an HOV facility is created by adding roadway capacity to an existing freeway facility, usually by widening the freeway or modifying the median or outside shoulder.

Articulated bus. An extra-long, high-capacity segmented bus that has the rear portion flexibly but permanently connected to the forward portion with no interior barrier to hamper movement between the two parts. The seated passenger capacity is 60 to 80 persons with space for many standees, and the length is from 18 m to 24 m. The turning radius for an articulated bus is usually the same as or less than that of a standard urban or inter-city bus.

Barrier-separated facility. An HOV facility that is physically separated, frequently by barriers, and access controlled from adjacent mixed-flow freeway lanes. Barrier-separated facilities can be operated either as reversible-flow or two-way. The opposing directions within a barrier-separated facility are separated by either a barrier or buffer.

Barrier-separated lane. A lane that is physically separated and access controlled from adjacent general purpose traffic and reserved for the exclusive use of HOVs.

Barrier separation. A physical barrier (either concrete or guiderail) that is used to separate an HOV from general-use freeway traffic.

Bicycle lane (bike lane). A portion of a roadway which has been designated by striping, pavement markings, and signing for the preferential use of bicyclists.

Bikeway. Any road, path, or way which in some manner is specifically designated as being open to bicycle travel, regardless of whether such facilities are designated for the exclusive use of bicycles or are to be shared with other transportation modes.

Buffer-separated facility. An HOV lane that is separated from adjacent mixed-flow freeway lanes by a designated buffer. Buffer widths should not be less than 0.3 m or greater than 1.2 m. They are either traversable or non-traversable (i.e., the buffer can be legally crossed at any point or cannot be legally crossed except at designated access points). Buffer widths greater than 1.2 m should not be provided, to prevent their use as breakdown lanes or travel lanes. Where wide buffers are required, they should be no less than 3.0 m wide and no greater than 4.2 m wide.

Buffer-separated lane. A lane operating in the same direction as general purpose traffic that is separated by a designated buffer width of 0.3 m or more. The buffer can either be traversable or non-traversible.
24.10 GLOSSARY OF TERMS (continued)

**Buffer separation, buffer strip.** Part of a roadway area that is used to physically separate an HOV lane from a regular use lane. Buffer widths should not be less than 0.3 m or greater than 1.2 m.

**Bus bay.** A specially constructed area off the normal roadway section for bus loading and unloading.

**Bus lane.** A lane reserved primarily for buses, either all day or during specified periods.

**Bus priority system.** A means by which transit vehicles are given special advantage over other traffic (e.g., preemption of traffic signals, or bus lanes).

**Busway.** A preferential roadway designed for exclusive or predominant use by buses in order to improve bus movement and travel times. A busway may be constructed either at, below, or above grade, and located either in separate right-of-way or within freeway right-of-way.

**CALTRANS.** The California Department of Transportation.

**Carpool.** Any vehicle, usually an automobile, carrying two or more occupants including the driver, or a group of people sharing automobile transportation.

**Change of mode.** The transfer from one type of transportation vehicle to another (e.g., auto to bus or pedestrian to auto).

**Concurrent-flow lane.** A buffer-separated lane on which, during the entire day or certain hours of the day, HOVs operate in the same direction as the normal flow of traffic.

**Congestion.** The level at which transportation system performance is no longer acceptable to the traveling public due to traffic interference. The level of acceptable system performance may vary by type of transportation facility, geographic location and/or time of day.

**Contiguous lane.** A non-separated concurrent flow lane.

**Contraflow lane.** A lane on which, during certain hours of the day, HOVs operate in a direction opposite to that of the normal flow of traffic (commonly the inside lane in the off-peak direction of travel). For freeway applications, the lane is typically separated from the opposing direction travel lanes by pylons or movable concrete barrier.

**Corridor.** A broad geographical area that defines general directional flow of traffic. It may encompass a mix of streets, highways, and transit alignments.

**Curb-side stop.** A bus stop in the travel lane immediately adjacent to the curb.
24.10 GLOSSARY OF TERMS (continued)

Delay. The time lost by a person or vehicle during travel due to circumstances which impede the desirable movement of traffic. It is the travel time difference between congested and free-flow travel times.

Diamond. A uniform traffic control symbol used on signing and pavement markings to designate restricted use of preferential (HOV) facilities.

Dwell time. The time a bus spends at a stop, measured as the interval between its stopping and starting.

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

Enforcement. The function of maintaining the rules and regulations to preserve the integrity of a preferential (HOV) facility.

Enforcement area. A dedicated space on which enforcement can be performed. Enforcement areas can be delineated within an available shoulder or provided at specific locations.

Exclusive facility, freeway right-of-way. An HOV roadway or lane(s) located within a freeway right-of-way that is physically separated from the general purpose freeway lanes and designated for HOVs for all or portions of the day. Physical separation is usually via a concrete barrier, but separation can also be via a wide painted buffer.

Exclusive facility, separate right-of-way. An HOV roadway or lane(s) located in a separate right-of-way that is usually, but not always designated for the exclusive use by buses. The facility is typically a two lane, two-way operation.

Express bus service. Bus service with a limited number of stops, either from a collector area directly to a specific destination or in a particular corridor with stops en route at major transfer points or activity centers. Express bus service is usually routed along freeways or HOV facilities where they are available.

Far-side stop. A bus stop located immediately after an intersection.

General-use, general purpose, mixed-flow, mixed-use. A traffic lane that is available for use by all types of vehicles.

Ground loop. A series of three horizontal right turns around a city block, made by a vehicle after passing through an intersection where no left turn is allowed, to achieve travel in the direction of the disallowed left turn.
24.10 GLOSSARY OF TERMS (continued)

**Headway.** The time interval between successive passing of vehicles, measured from front end to front end, moving along the same lane in the same direction on a roadway, expressed in seconds or minutes.

**High-occupancy vehicle (HOV).** Motor vehicles carrying at least two or more persons, including the driver. An HOV could be a transit bus, vanpool, carpool or any other vehicle that meets the minimum occupancy requirements, usually expressed as either two or more (2+), three or more (3+), or four or more (4+) persons per vehicle.

**High speed.** A speed of 80 km/h or more.

**HOV facility.** The collective application of physical improvements that support an HOV operation, including lanes, ingress/egress, park-and-ride lots, park-and-pool lots, and transit facilities that are developed so as to effectively integrate all elements as a unified whole.

**HOV lane.** A preferential lane that is reserved for the use of high-occupancy vehicles.

**HOV system.** The collective application of HOV facilities, programs and policies that are effectively integrated to provide a comprehensive application of HOV incentives in a corridor or region.

**Ingress/egress.** The provision of access to/from an HOV facility.

**Kiss-and-ride.** An access mode to transit whereby passengers (usually commuters) are driven to a transit stop and left to board the vehicle, then met after their return trip.

**Line haul.** That portion of a commute trip that is express (non-stop) between two points.

**Low speed.** A speed of 60 km/h or less.

**Main lane.** One of the mixed-flow freeway through lanes.

**Midblock stop.** A bus stop within the block.

**Mode.** A particular form of travel (i.e., walking, bicycling, traveling by bus, traveling by carpool, traveling by train, etc.).

**Near-side stop.** A bus stop located immediately before an intersection.

**Nonseparated (HOV) lane.** An HOV lane that is not separated from adjacent mixed-flow freeway lanes (i.e., delineation is via a standard dashed pavement stripe).

**Nub.** A stop where the sidewalk is extended into the parking lane, which allows the bus to pick up passengers without leaving the travel lane, also known as bus bulbs or curb extensions.
24.10 GLOSSARY OF TERMS (continued)

**Off-line station.** A mode transfer facility located off of the HOV lane, either adjacent to the freeway or some distance away. Mode transfers could involve bus, rail, auto, or pedestrian modes.

**Off-peak direction.** The direction of lower demand during a peak commuting period. In a radial corridor, the off-peak direction has traditionally been away from the CBD in the morning and toward the CBD in the evening.

**On-line station.** A mode transfer facility located along the HOV lane. Mode transfers involve bus, auto and/or pedestrian modes.

**Operation plan.** A comprehensive document that specifies how an HOV facility is to be administered, operated, enforced and maintained.

**Paratransit vehicle.** Forms of intra-urban demand-responsive transportation services with low- or medium-capacity highway vehicles such as vans or taxis, that are available for hire to the public. They are distinct from conventional transit as they generally do not operate on a fixed schedule and are smaller than conventional transit vehicles.

**Park-and-pool lot.** A parking facility where individuals rendezvous to use carpools and vanpools. The facility is not served by public transportation.

**Park-and-ride lot.** A parking facility where individuals access public transportation as a transfer of mode, usually with their private automobiles. Public transportation usually involves express bus from the lot to a CBD or major activity center. A park-and-ride lot can also be allowed to serve the dual function of a park-and-pool lot facilitating the formation of carpools and vanpools.

**Peak direction.** The direction of higher demand during a peak commuting period. In a radial corridor, the peak direction has traditionally been toward the central business district in the morning and away from the central business district in the evening.

**Peak hour.** That hour during which the maximum amount of travel occurs, usually specified as the morning peak hour or evening peak hour.

**Peak period.** The period during which traffic levels rise from their normal background levels to maximum levels, generally specified as the morning or evening period.

**Preferential lanes.** A form of preferential treatment in which lanes on streets or highways are reserved for the exclusive use of buses, carpools, or vanpools, or all of the above during at least a portion of the day.

**Preferential parking.** Parking lots or spaces that are reserved for HOVs as a means to encourage ridesharing. They are usually located closer to a terminal or building entrance than other vehicle spaces and may also enjoy a reduced parking fee.
Preferential treatment. In transportation, giving special privileges to a specific mode or modes of transportation (e.g., bus lanes).

Priority Investigation Location (PIL). A section of a State highway where the accident rate (accidents/million vehicle miles [MVM]) exceeds the average for that highway type to such an extent as to suggest that some factor (other than pure chance) may be contributing to the accident experience.

Queue bypass (HOV). An HOV facility that provides a bypass around a queue of vehicles delayed at a ramp or mainline traffic meter, toll plaza, bridge, tunnel, ferry landing, or other bottleneck location.

Queue-jumper bus bay. A bus bay designed to provide priority treatment for buses, allowing them to use right-turn lanes to bypass queued traffic at congested intersections and access a far-side open bus bay.

Ramp meter bypass. A form of preferential treatment at a ramp meter in which a queue bypass of one or more lanes is provided for the designated use of high-occupancy vehicles.

Ramp metering. A procedure used to reduce congestion on a freeway facility by managing vehicle flow from local access entrance ramps. An entrance ramp is equipped with a metering device and traffic signal that allows vehicles to enter a facility at a controlled rate.

Reversible-flow lane. A lane on which the direction of traffic flow can be changed to match the peak direction of travel during peak traffic periods.

Right-turn ground loop. Three consecutive right turns around a city block.

Shoulder lane. A lane that is created on an existing median or outside shoulder of a freeway.

Stopping sight distance (SSD). See Chapter 2, Section 2.6.8 in this Manual.

Support facility. A facility that enhances HOV operation, including park-and-ride lots, park-and-pool lots, transfer terminals, or other physical improvement that is considered a supporting element of the operation.

Take-a-lane. A general implementation approach whereby an HOV facility is created by consuming or borrowing use of a mixed-flow lane on a freeway facility, usually by pavement markings and signing. This approach has rarely been applied.

Transit center (or transit station). A mode transfer facility serving transit buses and other modes such as automobiles and pedestrians. In the context of this document, transit centers can be located either alongside an HOV lane or busway (i.e., on-line station), or be physically separated from the HOV lane (i.e., off-line station).
24.10 GLOSSARY OF TERMS (continued)

Transportation demand management (TDM). The operation and coordination of various transportation system programs to provide the most efficient and effective use of existing transportation services and facilities. TDM is one category of traffic system management actions. Refer to the Scoping Procedure Manual, Appendix D.

Transportation system management (TSM). Actions that improve the operation and coordination of transportation services and facilities to effect the most efficient use of the existing transportation system. Actions include operational improvements to the existing transportation system, new facilities, and demand management strategies. Refer to the Scoping Procedure Manual, Appendix C.

Vanpool. A prearranged ridesharing function in which a number of people travel together on a regular basis in a van, usually designed to carry six or more persons.

Violation. An infraction of the rules and regulations for roadway use. In an HOV context, a violation can include vehicle occupancy eligibility.