3. Design Guidelines for Transit Facilities on Highways

This chapter provides guidelines for the development of transit facilities on highways, freeways, and exclusive transit facilities located in separate rights of way. General planning and design considerations are discussed, followed by specific design guidance for transit vehicle facilities, transit passenger facilities, and loading area options.

A list of operating and planned bus / HOV facilities on highways and freeways in North America is included as Appendix C.

3.1. General Planning and Design Considerations

3.1.1 TYPES OF HIGHWAY TRANSIT SERVICES AND FACILITIES

Types of Highway Transit Services

A variety of transit services can be provided on highways or can make connections with highway facilities. These include:

- Local service
- Peak hour express variations of local service
- Regional express service
- Intercity bus service

Some of these services may use the highway for travel but not stop on the highway. Others may not actually travel on the highway but will make connections at highway interchanges. A sound understanding of existing and potential bus routes and passenger patterns is a prerequisite to considering transit infrastructure planning and design requirements.

Types of Highway Transit Operation Facilities

Buses may operate on highways in three types of lane:

- General traffic lane
- High Occupancy Vehicle (HOV) lane shared with carpools
- Bus-only lane

Each lane type may take various forms – median, shoulder, barrier-separated, part-time, etc. These forms are described in this chapter.
In addition, buses may operate on a separate bus-only roadway (Busway / Transitway) within or adjacent to a highway / freeway corridor.

Bus or HOV bypass lanes at metered entry ramps, direct HOV-only or bus-only access / egress ramps, and other special transit facilities may also be considered.

**Types of Highway Transit Passenger Facilities**

The following highway transit passenger facilities are discussed in this chapter:

- **On-Line Transit Station**
  - Freeway Median
  - Freeway / Highway Right Side
  - Busway

- **Off-Line Bus Stops at Interchange**
  - Bus Stops on Freeway Ramps
  - Bus Stops at Street Level
3.2. Transit Vehicle Facilities

3.2.1. LANE TREATMENT CROSS SECTIONS AND DESIGN CONSIDERATIONS

Busways / Separate Right-of-Way HOV

Cross Section

Figure 3-1

Examples of Cross Section for Busway or HOV Facility in Separate Rights-of-Way

Reference: [3]

Design Considerations

The cross section of a busway or HOV facility in a separate right-of-way consists of travel lanes, shoulders, and roadside areas. Figure 3-1 illustrates an example of desirable and reduced design widths for these cross section components. In some cases, a facility may also have a separation or median between opposing flows of traffic. Each of these elements is discussed briefly in this section.
Median Component. AASHTO suggests the use of a median barrier to separate opposing flows on high speed facilities that allow carpools (two-way HOV facilities). If a barrier is not used on these facilities, a flush median is recommended. These medians are recommended to be 2.4 to 3.0 meters (8 to 10 feet) wide and have appropriate pavement markings. From a safety and operational point of view, the use of medians to separate opposing high speed traffic flow is desirable.

If the roadway is a busway (restricted to use by professional trained drivers in a low-volume setting), there is no need for a median. For example, the busways in Ottawa, Pittsburgh, and Minneapolis/St. Paul use two continuous solid yellow lines to separate the opposing traffic lanes.

Roadway Component. Existing busways typically have one lane in each direction of travel, except in station areas where passing lanes are provided. The number of lanes for a specific project should be based on the expected traffic volumes and the desired level of service. As illustrated in Figure 3-1, the width of these lanes are typically 3.6 meters (12 feet). Lane widths of 3.3 meters (11 feet) may be considered in some situations.

Travel lane cross slopes of 1.5 to 2.0 percent are recommended with a centerline crown. Although areas experiencing high rainfall may use a 2.5 percent cross slope for drainage purposes, this approach is not recommended from an operational standpoint. Shoulders should have a cross slope at least 1 percent higher than the adjacent travel lanes. Paved shoulders typically have a cross slope of between 2 and 6 percent. The difference between the cross slopes of a traveled lane and the adjacent shoulder should be below 8 percent at all points along the HOV roadway.

Shoulder and Curb Component. Design guides normally recommend paved shoulders on busways due to the large design vehicle and relatively high operating speeds. The width of these shoulders normally ranges from 3.0 to 3.6 meters (10 to 12 feet). A vehicle stopped on the shoulder should be outside the through lane by 0.3 to 0.6 meters (1 to 2 feet). Narrower shoulder widths of 2.4 to 3.0 meters (8 to 10 feet) may be appropriate in special circumstances. Shoulder widths less than 2.4 meters (8 feet) wide are not recommended, except for short segments, as this width does not allow for efficient passing of disabled vehicles.

It may be noted, however, that many busways operate successfully with lesser shoulder widths. The ability to implement a busway within a narrow right-of-way may be critical to its feasibility. The Ottawa system has continuous wide shoulders but the experience has been that they are rarely used for other than snow storage, since if a bus breaks down it tends to be at a station or stop rather than between stations. Furthermore, the relatively low volume of opposing traffic, the direct radio communication between all buses and a controller / dispatcher, and the prompt dispatch of maintenance staff all work together to nearly eliminate the “passing of a disable vehicle” as a rationale for investing in continuous wide shoulders.

The use of non-mountable curbs at the edge of a travel lane is not generally recommended with design speeds over 60 km/h (40 mph). The use of barrier curbs for design speeds under 80 km/h (50 mph) is controlled by the nature of the roadway. If used on a busway, curbs should be mountable and located outside the shoulder.
Roadside Area or Lateral Clearance Component. Similar to a two-lane arterial roadway or a freeway, the cross section of a busway or an HOV facility on a separate right-of-way should include clear zones. A clear zone or lateral clearance is the distance from the edge of the roadway lane to the nearest median barrier, obstacle, or obstruction. This distance is intended to allow for the safe recovery of an errant vehicle by drivers. Lateral clearance is especially important if the facility will be open to carpools and vanpools.

A minimum clear zone width of 9 meters (30 feet) is desirable on each side of the roadway, but the width is also dependent upon design speed, daily traffic flow, type and steepness of the roadside slope, and horizontal degree of curvature. In order of preference, obstacles within the clear zone should be removed, relocated, redesigned to breakaway, shielded to redirect vehicles, or at least delineated. Cross slopes of 6:1 or flatter are desirable, but steeper slopes may be acceptable in urban areas or on low speed facilities. Local agency guidelines typically prevail, since little data exists on recoverable slopes for buses. Steeper slopes or obstacles in the clear zone may require the use of a protective roadside barrier.

Right-of-way for clear zones that are 9 meters (30 feet) wide are not always available in urban areas. Options that allow the clear zone width to be reduced include lowering the design speed or limiting the use of the facility to professional drivers that will not exceed the posted speed limit on the facility.

Another design approach that can be used in areas of restricted right-of-way provides barriers on both sides of the busway, with acceptable or desirable lateral clearance or shoulder width. A 0.6 to 1.2 meter (2 to 4 feet) minimum lateral clearance has been suggested for use when an HOV facility is located next to a barrier. A 1.2 meter (4 foot) offset between the travel lane and roadside barrier is a desirable minimum for facilities with speeds of 80 km/h (50 mph) or greater. A 0.6 meter (2 foot) width is recommended on low-speed (60 km/h or 30 mph), low volume facilities commensurate to a busway setting.
Figure 3-2

Busway Located Between a Freeway and a Parallel Frontage Road

Reference: [4]

Cross Section Design Summary. A two-way busway or bus/HOV roadway on a separate right-of-way should be designed to the geometric standards recommended by AASHTO and others. Reduced design standards may be considered only if available right-of-way is limited or if the facility is being retrofitted into an existing railroad or roadway. If reduced design standards are used, an engineering study may be needed with respect to the safety and operational impacts of these geometric elements and their justification. In most cases, busways should be constructed to the same standards as a newly constructed two-lane arterial roadway or freeway. The safety impacts of using a less than desirable design elements will be magnified on these facilities if carpools, vanpools, or trucks are allowed use on a facility otherwise intended for trained transit drivers.

In a freeway corridor, consideration may be given to locating a busway or HOV lane parallel to the freeway but located to one side rather than in the median area, to resolve some of these problems inherent to freeway median bus station. Figure 3-2 shows a bus roadway located between the freeway and a parallel frontage road. Access to the bus roadway can be obtained from the frontage road (if present) or from crossing streets via carefully-designed bus-only road links. The station is removed from the congestion of the interchange area, adequate space is available for auto or bus turnouts, and space for off-street parking may be more readily available. These aspects may enhance intermodal transfers. Slip ramps from the bus roadway to the frontage road permit local vehicle access without disruption to line haul bus/HOV or freeway operations.
Barrier Separated Bus/HOV Lanes– Two-Way Cross Section

Cross Section

Figure 3-3

Examples of Cross Sections for Exclusive Two-Directional HOV Facilities

Reference: [3]
Design Considerations

Two-way bus/HOV lanes constructed within the freeway median may or may not be separated by barrier. Only a few barrier-separated examples currently exist. Where they have been implemented, barriers are used to separate each direction from the general use lanes and from opposing bus/HOV traffic.

These facilities are usually open to all types of HOVs, including buses, vanpools, and carpools. Because of the barrier separation, they have limited at-grade access points, and may include direct access ramps. As illustrated in Chapter 5, examples of two-way barrier-separated bus/HOV facilities include the San Bernardino I-10 Busway in Los Angeles and portions of I-5 through Santa Ana, California.

The general design approach is similar to a normal freeway design. The following design components should be considered with a two-way barrier-separated facility. These elements are highlighted in the example cross sections provided in Figure 3-3.

- **Separation.** Barriers separate the bus/HOV facility from adjacent traffic or right-of-way. Where adjacent traffic is present, inside shoulders for general traffic lanes alongside the barrier may be required. The opposing direction is normally separated by a median barrier. AASHTO, federal, and state guidelines are applied to design the median barrier, which is typically 0.6 meter (2 feet) in width. A 0.6 to 1.2 meter (2 to 4 feet) lateral clearance should be provided adjacent to the median barrier. If a median barrier design is not possible, a shared median shoulder of 3.0 to 4.3 meters (10 to 13.5 feet) may be considered as shown in Figure 3-3, but this application may not be applicable for high volumes composed of mixed HOV users. Only one example currently exists on US 290 along a viaduct in Houston.

- **Lane Width.** Travel lanes are 3.6 meters (12 feet) for all forms of dedicated lane treatments. Narrower lane widths should be considered only in special circumstances or for short distances due to limited right-of-way or isolated constraints.

- **Cross Section Design Summary.** A total design envelope of 11.4 to 16.5 meters (38 to 54 feet) will generally be needed for a two-way facility. A wider design envelope will be needed if on-line transit stations are provided. Reduced design standards should be considered only in special circumstances for limited distances.
Barrier Separated Bus/HOV Lanes – Reversible

Cross Section

Figure 3-4
Barrier Separated Bus/HOV Lanes – Reversible (one lane)

* Lateral clearances may be combined to provide a dedicated 2.4 m (8 ft) shoulder on one side or the other, or a 7.3 m (24 ft) envelope may be striped with two 3.7 m (12 ft) travel ways with traffic always operated to the right of the center stripe.

Reference: [3]
**Design Considerations**

Like a two-way facility, reversible lanes are typically located within the freeway median and are always physically separated from the general-purpose freeway lanes. The lanes need to be gated and operated directionally—typically input inbound toward the central business district (CBD) in the morning and outbound in the afternoon. Daily set up is required with reversible facilities, which often include opening gates to the lanes in the morning, closing the lanes to inbound traffic, reopening the lanes in the reverse direction of travel in the afternoon, and closing the lanes in the evening. Both manual and automated techniques are used to open and close reversible HOV facilities.

Currently, barrier-separated reversible HOV lanes are in operation at a number of locations including Houston, Minneapolis, Seattle, San Diego, Pittsburgh, Denver and the northern Virginia/Washington D.C. area. Figure 3-4 illustrates cross section examples of the design components for a one-lane reversible facility, and Figure 3-5 shows a two-lane reversible facility.

**Figure 3-5**

*Barrier Separated Bus/HOV Lanes – Reversible (two lane)*

Reference: [3]
- **Lane, Shoulder, Lateral Clearance, and Separation.** Lane widths are 3.6 meters (12 feet) each. The major design differences among existing reversible HOV facilities relate to the width of the shoulder or lateral clearance provided on both sides of the travel lane or lanes. Single lane reversible facilities in Houston include 1.2 meter (4 foot) shoulders on each side and a 0.6 meter (2 foot) barrier. Most two lane facilities provide a 3 meter (10 foot) shoulder on one side and a 0.6 to 3 meter (2 to 10 foot) lateral clearance or shoulder on the other side. AASHTO recommends at least one 3 meter (10 foot) shoulder. Shoulder widths between 1.2 meters (4 feet) and 2.4 meters (8 feet) are generally avoided on freeways when adjacent to curbs or barriers as they may encourage the unsafe use of the shoulder as a breakdown or emergency stopping area.

- **Cross Section Design Summary.** A design envelop of 8.5 meters (28 feet) is recommended for a single reversible lane. A narrower envelope of 6.1 to 6.6 meters (20 to 22 feet) may be considered in special circumstances. A design envelope of 13.4 meters (44 feet) is recommended for a two-lane facility, with a reduced design envelope of 11 meters (36 feet). The main differences in the design envelope are the width of the shoulders and lateral clearances provided. The key design elements with reversible facilities include ensuring that a disabled bus does not block the envelope.
**Concurrent Flow HOV**

*Cross Section – Median-side Orientation*

**Figure 3-6**

**Concurrent Flow HOV – Buffer Separated**

NOTE: Assumes mandatory outside breakdown shoulders exist.

Reference: [3]
**Cross Section – Right-side Orientation**

**Figure 3-7**

Concurrent Flow HOV – Non-Separated (Right Side)

NOTE: Reduced cross-section assumes part-time peak period use, with bus/HOV lane reverting to shoulder use at other times.

Reference: [3]

**Design Consideration**

Concurrent flow dedicated bus/HOV lanes are defined as a freeway lane operating in the same direction of travel, though not physically separated from the general-purpose traffic lanes, and designated for exclusive use by buses and HOVs for all or a portion of the day. Concurrent flow lanes are usually open to buses, vanpools, and carpools. A few facilities are open only to buses. Concurrent flow lanes are usually, although not always, located on the inside lane next to the median shoulder. Paint striping is a common means used to separate these dedicated lanes. Unlimited ingress and egress may be allowed with a concurrent flow HOV lane or access may be restricted only to specific access points typically spaced every several miles.

Concurrent flow bus/HOV facilities are the most common application for transit priority in a freeway setting in North America, and represent more than two-thirds of all dedicated lane mileage.
Concurrent flow bus/HOV facilities are often developed by retrofitting an existing freeway cross section. For example, the inside shoulder or center median area may be converted to an additional lane, or the freeway right-of-way may be expanded and a HOV lane added. As a result, a wide range of design treatments is found with these types of projects. The various approaches that are currently used and the design elements that should be considered with concurrent flow bus/HOV lanes are highlighted in Table 3-1.

### Table 3-1

Examples of Design Elements for Operating Freeway Concurrent Flow HOV Facilities

<table>
<thead>
<tr>
<th>Location and HOV Facility</th>
<th>Left Shoulder or Lateral Clearance</th>
<th>HOV Lane Width</th>
<th>Separation</th>
<th>Mixed-Flow Freeway Lanes</th>
<th>Right Shoulder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dallas</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I-335</td>
<td>0.6 m (2 ft)</td>
<td>3.5 m (11.5 ft)</td>
<td>0.9 m (3 ft)</td>
<td>3.3 m (11 ft)</td>
<td>3.0 m (10 ft)</td>
</tr>
<tr>
<td>GDOT</td>
<td>0.9 m (3 ft)</td>
<td>3.3 m (11 ft)</td>
<td>0.9 m (3 ft)</td>
<td>3.3 m (11 ft)</td>
<td>3.0 m (10 ft)</td>
</tr>
<tr>
<td>Honolulu, Moanalua Expwy</td>
<td>2.1 m (7 ft)</td>
<td>3.6 m (12 ft)</td>
<td>0</td>
<td>3.6 m (12 ft)</td>
<td>2.1 m (7 ft)</td>
</tr>
<tr>
<td>Los Angeles</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Century, I-105</td>
<td>variegated</td>
<td>3.6 m (12 ft)</td>
<td>1.2 m (4 ft)</td>
<td>3.6 m (12 ft)</td>
<td>3.0 m (10 ft)</td>
</tr>
<tr>
<td>Harbor, I-110</td>
<td>3.6 m (12 ft)</td>
<td>3.3 m (11 ft)</td>
<td>0.6 m (2 ft)</td>
<td>3.6 m (12 ft)</td>
<td>3.0 m (10 ft)</td>
</tr>
<tr>
<td>SR 91</td>
<td>0.9 m (3 ft)</td>
<td>3.3 m (11 ft)</td>
<td>(11.75 ft)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Miami and Ft. Lauderdale, I-95</td>
<td>3.0-3.6 m (10-12 ft)</td>
<td>3.6 m (12 ft)</td>
<td>0.6 m (2 ft)</td>
<td>3.6 m (12 ft)</td>
<td>3.6 m (12 ft)</td>
</tr>
<tr>
<td>Minneapolis, I-394</td>
<td>3.0 m (10 ft)</td>
<td>3.6 m (12 ft)</td>
<td>0(^2)</td>
<td>3.6 m (12 ft)</td>
<td>3.6 m (12 ft)</td>
</tr>
<tr>
<td>Orlando, I-4</td>
<td>3.0 m (10 ft)</td>
<td>3.6 m (12 ft)</td>
<td>0</td>
<td>3.6 m (12 ft)</td>
<td>3.0 m (10 ft)</td>
</tr>
<tr>
<td>Orange County</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SR-55</td>
<td>0.6 m (2 ft)</td>
<td>3.3 m (11 ft)</td>
<td>0.6 m (2 ft)</td>
<td>3.6 m (12 ft)</td>
<td>2.4 m (8 ft)</td>
</tr>
<tr>
<td>I-405</td>
<td>1.2 m (4 ft)</td>
<td>3.6 m (12 ft)</td>
<td>1.2 m (4 ft)</td>
<td>3.6 m (12 ft)</td>
<td>3.0 m (10 ft)</td>
</tr>
<tr>
<td>Phoenix, I-10</td>
<td>3.6 m (12 ft)</td>
<td>3.6 m (12 ft)</td>
<td>1.2 m (4 ft)</td>
<td>3.6 m (12 ft)</td>
<td>3.6 m (12 ft)</td>
</tr>
<tr>
<td>Marin County, US 101</td>
<td>(3-6 ft)</td>
<td>3.3-3.6 m (11-12 ft)</td>
<td>0(^3)</td>
<td>3.3 and 3.6 m (11 and 12 ft)</td>
<td>2.4-3.3 m (8-11 ft)</td>
</tr>
<tr>
<td>Santa Clara County</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>San Tomas Expwy</td>
<td>0</td>
<td>3.9 m (13 ft)(^4),(^5)</td>
<td>0(^5)</td>
<td>3.3 and 3.9 m (11 and 13 ft)</td>
<td>0-3.0 m (0-10 ft)</td>
</tr>
<tr>
<td>Mira Lago Expwy</td>
<td>0</td>
<td>3.9 m (13 ft)(^4),(^5)</td>
<td>0(^5)</td>
<td>3.3 and 3.9 m (11 and 13 ft)</td>
<td>0</td>
</tr>
<tr>
<td>Rte. 237</td>
<td>0</td>
<td>3.9 m (13 ft)(^4),(^5)</td>
<td>0(^5)</td>
<td>3.3 and 3.9 m (11 and 13 ft)</td>
<td>0</td>
</tr>
<tr>
<td>US 101</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I-280</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seattle</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I-5</td>
<td>3.0 m (10 ft)</td>
<td>3.6 m (12 ft)</td>
<td>0</td>
<td>3.3 and 3.6 m (11 and 12 ft)</td>
<td>3.0 m (10 ft)</td>
</tr>
<tr>
<td>I-405</td>
<td>1.2 m (4 ft)</td>
<td>3.6 m (12 ft)</td>
<td>0</td>
<td>3.3 and 3.6 m (11 and 12 ft)</td>
<td>1.8 m (6 ft)</td>
</tr>
<tr>
<td>SR 520</td>
<td>0.3 m (1 ft)</td>
<td>3.6 m (12 ft)</td>
<td>0</td>
<td>3.3 m (11 ft)</td>
<td>1.2-3.0 m (4-10 ft)</td>
</tr>
</tbody>
</table>

1\(^\) Limited access facilities with some signalized intersections.
2\(^\) HOV lane on outside shoulder.
3\(^\) Peak-period-only operation, HOV lane reverts to another mixed-flow lane outside operation period.

Reference: [3]

- **Lane and Shoulder Widths.** As illustrated in Figures 3-6 and 3-7, the desirable cross section for a concurrent flow lane located on the inside includes a full width breakdown shoulder. AASHTO identifies a shoulder width of 3.0 to 4.2 meters (10 to 14 feet) as desirable next to the median barrier. Many of the current projects have shoulders, although a high percentage of the US lane mileage employ narrower designs. The application of narrower shoulders or limited lateral clearances next to a median barrier involve careful examination on a project by project basis.
Separation from General-Purpose Lane. A variety of treatments are currently used to separate the HOV lane from the general-purpose lanes. As illustrated in Figures 3-6 and 3-7, these range from no separation other than additional paint striping to a narrow buffer of 0.6 to 1.2 meters (2 to 4 feet) to in some limited cases a wide buffer of 4.2 meters (14 feet) or more. An advantage of a narrow buffer is the additional separation provided between the HOV and the general-purpose lane. A potential disadvantage of this approach is that some drivers may perceive and use the space as a breakdown area if it is very wide, causing a safety hazard. Further, if limited access points are used with this treatment, weaving movements may be concentrated in these areas making the effects of weaving worse than with other approaches.

Cross Section Design Summary. The desirable cross section for a concurrent flow lane on the inside of a freeway includes the center median, a shoulder or lateral clearance, the bus/HOV lane, and a paint strip or buffer separating the HOV lane from the general-purpose lane. The desirable general design envelope for all these elements is 16.3 to 18.8 meters (54 to 62 feet). Consideration may be given to reducing some of these elements under special circumstances. A narrower design envelope to 10.3 meters (34 feet) may be considered in special cases. Reductions should not be made if they will, in the opinion of local agencies and designers, adversely affect the safe and efficient operation of a facility.

Right-side Orientation

In several locales, dedicated lanes are oriented as the outside lane or on a designated outside shoulder or lane. For these applications, conflicts may occur with freeway on- and off-ramps. Accordingly, these applications generally are limited to locations where transit only or 3+ occupancy use is justified, there are few conflicting ramps, and where the conflicting volumes at ramps are relatively low. SR 520 dedicated lanes in Bellevue, Washington provides an example of this type of treatment. In Ottawa, Canada, buses avoid conflicts at ramps by either merging with general through traffic or exiting the freeway to an off-line bus stop at the crossing road and re-entering the right lane from the freeway entry ramp. In Minneapolis-St. Paul, buses operate on freeway shoulders in a queue-jump mode but only when congestion dictates.

Figure 3-7 provides an example of a cross section for a concurrent HOV lane on the outside of a freeway. A paint stripe is the normal method of separation from the general-purpose traffic lanes, and since the outside shoulder may be borrowed for the bus/HOV lane, there may be either no shoulder or only a very narrow one.
Contraflow Lane

Cross Section

Figure 3-8
Contraflow Lane

DESIRABLE

REduced

Reference: [3]

Design Considerations

Contraflow lanes borrow a general purpose lane from the off-peak direction of travel for use by buses and other HOVs operating in the peak-direction. Contraflow lanes should be considered only in cases where there is a high directional traffic split, where capacity exists in the off-peak direction of travel to borrow a lane or lanes without adversely affecting existing traffic level of service, and where the dedicated lane can be designed and operated safely. Since contraflow lane facilities involve traffic operating in opposing directions on the same side of a freeway, safety for both transit and general-purpose traffic should be a critical element in the design process and involve employment of physical separation. This separation typically involves the application of pylon placement or moveable barrier technology.
Currently, several contraflow bus/HOV lanes are in operation on freeways in the United States. Two of these facilities --Route 495 and the Long Island Expressway which are in the New York City/New Jersey area— use plastic pylons inserted into holes in the pavement to separate the traffic lanes. The second approach uses a moveable barrier to separate the contraflow HOV lane. This technique is used on the East R. L. Thornton Freeway (I-30 East) in Dallas, Gowanus Expressway in New York, Highway H-1 in Honolulu and the Southeast Expressway in Boston. The Long Island Expressway project is currently in the process of being changed over to moveable barrier technology.

Table 3-2 highlights the design elements of various operating contraflow facilities. Figure 3-8 provides examples of cross section for contraflow HOV lanes facility using both types of treatments. These elements are described next.

**Table 3-2**

**Examples of Design Elements for Operating Contraflow HOV Lanes**

<table>
<thead>
<tr>
<th>Location and HOV Facility</th>
<th>Left Lateral Clearance</th>
<th>HOV Lane Width</th>
<th>General-Purpose Lane Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>New York City/New Jersey Route-495</td>
<td>0</td>
<td>3.0-3.2 m (10-10.7 ft)</td>
<td>3.0-3.2 m (10-10.7 ft)</td>
</tr>
<tr>
<td>Long Island Expressway</td>
<td>0-1.8 m (0-6 ft)</td>
<td>3.6 m (12 ft)</td>
<td>3.6 m (12 ft)</td>
</tr>
<tr>
<td>Dallas East R. L. Thornton</td>
<td>2.4 m (8 ft)</td>
<td>3.6 m (12 ft)</td>
<td>3.6 m (12 ft)</td>
</tr>
<tr>
<td>Boston Southeast Expressway</td>
<td>0</td>
<td>3.6 m (12 ft)</td>
<td>3.6 m (12 ft)</td>
</tr>
</tbody>
</table>

*Reference: [3]*

- **Lane, Median and Shoulder Width.** Contraflow lanes typically use the inside general-purpose lane in the opposite direction of travel. The width of these lanes are commonly the normal freeway lane width of 3.6 meters (12 feet), although examples of narrower lanes exist, including the Route 495 Exclusive Bus Lane (XBL) on the approach to the Lincoln Tunnel which has narrower lanes. The existing freeway median and inside shoulder are on the right of vehicles using a contraflow lane. Since most contraflow lanes are retrofitted into an existing freeway, there may be little flexibility with the provision of an inside shoulder if one does not exist. A 3.0 meter (10 foot) shoulder is desirable, but none of the existing contraflow facilities has a full shoulder. If a continuous shoulder cannot be provided, periodic breakdown areas should be considered for disabled vehicles, as is applied to the Boston project.

- **Cross Section Design Summary.** The design of a contraflow HOV lane should strive to incorporate all the appropriate AASHTO, ITE, FHWA, state, and local guidelines. Careful consideration should be given to the design of a contraflow lane to ensure the safe operation for both HOVs and general-purpose traffic. As illustrated in Figure 3-8, a 6.6 to 7.2 meter (22 to 24 foot) envelope should be considered for the travel lane, breakdown shoulder, and pylons or moveable barrier. The available width will have a direct effect on the operating speeds of vehicles in the contraflow lane. Restricted widths may require lower operating speeds as evidenced by the transit facilities in the New York City area.
3.2.2. TERMINATION AND ACCESS

Vehicles may enter a bus/HOV facility at the beginning or in most cases at some point along the lane. Correspondingly, an HOV may exit a facility at the end or at other egress locations. As discussed previously, the type of access provided will depend on the nature of the HOV lane, the objectives of the project, land uses in the corridor, available right-of-way, and funding. See the HOV Systems Manual (NCHRP Report 414 [3]) for additional guidance.

Terminal Treatments for Beginning and Ending a Freeway HOV Lane

The design of the start and end of a bus/HOV facility is important for a number of reasons. First, the design should allow for buses to easily and safely enter and exit the facility. Carpoolers and vanpoolers, as well as professional bus operators, should be able to easily understand how to enter and leave the dedicated lane. Second, the terminal treatments should provide a safe means for buses to merge into and out of general traffic lanes. Third, the start and end of a bus/HOV facility should not adversely affect the operation of the general-purpose lanes.

Terminal treatments are further complicated by the fact that most bus/HOV lanes on freeways are located in the center median or the left travel lane or left shoulder. Current practices indicate that these lanes are usually added, and terminations require either merges from the left or extending the lane as a general-purpose lane. For example, the preferred approach is to open the HOV lane to all traffic and drop the right general-purpose lane at the next interchange. Few examples of right side HOV lanes exist. These facilities require merges to and from the right for HOVs.

- **Lane Entrances.** The entry point is usually located on the left side of the facility or as a direct access ramp. The exact design of the entrance will depend on the type of lane and local conditions. Figure 3-9 provides layout examples of the different entry treatments.

- **Lane Exits.** The end of a dedicated lane is designed so that buses and HOVs can safely merge back into the general-purpose lanes without causing congestion for other. Wherever bus/HOV lanes experience high volumes, another approach is to open the bus/HOV lane to all traffic downstream of the project’s termination and drop the right general-purpose lane at a downstream interchange. Figure 3-10 provides examples of layouts for different end treatments with HOV lanes.

Direct Merge or At-Grade Access

Direct merge or at-grade access represents the most commonly used treatment with concurrent flow lanes. Two types of approaches—unrestricted or unlimited access and restricted or limited access—are currently in use with concurrent flow HOV lanes in North America. Of the two, unrestricted ingress and egress is almost always used with bus/HOV facilities operating only during the peak-periods. This approach allows the bus/HOV lane to easily revert to a general-purpose lane at other times.
Figure 3-9
Examples of Layouts for HOV Lane Entry Points

Example of Entrance to Concurrent Flow HOV Lane

Reference: [3]
Another relatively inexpensive access treatment is the use of slip ramps. This type of access may be used at the start, end, or intermediate points of an HOV lane. Slip ramps may be used with barrier-separated, buffer-separated, and contraflow HOV lanes. Slip ramps provide a break in the barrier or buffer, allowing HOVs to enter or exit the facility. Slip ramps can be provided for ingress or egress but not for both movements at the same time. Potential safety issues should be examined in the design slip. Figure 3-11 provides examples of layout for this type of access treatment. A merge area of approximately 460 meters (1,500 feet) downstream of the slip ramp is suggested, and volumes of more than 1,000 vehicles an hour may justify continuing the lane as a general-purpose lane.

Reference: [3]

**Slip Ramps**

Figure 3-10

Examples of Layouts for HOV Lane Exit Points

Example of Exit from Concurrent Flow HOV Lane

Example of Exit from Barrier-Separated HOV Lane
**Figure 3-11**

Examples of Layouts for Slip Ramps

**BARRIER-SEPARATED OPTION**

![Diagram of BARRIER-SEPARATED OPTION](image)

**NARROW BUFFER-SEPARATED OPTION**

![Diagram of NARROW BUFFER-SEPARATED OPTION](image)

**REDUCED NARROW BUFFER-SEPARATED OPTION (NO WEAVE LANE)**

![Diagram of REDUCED NARROW BUFFER-SEPARATED OPTION (NO WEAVE LANE)](image)

Reference: [3]
Direct Access Ramps

Grade separated or direct access ramps can provide effective dedicated ingress and egress for buses and HOVs where high passenger and vehicle volumes are anticipated or where additional time savings and operational efficiencies can be gained. A variety of design treatments may be used to provide a direct access ramp. Direct access is typically from another transit facility, such as park-and-ride lots and transit stations. These ramps may be used anywhere along a bus/HOV facility.

Advantages of direct connections include the ability to move high passenger volumes into and out of a bus/HOV facility, providing a faster, safer and reliable means of handling transit service. Potential disadvantages include the need for additional right-of-way and the capital costs associated with these ramps.

A variety of common ramp alignments have been implemented, including drop ramps, T-ramps, and flyover ramps. The exact design will depend on the operation and design of the bus/HOV lane, orientation with the adjacent roadway, available right-of-way, and national and state design practices. The following information provides examples for access treatments.

- **Drop and T-Ramps.** Figures 3-12 and 3-13 provide examples and layouts for different drop ramps and T-ramps respectively. These names reflect the fact that this type of direct access ramp looks like the letter T and drop to or from a local roadway, park-and-ride lot, or off-line transit station facility.

  The design speed for the drop or T-ramp should be based on the characteristics of the individual project. The bus/HOV mainlane should not be adversely affected by the ramp design speed. Providing acceleration and deceleration lanes along the main lanes is required to help ensure the safe and efficient operation.

  A shoulder is typically provided for each direction of travel on the ramp, but some examples exist where no shoulder is provided along the ramp grade. A center barrier is typically applied with two-way ramps, especially if high vehicle volumes are anticipated.

  A cross section of 6.7 to 7.3 meters (22 to 24 feet) is desirable for a single direction or reversible flow T-ramp. The desirable cross section for a two-way ramp is 14 meters (46 feet). A narrower cross section width of 11.5 meters (38 feet) for a two-way ramp may be considered in certain instances where low volumes are anticipated.

- **Flyover Ramps.** This ramp concept accommodates a higher-speed, higher-volume to and from a bus/HOV facility. The function of a flyover ramp is to provide direct, high-speed connections between other roadways, park-and-ride lot or transit facilities. A variety of design treatments can be used with flyover ramps. Figures 3-14 and 3-15 illustrate typical layouts for flyover ramps. Flyover ramps usually include extensive elevated construction, which can increase cost. Retrofitting a flyover ramp into an existing multi-level interchange can be difficult. If possible, the cross section for a flyover ramp should be similar to the bus/HOV main-lane design.
Figure 3-12

Illustration and Example Layout for an HOV Drop Ramp

Reference: [6]
Figure 3-13

Example of Layout for Low Volume Busway T-Ramp or Intersection

Reversible-Flow HOV Drop Ramp Concept

Reversible-Flow HOV “T” Ramp Concept

Reference: [3]
Figure 3-14

Example of Layout for HOV Y-Ramp

Reference: [3]
Ramp Meters with Transit Bypass

Metering freeway entrance ramps is a technique used to better manage traffic. Metering vehicles entering a freeway can improve the overall level-of-service by regulating the flow of traffic and by dispersing the platoons of vehicles that typically enter a freeway during the peak-periods. Ramp metering may also discourage drivers from using a freeway for local trips that can be more effectively served on the street system.

Providing buses and other HOVs with a way to bypass the queues that frequently form upstream of ramp meters, especially during the peak-hours, can help promote ridership and route reliability. These treatments do not have to be implemented in conjunction with any other form of dedicated lane or transit treatment to be effective.

Two design approaches are usually applied for transit bypass lanes at metered freeway entrance ramps. These are providing an additional transit lane as part of the existing ramp and providing a separate transit ramp usually downstream of the metered ramp. The former approach, which uses the same ramp but involves a separate lane for buses and HOVs around the meter, is more common. Figures 3-16 and 3-17 provide examples of layouts.

Reference: [3]
3.2.3. ENFORCEMENT PROVISIONS

The important role enforcement plays in the success of a highway transit facility is stressed throughout this chapter. There are several design elements that should be considered in designing enforcement areas associated with the various types of bus/HOV facilities on highways and busways in separate rights-of-way. Bus/HOV lanes should be designed so that they can be safely and efficiently enforced. The safety of police personnel should be key considerations in the design process. Experience indicates that poorly designed and unsafe enforcement areas will not be used and thus, violations could adversely affect the transit facility.
The enforcement design considerations need to address a variety of enforcement techniques including stationary, roving, team, and multi-purpose patrols, electronic monitoring, self enforcement programs, and issuing tickets or citations by mail. The ease or difficulty associated with enforcement will be related to the type of bus/HOV facility and specific issues in the area. Each type of facility and operation reflects different enforcement needs, requiring different design provisions. Table 3-3 highlights some of the attributes associated with enforcing different types of HOV facilities. Busways in separate rights-of-way and barrier-separated facilities are generally considered easier to enforce than other facilities because of the limited and controlled access they provide. Contraflow facilities and queue bypasses may be enforced through a single strategically located monitoring area. Concurrent flow HOV lanes, especially those allowing continuous access, are the most difficult to enforce.

**Table 3-3**

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

Reference: [3]
General Enforcement Design Considerations

The term enforcement area is used to refer to a number of potential design treatments that provide space for police personnel to monitor a bus/HOV facility, to pursue a violator, and to apprehend a violator and issue a ticket or a citation. Space adjacent to a dedicated lane is required for these functions. The primary type of infraction enforcement officers confront is occupancy violations, which requires the ability to see inside a vehicle. Good lighting and good visibility from a safe vantage point is needed to perform these enforcement functions. The provision of continuous, full width shoulders adjacent to a dedicated lane is the best method to meet this need. The design examples that follow assume this treatment.

A variety of enforcement practices may be used on a dedicated lane. The design of enforcement areas should be flexible to account for a variety of enforcement strategies. On barrier-separated facilities (either reversible or two-way), enforcement actions are usually performed near the entrance or exit ramps where traffic is often moving more slowly. The enforcement area serves as both a monitoring and apprehension site. For concurrent flow lanes, enforcement areas may allow officers to monitor traffic, with the apprehension of violators occurring at a downstream location, which may be another enforcement area or a wide left or right shoulder.

Two general classifications for enforcement areas are often used. These categories relate to the degrees of separation or lack thereof. The two approaches are low-speed enforcement areas at entrance and exit ramps, and high-speed settings along the HOV mainline. Enforcement areas are shown in Figures 3-18 through 3-20.

- **Low-Speed Enforcement Area.** Low-speed enforcement areas are usually located at access points on busways and barrier-separated treatments. Specific locations may include ramps, reversible lane entrances, and queue bypasses where vehicle speeds are relatively slow, usually below 75 km/h (45 mph). Low-speed enforcement areas are often designed to provide for monitoring, apprehension, and citing of violators, and where practicable, violator removal from the HOV facility. The following design features may be considered with slow-speed enforcement areas.

  - The enforcement area should be at least 30 meters (100 feet) in length and preferably up to 60 meters (200 feet) on high-volume facilities, not including approach and departure tapers.
  - The enforcement area should be at least a width of 4.2 to 4.5 meters (14 to 15 feet).
  - The enforcement area should have an approach taper of 2:1, or 9.1 meters (30 feet).
  - The enforcement area should have a departure taper of 10:1 or 45.5 meters (150 feet) to allow for acceleration into the lane.

- **High-Speed Enforcement Area.** If a dedicated lane includes a number of high-speed 75 km/h (45 mph) or higher at-grade access locations or lacks continuous shoulders wide enough for enforcement, consideration should be given to periodically spaced enforcement areas. These areas are usually designed for monitoring traffic or for monitoring and apprehending violators. For either application, police personnel often prefer that periodic enforcement areas be designed in conjunction with full outside shoulders. Most apprehension activities are performed in the right freeway shoulder, and some state vehicle codes
require that motorists being pursued by police move to the right. The following elements should be considered in the design of high-speed enforcement areas.

- The length of a high-speed monitoring area should be at least 30 meters (100 feet), not including the approach and departure tapers. For monitoring and apprehension the length should be preferably 394 meters (1,300 feet).
- The enforcement area should be at least 4.2 to 4.5 meters (14 to 15 feet) in width.
- The enforcement area should have an approach taper of 20:1 and departure taper of 80:1 or higher, or controlled by general freeway criteria as required to fit in the design for proper acceleration to the design speed.
- Enforcement areas should be provided at minimum interval of 3.2 to 4.8 kilometers (2 to 3 miles) along the mainline HOV facility.

**Enforcement Design Considerations for Busways in Separate Rights-of-Way**

Special enforcement areas are not usually needed with busways due to the limited access points and the restricted vehicle mix. Access to busways is frequently through park-and-ride lots or on-line transit stations, with limited local street access. In addition, buses are the only vehicles authorized to use these facilities. As a result, unauthorized vehicles, including passenger automobiles, vans, and motorcycles, can be easily spotted. The existing busways in Pittsburgh, Ottawa, Miami, and Minneapolis/St. Paul, do not include dedicated enforcement areas. These facilities are designed and signed to limit the potential of unauthorized vehicles from entry. Enforcement is accomplished by bus operators and on-street supervisors and transit police reporting and dealing with violators.

**Enforcement Design Considerations for Freeway Concurrent Flow HOV Lanes**

Concurrent flow lanes provide no physical separation from the adjacent freeway lanes. As a result, they are the most difficult type of facility to enforce, as violators can merge in and out at will. The perception of enforcement, as much as an actual enforcement presence, is an important attribute to managing violations on these facilities, and the more effective the design is at meeting this objective, the better the design is at addressing enforcement needs.

Wide, continuous shoulders are used in many areas for enforcement. Where full shoulders are not available, median enforcement areas should be considered at regular intervals. Spacing is typically 3.2 to 4.8 km (2 to 3 miles). Enforcement areas should meet the guidelines defined previously for high-speed conditions. Augmenting the entrance areas with continuous outside shoulders along the freeway is also beneficial. A sufficient length should be provided to pull over a violator and once cited, allow the violator to safely re-enter the traffic stream. The minimum length required for this operation is approximately 394 meters (1,300 feet), excluding tapers. Additional features, including an offset in the barrier to provide protection for the officer while monitoring traffic, a median opening that allows the officer to observe both directions of traffic, lighting, and removal of any glare screen on the barrier in the affected area are good considerations. The opening is a particularly beneficial consideration for motorcycle officers who can maneuver within the median opening. The enforcement area should not be signed or otherwise draw attention to its function, but it may require extra lighting.
Figure 3-18
Examples of Cross Sections of Enforcement Areas Along a Reversible Barrier-Separated HOV Lane

Reference: [ ]
Figure 3-19
Examples of Cross Sections of Enforcement Areas
Along Concurrent Flow and Exclusive Buffer-Separated HOV Lanes

Reference: [3]
Figure 3-20

Examples of Directional and Bi-Directional Enforcement Area Layouts

Reference: [3]
3.2.4. TRANSIT SPECIFIC SIGNING AND PAVEMENT MARKINGS

Providing a standard set of symbols, signs, and pavement markings for bus/HOV facilities is important to building public awareness, understanding, and acceptance. Adequate regulatory and guide signs are critical for both users and non-users. Signing also plays a key role in public education and enforcement strategies.

The Manual of Uniform Traffic Control Devices (MUTCD) should be used in designing and locating signs and pavement marking for HOV facilities on freeways and in separate rights-of-way. Section 2B-20, Preferential Lane Signing, and Section 3B-22, Preferential Lane Markings, relate specifically to bus and HOV facilities. Other sections of the MUTCD address several other types of signs and markings commonly used with transit projects.

Many traffic control signs and pavement markings used on HOV facilities are similar to those found on freeways and roadways. For example, common pavement markings may include flush median delineation, solid yellow center or left shoulder lines, solid white pavement edge lines, and turn-lane arrows and lane lines. Examples of common traffic control signs include those related to speed limits, wrong way or prohibited movements, vertical clearance, ramp locations, advance and action guide signs, and curve or other caution and warning signs. Although freeways and HOV facilities share many common signing and pavement markings, there are also many unique elements associated with signs and markings on bus/HOV projects. Recent proposed changes in the MUTCD help provide greater clarity in guide and regulatory signing associated with transit facilities, particularly where a mix of users, including transit buses and carpools, share the same facility.

Regulatory and Guide Signs

The MUTCD, AASHTO, and other federal and state guidelines should be used in the design and placement of signs associated with an HOV facility. Some states, including California, Texas, and Washington, have developed typical bus/HOV sign applications and layouts to promote statewide consistency. The following general applications apply to regulatory and guide signs.

- Regulatory signs should use the standard black lettering on a white background. A diamond symbol should be considered on all signs to help build awareness and to reinforce the special nature of transit and HOV lane facilities.

- The size of a sign should be related to its location and the design speed of the facility. The same guidelines on letter size used with other highway signs should be followed with transit signs.

- Signs relating to HOV lane restrictions, including vehicle-occupancy requirements and operating hours, should be provided at regular intervals along the facility. Overhead or side mounted signs may be appropriate for use.

- Additional signs should be considered at all access points, as well as in advance of the start of an HOV lane. Signs should be provided in advance of access points to alert users and non-users of the approaching ingress and egress. Static and changeable message signs may both be used with transit facilities.

Examples of regulatory and guide signs are shown in Figure 3-21.
Figure 3-21

Examples of Regulatory Signs Used with HOV Facilities

Reference: [3]
Guide signs may be used to alert motorists of park-and-ride and park-and-pool lots, transit facilities, and dedicated lanes. A guide or trail blazer sign located along a freeway or other federal or state highway should conform to the MUTCD. Guide signs on these facilities are generally white lettering on a green background. Some states allow placing the transit rideshare agency logo on these signs. Information signs on federal and state highways are white on blue backgrounds. Information signs commonly associated with HOV facilities include telephone numbers for rideshare matching and transit services. Local sign ordinances and standards will guide the location and design of signs on local streets approaching transit facilities. Like all traffic signs, the key elements to consider with guide and trail blazing signs is to keep the message simple, direct, and easy to understand.

**Pavement Markings**

The use of a white diamond symbol painted on the pavement is commonly used to denote dedicated transit and HOV lane facilities. In the past, the MUTCD recommended the use of the diamond symbol for preferential lanes, as well as for other special facilities. These did include bicycle lanes, truck-only lanes, and other special facilities. The newest version of the manual reserves this symbol for transit and HOV lane use.

Standard specifications for the white diamond symbol pavement marking should be used. The diamond should be 3.9 meters (13 feet) long and 0.9 meters (3.2 feet) wide. The exact placement and location of the symbol along a facility should be based on the operating characteristics of the lane and engineering judgment. The MUTCD recommends spacing the symbol 151 to 303 meters (500 to 1,000 feet) intervals. Their location on a specific facility should be frequent enough to remind users of the restricted nature of the lane. In addition to the diamond symbol, many areas use wording to further communicate the restricted nature of the transit lane. Common words associated with the diamond symbol include Bus Lane Ahead, Bus Only, and other similar letter markings. The use of unfamiliar acronyms should be avoided. Figures 3-22 and 3-23 provide examples of the pavement markings in use with existing HOV facilities. Consideration should also be given to the pavement markings in enforcement areas. Special striping or other techniques may be used to differentiate the enforcement area from the bus/HOV and general-purpose lanes.

Although the use of the MUTCD diamond symbol is widely accepted, there is less agreement on the paint striping that should be used to delineate a bus/HOV lane from general-purpose traffic lanes. The following general practices are suggested for consideration. The paint color and striping for a specific project should be based on AASHTO, ITE, MUTCD, federal, state, and local guidelines and practices, as well as engineering judgment.

- **Busways in Separate Rights-of-Way.** These facilities usually use the same pavement markings as a regular roadway except that a solid center line is frequently used to indicate that passing is not allowed. Additional striping may be needed if carpools and vanpools are allowed to use the facility.

- **Barrier-Separated Two-Way Facilities.** These lanes frequently use striping similar to busways. These include a solid white strip to delineate the right shoulders, and a solid white or yellow stripe in the center to separate the two travel lanes.
Concurrent Flow Lanes. The widest variety of paint striping is found with concurrent flow lanes in different states. Lanes that allow continuous access may use only the normal skip stripe to provide separation from the general-purpose traffic lanes. This approach is commonly found with part-time lanes that revert back to general-purpose lanes for most of the day. Double skip stripes are used in some areas to delineate continuous access. Concurrent flow lanes that allow ingress and egress only at specific locations often use a solid double line to delineate sections where access is not allowed and single skip striping in areas where access is allowed. Both solid white and solid yellow markings are used to define buffer areas. The MUTCD should be used to provide guidance on the appropriate markings.

Contraflow HOV Lanes. Contraflow lanes usually use some type of physical separation from the general-purpose lanes. Current techniques include drop-in traffic cones and the moveable barrier technology. Double skip stripes are used in some areas to delineate the buffer area for the placement of the traffic cones or barriers.

Figure 3-22
Examples of HOV Lane Pavement Markings

Reference: [3]
3.3. Highway Transit Passenger Facilities

Following an outline of the general considerations involved in planning and designing bus passenger facilities in the highway / freeway environment, the following specific facilities are discussed in this chapter:

- On-Line Transit Station
  - Freeway Median
  - Freeway / Highway Right Side
  - Busway
3.3.1. GENERAL SITE CONSIDERATIONS

Combining mass transit facilities on freeways is a means of accommodating the needs of multiple modes and services in the same corridor. This can be accomplished by the joint use of right-of-way to include separate facilities for rubber-tired transit, including buses and perhaps other high-occupancy vehicles, such as car and van pools. The total right-of-way cost not only is less than for two separate transportation improvements, but it can potentially reduce the displacement of businesses and persons, and lessens impact on neighborhoods.

However, a typical freeway design does not effectively accommodate transit needs (other than long-distance express services), which are to combine rapid congestion-free operation with stops at selected locations. The ability to create and operate bus passenger facilities that are easy to get to from both the freeway and the crossing road or surrounding area, that are safe, attractive, and comfortable to users, and that do not disrupt the safe and efficient operation of general traffic is key to effective bus use of highways.

Transit passenger facilities are therefore vital to the transit operational design. A number of issues influence the location and siting of passenger facilities.

Station / Stop Geometry and Access

True rapid transit service by bus has had only limited application because normal bus service usually combines collection and distribution with suburb-to-city transportation, and most street or highway facilities for such bus routes are not adaptable to high-speed operation. Many metropolitan areas have non-stop freeway express buses that operate on the freeway system from suburban pickup points near the freeway to locations within the central business district or to other heavy traffic generators. The number of buses operating during peak hours, the spacing of bus stops, and the design of bus turnouts determine the efficiency of bus operation and its effect on highway operations. Buses operating with short headways and frequent pickup and discharge points are likely to accumulate at stops and interfere with through traffic. On the other hand, express bus operation with few, if any, stops along the freeway provides superior transit service for outer urban areas and affects freeway operation the least.

The spacing of bus stops largely determines the overall speed of buses. Bus stops on freeways should be spaced to permit buses to operate at or near the prevailing speed of traffic on the highway. To achieve this goal, a spacing of at least 3.5 km [2 mi] between bus stops is normally appropriate. Bus stops along freeways are usually located at intersecting streets where passengers transfer to or from other lines or passenger cars. These stops may be provided at the freeway level, which requires stairs, ramps, or escalators, or at the street level, which requires bus access via interchange ramps. Bus turnouts should be located where site conditions are favorable and, if practical, where gradients on the acceleration lane are flat or downward.
Bus Stop Arrangements

The benefit of bus stops located at the freeway level is that buses consume little additional time other than that for stopping, loading, and starting. The disadvantage is that turnouts, stairways, and possibly extra spans at separations may be needed. With bus stops at street level, less special construction is needed and passengers do not need to use stairs or ramps. However, buses have to mix with traffic on the ramps and frontage roads and generally must cross the intersecting street at grade. Where traffic on the surface street is light, these disadvantages are lessened. However, where the streets are operating at or near capacity, buses crossing them will experience some delay. Generally, street-level stops are appropriate in and near downtown districts, and freeway-level stops are appropriate in suburban and outlying areas. Combinations of these two types may be used on any one freeway.

Figure 3-24

Bus Turnouts

Reference: [4]
Bus Turnouts for Bus Stops

The basic design objective for a freeway bus turnout is that the deceleration, standing, and acceleration of buses take place on pavement areas clear of and separated from the traveled way. Other elements in the design of bus turnouts include passenger platforms, ramps, stairs, railings, signs, and markings. Speed-change lanes should be long enough to enable the bus to leave and enter the traveled way at approximately the average running speed of the highway without undue discomfort to passengers. The length of acceleration lanes from bus turnouts should be well above the normal minimum values, as the buses start from a standing position and the loaded bus has a lower acceleration capability than passenger cars. Normal-length deceleration lanes are suitable. The width of the bus standing area and speed-change lanes, including the shoulders, should be 6.0 m [20 ft] to permit passing a stalled bus. The pavement areas of turnouts should contrast in color and texture with the traveled way to discourage through-traffic from encroaching on or entering the bus stop.

The dividing area between the outer edge of freeway shoulder and the edge of bus turnout lane should be as wide as practical, preferably 6.0 m [20 ft] or more. However, in extreme cases, this width could be reduced to a minimum of 1.2 m [4 ft]. A barrier is usually needed in the dividing area, and fencing is desirable to keep pedestrians from entering the freeway. Pedestrian loading platforms should not be less than 1.5 m [5 ft] wide and preferably 1.8 m to 3.0 m [6 to 10 ft] wide. Some climates may warrant the covering of platforms. Figure 3-24 illustrates typical cross sections of turnouts including a normal section, a section through an underpass, and a section on an elevated structure.

Median

Normal design practice recommends a median barrier to separate opposing travel lanes in the station area. A median barrier is especially important if significant volumes of automobiles and vans will be traveling through a station. A center median may not be as critical on bus-only facilities, where lower bus volumes traveling at slower speeds, and operated by professional drivers, are anticipated. For example, center medians are not used on either the Ottawa or the Pittsburgh busway systems.

Through Lane

A lane should be provided to allow buses, as well as carpools and vanpools if authorized to use the facility, to travel through a station without stopping. If a through lane is not provided, these vehicles would have to stop and wait while buses drop-off and pick-up passengers, negatively impacting travel time savings. A 3.6 meter (12 foot) through lane should normally be considered.

Loading Area Options

The design of the loading lane and platform will depend on the operating characteristics of the facility. Two general types of platforms and loading areas may be considered. These are parallel and sawtooth designs. The parallel design allows buses to simply pull to the curb at a designated spot. The bus then pulls away from the curb and merges back into the through lane after picking-up and dropping-off passengers. The sawtooth design provides staggered berths for buses to pull in and pull out. Chapter 5 includes a more thorough discussion of bus passenger interface facilities, including guidance on loading area cross sections and design considerations.
The parallel design requires less width but more length than the sawtooth design. The parallel design is preferable from a transit operations standpoint as it does not require bus operators to maneuver in and out of bus bays. Parallel platforms are found more frequently with existing on-line stations, although sawtooth designs are found with park-and-ride and off-line stations.

The loading lane is located adjacent to the platform area. With parallel platforms, the loading lane is typically 3.6 meters (12 feet). Wider loading lanes are needed with sawtooth platforms to accommodate the necessary bus maneuvers. Typical widths for sawtooth platforms are in the range of 4.8 to 6.1 meters (16 to 20 feet).

**Acceleration and Deceleration Lane**

Space will also need to be provided to allow buses to decelerate to enter the station area and to accelerate and re-enter the main travel lane. The distance of the approach and departure area will depend on the mainline travel speeds, the length of the station or platform area, and the vehicle mix authorized to use the facility.

Separate busways normally feature restricted operating speeds for through buses in station areas (30 km/h to 50 km/h (20 to 30 mph). Although full acceleration lanes of between 120 and 220 meters (400 and 725 feet) in length have been provided on some facilities, operating experience in Ottawa, Pittsburgh and elsewhere has demonstrated that the low bus volumes, professional drivers, and a controlled environment allow smooth and safe operation with acceleration and deceleration lanes as short as 21 meters (70 feet).

Vehicles on freeway HOV facilities such as the San Bernardino Busway and the I-110 Transitway in Los Angeles, which include buses, carpools, and vanpools, maintain higher operating speeds through station areas. Longer deceleration and acceleration lanes should be provided on these types of facilities. Approach and departure lanes for buses in these cases are in the range of 636 to 848 meters (2,100 to 2,800 feet), based on California design criteria and posted speeds of 75 km/h (45 mph).

**Passenger Platform Components**

**Platform Length**

The length of the passenger platform area and the station will depend on the number of transit vehicles anticipated to use the facility, projected passenger demand, and the types of buses. The general length of platforms at existing on-line stations are 30 meters (100 feet) in Pittsburgh, 55 meters (180 feet) in Ottawa, and 61 meters (200 feet) or more on the San Bernardino Busway. At least 12 meters (40 feet) is needed at a parallel loading area for a standard bus and 18 meters (60 feet) is needed for an articulated bus. These dimensions do not include maneuvering space.

**Platform Width**

The width of a platform will depend on the number of passengers projected to use the facility, especially during the peak hour, and other features that may be provided. Width will also be affected by the available right-of-way, which in a constrained freeway median environment will normally be minimal. Passenger platform widths of 3.0 meters (10 feet) are used in Pittsburgh, with 3.6 meters (12 feet) used in Ottawa. Additional space will be needed for passenger waiting areas, pedestrian or feeder bus access, and other amenities.
Waiting Areas, Access, and Amenities

On-line stations frequently include additional features and amenities. Stairways, elevators, pedestrian ramps, benches, shelters, enclosed waiting areas, newspaper racks, vending machines, and other amenities may all need to be considered in the design process. The requirements of the Americans with Disability Act (ADA) and subsequent rules will need to be consulted to ensure the station is fully accessible to all individuals. The design of these elements should follow the appropriate federal, state, and local guidelines.

Passenger safety and security should be carefully considered in the development of station plans. The principles of CPTED (Crime Prevention Through Environmental Design) should be followed, in a similar manner to that discussed in Chapter 5.2. Station and access lighting, visibility, transparency, emergency communications systems, and remote monitoring are some of the elements of a safe and comfortable transit environment.

Passenger shelters or enclosed waiting areas should be provided at stations / stops within the harsh freeway environment.

Pedestrian Environment and Access

Pedestrian Bridges

A grade-separated pedestrian facility allows pedestrians and motor vehicles to cross at different levels, either over or under a roadway. It provides pedestrians with a safe refuge for crossing the roadway without vehicle interference. Pedestrian separations should be provided where pedestrian volume, traffic volume, intersection capacity, and other conditions favor their use, although their specific location and design require individual study. They may be warranted where there are heavy peak pedestrian movements, such as at central business districts, factories, schools, or athletic fields, in combination with moderate to heavy vehicular traffic or where unusual risk or inconvenience to pedestrians would otherwise result. Pedestrian separations, usually overpasses, may be needed at freeways or expressways where cross streets are terminated. On many freeways, highway overpasses for cross streets may be limited to three- to five-block intervals. As this situation imposes an extreme inconvenience on pedestrians desiring to cross the freeway at the terminated streets, pedestrian separations may be provided. Local, State, and Federal laws and codes should be consulted for possible additional criteria concerning need, as well as additional design guidance.

Where there are frontage roads adjacent to the arterial highway, the pedestrian crossing may be designed to span the entire or only the through roadway. Separations of both through roadways and frontage roads may not be justified if the frontage roads carry light and relatively slow-moving traffic; however, in some cases the separation should span the frontage roads as well. Fences may be needed to prevent pedestrians from crossing the arterial at locations where a separation is not provided. Pedestrian crossings or overcrossing structures at arterial streets are not likely to be used unless it is obvious to the pedestrian that it is easier to use such a facility than to cross the traveled way.

Generally, pedestrians are more reluctant to use undercrossings than overcrossings. This reluctance may be minimized by locating the undercrossing on line with the approach sidewalk and ramping the sidewalk gently to permit continuous vision through the undercrossing from the sidewalk. Good sight lines and lighting are needed to enhance a sense of security. Ventilation may be needed for very long undercrossings.
Pedestrian ramps should be provided at all pedestrian separation structures. Where warranted and practical, a stairway can be provided in addition to the ramp. Elevators should be considered where the length of ramp would result in a difficult path of travel for a person with or without a disability.

Walkways for pedestrian separations should have a minimum width of 2.4 m [8 ft]. Greater widths may be needed where there are exceptionally high volumes of pedestrian traffic, such as in the downtown areas of large cities and around sports stadiums.

A serious problem associated with pedestrian overcrossings and highway overpasses with sidewalks is vandals dropping objects into the path of traffic moving under the structure. The consequences of objects being thrown from bridges can be very serious. In fact, there are frequent reports of fatalities and major injuries caused by this type of vandalism. There is no practical device or method yet devised that can be universally applied to prevent a determined individual from dropping an object from an overpass. For example, small objects can be dropped through mesh screens. A more effective deterrent is a solid plastic enclosure. However, these are expensive and may be insufferably hot in the summer. They also obscure and darken the pedestrian traveled way, which may be conducive to other forms of criminal activity. Any completely enclosed pedestrian overpass has an added problem that children may walk or play on top of the enclosure. In areas subject to snow and icing conditions, the possibility that melting snow and ice may drop from the roof of a covered overpass and fall onto the roadway below should be considered.

At present it is not practical to establish absolute warrants as to when or where barriers should be installed to discourage the throwing of objects from structures. The general need for economy in design and the desire to preserve the clear lines of a structure unencumbered by screens should be carefully balanced against the need to provide safe operations for both motorists and pedestrians.

Locations where screens definitely should be considered at the time the overpass is constructed include:

- On an overpass near a school, a playground, or elsewhere where it would be expected that the overpass would be frequently used by children unaccompanied by adults.
- On all overpasses in large urban areas used exclusively by pedestrians and not easily kept under surveillance by police.
- On an overpass where the history of incidents on nearby structures indicates a need for screens.

Screens should also be installed on existing structures where there have been incidents of objects being dropped from the overpass and where it seems evident that increased surveillance, warning signs, or apprehension of a few individuals involved will not effectively alleviate the problem.

More complete information on the use of protective screens on pedestrian overpasses is available in the AASHTO Roadside Design Guide.

Figure 3-25 illustrates two typical pedestrian overcrossings of major highways.
Figure 3-25

Typical Pedestrian Overpasses on Major Highways

Reference: [4]
**ADA and Accessibility**

*Stairs, Ramps, and Escalators*

With bus stops at the freeway level, stairs, ramps, escalators, or combinations of these are needed for passenger access between the freeway and local street levels. Transit facilities must be accessible to persons with disabilities. Therefore, stair-only access at transit stops is not permitted. Stairways, ramps and elevators at transit stops should be easy to climb and present an inviting appearance. This effect is partially accomplished by providing railings and ample lighting both day and night and by providing landings at every 0.8-m [2.5-ft] change in elevation. A covering over the stairways, ramps, and platforms may also be desirable. Stairways should be located where the climb will be minimal, preferably not more than 5.4 to 6.0 m [18 to 20 ft]. Where space is available, and only buses are to be served, the bus roadway under the structure might be raised 0.6 to 1.2 m [2 to 4 ft] by reducing vertical clearance to about 3.8 m [12.5 ft] (Most intra-city buses are less than 3.0 m [10 ft] high). When the stairs are located a little distance from the point of loading and unloading, the connecting walkway may be inclined at about a 4 percent grade, and another 0.3 to 0.6 m [1 to 2 ft] may be gained in elevation. Thus, it may be practical in some instances to reduce stairway height to 4.5 m [15 ft] or less.

Stairs and ramps are likely to be installed at bus stops in built-up districts. In addition, pedestrian ramps are well adapted to bus stops in suburban or park-like areas. Railings are desirable and usually necessary and combinations of ramps and stairs may be appropriate at some locations. If the bus line serves a large percentage of older passengers, is extremely busy, or the climb is extra long, the use of escalators should be considered. Provisions for persons with disabilities are to be included, and use of elevators is more desirable than a series of switchback ramps. Wide passageways and doors and the elimination of other barriers is desired. The Americans with Disabilities Act Accessibility Guidelines (ADAAG) provides guidance on the design of facilities for persons with disabilities [1].

*Bicycle Storage and Access*

The provision of bicycle accommodation is an important element of passenger facilities, as it helps to reduce the need for parking of automobiles and facilitates another viable option for accessing the facility. Bicycles should be accommodated at all pedestrian bridges (i.e. provide an alternative to stairs). Bicycle access to station platforms should be provided where the bus service has, or may have in the future, a bike-on-bus (bicycle rack) capability. Examples of bicycle accommodation are provided in Chapter 5.

### 3.3.2 ON-LINE TRANSIT STATION

Transit stations provide a means for transit passengers to transfer between different bus routes and services. For example, passengers can transfer from high-speed limited-stop express buses to local routes that may serve as circulators through an employment area. Passengers may access the station by walking, bicycling, driving, feeder bus or being dropped off.

Transit stations have traditionally been implemented in two settings along a freeway or highway – either off-line or on-line. Off-line stations are located outside the freeway right-of-way, sometimes connected to the freeway by either a direct ramp or to a median HOV lane by a median direct access ramp. On-line stations are located
either within the freeway median (see Figure 3-26) or on the outside (right side) shoulders (see Figure 3-30).

A median HOV lane can serve as a rubber tired transit guideway, offering buses opportunities to transfer passengers with a minimum of enroute time penalty. This station collection and distribution function mirrors other forms of fixed transit guideways and embodies the principles of service described for an exclusive bus rapid transit operation.

**Figure 3-26**

Example High-Speed Freeway On-Line Stations

I-110 Transitway, Los Angeles  
I-10 El Monte Busway, Los Angeles

**Freeway Median**

The situation where a bus uses a stop in a freeway median is most likely to coincide with bus use of a median HOV lane. These lanes serve a mix of buses, carpools, vanpools and motorcycles and are designed for high speeds and high volumes approaching or exceeding 1500 vehicles/lane. Median on-line stations offer the advantage of truly rapid transit with minimum delay time for transferring passengers. However, under these operating conditions, designing a station alongside high speed travel lanes poses safety and operational challenges. Segregating stations from general purpose and HOV traffic and creating grade separated pedestrian access can be expensive.

While various design treatises since the mid 1970s have offered guidance for freeway on-line stations, few implemented examples can be found in the U.S. As of 2002, the I-110 freeway in Los Angeles was the only nationwide corridor providing about a half dozen examples of median on-line stations in operation. Several other high-speed on-line station designs have also been implemented along the I-10 El Monte Busway in Los Angeles, but those examples are not located in the freeway median. Plans for on-line stations along various freeways are being considered in several other metropolitan areas.

When transit facilities are located within a freeway median, access to the transit is sometimes provided from the crossroad interchange locations. Such an arrangement does not lend itself well to transfers from one bus or mode to another. Transfers can add congestion to the interchange area, and off-street parking is usually so remote from interchange areas that it discourages some ridership. Median station facilities are not very attractive or comfortable for passengers, due to noise and proximity to high-speed traffic. Passenger safety is difficult to accommodate. Placing transit
facilities over the mainline may create security issues and be prohibitively expensive. The longevity of such facilities is problematic if located at grade in the freeway median, as freeways undergo major repair or reconstruction, and it may be necessary to close stations during such activities, creating disruption of transit operations. For these reasons, access ramps to off-line transit stations sited a short distance from the freeway, or placement of transit station facilities on the side of the freeway, is sometimes preferred.

Through lanes must be separated by barriers from bus loading lanes due to the opposing flow condition. Platforms and pedestrian access require the same considerations as for side platform designs. This design will require special attention for ensuring that all opposing flow conditions have full barrier separation.

**Stations with Side Platforms.**

The most typical application of an on-line station applies side platforms similar to the busway on-line station (see below). Dimensions for each platform length and width are governed by the same variables as for busway stations. However, the high-speed freeway setting requires that the rear of each platform be protected by barrier or wall. Opposing flow traffic movements through the station need full barrier separation to prevent wrong way movements. Attenuation and barrier protection is needed to protect the front of the platform and shelter from errant motorists. A transition barrier is typically applied some distance from the platform to serve this purpose. Pedestrian access needs full grade separation treatments above or below the freeway to the station platform. Adequate lighting, shelter and security for pedestrian access is important. Parallel bus bays are the only design applied due to the restricted width setting.

If present, through HOV lanes are located around the station area. Only buses are permitted to access the station bus-loading lane due to the limited maneuvering room available for loading vehicles. Loading lanes are typically 3.6 to 4.3 meters (12 to 14 feet) wide. Through lanes are 3.6 meters (12 feet) and include a protective shoulder area next to the rear of the platform of 2.4 meters (10 feet).

**Center Platform Stations**

The Center Platform design for an on-line bus station in a freeway median attempts to reduce the overall width of the station area by condensing platform requirements and reversing the bus loading lane movements “English style” so that bus doors properly align to the parallel bays alongside the platform. A median oriented platform requires careful consideration of how traffic control is protected at the conflict points where bus paths criss-cross. One state design guide suggests posting stop signs where the acceleration lane intersects the deceleration lane, due to the lower speed that buses would be traveling. Another potential issue is controlling wrong way movements by errant motorists. One solution proposed in a state design guide is gating the exit ramps so that only buses can enter the respective deceleration lane. Only one example of the center platform layout is currently in operation in the U.S. (on the I-110 transitway in Los Angeles), and this example applies stop signs at conflict points bus but no gating.

The need for the crossover could be eliminated by either operating dedicated buses with left-side doors exclusively in the corridor, or by using buses with doors on both sides of the vehicle which could pick passengers up on the street in a conventional manner and use the left-side doors where a center platform is provided.
Figure 3-27

Examples of Cross Sections for On-Line Transit Stations

Reference: [3]
Station Functions from Direct Access Ramp

Some transit functions can be handled via a direct access ramp that may also serve other HOVs. This approach places the side platforms on the ramp grade separation over (or under) the freeway. Buses use the ramp to load and unload passengers, then re-enter the HOV lane on the other side. Buses and other types of HOVs may also use this same ramp to enter and exit the HOV lane. The over or undercrossing street becomes a new freeway access location for HOVs only. This design may be added to an existing freeway grade separation where no general-purpose ramps exist.

A summary comparison of trade-offs is shown for each freeway on-line station design in Table 3-4.
Figure 3-29

HOV Direct Access Ramp Serving Bus Transfers at an Intersection

Reference: [7]
### Table 3-4
Comparison of Trade-Offs between Platform Locations

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Side Platforms</th>
<th>Median Platform</th>
<th>Platform on Elevated Ramp (or below freeway)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Through Lane</td>
<td>Around rear of platform</td>
<td>Barrier separated from loading lane</td>
<td>Around and below ramp</td>
</tr>
<tr>
<td>Platform</td>
<td>Two 3-3.6 meters (10-12 feet)</td>
<td>One 3.6 meters (12 feet)</td>
<td>Cantilevered over through lanes</td>
</tr>
<tr>
<td>Access</td>
<td>Separate loading lanes next to median barrier</td>
<td>Loading lanes that reverse on each end of platform</td>
<td>Via typical two-way HOV ramp from median</td>
</tr>
<tr>
<td>Traffic Control</td>
<td>None</td>
<td>Stop signs and possibly automated gates to preclude wrong way movements</td>
<td>Signed or signalized at intersection on top of ramp</td>
</tr>
<tr>
<td>Overall Width (assuming concurrent flow lanes with buffers)</td>
<td>21-27 meters (68-90 feet)</td>
<td>19.5-31.4 meters (64-103 feet)</td>
<td>Controlled by ramp. No extra width for platforms. Appx. 24.6 meters (80 feet)</td>
</tr>
</tbody>
</table>

#### Advantages
- Considered safer than center platform
- Requires no traffic control
- Closest to accepted practice
- Less overall width
- More protected platform area
- Serves bus and carpool needs
- Reduces added width for platforms
- Potential for lower cost

#### Disadvantages
- Wider and more costly
- Harder to get from one platform to the other
- Harder to enforce
- Requires traffic control for reverse movements
- Less amenable to protected pedestrian access
- Requires new local access from freeway

**Freeway / Highway Right Side**

Figure 3-30 provides a couple of examples of provisions for bus stops on the right side of a freeway. Bus stops logically are located at or near major intersections where passengers can use the grade-separation structure for access from either side of the freeway.

Figure 3-31A shows an arrangement at an overcrossing street without an interchange. The turnouts and loading platforms are under the structure, requiring greater span lengths or additional openings. Each stairway should be located on the side of the cross street used by most passengers. Two additional stairways can eliminate any crossings of surface streets by transferring riders.
Figure 3-30
Example Right-Side Bus Stops

Seattle
Ottawa

Figure 3-31B shows an arrangement at an undercrossing street without an interchange. As indicated at the top left of this exhibit, platform exits and entrances may be connected directly to adjoining developments such as public buildings and department stores.

Sometimes transit stops are needed at locations other than at overcrossing streets, such as in outlying areas or in built-up districts where it is neither feasible nor desirable to provide stops at cross-street structures. Such stops preferably should be located opposite cross streets intercepted by frontage roads or major passenger walkways. A pedestrian overpass is needed to make bus stops usable from either side of the freeway.

Figure 3-31C illustrates two likely layout plans. In the lower half of the exhibit, the turnout is located at the freeway level under the pedestrian structure. Pedestrians may reach this structure by stairs or ramps. An alternative layout, shown in the upper half of the exhibit, features a turnout located at the level of the frontage road, eliminating the need for passengers to climb stairs or ramps.

In Figure 3-32A, the entrance to the turnout is located beyond the exit ramp nose, and the exit from the turnout is located in advance of the entrance ramp nose. In Figure 3-32B, buses use the freeway ramp exit to enter the turnout. In this case, the bus stop is usually located through a separate structure opening. Such consolidation of access points improves the efficiency of through and ramp traffic. Bus drivers readily adapt themselves to the appropriate route to enter and exit the bus turnout. Figure 3-33 shows a bus stop between the outer connection and the loop of a cloverleaf interchange. A collector or distributor road is desirable so that the bus turnouts will not connect directly to the through roadway. The bus turnout should preferably be located beyond the structure to minimize conflicts. When the turnout is located in advance of the structure, buses must merge with traffic from the entrance loop and weave with traffic destined for the exit loop.
Figure 3-31

Bus Stops at Freeway Level

NOTE: Elevators/stairs will need to be outside the clear zone for vehicular traffic on the roadway or be shielded by a barrier.

Reference: [4]
Figure 3-32

Bus Stops at Freeway Level – Diamond Interchange

Reference: [4]
Busway

When stations and guideways are located on separate rights-of-way like examples in Pittsburgh and Ottawa, they are commonly referred to as “busways.” The design speed of a busway can vary from segment to segment, to reflect the corridor environment and geometric restrictions. The design of an on-line station in this setting can take different forms (see Figures 3-34 and 3-35). Many on-line stations in these cities have been integrated into the adjacent land uses and developments, although common design elements are used.

Specific operation characteristics of transit services will influence the design of busway stations. For example, whether a busway is open to carpools will influence the need for barrier treatments, signing and segregation of through traffic from stopping buses. The number of intended buses that will use the station simultaneously will influence platform length. The nature and magnitude of transfers to other modes will influence whether pedestrian circulation is grade separated or not.

A typical busway station layout includes side platforms and pull-out lanes, and related pedestrian access ramps for access. Pull-out lanes are often symmetrically aligned on each side, sometimes with enough offset at low volume stations that a common walkway on the end of the platform is used to connect the two platforms and permit drivers to stopped buses to safely view pedestrians crossing at grade. Preferably, pedestrian access to each platform is fully grade separated. The pull-outs are wide enough to allow through buses to bypass the station in both directions.
Figure 3-34
Example Busway Stations

Pittsburgh, PA
Ottawa, Ontario

Figure 3-35
Typical Busway On-line Station Layout

Reference: [7]
A lane should be provided to buses to travel through a station without stopping. If a through lane is not provided or is required to be shared with oncoming traffic, these vehicles could be forced to stop and wait while buses drop-off and pick-up passengers, negatively impacting travel benefits and time savings. A 3.6 meter (12 foot) through lane for each direction of travel should be considered.

All of these elements will need to be considered in the design of an on-line busway station. In general the total width required for on-line stations will typically range from 18 to 27 meters (60 to 90 feet). The exact width and length will depend on variables related to busway design speeds, locally adopted standards for pedestrian access and mode transfer needs.

### 3.3.3. OFF-LINE BUS STOPS

**Bus Stops on Freeway Interchange Ramps**

Most of the users of a freeway transit or HOV facility will access the freeway corridor from the crossing arterial road system, and most major arterials have interchanges with the freeway. The need to transfer passengers to the express services, for local buses to access the transit / HOV lane, and for mixed flow traffic to use the interchange ramps efficiently and safely all conflict at the typical interchange.

The most common strategy is to operate buses on the outer (right-side) lanes or shoulders of the freeway, and to provide “off-line” bus stops on the freeway interchange ramps. The key to successful operation is to allow the freeway buses to exit and re-enter the freeway as quickly, reliably, and comfortably as possible, while providing adequate stop facilities at the crossing street to facilitate passenger boarding and transfer in a safe and comfortable environment without disrupting auto traffic.

An interchange type which is well suited to off-line transit interface is the full diamond layout. Another option is the Partial Cloverleaf (Parclo) layout, although the design must accommodate bus movement between the exit and entry ramps. If one or both of the loop ramp is a low-volume ramp (i.e. if less than 100 vehicles in the peak hour are projected to use the loop ramp) consideration may be given to replacing the loop with a left turn at the off ramp terminus signal, thereby freeing up significant flexibility for transit interface options, as well as property which could be used for a Park and Ride lot or transit facility.

Configurations for three interface types are shown in Figures 3-36 through 3-40. It should be noted that such interfaces are well suited to interchanges with ramp metering and accompanying HOV Bypass Lanes. although there are some implications as to the location of the bypass lane (e.g. on the left side of a metered entry ramp for a loop ramp) and for property requirements.

Rather than attempting to accommodate all of those conflicting demands at a busy interchange, it may be more appropriate to group Park and Ride, carpool parking, local-express transit interface and walk-in transit facilities in a single dedicated off-line station linked with an HOV lane or transit lane, either by direct ramp to the adjacent freeway median or by slip ramp to / from a right side facility. The provision of a direct ramp requires cost-effectiveness justification in the form of significant demand levels (provided by the large multipurpose parking lot).
Figure 3-36

Freeway Interchange Bus Interface Type I

Reference: [2]
Figure 3-37

Freeway Interchange Bus Interface Type II

Reference: [2]
Figure 3-38

Freeway Interchange Bus Interface Type III

Reference: [2]
**Figure 3-39**

Interface of Freeway and Local Bus Services at “Parclo A” Interchanges (Type I & II)

**GUIDELINES**

**STEP 1**
- if intersecting angle is 70°-110° then proceed to step 2
- if angle is beyond this range then proceed with layout of bus interface

**STEP 2**
- if “OFFSET A” is >20 m then “OFFSET B” must be ≥ 100 m to provide TYPE II interface
- if “OFFSET A” is 10-20 m and intersecting angle is ≥ 90° then “OFFSET B” must be ≥ 140 m to provide TYPE I interface with or without local bus exit
- if “OFFSET A” is 10-20 m and intersecting angle is < 90° then proceed with layout of bus interface
- if “OFFSET A” is < 10 m then proceed with layout of bus interface

**STEP 3**
- provide crossing road grade of ≤ 3% for TYPE I interface with or without local bus exit
- provide entrance ramp grade of ≤ 3% for(TYPE I or TYPE II interface
- if grades are > 3% then proceed with layout of bus interface

**NOTE**
These guidelines are intended for use in conceptual, functional and preliminary design of interchanges only. Design standards should be followed in pre-design and detail design.

Reference: [2]
Figure 3-40

Interface of Freeway and Local Bus Services at “Parcio A” Interchanges (Type III)

GUIDELINES

STEP 1
- If bypass ramp lanes are being considered for eventual construction then proceed to STEP 2
- If not then ensure that an envelope of land is available adjacent to the freeway ramp such that the bus bay can be constructed and will not interfere with arterial operations
- Length of bus bay measured along the ramp should be 35 m and width from the outside edge of ramp to back edge of bus shelter, along the platforms should be 8.7 m
- Ensure that buses turning left from the freeway exit ramp can manoeuvre into the bus bay at an appropriate approach angle. (A minimum distance of 12 m from bus turning lane to start of bus bay)

STEP 2
- Locate the downstream end of the bus bay 95.0 m along the ramp from the start of the curve on the arterial
- Ensure that the downstream end of the bus bay is adjacent to or upstream of end of taper/start of the bypass lane (the point at which 2 vehicles can travel side-by-side)
- Ensure that buses turning left from the freeway exit ramp can manoeuvre into the bus bay at an appropriate approach angle. (A minimum distance of 12 m from bus turning lane to start of bus bay)
- For the length of the platform provide an offset from edge of ramp of 8.7 m.

NOTE
These guidelines are intended for use in conceptual, functional and preliminary design of interchanges only. Design standards should be followed in pre-design and detail design.

Reference: [2]
**Bus Stops at Street Level**

Street-level bus stops can be provided at interchanges. For example, on diamond ramps, the bus stop may consist of a widened shoulder area adjacent to the ramp roadway or may be on a separate roadway. Generally, street-level bus stops adjacent to on-ramps are preferred. Figure 3-41 shows several examples of street-level bus stops on diamond interchanges. Transit signal priority can be provided if and as necessary, to minimize the time spent off-line.

**Figure 3-41**

*Bus Stops at Street Level on Diamond Interchange*

*Reference: [4]*
Figure 3-41A illustrates two possible locations for a bus stop at a simple diamond interchange without frontage roads. The bus stop can be provided on either the on-ramp or off-ramp by widening the ramp. An analysis of turning conflicts should be made to determine the feasibility and appropriateness of either option.

Figure 3-41B illustrates a street-level bus stop on a one-way frontage road at diamond interchanges. Buses use the off-ramp to reach the surface level, discharge and load their passengers at the cross street, and proceed via the on-ramp. Added travel distance is minimal, and where traffic on the cross street is light, little time is lost. However, where cross-street traffic is heavy and buses are numerous, operation may be difficult because buses must weave with the frontage road traffic to reach the sidewalk, cross the cross street, and then weave again on their way to the on-ramp.

### 3.4. References


