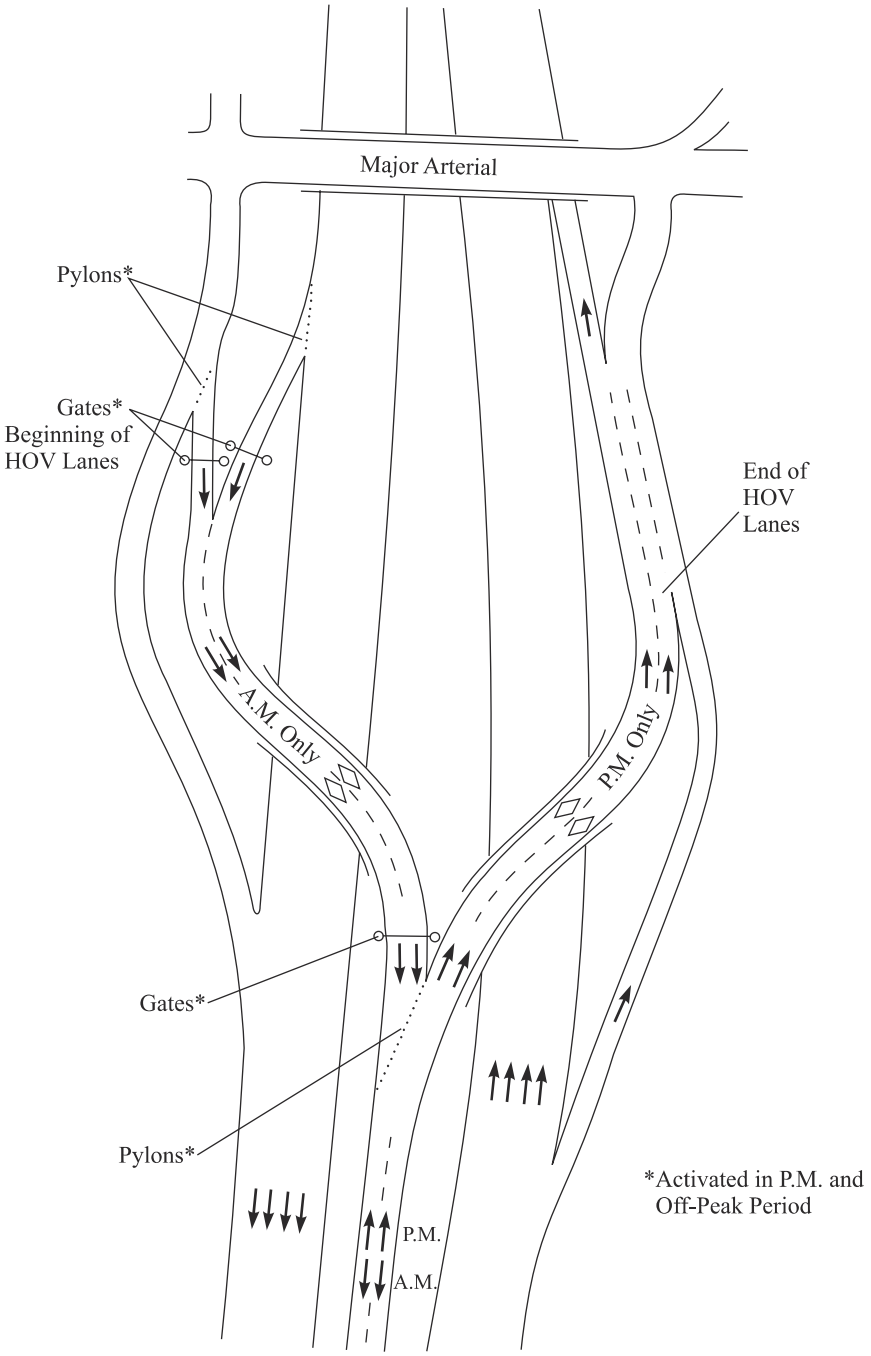


FIGURE 3-6. Example Flyover Ramp for a Two-Lane, Reversible HOV Facility (Adapted from References 18, 21).

a significant capital cost. The need for this type of facility should be considered during the planning process. Elements that may be considered in this analysis include high levels of HOV demand (i.e., minimum of 800 to 1,000 vehicles per hour), safety and operational enhancements, and cost.

The design of a freeway-to-freeway direct HOV connections ramp is similar to a general-purpose, freeway-to-freeway ramp. The same design speeds, geometrics, cross sections, and other design elements used with a normal freeway-to-freeway ramp should be applied with a freeway-to-freeway, direct HOV connection. Figure 3-7 provides an example of a freeway-to-freeway, direct HOV connection.

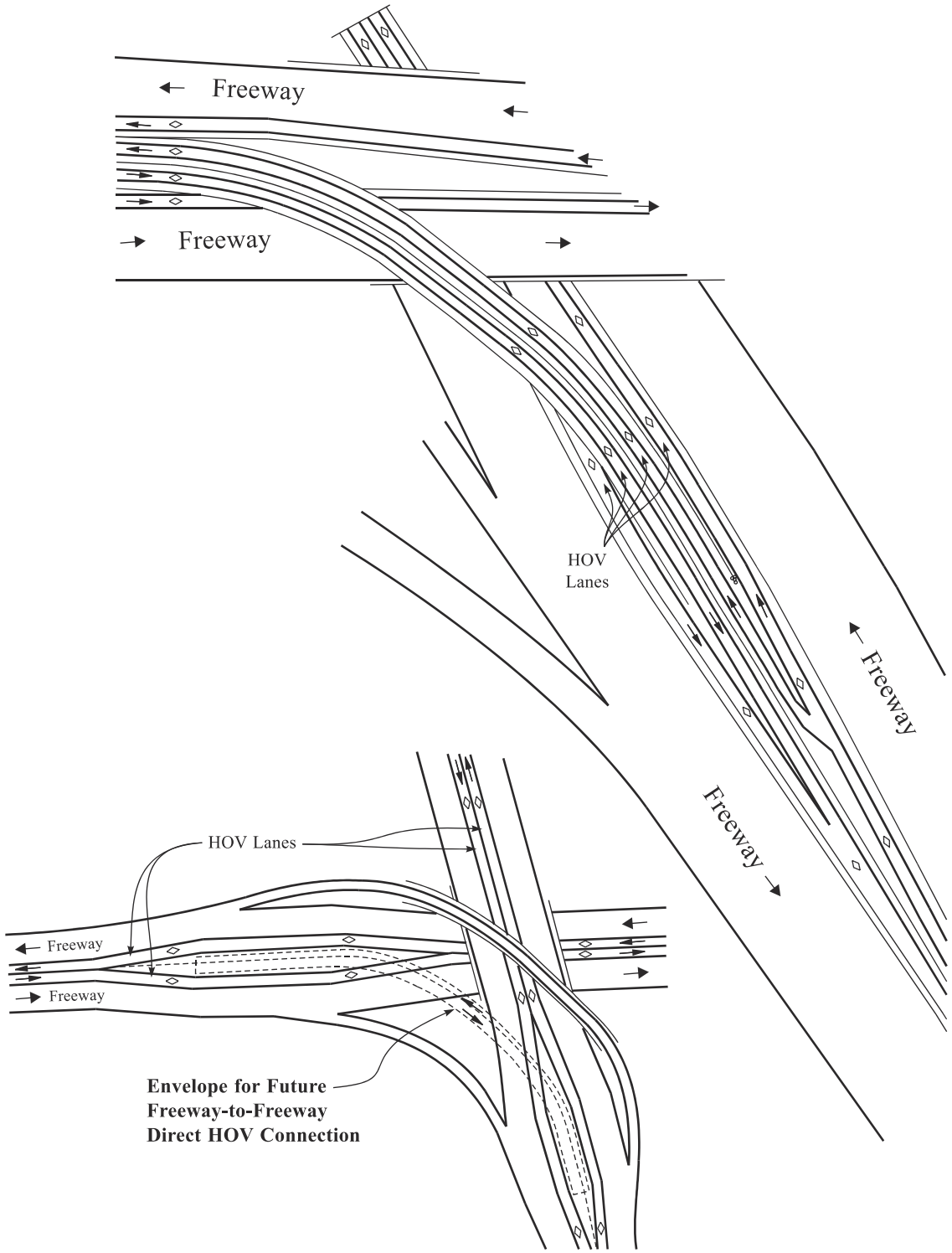


FIGURE 3-7. Illustration of Freeway-to-Freeway, Direct HOV Connection (Adapted from References 18, 21, 56).

Drop Ramps and T-Ramps. The names of these facilities reflect the fact that this type of direct access ramp looks like the letter ‘‘T’’ and the ramp ‘‘drops’’ from the HOV lane to the freeway, local roadway, park-and-ride lot, or other facility. These access treatments are usually used with barrier-separated HOV lanes, but they may also be used with other types of HOV facilities. Figure 3-8 shows an example of a T-ramp design from a reversible-flow HOV lane to a park-and-ride lot or arterial street. The figure shows

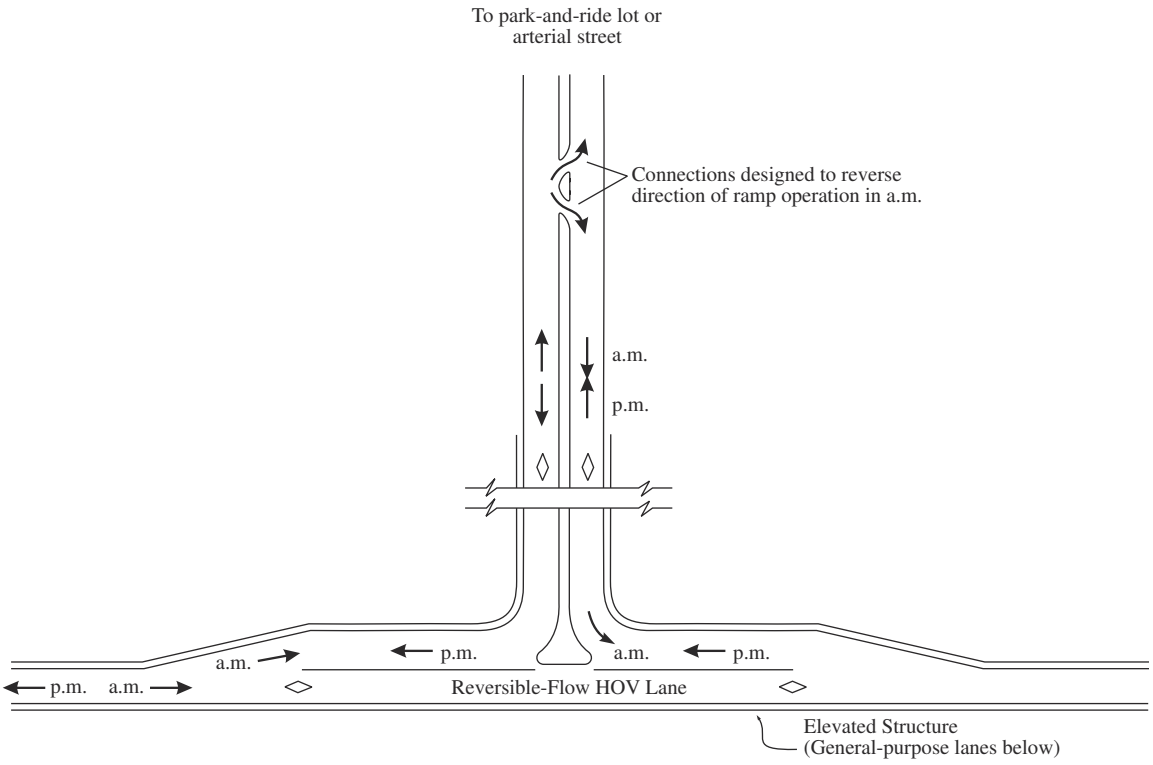


FIGURE 3-8. Example T-Ramp for Single-Lane, Reversible HOV Lane (Adapted from Reference 18).

how the connections on the ramp reverse for changing a.m. and p.m. operations. General-purpose through vehicles are handled at the ground level.

Figure 3-9 shows an example schematic of a drop ramp that provides access to a two-lane, reversible-flow HOV facility. Notice the use of double gating to ensure there are no wrong-way movements. The intersection should also have adequate lighting. Figure 3-10 shows a two-way drop ramp to a cross street. The upper schematic of Figure 3-10 shows barrier separation on the ramp, while the lower schematic does not have barrier separation on the ramp. This ramp configuration would be most appropriate for 24-hour operation of the HOV facility. Signing and striping should be placed to ensure there are no wrong-way movements on the two-way ramp. Figure 3-11 shows a direct access drop ramp with transit stations. This design could also be used without the online stations. Signing and pavement markings should be located to ensure there are no wrong-way movements on the ramps due to the two-way operation.

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

A shoulder should be provided for each direction of travel. If a full shoulder cannot be provided, other approaches may be used. A center barrier should be considered with two-way ramps, especially if high volumes of carpools and vanpools are projected to use the facility.

3.4.1.2 At-Grade Access

At-grade access can be used with barrier-separated facilities. At-grade access can also be used with concurrent flow HOV facilities (see Section 3.5). The first step when determining access locations on barrier-separated facilities is to determine whether grade-separated (direct access) or at-grade access is best.

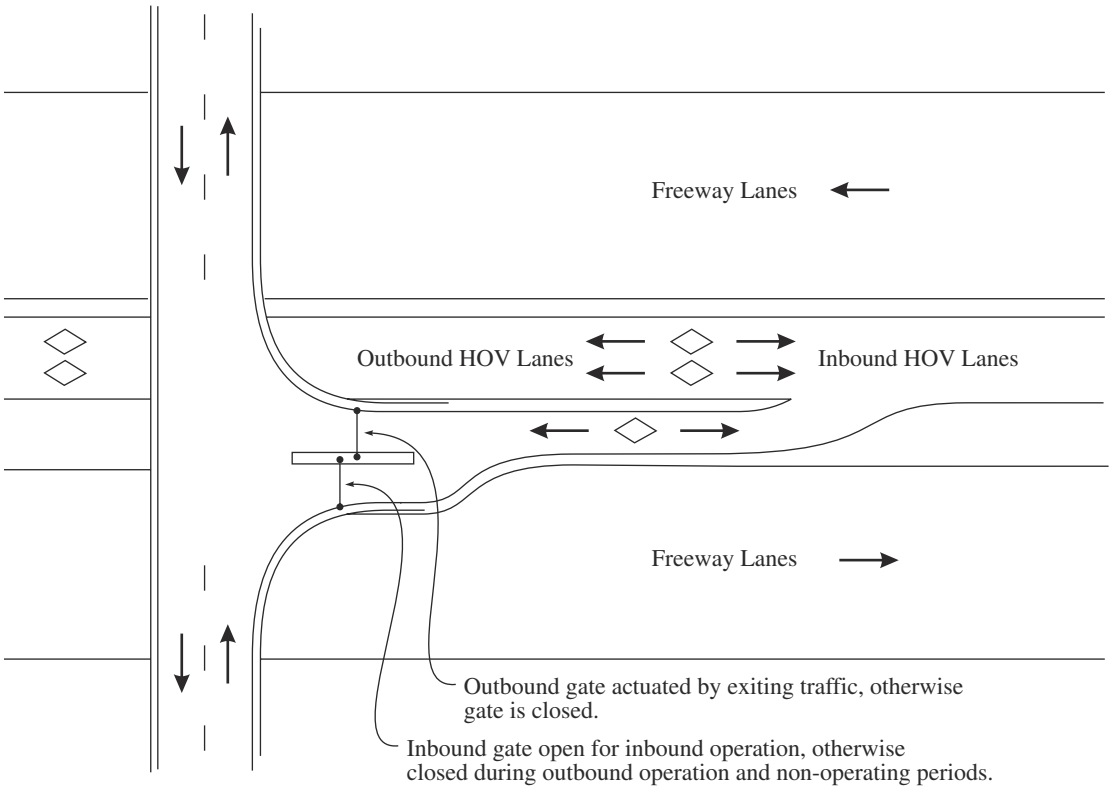


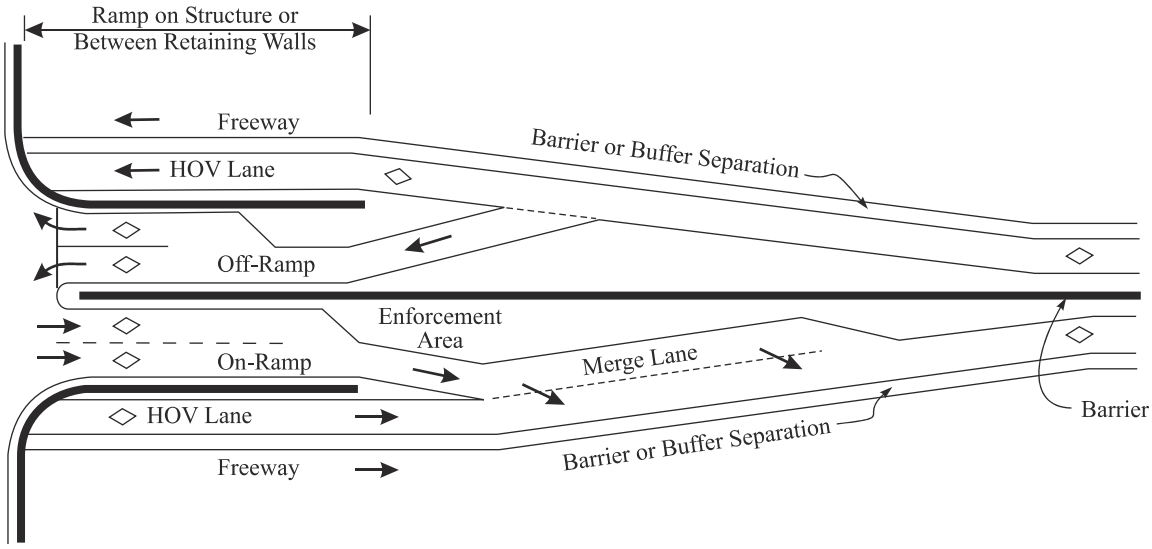
FIGURE 3-9. Example Drop Ramp Providing Access to a Two-Lane, Reversible Flow HOV Lane Facility (Adapted from References 18, 21).

If the location of the proposed access is a terminal point at the far end of the radial freeway lane, it may be appropriate to use an at-grade ramp because it can be relocated if congestion worsens beyond the location of the access point. Typically, a tapered entrance/exit can also be provided (see Figure 2-4). If the access location is intermediate, a high-volume or high-bus activity area, it may not be appropriate to use an at-grade access point.

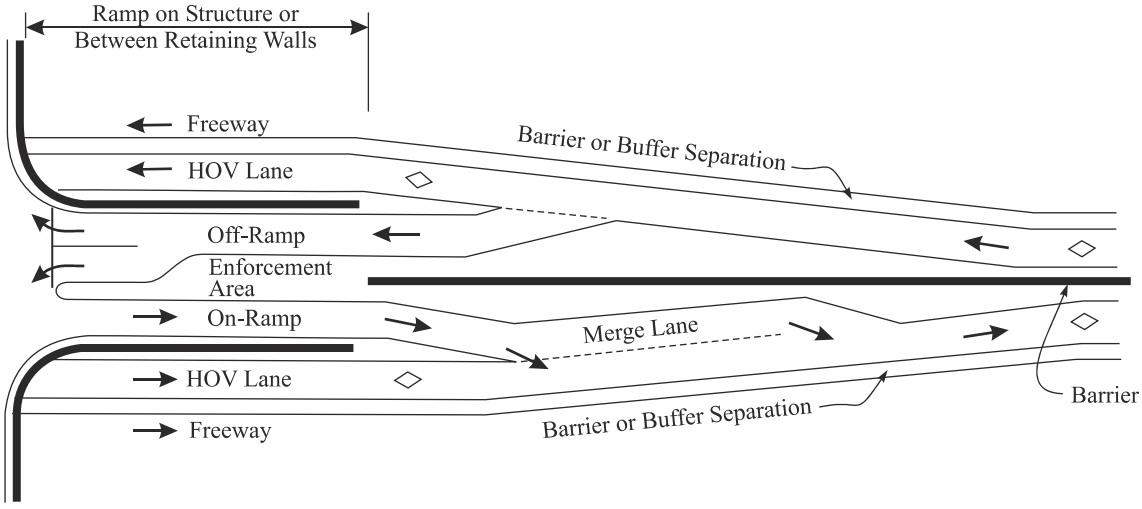
Figure 3-12 provides examples of entrance and exit terminal locations with at-grade access treatments showing a taper. At the termination of the HOV lane, many factors should be considered to best address any queuing caused by the lane drop and whether it is better to drop the HOV lane on the left or to drop the general-purpose lane further downstream on the right. Some of the factors that would need to be considered in the analysis include:

- Volume of HOVs using the lane at its terminus;
- Volume of traffic in the general-purpose lanes that are exiting and not exiting;
- Geometry between terminus and exit ramp;
- Roadway geometry (i.e., vertical and horizontal curvature);
- Proximity to major interchanges;
- Truck percentage in the general-purpose lanes; and
- Drainage needs.

Making a decision based on how and where to drop the HOV and general-purpose lane may require the use of a simulation tool to evaluate the operations of different alternatives.



BARRIER-SEPARATION ON RAMP



NO BARRIER-SEPARATION ON RAMP

FIGURE 3-10. Example Two-Way Drop Ramp (Adapted from References 21, 56).

Signing at the entrance to an HOV facility is essential. In all cases, signing should be located at least 1.6 km (1.0 mile) in advance of the entry point and shall be as directed in the MUTCD and any state and local guidelines. The entrance to the HOV lane facility should be a lane change, not simply a redesignation of the lane, to prevent unaware motorists from entering the facility.

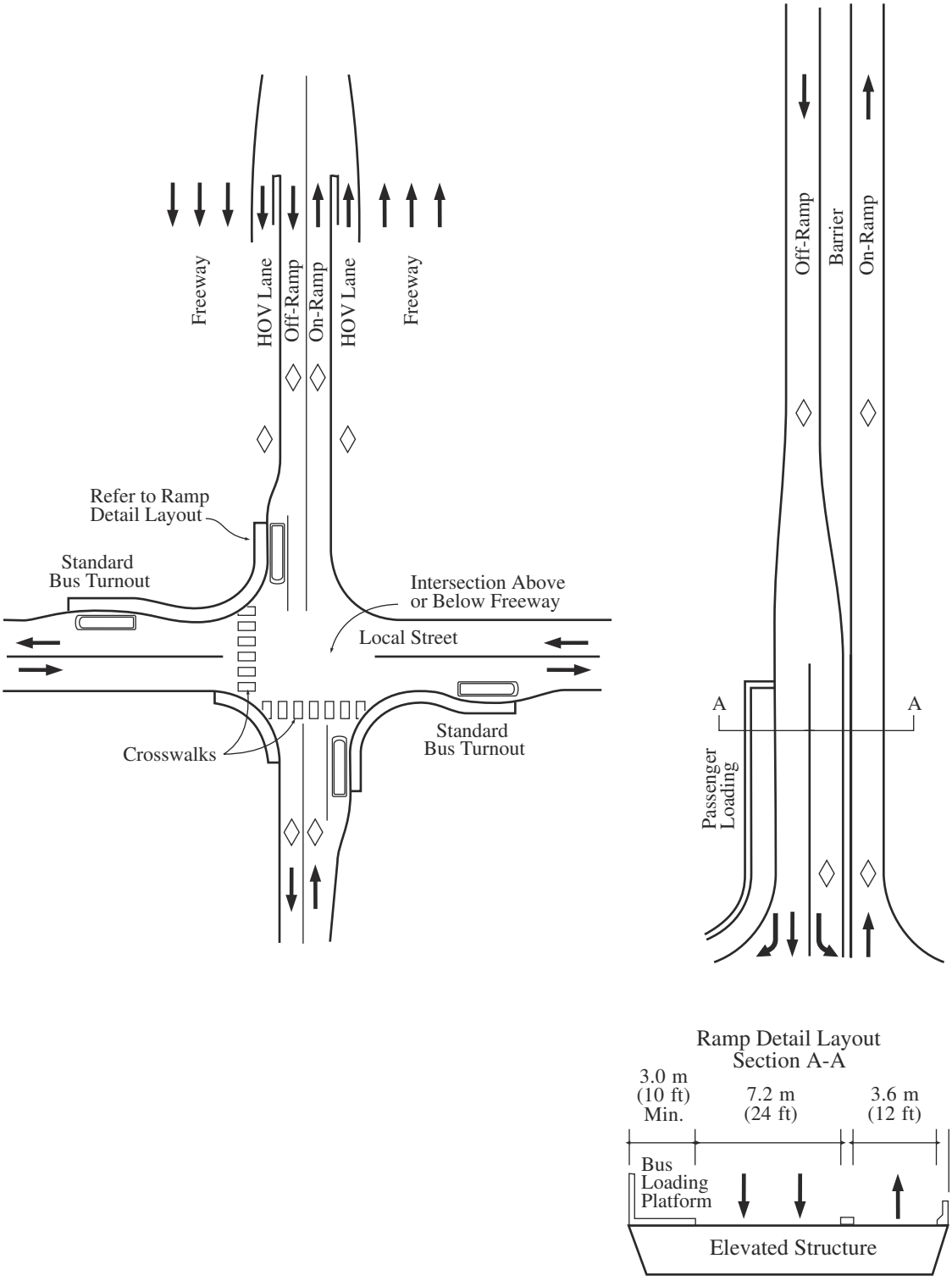
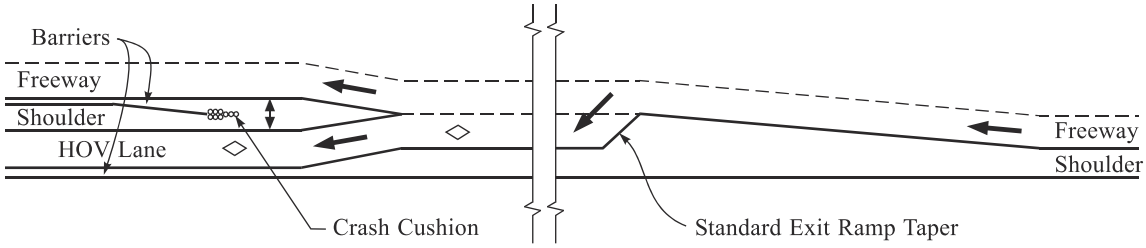
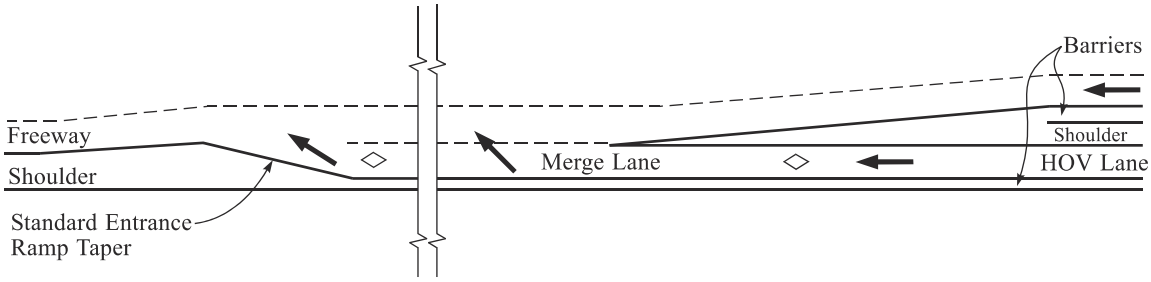


FIGURE 3-11. Example Direct Access Ramp Design Serving Online Station Functions (Adapted from Reference 21).



EXAMPLE OF ENTRANCE TO BARRIER-SEPARATED HOV LANE



EXAMPLE OF EXIT FROM BARRIER-SEPARATED HOV LANE

FIGURE 3-12. Example Schematics of HOV Lane Entrance and Exit (Adapted from References 18, 21, 56).

3.4.1.3 Summary of Egress/Ingress Alternatives for Barrier-Separated HOV Facilities

The previous sections have described egress/ingress alternatives for barrier-separated HOV facilities. Table 3-5 summarizes the objectives, advantages, and limitations of various access treatments applicable for barrier-separated HOV facilities. Table 3-6 provides some tradeoffs for various types of ingress/egress treatments for barrier-separated HOV facilities.

3.4.2 Barrier-Separated HOV Lane Operation and Enforcement

The operation of barrier-separated HOV lanes may be reversible or two way. Limiting access to a reversible HOV facility is crucial if the facility is to be operated in a safe and efficient manner. At each end, a system of gates should be considered to prevent wrong-way traffic from entering the facility. In addition to these features, this type of facility should also have a system of DMS that informs commuters of the operational status of the facility (open or closed). This system of safeguards can be operated from a remote operations center but should be checked by field personnel prior to each opening. Enforcement areas for all types of HOV facilities should be designed not to draw attention from motorists.

A reversible HOV lane operation can be expensive in terms of operational features, as well as personnel support. A benefit-cost analysis should be done to determine if a reversible operation is justified. It should also be noted that by its nature, a reversible facility cannot be a fulltime facility or an off-peak direction facility. Transition time will be needed to prepare the system for each directional change.

TABLE 3-5. Objectives, Advantages, and Limitations of Access Treatments for Barrier-Separated HOV Lanes (Adapted from References 21, 56).

Flyover Ramp

- Highest speed design, intended for high interfacing volumes; most closely approximates other freeway ramp in design speed.
- Serves all HOV lane users well.
- Can be applicable as an intermediate access or termination treatment.
- Can be cost-prohibitive as a means of accessing support facilities.
- Least flexible treatment; sometimes overlooked on an interim HOV lane operation and added later as demand warrants.
- Equally appropriate for two-way or reversible-flow operations.

Drop Ramp or T-Ramp with a Street

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

Drop Ramp or T-Ramp to a Park-and-Ride Lot or Off-Line Bus Transit Station

- A very effective way of extending an HOV facility into an off-line support facility, thereby increasing travel-time savings.
- Not recommended for serving other HOVs who have no affinity for the support facility; requires circulation consideration within the support facility.
- Generally requires high transit and/or rideshare volumes to be cost effective.
- Can operate with two-way operations, although it can also operate with reversible-flow if T-ramps are reversed as well.

At-Grade Access at Project Termination

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

At-Grade Access as an Intermediate Access

- Lowest cost intermediate access approach; can be easily modified (relocated or removed).
- Most compatible with restricted envelopes; requires little widening.
- Consider parallel weave lane with high accessing volumes.
- High-volume conditions can increase conflict points; can disrupt the adjacent freeway or HOV lane level of service.
- Enforcement is difficult.
- Location is critical; if too close to nearby freeway intersections, weaving conflicts across the freeway increase.
- Preview signage of downstream exits may be required.

TABLE 3-6. Tradeoffs for Applying Ingress/Egress Treatments for Barrier-Separated HOV Lanes (Adapted from Reference 21).

Objective	Type of Treatment[1]			
	Flyover Ramp	Drop Ramp or T-Ramp with Street	Drop Ramp or T-Ramp with Park-and-Ride Lot or Transit Station	At-Grade Access Ramp with Freeway
Frequent spacing [<4.8 km (< 3 mi.)]	−	0	+	0
Maximize bus travel-time savings	0	0	+	0
User mix requirements				
Buses only	+	+	+	+
Buses and other eligible vehicles	+	+	+	+
Primarily carpools and vanpools	+	+	+	+
Potential conflict with general-purpose traffic	+	+	+	0
Enforceability	0	+	+	−
Traffic regulation capability[2]	+	+	+	−
Capital cost	−	0	0	+
High vehicle ramp volumes (> 400 vph)	+	+	−	Terminations + Intermediate sites −
Low vehicle ramp volumes (< 400 vph)	−	+	+	+
High ramp design speed [>55 km/h (> 35 mph)]	+	−	−	+
Low ramp design speed [<55 km/h (< 35 mph)]	N/A	+	+	−
Retrofit compatibility with existing freeway	0	+	0	+
Flexibility to modify later	−	−	−	+

Legend:
+ = favorable;
0 = neutral, often depends on the design or site specifics;
− = less favorable;
N/A = not applicable.

[1] Not included are busway street intersections used for low-volume, bus-only operation in separate rights-of-way.

[2] Assumes use of meters to regulate entering flow of vehicles.

Chapter 2, the freeway operations chapter of this guide, presented additional considerations, including vehicle eligibility, hours of operation, etc. Enforcement considerations for barrier-separated HOV facilities are described in the following sections.

3.4.2.1 Low-Speed Enforcement Area

Low-speed enforcement areas are usually located at access points on busways, HOV lanes on separate rights-of-way, and barrier-separated HOV facilities. Specific locations may include ramps, reversible lane

entrances, and queue bypasses where vehicle speeds are relatively low, usually below 70 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 lane facility. The following design features may be considered with low-speed enforcement areas:

- The enforcement area should be at least 30 m (100 ft) in length and preferably up to 60 m (200 ft) on high-volume facilities, not including approach and departure tapers.
- The enforcement area should be at least a width of 3.6 to 4.3 m (12 to 14 ft).
- The enforcement area should have an approach taper of 9.1 m (2:1 or approximately 30 ft).
- The enforcement area should have a departure taper of 45.7 m (10:1 or approximately 150 ft) to allow for acceleration into the lane.

3.4.2.2 Enforcement Design Considerations for Busways or an HOV Facility 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 transit stations, with limited local street access. In addition, buses are usually the only vehicles authorized to use these facilities. As a result, nonauthorized 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 designated 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 reporting and dealing with violators. If an HOV facility in a separate right-of-way is opened to HOVs other than buses, the facility will operate similar to a two-way HOV facility, and enforcement would be performed similarly to that design (see Section 3.4.2.3).

3.4.2.3 Enforcement Design Considerations for Barrier-Separated, Freeway HOV Facilities

Enforcement of two-way and reversible barrier-separated HOV facilities is easier than with concurrent flow lanes (Section 3.5) due to limited access points. Violators can be stopped at entry and exit points, where travel speeds are usually lower. Enforcement designs used with reversible lanes are discussed below first, followed by the design approaches used with two-way facilities.

Reversible, Barrier-Separated HOV Facilities. Reversible, barrier-separated HOV lanes may be the easiest to enforce. The design of these facilities significantly reduces the number of access points and prohibits random ingress and egress. Most HOV lanes of this type contain from one to five access locations, making surveillance and apprehension at entrances or exits efficient and effective. Barrier-separated lanes also act as a deterrent to potential misuse, as violators are trapped in the lanes. Enforcement officers may work in tandem, reporting violators at one entrance and allowing a second officer downstream to apprehend and cite violators. In addition, the geometric requirements for a reversible facility provide enforcement pockets within the ramps that can serve as enforcement areas for the opposing direction. In some cases, these pockets are large enough to provide a means of removing violators by sending them out in the off-peak direction, thus penalizing the offending commuter with a travel delay as well.

Two-Way, Separated HOV Facilities. Two-way, barrier-separated HOV facilities offer the same advantage of limited ingress and egress as reversible HOV lane facilities. There are two differences, however, which make enforcement more difficult. First, if an enforcement shoulder is not provided, there are no unused elements of the HOV lane roadway in which enforcement vehicles can perform their operations. Second, because there may be more options for accessing the lanes, there is less likelihood that enforcement can