MTO Design Supplement

For
TAC Geometric Design Guide (GDG) for Canadian Roads

Appendix 12

Managed Lanes

~~October 2023~~July 2026

All the following material is additional guidance as the TAC GDG does not contain a chapter on Managed Lanes.

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Appendix 12
Managed Lanes

12.1 Introduction and Organization of Chapter

The transportation system in Ontario is rapidly changing due to traffic demand constantly increasing. When traffic demands cannot be accommodated by the existing roadways, travel times and the cost of congestion increase, the air quality worsens, and more greenhouse gas emissions are released. Meanwhile, the space required to expand the transportation network and government funds are limited. Incorporating managed lanes into transportation planning is a useful strategy to address some of the issues faced by corridors with heavy congestion.

Transportation is one of the largest sources of emissions in Ontario. Reducing transportation emissions through influencing~~e of~~ mode choices and encouraging the transition of existing drivers to transit, carpooling, cycling and walking, highlights an important role of the implementation of managed lanes to alleviate congestion on the highways.

The purpose of this chapter is to present technical guidance and recommended practices for managed lanes to assist transportation professionals as they consider planning and the implementation of managed lane-facilities within highway corridors.

The chapter is organized into eleven (11) sections and additionally contains a list of references reviewed during the preparation of relevant material included in this chapter. -B~~e~~elow is a summary of the topics covered in each section:

- Section 1 primarily includes definitions and types of managed lanes~~,~~
- Section 2 outlines managed lane strategies for Ontario~~,~~
- Sections 3 and 4 include planning and operational considerations for the implementation of managed lanes, including HOV alternatives~~,~~
- Section 5 outlines specific design guidelines for different types of managed lanes~~,~~
- Section 6 addresses the safety implications of managed lane cross-sections~~,~~
- Section 7 includes traffic control systems for the implementation of managed lanes and/or toll lanes~~,~~
- Section 8 includes performance monitoring and enforcement of managed lanes~~,~~

- Sections 9 and 10 include illumination and maintenance aspects for managed lanes~~,~~
- Section 11 discusses the provisions of transit facilities within managed lane corridors~~.~~

12.1.1 Managed Lanes Overview and Definitions

12.1.1.1 Managed Lanes (ML)

Managed lanes are designated lanes within the highway right-of-way where traffic is managed to improve congestion by restricting vehicle eligibility, limiting facility access, or in some cases, collecting variably priced tolls. Examples of managed lanes include High Occupancy Vehicles (HOV), High Occupancy Toll (HOT), Express Toll, Bus Only Lanes or Bus Reserved Lanes and Truck Only Lanes (**Section 12.1.1.3**).

12.1.1.1.1 Benefits of Managed Lanes

- Provide more reliable and predictable travel times for all vehicles in managed lanes, including buses.
- Provide~~Offer~~ drivers with a choice of travel options, including using carpool lane with a toll that is set according to how heavy traffic is, or use of carpool lane for drivers with two or more people.
- May increase safety by removing commercial motor vehicles and transit vehicles from main traffic flow.
- Improve air quality by reducing the time vehicles idle on freeways.
- Create better highway connectors and transitions to move vehicles more efficiently.
- Could provide toll revenue.
- Encourage transit and carpool use.

12.1.1.1.2 Success of Managed Lanes

The important prerequisite condition necessary for managed lane demand to materialize is the presence of recurring traffic congestion.- Managed lanes are a congestion management strategy and have benefits that are only fully realized in areas of frequent traffic congestion that causes significant travel time delays and uncertainty over trip time.

There are implicit conditions that should exist for managed lanes to be considered viable. These include:

- Recurring congestion ~~generally defined~~defined as level of service [LOS] D or worse, or average travel speeds 40 – 50 km/h~~r~~ below posted speed limits, within a corridor for a significant period.- A volume to capacity (V/C) ratio of 0.85 is selected as an applicable threshold consistent with a highway planning LOS of D (according to the Highway Capacity Manual (HCM)).- Corridors with V/C of 0.85 or higher during AM Peak direction can be identified as a qualified corridor for managed lanes.
- The total delay times (from 6am to 9pm) for all vehicles/vehicle occupants or the standardized average delay time for vehicle/vehicle occupant could be used also to select sections of the roadways with the highest potential for improvements and highest potential benefits.
- Lack of available resources (right-of-way, funding, and environmental support) to address capacity needs. Interest and ability to minimally increase or alter existing roadways by managing their use for specific dedicated purposes to ensure that a high level of service can be provided as an alternative to recurring congestion.
- Consideration of managed lanes within the overall framework of congestion management and TDM strategies (i.e., managed lanes are not a stand-alone solution).

12.1.1.2 Suitability of Corridors for Managed Lanes

12.1.1.2.1 Congested Corridors

Recurring congestion within a corridor or segment of a corridor during the defined (AM and/or PM) peak periods is a key requirement for considering any type of managed lanes. -Recurring congestion is ~~generally defined~~defined as a breakdown in traffic flow and a reduction in speed as demand approaches or exceeds capacity resulting in increased air pollution and greenhouse gas emissions.

Given that any qualified section is part of a larger corridor, and the importance of having a ML network, a section of a corridor would be considered qualified even if uncongested, but critical to the continuity and connectivity of the ML network.- Adding or removing the connectivity of a ML can impact the operations of the ML network and the overall performance of the corridor or network.

12.1.1.2.2 Vehicle Eligibility

The vehicle eligibility for a ML network option defines the minimum number of occupants required for a vehicle or the vehicle requirements to be allowed to use the ML. For high-occupancy lanes, the key evaluation is to identify whether HOV2+ or HOV3+ should be the governing policy.~~ ~~For example, a threshold of a minimum of 500 vehicles per hour per lane (vphpl) has been used as a minimum volume requirement for HOV lane identified in ~~a~~ several studies in North America.

In Ontario, most HOV lanes can be utilized by vehicles with at least two people (including the driver) in one of these vehicles:

- Cars~~.~~
- V~~v~~ans or light trucks~~.~~
- C~~c~~ommercial motor vehicles less than 6.5 m~~eter~~ long with a gross weight of 4,500 kg or less~~.~~
- T~~t~~owing a trailer if the combined vehicle-trailer length is less than 6.5 m~~eters.~~

Also, the following vehicles have unrestricted access to HOV lanes, no matter how many passengers they are carrying:

- B~~b~~uses of all types~~.~~
- L~~l~~icensed taxis and airport limousines (until June 30, 2020)~~.~~
- E~~e~~mergency vehicles~~.~~
- V~~v~~ehicles with Ontario green licence plates
- M~~m~~otorcycles

12.1.1.3 Types of Managed Lanes

Managed Lanes (ML) have become more prevalent on highway facilities with various types as outlined below.

12.1.1.3.1 HOV Lanes

HOV lanes have been the most widely applied form of managed lanes. Incorporating high-occupancy vehicle (HOV) facilities into the freeway system is one means of improving the operational conditions on freeways. HOV lanes help move more people faster on highways by influencing/encouraging people to carpool or take transit. This is important during peak travel times when other lanes are slow and congested. The HOV lanes can also provide a congestion-free bus route, allowing operators to provide faster, more reliable service.

HOV Lanes Benefits to Motorists

- Save time**:** avoid congestion and arrive at their destination more quickly~~er~~.
- More reliable commute: avoiding congestion and a more consistent commute time.

- Save money: it costs less to ride a bus or to share a ride than to drive alone.
- Conserve fuel: waste less fuel than sitting in traffic.
- Less stress: letting someone else drive or taking turns.

HOV Lanes Benefits to Highway System

- Manage congestion: HOV lane can handle a lot of growth in demand. Once a general-purpose lane reaches capacity, it becomes congested and moves fewer people.
- Make better use of infrastructure: highway lane capacity varies from 1,500 to 2,200 vehicles per hour. A lane full of buses and carpools moves many more people than a general traffic lane.
- Transit priority: Buses and transit riders have priority. A single transit bus can replace 57 single-occupant cars.
- Provide choices: HOV lanes make carpooling and public transit more effective and reliable choices for commuters.
- Support mobility: Taxis and airport limousines that use HOV lanes can return to duty faster after dropping off or arrive sooner to pick up.
- Support electric vehicles: Vehicles with Ontario green licence plates are allowed on all provincial HOV lanes - even with only one person in the vehicle.
- Lower greenhouse gas ~~emissios~~emissions in an effort to meet 2030 emission targets.

In December 2005, MTO opened its first HOV Lanes on sections of Highways 403 and 404.- By 2031, a network of more tha~~t~~n 300 km of HOV lanes are planned on 400-series highways as part of MTO HOV Lane Network for the Greater Golden Horseshoe area.

In Ontario, HOV lanes are designated under the ***Highway Traffic Act***, pursuant to the High Occupancy Vehicle Lanes Regulation. Occupancy and eligibility may be adjusted over time. In Ontario, there are certain exemptions to the multiple occupancy requirements for HOV lanes. These vehicles are permitted to use the lanes regardless of occupancy. Detailed definitions of exemptions are laid out in the ***Ontario Regulation 620/05: HIGH OCCUPANCY VEHICLE LANES.***

Exhibit 12A~~Table 12.1.1~~

HOV Users

User Groups		
Permitted		**Prohibited**
Toll/Fee	**Non-tolled**	
• N/A	• Motor vehicles[1] with at least two occupants[2]	• Motor vehicle with one occupant • Commercial motor vehicles

User Groups		
Permitted		Prohibited
Toll/Fee	Non-tolled	
	• Buses • Exempt vehicles[3]	longer than 6.5 metres

[1] Eligible vehicle must be less than 6.5 m~~etres~~ long with a gross weight of 4,500 kg or less.
[2] Occupancy requirements may be adjusted over time to manage congestion.
[3] Exempt vehicles include police vehicles on duty, vehicles owned or leased by the Province of Ontario, vehicles engaged in road construction or maintenance activities, vehicles with green licence plates, taxicabs, or limousines.
Effective July 1, 2019, HTA was amended to allow single-occupant motorcycles to access High Occupancy Vehicle lanes (HOV).

12.1.1.3.2 HOT Lanes

Typically, HOT Lanes are HOV facilities that allow lower-occupancy vehicles, such as solo drivers, to use the facilities in return for toll payments, which could vary by time of day or level of congestion.- Vehicles with more than one occupant could be exempted from the toll.- Most HOT lanes are created within existing general-purpose highway facilities and offer potential users the choice of using general-purpose lanes or paying for premium conditions on HOT lanes.

HOT lanes may~~could~~ be created through new capacity construction or converting HOV lanes to HOT lanes. Since both right of way and construction funds are limited, conversion of existing HOV lanes to HOT operation is the most common approach.

Where HOV lanes are seen to be under-utilized, High Occupancy Toll lanes (HOT) may be considered. HOT lanes permit single occupant vehicles (SOVs) to use HOV lane by paying a toll. The HOT lanes concept is a managed lane that combines HOV with pricing strategies to improve overall facility operations. Previous studies on HOT lanes show that they reduce congestion not only in tolled lane but also in general-purpose lanes.

HOT lanes typically are limited-access separated highway lanes. Separation from the adjacent general-purpose lanes can be achieved by treatments that range in cost, permanence and permeability from a simple painted line to concrete traffic barriers.

HOT lanes often utilize sophisticated electronic toll collection (ETC) and traffic information systems that make variable, real-time toll pricing of non-HOV vehicles possible. Information on price levels and travel conditions is normally communicated to motorists via variable message signs (VMS), providing potential users with the facts they need to decide between utilizing the HOT lanes or the parallel general-purpose lanes that may be congested during peak periods.

HOT Lane Benefits

HOT lanes are intended to provide a variety of benefits to multiple user groups. When applied in conjunction with other management tools and provision of additional lane capacity, HOT lanes have the potential to generate significant improvements in congestion level. Also, HOT Lanes may represent an opportunity for transit agencies as they provide faster travel speeds.

HOT lanes also have a wide range of secondary benefits, including:

- Generate revenues that can be used to support construction of HOT lanes themselves or other initiatives, such as improved transit service~~;~~
- Traffic service improvements on congested parallel highway mainline lanes and improving corridor-wide mobility~~;~~
- Performance reliability compared to general-purpose lanes during peak periods~~.;~~
- Faster highway trips for express transit services such as bus rapid transit (BRT)~~;~~
- Environmental advantages such as reducing greenhouse gas emissions and air pollution by providing opportunities to encourage carpooling, improve transit service, and move more people in fewer vehicles at faster speeds~~; and,~~
- Improving the utilization of HOV lanes and eliminating potential pressure to convert underperforming HOV lanes to general-purpose use~~.~~

Exhibit 12B~~Table 12.1.2:~~
Users of HOT L~~l~~anes

User Groups		
Permitted		Prohibited
Tolled	Non-tolled	
• Authorized single occupant vehicles	• Motor vehicles[4] with at least two occupants[5] • Buses • Exempt vehicles[6]	• Unauthorized single occupant vehicles • Commercial motor vehicles longer than 6.5 m~~etres~~

[4] Eligible vehicles must be less than 6.5 m~~etres~~ long with a gross weight of 4,500 kg or less.
[5] Occupancy requirements may be adjusted over time to manage congestion.
[6] Exempt vehicles include police vehicles on duty, vehicles owned or leased by the Province of Ontario, vehicles engaged in road construction or maintenance activities, vehicles with green

licence plates, taxicabs or limousines (currently exempt until July 2018).
Effective July 1, 2019, HTA was amended to allow single-occupant motorcycles to access High Occupancy Vehicle lanes (HOV).

Exhibit 12C
Hwy 403/QEW, HOT Lane Pilot Project in Ontario

~~**Figure 12.1.1 Hwy 403/QEW, HOT Lane Pilot Project in Ontario**~~

12.1.1.3.2.1 Ontario HOT Lanes

The Ministry of Transportation (MTO) first launched High Occupancy Toll (HOT) lanes as a pilot project on the Hwy 403/QEW (16.5 km of the QEW, in both directions, from Trafalgar Road in Oakville to Guelph Line in Burlington, (~~**Figure 12.1.1**~~**Exhibit 12C**) to test a new way to improve traffic flow and encourage carpooling.- This pilot project helped the ministry to plan for a more efficient highway network in Ontario.- During the pilot, the ministry explored and ~~tested~~evaluated innovative technology to support HOT lanes, including tolling, compliance and performance.

The ministry approved an amendment to the **Highway Traffic Act, Ontario Regulation 620/05** - High Occupancy Vehicle Lanes (HOV) to extend the pilot allowing single-occupant taxicabs and airport limousines to access the lanes. The amendment; **O. Reg. 244/18 to O. Reg. 620/05** - High Occupancy Vehicle Lanes came into force on April 13, 2018.

The HOT pilot program and supporting retail and distribution system was developed and delivered in less than nine months as an online service.- MTO and Service Ontario collaborated to simultaneously develop policy, performance measures and program design, including an online digital retail service.- MTO partnered with Service Ontario to develop the public facing online application, administrative back-end console, permit fulfillment process and contact center support for customer service functions.

MTO partnered with the Ontario Ministry of Economic Development and Growth in a Small Business Innovation Challenge providing grants to Ontario-based small and medium enterprises for the purposes of developing prototypes that support automated vehicle occupancy detection. There were few viable options in the marketplace for automated vehicle occupancy detection.

Overall, the pilot helped MTO refine HOT lanes implementation to suit Ontario and ensure they are an effective part of the transportation network. This included investigating the opportunity to include HOT lanes in future highway expansions.

Exhibit 12D
HOT Lanes Pilot Digital Message Signs

~~**Figure 12.1.2 HOT Lanes Pilot Digital Message Signs**~~

12.1.1.3.3 Express Lanes / Limited Access Lanes

An Express Lane (EL) is a type of managed travel lane physically separated from a general-purpose lane or general toll lane within a roadway corridor. Express lanes are limited-access facilities that typically operate adjacent to general use lanes. The separation technique is one of the key design decisions that influence the feasibility, operations, and constructability of an express lane project.

Express lanes can provide a high degree of operational flexibility, which enables them to be used in actively responding to changes in traffic demands. Express lanes can be located within tolled or non-tolled facilities and can be operated as reversible-~~-~~flow or bi-directional facilities to best meet peak demands.

Limited-Access Lanes limit vehicle access over long stretches of the facility. Limiting access and egress points is a strategy used on provincial highways, however in the context of managed lanes in Ontario it will typically be employed along with another managed lane strategy.

Limiting access to certain points can help reduce occurrence of traffic flow disruptions and weaving issues due to merging and lane changes.- All express lane facilities should be constructed to the inside (median side) of the general use lanes to reduce costs and maintain general-purpose lane access to cross streets.

12.1.1.3.4 Bus Lane / Bus Only Lane (BOL)

A bus-lane or a bus-only-lane, is more commonly located on a major roadway on a separate right-of-way.- It is ~~usually~~ typically a component of a Bus Rapid Transit (BRT) system and as a result the terms bus-lane, busway, and BRT are sometimes used synonymously. However, there is a distinction between a lane dedicated to exclusive use by buses and BRT, which may include various operational improvements and station design features to provide high quality service for express bus trips.

Bus operation can be integrated into HOV lanes on freeway corridors that experience high levels of congestion and have high use for bus transit services (**Exhibit 12E**~~**Figure 12.1.3**~~).- Bus -lanes on freeway are ~~usually~~ typically shared with HOVs and other vehicles since buses use little capacity.- The purpose of bus lanes and supporting facilities (e.g., transit stations, park-and-ride lots and direct access treatments) is to provide more reliable bus service by cutting down delays that buses would have incurred in congested traffic environment, thereby increasing service efficiency by allowing more peak trips by the same bus and providing patrons a faster trip.

12.1.1.3.5 Part-Time Shoulder Use / Bus on Shoulder (BOS)

Part-time shoulder use is the conversion of shoulders to travel lanes during ~~some~~ certain hours of the day as a congestion relief strategy. This strategy is also known as temporary shoulder use or hard shoulder running and is typically implemented on freeways to provide additional capacity when it is most needed and preserves shoulders as refuge areas during most of the day.

There are many forms of part-time shoulder use or “shoulder running”; that vary in terms of location of shoulder used (left/right options), vehicle-use options [bus only, high-occupancy vehicle (HOV) only, all vehicles except commercial motor vehicles], operating schedule, and special speed controls.- In all options, the use is “temporary” for part of the day, and the lane continues to operate as a refuge/shoulder when not being used for these travel purposes.

Exhibit 12E
Freeway HOV lane – Bus Rapid Transit (BRT) use for HOV
(Hwy 403, Mississauga)

~~**Figure 12.1.3 Freeway HOV lane – Bus Rapid Transit (BRT) use for HOV**~~
~~**(Hwy 403, Mississauga)**~~

Although part-time shoulder use can be a very cost-effective solution, it is not an appropriate strategy where minimum geometric clearances, visibility, and pavement requirements cannot be met, or if it has an adverse impact on safety.- The physical (e.g. lane width and lateral offset to obstructions such as median barriers, guardrails, and bridge rails) feasibility of part-time shoulder use should be evaluated to determine if it is an appropriate option for consideration, and if it is consistent with long-term transportation goals and objectives.

Assessment of safety impacts of part-time shoulder use begins with a review of three or more years of historical collision data, considering the collision type, temporal factors (e.g., time of day, day of week), and location.- -North American experiences indicate that congestion-related collisions, such as rear-ends, occurring during times when the shoulder is open, are reduced as congestion is reduced. –Also, collisions related to erratic driver behavior or sub-standard geometry, such as run-off-road, fixed-object, or sideswipe collisions, increase with part-time shoulder use.- -Collisions related to right-side ramp-freeway may also increase with right part-time shoulder use. -The mere presence of collision types that may increase with part-time shoulder use should not prevent the application of part-time shoulder use, but a preponderance of those collision types would indicate if a given freeway may be a poor candidate for part-time shoulder use.

Overall, there appears to be a link between changes in congestion and changes in safety performance when shoulders are narrowed to implement part-time shoulder use. The application of the HSM freeway crash prediction models indicate reducing congestion (by increasing capacity) can offset the increase in collisions associated with increasing the number of lanes while reducing lane and shoulder width.

Ontario Regulation 618/05 includes designation of Bus By-Pass shoulders on King's Highways describing all parts of highways (example, Highway No. 417 in the City of Ottawa (**Exhibit 12F~~Figure 12.1.4~~**) which is designated as having paved shoulders for use by a bus operated in accordance with a license issued under the **Public Vehicles Act** and an authorization provided by the Ministry. Also, regulations include all signs marking bus by-pass shoulders with text alternatives and dimensions of signs.

Advantages of placing Bus Rapid Transit (BRT) running way on shoulders:

- Transit vehicles can enter and exit the shoulder whenever necessary to leave or enter the general-purpose lane.
- The investment costs to convert a conventional shoulder to a BRT guideway are relatively low, typically limited to upgrading pavement structure on shoulder and adjustment of stormwater inlets.
- Freeway design standards ~~usually~~ typically permit high BRT vehicle operating speeds.

The disadvantages of having BRT running way on a freeway shoulder:

- Disabled vehicles on shoulder require that all transit vehicles re-enter the adjacent general-purpose lane.

- Upgrading of shoulder pavement structure to accommodate loadings from BRT vehicles may create delays to freeway traffic during construction work, unless there is enough room in the median to permit lanes to be shifted during construction.
- Extra signage and motorist information are required to explain the use of shoulders by buses.
- Transit vehicles may have to merge into the general-purpose lanes in advance of interchange exits if the bus does not exit at that location.
- Consideration needs to be given in operating policies to possible major speed differentials between buses and other traffic on adjacent congested general-travel lanes.

It is desirable that bus-pass shoulders have a minimum 3.35~~-meter~~ m wide travel lane width, with an additional 0.6 m~~-meter~~ wide paved shy distance between the edge of the running way and any obstructions, including but not limited to; piers, sign supports, walls, ditch edges or guiderails.~~,~~ In addition, a 0.6~~-meter~~ m buffer zone between shoulders and adjacent general-purpose lanes is desirable.

12.1.1.3.6 Truck Only Lanes

Truck-only lanes are lanes designated for usage of commercial motor vehicles (CMV). The purpose of truck-only lanes is to separate from other mixed-flow traffic to enhance safety and stabilize traffic flow. Truck-only lanes can be separated using physical barriers or operational measures (e.g., rumble strips, signage, and paint striping) and can be operated during specific hours of the day if appropriate.

Truck-only lanes when implemented and operated appropriately, ~~they~~ can increase commercial motor vehicle productivity, improve overall mobility and safety performance of a transportation system, and contribute to the economic development.– Although truck-only lanes offer the potential to address multiple transportation issues, insufficient data and lack of experience with their operation make it difficult to determine their impact.

Truck-only lane implementation is currently not that common in North America~~.~~, and a decision on the potential implementation of these types of lanes in Ontario has not been decided yet. After policy related issues are finalized and these types of lanes have been approved for consideration of implementation, the following design recommendations are to be considered by designers of managed lanes to accommodate commercial motor vehicles:

- Provide full 3.75 m travel lanes and full width shoulders
- Use low grades on vertical alignment and avoid use of long downgrades

- Increase lengths of vertical curves to increase sight distance for commercial motor vehicle drivers
- Lengthen acceleration lanes to provide commercial motor vehicles adequate space to reach mainline operating speeds
- Lengthen deceleration lanes to allow commercial motor vehicles to exit from mainline
- Use larger radii on curves to better account for commercial motor vehicles negotiating multi-curve ramp systems
- Use adequate lane widening in horizontal curves
- Provide signing and variable message signing in proper placement for better visibility for commercial motor vehicles
- Use continuous shoulder rumble strips to alert motor vehicle drivers if they leave their designated lane
- Use concrete barrier (the most effective barrier type for containing trucks); and barrier curve delineation systems on curves

Exhibit 12F
Bus on Freeway Right Shoulder (Ottawa)

~~**Figure 12.1.4 Bus on Freeway Right Shoulder (Ottawa)**~~

~~**Figure 12.1.5 Bus on Shoulder in Minneapolis**~~

12.1.1.4 Separation Types

Most concurrent-flow MLs are separated from general-purpose lanes (GP) by a painted stripe (double solid white lines) or narrow buffer.- As a result of the proximity of GP and ML traffic, increasing congestion levels on GP lanes may have an adverse effect on ML operations.

This adverse effect on ML operations is referred to as frictional effect.- The cause of frictional effect is drivers in stripe or buffer separated MLs observing the slow traffic in adjacent lanes and feeling uncomfortable passing congested GP traffic at a high-speed differentials.

–In order to increase the capacity and functionality of the ML facility, design considerations which reduce the potential for frictional effect should be considered. These design considerations could include using a concrete barrier between the GP lanes and MLs to reduce the interaction between the two parallel lane groups.

12.2 Managed Lanes Strategies

Vision: To use managed lanes to provide safe, reliable, predictable travel on Ontario's highways as part of an integrated transportation network.

Managed lanes strategies can pertain to one or more of the following:

1. Pricing - using varying or fixed tolls
2. Eligibility (vehicle/user) – permitting or restricting certain vehicles or occupancy
3. Access control – limiting entry to designated locations

Exhibit 12G
Managed Lanes Strategy Interdependencies

~~**Figure 12.2.1 Managed Lanes Strategy Interdependencies**~~

12.2.1 Goals and Objectives

~~Goals for the implementation of m~~Managed lanes implementation goals vary by corridor and regional context (~~**Table 12.2.1**~~**Exhibit 12H**). The following performance goals can help determine conceptual feasibility for both concept designs and operations:

- Sustain or improve mobility, particularly during peak periods~~.~~
- Improve roadway efficiency, safety, and reliability~~.~~
- Improve air quality and reduce greenhouse gas emissions~~.~~
- Promote bus transit and ridesharing~~.~~
- Generate revenue~~.~~

~~Table 12.2.1~~Exhibit 12H

Managed Lanes Goals and Objectives

GOALS	OBJECTIVES
1) Enhanced Mobility - provide travel options for the efficient movement of people and goods	• Mitigate traffic congestion
	• Optimize vehicle/person/goods throughput
	• Facilitate behaviour change towards more sustainable transport options
	• Provide travel options for all users
2) Integrated program – align with government priorities and plans	• Reduce GHG emissions and improve air quality from mobile sources
	• Increase transit ridership
	• Reduce socio-economic impacts of congestion
	• Foster strong partnerships with communities and service providers
3) Adaptable system – evolve with conditions and environment	• Integrate innovative technologies
	• Optimize traffic flow
	• Provide efficient and intuitive interfaces
	• Adjust to changing trends (e.g., demographics, travel patterns)
4) User-focused service – provide value to users and community	• Provide a positive user experience
	• Prioritize safety for all users
	• Maintain integrity of the network
	• Provide equitable access

12.3 Planning Considerations

Development of managed lanes is one method of improving the efficiency of a road network, by assessing and implementing an inter-connected regional network of multi-purpose reserved lanes that build-on existing plans for high occupancy vehicle (HOV) lanes with potential for high occupancy toll (HOT) lanes. The use of both existing and new lane capacity, as well as shoulders, should be explored~~,~~ with an emphasis on interconnectivity and more efficient use of available capacity.

12.3.1 Managed Lanes Considerations

Typically, the needs that best characterize managed lane consideration include:

- Manage travel demand growth~~.~~
- Support throughout for longer-distance travel~~.~~
- Lack of available right-of-way and related resources to meet forecasted demand
- Improving corridor travel mobility and reliability~~.~~
- Desire for increased person movement/vehicle throughput~~.~~
- More modal choices~~.~~
- Increasing access controls~~.~~

Historically, managed lane implementation in North America has involved setting aside dedicated lane or lanes, at least during respective peak commute periods, and restricting usage to accomplish desired mobility goals. In Europe, more aggressive lane management is practiced on entire freeways to achieve these same goals for an expanded number of users. Both approaches have distinct advantages and drawbacks from a safety, performance and implementation perspective (**~~Table 12.3.1~~Exhibit 12I**).

12.3.1.1 HOV Lanes

The provision of HOV lanes is a policy decision which stems from the needs of the transportation system and the effectiveness of an HOV lane in helping to resolve those needs. There are sound technical measures which may be considered in the decision-making process, such as cost, time savings, existing usage, etc. However, there are also planning goals, environmental requirements (greenhouse gas reduction & air quality standards) and community interests to be considered.

In this context, the decision to provide an HOV lane could be based on an area wide planning and/or policy commitment to not encourage growth in single occupancy auto travel, or it could be a site-specific response to a congestion situation where an HOV lane is shown to be a better solution than any other alternatives.- There is a balance required between an area wide strategy, the needs of the transportation system in that area, and opportunities of a corridor.

~~Table 12.3.1~~Exhibit 12I

Advantages and Disadvantages of Dedicated Lane and Corridor Management

Approach	**Advantages**	**Disadvantages**
Dedicated Lanes	• Limited impact to traffic--reserves only a small portion of the roadway to aggressively manage use, and assumes all other lanes may experience congestion regardless of other strategies applied • Keeps at least one lane operating at "free-flow" during congested periods	• Speed differential between segregated traffic streams which often requires physical separation • Not all users can benefit given the limited capacity provided
Managing All Lanes	• Achieves improved mobility benefits for all users • Lower cost than adding new lane capacity	• Requires greater management restrictions (such as more restrictive metering and speed management) and still does not assure a breakdown in LOS during peak demand periods • Can be costly and requires a dedicated and ongoing operation, maintenance and enforcement program

12.3.1.2 HOT Lanes

HOT lanes can be implemented at locations where demand for an existing HOV lane is below its operational capacity and where there is congestion during peak periods on parallel general-purpose lanes. In such cases, additional paying single occupancy vehicle motorists may be allowed to use the facility, with tolls set at levels that maintain desired traffic service standards.

HOT lanes implementation can be a response to the following reasons:

1. HOT lanes assist those carpooling, even if your carpooler cancels at the last minute, you can still pay for its use to make it to work on time.
~~2.~~ HOT lanes help those riding buses by reducing their travel time and improving transit commute reliability.
2.
3. ~~–~~HOT lanes provide a boost to every driver due to the total highway capacity being increased. A HOT lane moves more vehicles than a standalone HOV lane by ensuring that the lane is more fully used.

12.3.1.3 Part-Time Shoulder Use / Bus On Shoulder

Part-time shoulder use is defined as follows:

- The shoulder is used for travel only during times of day when the adjoining lanes are likely to be heavily congested.
- When not needed as an additional travel lane, the shoulder will be restored to its original purpose as a "shoulder," and the basic physical characteristics of the shoulder are retained and recognizable.

Part-time shoulder use may be used to fulfill any number of "functions," such as:

- Reduce peak-period recurring congestion~~.~~
- In lieu of a conventional add-a-lane capacity improvement~~.~~
- As an interim treatment while a conventional widening or expansion project works through the planning/design/construction process~~.~~
- Increase bus ridership by improving bus travel time and reliability~~.~~
- Provide short-term benefits for a minimal cost compared to ultimate solution~~.~~
- Mitigate the loss of general-purpose lane capacity if a general-purpose lane is converted to a managed lane such as an HOV lane~~.~~

Generally, all these options take advantage of existing shoulders and include a combination of treatments such as left/right shoulder options, vehicle-use options, operating schedules, and special speed controls, as listed below:

Left/Right Shoulder Option

- Right shoulder
- Left shoulder

Vehicle-Use Options

- Open shoulder to transit vehicles only~~.~~
- Open shoulder as an HOV lane that permits carpools and transit vehicles~~.~~
- Open shoulder as a HOT lane that allows vehicles to pay a toll to use~~.~~
- Open shoulder to all vehicles except commercial motor vehicles~~.~~
- Open shoulder to slow moving trucks in rural mountainous areas~~.~~

Operating Options

- Dynamically open shoulder when certain congestion thresholds are reached (an ATM strategy referred to as “Dynamic Shoulder Use”)~~.~~
- Statically open shoulder during specified historical peak periods (time of day)~~.~~

Speed Control Options

- Same speed limit as other lanes (at posted speed limits)~~.~~
- Same speed as other lanes (at a reduced speed relative to normal posted speed limits)~~.~~
- Lower speed limit than other lanes~~.~~

12.3.2 Freeway Expansion Versus Lane Conversion

Potentially one of the most contentious issues associated with managed lane implementation is whether the managed lane should be a new lane added to the freeway. This question ~~can be answered differently in different situations~~depends on corridor-specific conditions and a solution appropriate to the specific characteristics of the corridor under study is required.

The options both for and against the "takeaway" approach have strong arguments. -The rationale for converting an existing lane includes:

- E~~e~~asily implemented
- L~~l~~ow cost

- C~~c~~reates greatest ML~~-~~’~~‘~~s incentive
- A~~a~~voids community impact of road widening

The advocacy for building new ML lanes stems from:

- A~~a~~voids worsening existing congestion
- C~~c~~an be more readily designed to desirable standards
- P~~p~~rovides long term capacity to accommodate growth
- R~~r~~ealistically reflects current (and foreseeable) patterns of auto use
- B~~b~~ased on previous experience, is politically / publicly more acceptable

The weighing and balancing of such conflicting concerns require a detailed understanding of the corridor, the community, public attitudes, and the ML market under study. It also requires willingness to compromise and recognition that an "ideal" solution which resolves all concerns will be unattainable.

Currently, there is no specific policy related to lane takeaways for converting general-purpose lanes to Manged Lanes. To create a connected network of Managed Lanes, lane takeaways may need to be considered on certain corridors in the long-term when opportunities no longer exist for new facilities through planned highway expansion.

12.3.2.1 General Purpose Lane Conversion

Creation of HOV and HOT lanes is much more acceptable if it is done by adding capacity to an existing road. Conversion of existing lanes reduces the overall capacity of the roadway, thereby increasing congestion on the remaining general lanes.~~-~~ The greatest public acceptance is obtained by adding a lane for HOV use rather than conversion of an existing mixed flow lane.

12.3.2.2 HOV to HOT Conversion and Extensions of Existing Facilities

The conversion of an existing general-purpose or HOV lane to HOT lane use is less complicated from a design point of view if the prior design is found to support tolled traffic without safety ramifications, the pavement is already in place, and it is likely that little or no additional widening or right-of-way acquisition would be necessary. However, to maintain premium traffic service levels and discourage toll violations, HOT lanes generally require access control.

Converting existing HOV lanes to HOT lanes should be considered only if the HOV lanes are significantly underutilized to begin with. If an existing HOV lane is so heavily used by HOVs during peak hours that it is near the capacity it can handle while maintaining high speeds, converting it to a HOT lane may reduce the highway efficiency. Such conversion would allow some Single Occupancy Vehicles onto that lane during peak hours, and tolls might drive some HOVs away. That would reduce the total number of persons using these lanes in peak hours.

When converting an existing HOV lane to HOT lane, some operational changes may occur that are reflected in design changes, for example:

- Changing signing and pavement markings~~.~~
- Changing or restricting access and adding weave lanes
- Enhancing design treatments that help enforcement~~.~~
- Modifying utilities—providing power to tolling equipment and telecommunications back to office~~.~~
- Reconfiguring project limits and transitions/termini~~.~~
- Providing maintenance access~~.~~

12.-3.-3 Use of HOV / HOT Lanes by Trucks

Congestion on highways also creates delay for commercial freight vehicles. This delay could lead to increases in transportation costs, which may in turn drive up costs to consumers.- One potential method for reducing this cost and possibly reducing congestion for all vehicles is to provide trucks with alternate routes or separate (preferential) lanes that allow them to bypass congestion, while freeing up space in general purpose lanes.

Allowing commercial motor vehicles to access managed lanes during non-congested (non-peak) periods of the day, when there may not be much demand for the congestion-free managed lanes, could also provide an opportunity to make better use of unused capacity. As with shared-use vehicles (carpools, buses), large trucks have special needs and may warrant preferential treatment considering their importance to the economy.- **~~Table 12.3.3~~Exhibit 12J** outlines few pros and cons of allowing commercial motor vehicles to use ML.- The facility must be constructed with consideration of trucks, and it features full 4.5 m (15-footwide) lanes and 3 m (10-foot) shoulders on each side. The lengths of weaving areas are to be extended and horizontal curvature at entry points to be adjusted to accommodate trucks.

~~Table 12.3.~~Exhibit 12J

~~3~~ Pros and Cons of Allowing Commercial Motor Vehicles in Managed Lanes~~.~~

Pros	Cons

Increased revenue potential	Operational performance impacts
More reliable travel times for freight partners in nearby port	Driver expectations and comfort
	Increased capital cost
	Higher design standards

In Ontario, commercial motor vehicles must have two or more people in vehicle and less than 6.5 m in total length with a gross weight of 4,500 kg or less to use HOV lanes and can use HOT lanes for free if there are at least two people in the vehicle.- More specifically, in Ontario, trucks more than 6.5 m in length are not permitted to operate on the left (median) lane of any King's Highway of three or more lanes per direction (**R.R.O. 1990, REGULATION 608**).

Benefits to efficiency of highway networks can be achieved by allowing commercial motor vehicles to access managed lanes during non-congested (non-peak) periods of the day, when there may not be much demand for the congestion-free managed lanes.- Moreover, providing congestion-free alternatives for freight vehicles could present an economic development opportunity because shippers may decide to locate freight terminals, distribution centers, and related businesses near managed lane facilities.

Several issues need to be considered to allow heavy trucks access to managed lanes:

Safety

Trucks are slower to start and stop, are less flexible in maneuvering, and often maintain maximum speeds regulated by equipment installed on the vehicle. There is evidence that significant speed differentials among vehicles can lead to more collisions. Furthermore, for most managed lane facilities, slower-moving trucks would need to use the left-most freeway lane to access the managed lane, which could cause safety and traffic flow problems near access points since trucks would have to interact with light vehicles in the passing lane of the freeway, which typically has the highest speeds.

The main source of concern for safety is the traveling speed difference between light vehicles and heavy trucks, and there is evidence that a significant speed differential leads to more collisions. -Speed differential can be exacerbated in a managed lane situation because passenger cars already in the managed lane may be moving significantly faster than vehicles in the congested general use lanes.- At access areas along the corridor, heavy trucks would have to first change lanes to the far-left lane to be able to enter the lane.- This type of lane changing in the general use lanes could cause collisions and increase congestion. Once near the access point, the truck would have to merge from near standstill congested conditions into a fast-moving managed lane. With two-lane managed lane facilities, this type of merging would be less problematic.

Other safety issues arise due to the infrastructure of the managed lane.- Some lanes are separated by pylons along the length of the corridor or at the access points. Trucks, due to their size and slower lane changing, would be more likely to damage these pylons, thus posing a safety and maintenance problem due to debris in the road.- Some managed lanes have signs mounted on the center concrete median, which truck mirrors may be more likely to strike. Even in facilities that have been built for trucks, the breakdown lanes on shoulders must be wide enough for trucks. In areas under bridges and other structures, the vertical clearance over the shoulder must be high enough to allow a truck to park there.

Operations and Maintenance

The operations and maintenance of the facility would likely need to be adjusted to allow use of managed lanes by commercial motor vehicles. The signing required to communicate access rules and restrictions for a managed lane that also includes trucks should be adjusted to avoid last-minute lane changes.

Additionally, emergency response, traffic collision clearance, and enforcement activities could be affected by having commercial motor vehicles in managed lanes. In the event of an incident, ~~enough~~ sufficient shoulder width is required to allow large trucks to safely slow down, get out of the travel lane, and speed back up again. Commercial Motor Vehicles also create more pavement wear, so it is likely that the lane would have to be closed more frequently for pavement repair and maintenance if large or~~t~~ heavy trucks were allowed.

Highway Design

Many highway design features are calculated differently for trucks and cars. If a facility is being considered for commercial motor vehicle use, many design features might have to be modified. These include but are not limited to highway and ramp curvature, underpass/overpass height, shoulder width, pavement thickness, and roadside barriers.

12.3.4 Reserved Bus Lane Versus Occupancy Rates of 2+ / 3+ Lane

The establishment of a minimum vehicle occupancy rate for an HOV lane is a corridor-specific decision, but one which must be taken in the context of the project goals, the market to be served, and the needs and characteristics of the surrounding area.

On the freeway system, current bus usage is, due to congestion, generally relatively low and therefore this issue focuses more on operational needs of a lane design. The complex interaction of vehicle movement on a right side HOV lane at an interchange may produce a desire to minimize the number of vehicles contributing to the conflict by designating the lane for buses only (i.e. Reserved Bus Lane). In that same corridor, a median HOV lane could be designated for 2+ and operate smoothly and effectively. There are therefore no "rules" which apply to every HOV project with respect to eligibility; the appropriate designation will remain corridor-specific and subject to detailed analysis and iterative study.

12.4 Operational Considerations

Establishing an ML facility requires implementation of specific occupancy requirements and involves various other activities as indicated in the following sections.

For example, priority HOV treatments on highways involve much more than the provision of physical facilities dedicated to HOV use; a series of decisions must also be made as to what constitutes a viable HOV project in the context of both facility under study and area-wide HOV system. The decisions centre on determining the most effective and beneficial use of the HOV facilities available. These involve striking a balance between:

- M~~m~~oving as many people in HOVs as possible~~;~~
- A~~a~~voiding congestion in the HOV lane itself and at its points of interaction with mixed flow lanes~~; and~~
- E~~e~~nsuring the lane is adequately used, both relative to a non-HOV alternative and in the view of the public~~.~~

12.4.1 Eligible Vehicles

In Ontario, eligible vehicle types in managed lanes and facilities are outlined in **Exhibit 12A~~Table 12.1.1~~** and **Exhibit 12B~~Table 12.1.2~~.**

12.4.2 Vehicle Occupancy

The core of the HOV issue is the definition of a minimum auto occupancy rate; if too restrictive, few travellers will be able to take advantage of the incentives offered to HOV users, and the public may become dissatisfied with and disrespectful of the program; if too open, the priority facility may become congested, and limits will be placed on its ability to move significantly more people than a mixed-flow lane.

12.4.3 Operational Capacity

Like all freeway traffic lanes, an HOV lane under ideal conditions has the physical capability of accommodating a peak period vehicular flow of up to 2,200 vehicles per hour.- However, one of the requirements of an effective HOV lane is that a consistent, reliable, unimpeded trip be provided, to maximize the incentive to use and switch to HOVs. -The lowest "Level of Service" for mixed flow traffic which maintains stable, high-speed flow is "C", which corresponds to only approximately 1,500 vehicles (passenger car equivalents) per hour. -Beyond that point, traffic tends to slow down and be immediately influenced by small changes in flow characteristics. -It must be considered that HOV lanes will be used by local buses and that there will be no ability under most circumstances to overtake a vehicle while in the lane, rendering the operation even more influenced by a slower vehicle or an isolated constraint.

The design year traffic volume projection for a single HOV lane should not exceed 1,500 vehicles (auto equivalents) per hour in the peak period.- If necessary, the HOV criteria or operating strategy can be modified at that point to maintain LOS "C" flow.- Raising occupancy restrictions during peak periods, expanding HOV capacity, and enhancing transit/rideshare marketing and incentive programs are some of the techniques available in that situation.

12.4.4 Minimum Lane Usage

The key measure of effectiveness is whether the HOV lane carries an adequate number of vehicles. For a typical concurrent flow HOV lane the minimum figure is likely to be in the 500-600 vehicle per hour range.

Additional experience-based observations include:

- The minimum number depends to some extent on the vehicle mix in the HOV lane; a lower figure is generally acceptable for an HOV lane dominated by bus use, since each bus is readily perceived by motorists as moving more people.
-
- The minimum number depends on the facility operation:- fewer HOVs are required to make a contraflow HOV lane perceived to be adequately utilized than for a concurrent flow lane.
-
- The presence of a well-used HOV lane will generate public awareness and support for other subsequent contiguous or nearby HOV facilities which may have less usage.

- Acceptance of lane usage levels can be significantly affected by education/marketing campaigns, by the presence of a widespread program of HOV priority for all parts of the trip, and by the presence in the community of a strong, heavily utilized municipal transit system.
- Acceptance depends somewhat on the level of congestion in the adjacent mixed-flow lanes; the more severe the congestion the greater the HOV use required to dispel the perception of inequitable distribution of freeway capacity.
- Visible and effective enforcement is essential to generating and maintaining respect for the lanes; if lanes are under-utilized the temptation for ineligible vehicles to use them rises, and if a high level of violation occurs the remaining public will become less tolerant of the HOV lane.
- A lower level HOV lane usage may be acceptable for an initial or designated "pilot project" period, but this must be communicated effectively to the public.

Thus, the issue of minimum lane usage sweeps across the entire HOV spectrum and must be resolved to the satisfaction of the freeway operator, HOV users, the local community, and all other freeway users in the area. -Underlying this concern is the fact that HOVs make up a relatively small proportion (less than 10% for 3+, less than 20% for 2+) of the current traffic stream - far lower than the physical proportion of a freeway to be set aside for their exclusive use (e.g. 25% of an 8-lane freeway; 33% of a 6-lane freeway).

12.4.5 Access

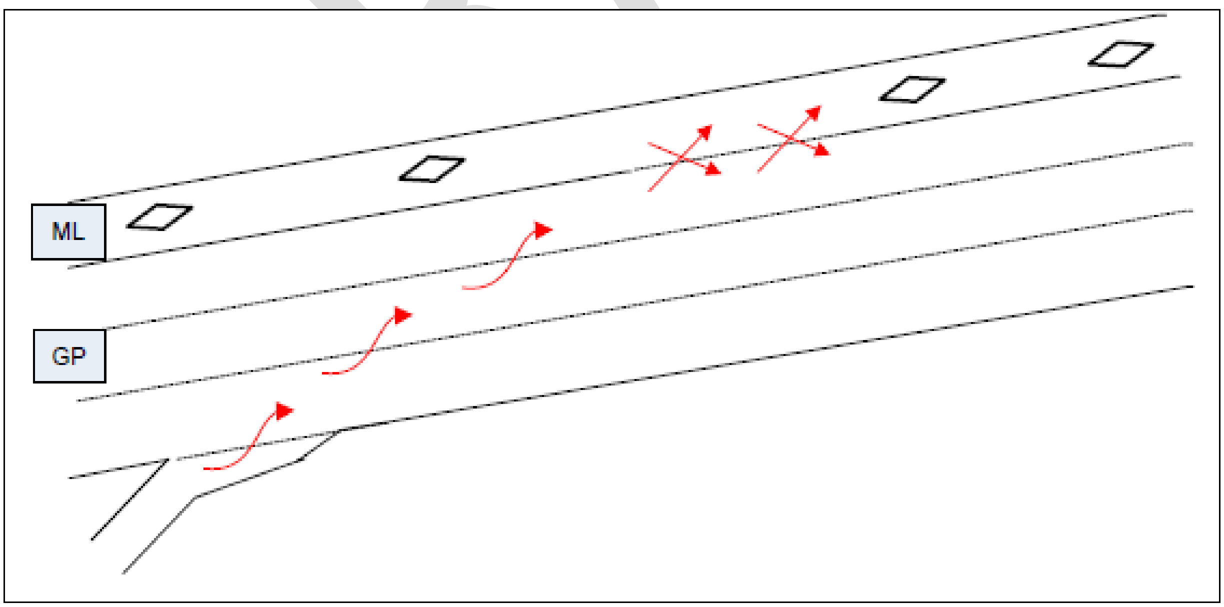
Vehicle access should be limited to certain locations for all managed lane facilities. Continuous access to the express lanes is prohibited. Vehicle ingress and egress points will be determined based upon considerations for traffic safety, traffic volumes, the surrounding roadway network, areas of congestion, and interchange spacing. Further details on vehicle access and design elements for access/egress are outlined in Section 12.5.4.

~~Limiting a~~Access restrictions ha~~s~~ve traditionally been applied to HOV and express lanes as a means of regulating entry and exit movements. Restricting access reduces friction caused by entering and exiting traffic and discourages shorter distance travel. Access restrictions may also help alleviate specific traffic bottlenecks where short-distance trips cause a lane to exceed its capacity. Access can be restricted by design or dynamically managed by (a) metering demand at entrance ramps via the use of traffic signals or gates, (b) limiting access at specific ramps to selected users like HOVs, or (c) limiting the number of entrance and exit ramps so that free-flow is ensured.

Access control is associated with concurrent flow managed lanes located next to the median barrier where access is provided every 1 to 3 k~~K~~m. Access control is not required for electronic tolling or variable pricing; however, restricting access makes toll collection easier to manage by having fewer toll zones than might otherwise be required.

Exhibit 12K~~**Figure 12.4.1**~~ illustrates a facility with limited access where vehicles can enter or exit the managed lane in certain designated locations only. ~~–~~This type of access is a cost-effective design when compared with other access types such as direct grade-separated access. However, it requires the general-purpose on-ramp traffic to weave across multiple general-purpose lanes and this cross-weave actions may cause significant frictions on general-purpose lane traffic depending on cross-weave demand, the distance available to complete the cross-weave maneuvers and the general-purpose lane density.

Exhibit 12K
At Grade Access With Limited Access Points



~~**Figure 12.4.1 At Grade Access with Limited Access Points**~~

12.4.6 HOV Lanes Alternatives

For an HOV lane on a limited access facility, consider the following operational alternatives:

- Inside (desirable) or outside HOV lane
- Lane conversion
- Use of existing shoulder—not recommended for permanent operations
- HOV direct access ramps
- Queue bypasses
- Flyer stops
- Hours of operation

When evaluating alternatives, designer would consider a combination of alternatives to provide the optimum solution for the corridor. Also, incorporate flexibility into the design in order not to preclude potential changes in operation, such as changing an outside lane to an inside lane or a reversible facility to two-way operations. Access, freeway to- freeway connections, and enforcement will have to be accommodated for such changes.

12.4.6.1 Inside or Outside HOV Lanes

The inside (left) HOV lane is most appropriate for a corridor with long-distance trip patterns, such as a freeway. These trips are characterized by long-distance commuters and express transit service.- Maximum capacity for an effective inside HOV lane is approximately 1,500 vehicles per hour. When HOVs weaving across the general-purpose lanes cause severe congestion, designers may consider providing HOV direct access ramps, separated HOV roadways, or a higher-occupancy designation.

The outside (right) HOV lane is most appropriate for a corridor with shorter, more widely dispersed trip patterns. These trip patterns are characterized by transit vehicle routes that exit and enter at nearly every interchange. The maximum capacity for an effective outside HOV lane is reduced and potential conflicts are increased by heavy general-purpose lanes congestion and large entering and exiting volumes.

12.4.6.2 Conversion of a General-Purpose Lane

The use of an existing general-purpose lane for an HOV lane is an undesirable option; however, conversion of a lane to an HOV lane might be justified when the conversion provides greater people-moving capability on the roadway. Use of an existing freeway lane as an HOV lane will be considered only with a Design Analysis.

Given enough existing capacity, converting a general-purpose lane to an HOV lane can provide additional people moving capability in future without significantly affecting existing roadway operations. The fastest and least expensive method for providing an HOV lane is through conversion of a general-purpose lane. Restriping and signing are sometimes all that is needed.

12.4.6.3 HOV Direct Access Ramps

Direct access ramps allow buses, carpools, vanpools, and motorcycles to directly access the high occupancy vehicle (HOV) lanes in the center of freeway. They come down from above the mainline, or up from below, and merge into the HOV lane from inside the median.

Direct access ramps are open only to carpools, vanpools, buses and motorcycles 24 hours a day, seven days a week. This is true even when HOV lanes are open to all traffic. The cost of constructing direct access ramps is substantial because they require separate structures above or below the freeway.

Direct access ramps improve safety, reduce congestion, save time, and increase travel time reliability for both HOVs and general-purpose freeway traffic. High occupancy vehicles may have hard time merging left through general purpose lanes to gain access to HOV lane during congested periods, creating a safety problem for all freeway users. When buses, particularly articulated (extra-long) buses attempt this merge, they can cause congestion in the lanes they pass through for quite a distance back. By enabling carpools, vanpools, buses, and motorcycles to connect directly with HOV lanes, these vehicles avoid the need to weave across other lanes of traffic.

Direct access ramps work much like other left-side on- and off-freeway ramps, except they are restricted to HOVs. Vehicles access the ramps from an adjacent park-and-ride facility or surface street. They merge into the left side of the freeway and enter the HOV lane. As with other left-side on- and off-ramps, drivers enter traffic to their right. Visibility is limited so ramp users should use extra caution when merging into a freeway HOV lane from a direct access ramp (**Exhibit 12L~~Figure 12.4.2~~**).

When using a direct access ramp to exit the freeway, HOV drivers should watch for signs and then exit to the left where indicated. This takes them up (or down) the direct access ramp and into a park-and-ride lot or to an intersection with a local street.

12.4.6.4 Use of Existing Shoulder

Shoulder-use managed lanes are permitted where buses can travel and bypass congestion. Consideration of shoulder conversion to an HOV lane is valid when traffic volumes are heavy, and the conversion is a temporary measure. -Another alternative is to use the shoulder as a permanent measure to serve as a transit-only or queue bypass lane during peak hours and then revert to a shoulder in off-peak hours.

The use of shoulder requires special signing that clearly defines the use of the shoulder and to establish special operations to clear the shoulder for the designated hours.
The existing shoulder pavement is often not designed to carry heavy volumes of vehicles, especially transit vehicles. As a result, repaving and reconstruction of the shoulder might be required.

Exhibit 12L
Aerial View of HOV Direct Access Ramps

~~**Figure 12.4.2Aerial View of HOV Direct Access Ramps**~~

12.4.6.4.1 Part-Time Shoulder Use / Bus Bypass Shoulder

Part-time shoulder use is the conversion of shoulders to travel lanes during some hours of day as a congestion relief strategy~~ (**Figure 12.4.3** and **Figure 12.1.4**)~~. This strategy is also known as temporary shoulder use or hard shoulder running and is typically implemented on freeways. Part-time shoulder use is a transportation system management and operations strategy that uses shoulders to provide additional capacity when it is most needed and preserves shoulders as refuge areas during rest of the day.

Vehicles can travel on paved shoulders (also known as part-time shoulder use or dynamic shoulder lanes) under specific conditions. A left shoulder may be converted and posted for part-time shoulder use operation using a variety of traffic control devices. Other right shoulders are conditionally used by transit buses whenever congested speeds fall below a given threshold.

Bus-on-shoulder operations are known as "bus bypass shoulder" (BBS). They are a low-cost strategy allowing buses to travel at or near free-flow speeds through congested freeway routes. ~~-~~Bus-on-shoulder is typically used only where roadway congestion is significant and traveling on the shoulder improves on-time reliability and even decreases overall trip time.

A variety of part-time shoulder use options exist. All~~ of~~ these options take advantage of existing shoulder infrastructure and include a combination of treatments such as left/right shoulder option, vehicle-use option, operating schedule, and special speed controls, as listed below:

- Left/Right Shoulder Option
  - Right shoulder
  - Left shoulder
- Vehicle-Use Options
  - Open shoulder to transit vehicles only
  - Open shoulder as an HOV lane that permits carpools and transit vehicles to use it
  - Open shoulder as a HOT lane that allows vehicles to pay a toll to use it if they don’t meet HOV occupancy requirements
  - Open shoulder to all vehicles except trucks
  - Open shoulder to all vehicles
  - Open shoulder to slow moving trucks in rural mountainous areas
- Operating Options

  - Dynamically open shoulder when certain congestion thresholds are reached (an ATM strategy referred to as “Dynamic Shoulder Use”)
  - Statically open shoulder during specified historical peak periods (time of day)
- Speed Control Options
  - Same speed limit as other lanes (at posted speed limits)~~.~~
  - Same speed as other lanes (at a reduced speed relative to normal posted speed)
  - Lower speed limit than other lanes~~.~~

~~Figure 12.4.3 — Bus-On-Shoulder (BOS) Operations in Chicago~~

~~**Figure 12.1.4 Bus on Freeway Shoulder (Ottawa, ON)**~~

12.5 Design Guidelines

The intended purpose of a facility has some effect on selection of certain design criteria, particularly for the design of access as well as requirements of potential toll collection accommodation.- Primary considerations are cross-sectional elements such as lane and shoulder widths, buffer width, median width, drainage, cross-slope, and traffic control devices, particularly if the facility is separated by buffers or barriers. Other important design elements include sight distance, horizontal curve design, and vertical clearance under toll gantries, sign bridges, and overpasses.

Design criteria for managed lane facilities that are part of general-purpose freeway corridors are the same as for the general-purpose lanes. These criteria apply to vertical and horizontal alignment, cross-slope, and lane and shoulder widths. When proposed design elements do not meet these criteria, approval for a design exception or deviation process is required (Section 12.5.5). -Also, managed lane design should match driver expectancy established by the presence of design elements and traffic control devices on nearby facilities.

Ramps are one of the critical geometric aspects to consider in making a managed lane facility safe and functional with other facilities. The important aspects in the design of ramps are ramp orientation (left versus right), type, and spacing. These guidelines typically vary by traffic level and appropriate design speed. -Understanding both current and future traffic impacts of the facility is important to ensure geometric adequacy both at time of construction and in future years of operation.

Other aspects of geometric criteria include establishing techniques for separation of managed lanes from adjacent general-purpose lanes and consistent orientation and treatment for access, as well as consideration of enforcement, incident management, and maintenance of traffic control devices and performance of the tolling systems.

12.5.1 Design Elements

There is a variety of elements that need to be considered in development and design of managed lane facilities. -The following are key design elements:

12.5.1.1 Design Speed

For managed lanes that are part of a general-purpose freeway corridor, it is recommended to use a design speed that is the same as the adjoining freeway.- A suggested design speed for ramp connections for managed lanes is approximately 0.7 times the mainline design speed. This criterion is applicable to flyover ramps and connecting drop ramps. -At-grade access locations can use this criterion if dedicated weave lanes are provided, or they may be designed at a higher speed based on the specific location and operating characteristics of freeway through lanes.

12.5.1.2 Cross Section and Alignment

Number of Lanes

Most managed lanes are designed to fit within available right-of-way, which is often quite constrained. For the majority of ML projects, retrofit means adding one lane in each direction. The designer should consider the constraints of the corridor and trade-offs to provide the best possible balance of managed lanes, shoulders, and separation in conjunction with lanes and shoulders in the general-purpose facility.

Lane Orientation

Almost all managed lanes are located on the left side next to the median such that long distance travel with limited access is facilitated. The traffic volumes, right-of-way, existing roadway infrastructure and cost considerations generally dictate the design of dedicated facilities. A left side orientation results in fewer conflicts with mixed traffic since there are few locations were left side ramps intervene. A right-side orientation frequently conflicts with local on and off-movements with the main lanes, so therefore, either the usage of right-side orientations needs to be low to mitigate the magnitude of conflicts, or usage must be restricted to selected drivers and vehicles such as buses only.

Lane Width

The recommended lane width for a managed lane facility is 3.5 – 3.75 m, just as with any other freeway lanes. For a managed lane facility that includes a buffer of 0.6 m – 1.25 m width, in constrained areas the designer may allow up to 0.3 m of lane width to be considered as part of this overall buffer dimension where full buffers and lane widths would not fit as the managed lane driver perceives this space as part of the overall width used for horizontal sight distance. **Exhibit 12M~~Figure 12.5.1~~** provides examples of cross sections for ~~barrier-separated~~barrier separated two-way HOV facilities (s*ource:* Guide for HOV facilities ASSHTO 2004). -Also, the ASSHTO Safety Manual provides information of trade-offs by lane width for freeways.

Shoulders Width

Ideally, managed lane shoulders should follow the TAC Geometric Design Guidelines and the MTO Design Supplement for the shoulder width of the general lane to provide clearance for disabled vehicles, enforcement activities, and emergency response. In practice, many retrofit applications have narrower shoulders so that the lane width is maintained and, to the extent possible, a shoulder width of at least 2.5 m is maintained. For concurrent directional lanes, shoulders should be to the left, next to the median barrier. -Shoulder space with a width between 1.2 m to 2.5 m should not be striped because drivers on a concurrent flow lane can misconstrue the space as wide enough to stop in, leaving their vehicles exposed to high-speed traffic that may not be able to negotiate around the exposed vehicles. **Exhibit 12N**~~**Figure 12.5.2**~~ shows examples of shoulder width options as per FHWA.

Median Width

Medians on managed lane facilities should be designed in the same manner as other freeway medians. When right-of-way is constrained, the median should be designed with enough width to accommodate the pedestals and bases for gantries and traffic control devices, the median barriers, and any enforcement activities that will be required for the facility so that vehicles can travel in the leftmost lane or the left shoulder without their path being infringed upon.

Buffer Width

Managed lane drivers are expected to shift away from the pylons placed in the buffer; however, a wider buffer can offset the impacts on lateral position.

Horizontal Clearance

For managed lane facilities within other freeways, the horizontal clearance may be affected by right-of-way constraints, but it should be enough to prevent vehicle from colliding with signs, guardrails, and other roadside apparatus. For stand-alone facilities, the MTO Roadside Design Manual should be applied.

Vertical Clearance

The facility should have the necessary vertical clearance for the design vehicle to pass under toll gantries, sign bridges, and overpasses without striking them. It is recommended that for facilities within other freeways, the vertical clearance provided be the same as that provided on the general-purpose facility.

12.5.1.3 Separation Between Managed Lane and General-Purpose Lanes

There are multiple ways to provide separation between managed lanes and general-purpose lanes of a freeway. Each approach reflects different operational goals and requirements. While all can be effective, selection of separation type should take into consideration the design setting, business rules, design vehicles, and level of anticipated demand. Barriers, buffers, pavement markings, and separate facilities are all used, and some facilities may have a combination of separation types (e.g., a mixture of buffer separation and pavement marking separation where cross section is limited). Each option has its own potential advantages and disadvantages, and these should be considered early in the design of managed lane facility to determine which treatment is best suited for that location.

If the project has adequate right-of-way (ROW) and a requirement to accommodate future corridor growth or future phasing, express lane configurations using a wide buffer separated system can provide room for future pavement when an additional lane is required.

A buffer is a physical space between managed lanes and general-purpose lanes operating in the same direction that provides separation without a barrier. A buffer is defined by pavement markings providing guidance to the driver, and access points are defined by changes in those markings.

Buffers promote more efficient traffic flow where travel speed differentials in adjacent lanes can be substantial, but where a barrier is not a practical or desired solution. Buffers are less costly than barriers; however, depending on the width of buffer provided, they may require additional right-of-way.

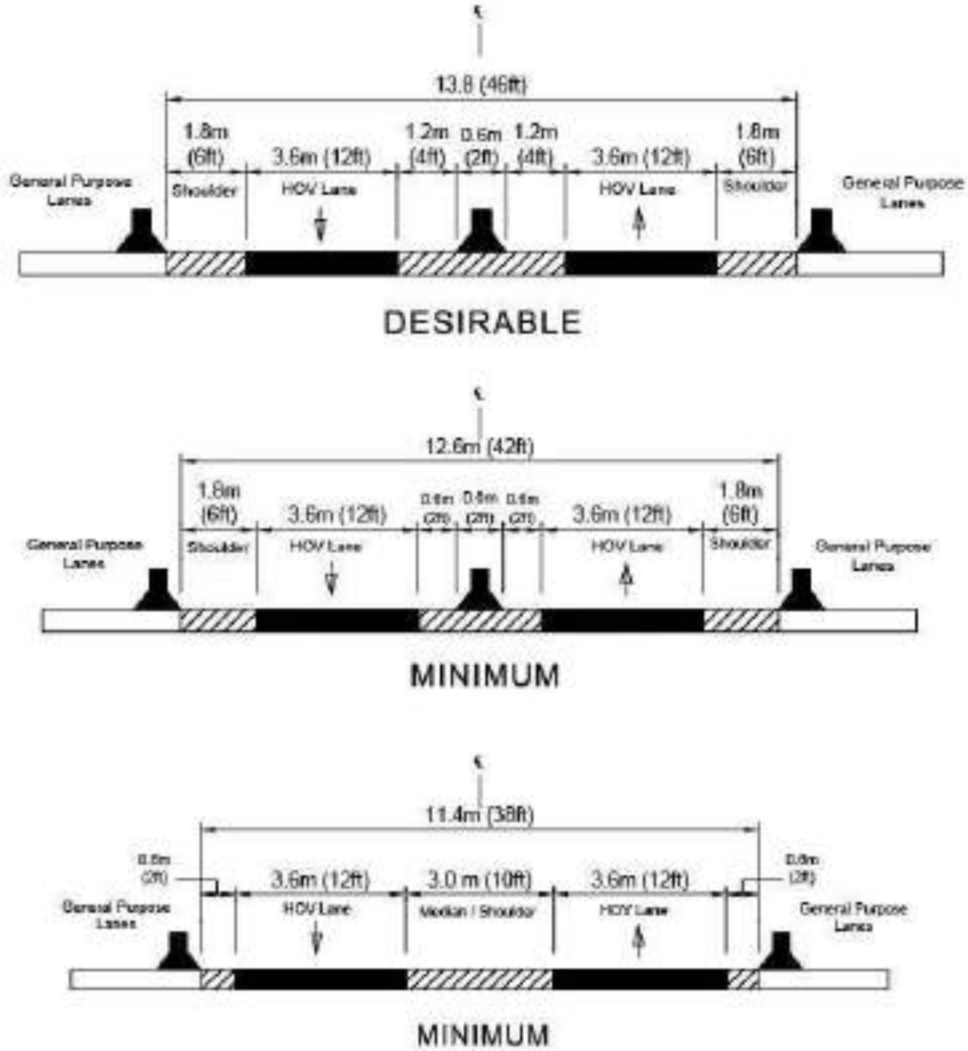
A 1.25 m ~~meter~~ buffer is commonly recommended, though wider buffers can sometimes provide additional benefits in terms of drainage, snow storage, capability to expand the number of lanes in future, and visual separation. **Exhibit 12O**~~**Figure 12.5.3**~~ shows cross-sections for buffer-separated HOV lanes. However, a buffer that is too wide may encourage drivers to use it as an additional travel lane. Conversely, 0.65 m buffers have been used to provide a measure of separation where a wider buffer is not possible due to cross-section constraints.

Some literature indicates that operational performance of MLs may impact, and be impacted by, operations of adjacent general-purpose lanes (GPs), despite some degree of physical separation. Such operational co-dependence may especially exist between the GP lane adjacent to the separation buffer and the ML lane.

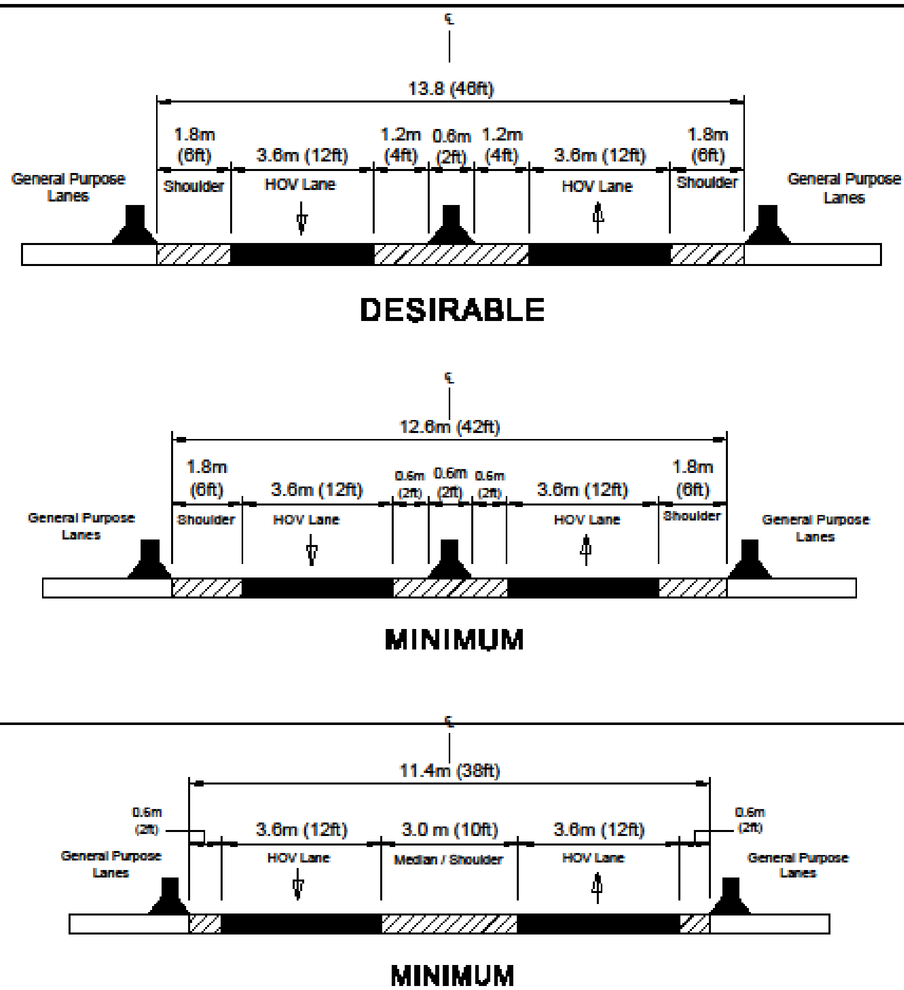
Exhibit 12M

Example of Cross Sections for Barrier-Separated Two Way HOV Facilities

Source: Guide for HOV facilities ASSHTO 2004



1. HOV envelopes in one direction over 6.7m (22ft) may invite passing. A full breakdown shoulder is not provided although vehicles can still maneuver around disabled vehicles. Enforcement of this facility is preformed at the ends and access locations.
2. Operational treatments should be used incorporation if the minimum design cross section are used. The minimum cross section should e used as a interim project or over short distances. Increased enforcement and incident management programs should be implemented to successfully operate the facility.
3. The width of the cross section provides the minimum space required for a us to pass a disabled bus at slow speed.
4. Shared median minimum cross section should e only used for two-ways ramps, short connector sections, low-volume HOV lanes, or other lower speed facilities.



1. HOV envelopes in one direction over 6.7m (22ft) may invite passing. A full breakdown shoulder is not provided although vehicles can still maneuver around disabled vehicles. Enforcement of this facility is preformed at the ends and access locations.
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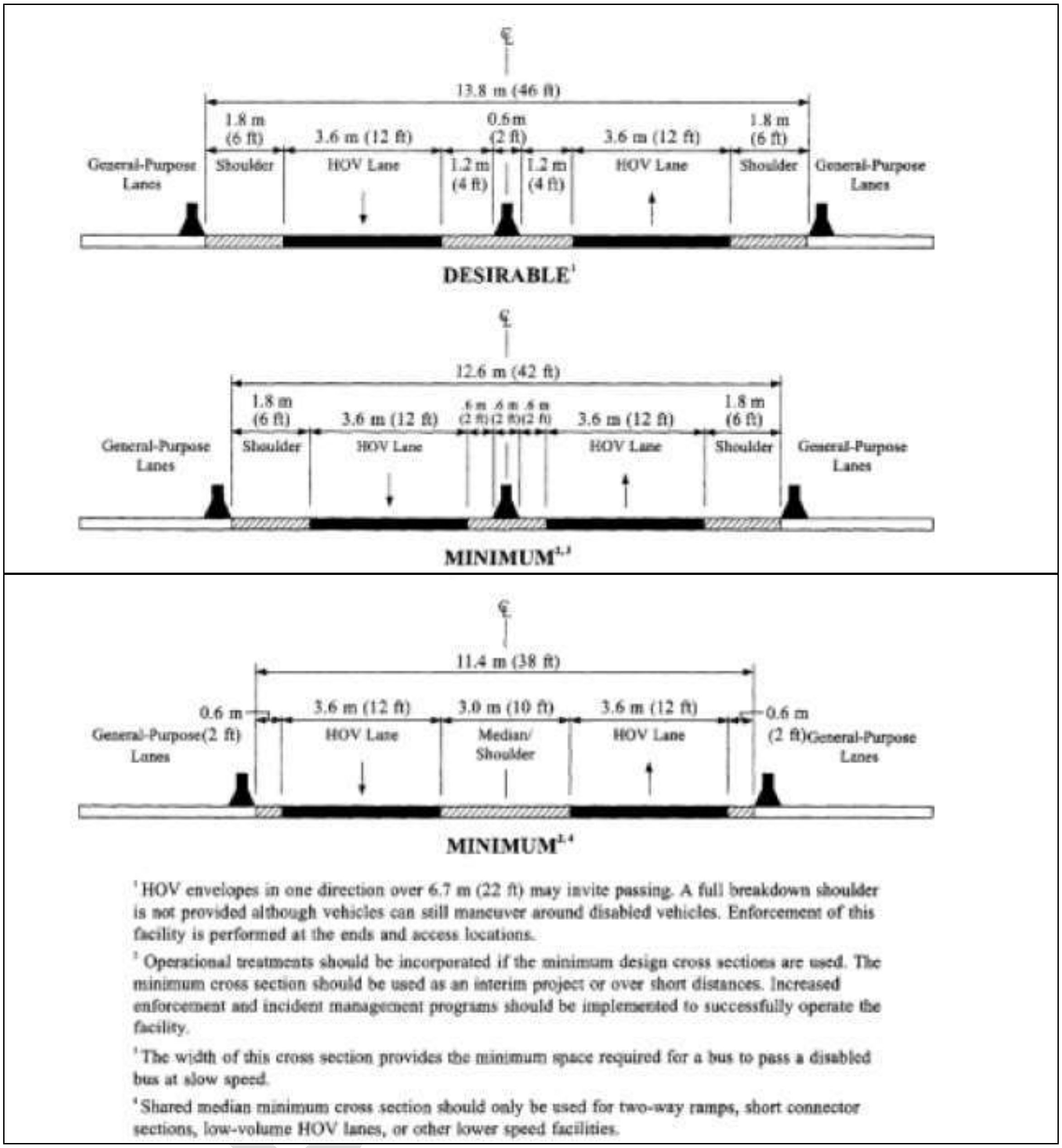
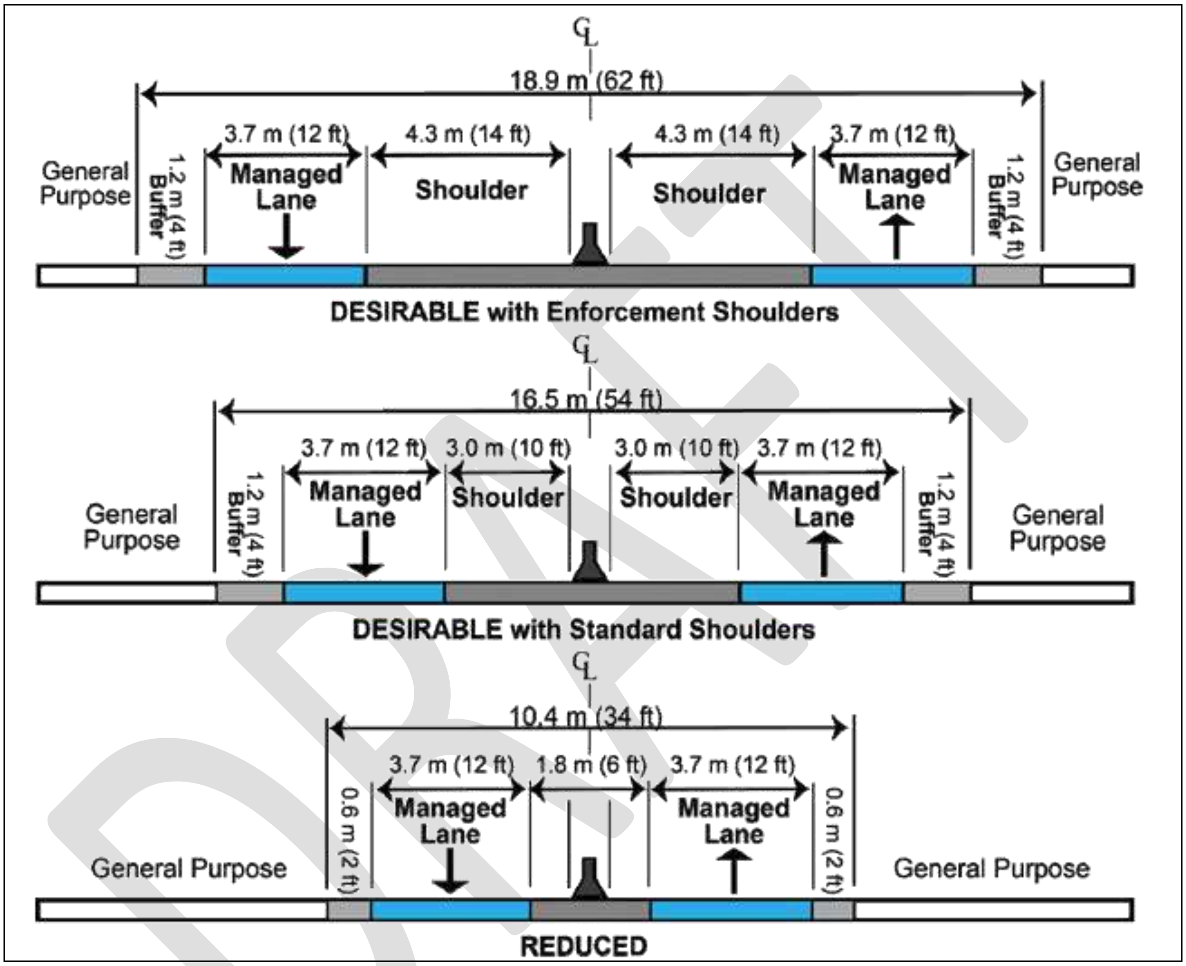


~~**Figure 12.5.1 Example of Cross Sections for Barrier-Separated Two Way HOV Facilities**~~

Exhibit 12N

Example of Managed Lane Shoulder Width / No Shoulder (FHWA)

~~*Source: Guide for HOV facilities ASSHTO 2004*~~



~~Figure 12.5.2 Example of Managed Lane Shoulder Width / No Shoulder (FHWA)~~

12.5.1.3.1 No Separation (Pavement Markings Only)

For most constrained rights-of-ways and for projects that only operate during peak periods and revert to general purpose operation at other times, the separation between managed and general-purpose lanes could be only a single-line pavement marking. –At a minimum, the separation ~~requires to~~should be a pavement marking that is wider than a typical lane line. While this treatment is the least costly option for separation, it is also the least restrictive and may be hardest to enforce when compared to other options. For tolling purposes, it may require more frequent toll readers to be installed.

12.5.1.3.2 Buffer Separated

12.5.1.3.3 Barrier Separated

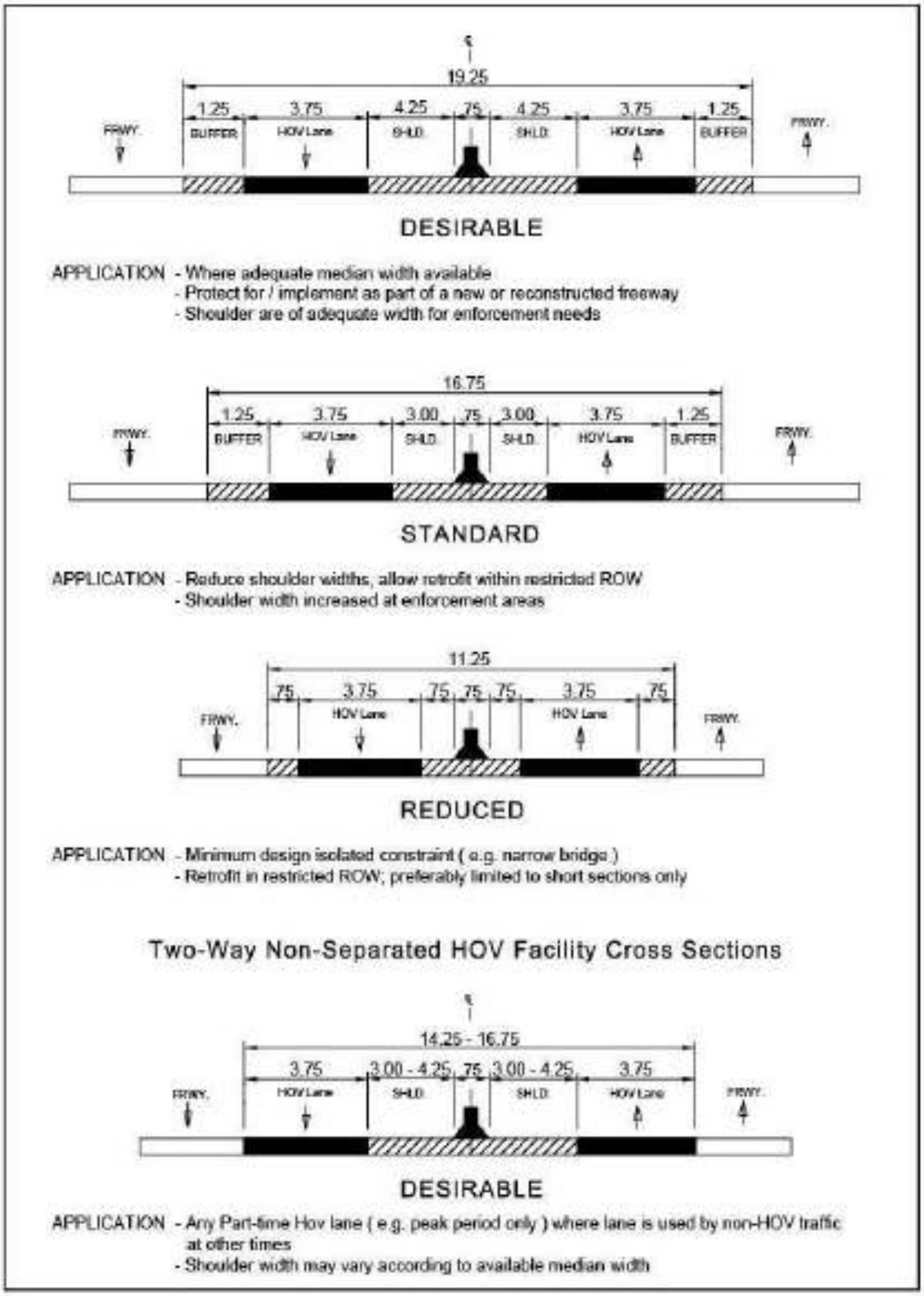
Concrete barrier separation provides the most positive separation between managed lanes and general-purpose lanes which makes it the easiest to enforce among managed lane facilities. -It also leads to the fewest opportunities for collisions between vehicles in the managed lanes and vehicles in the general-purpose lanes because access is physically limited.

Barrier separation is a costly separation treatment because of requirements for duplicate shoulders as well as additional width of the barrier. ~~Enough~~Sufficient shoulder width should~~to~~ be provided within the managed lane envelope to accommodate an emergency, a disabled vehicle, or other special event. -It is also the least flexible treatment, which makes changes to access points for the managed lanes difficult.

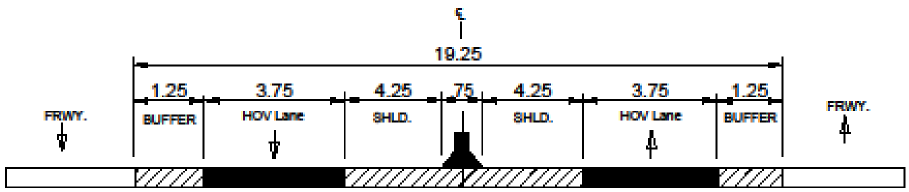
Exhibit 12P~~Figure 12.5.4~~ illustrates recommended cross-sections for barrier -separated median HOV lanes. Few urban freeways in Ontario have preserved adequate median width to allow retrofit of barrier-separated lanes.

Exhibit 12O

Examples of Cross Sections of Buffer Separated HOV and Non-Separated HOV

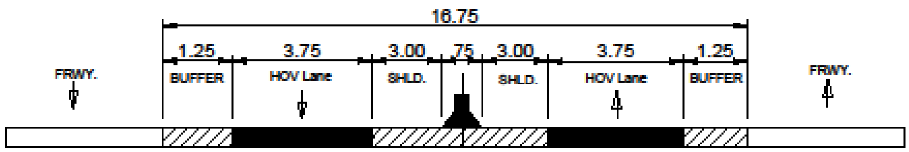


Two-Way Non-Separated HOV Facility Cross Sections



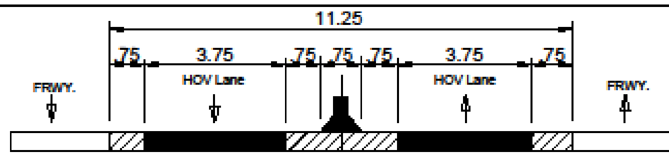
DESIRABLE

APPLICATION - Where adequate median width available
- Protect for / implement as part of a new or reconstructed freeway
- Shoulder are of adequate width for enforcement needs



STANDARD

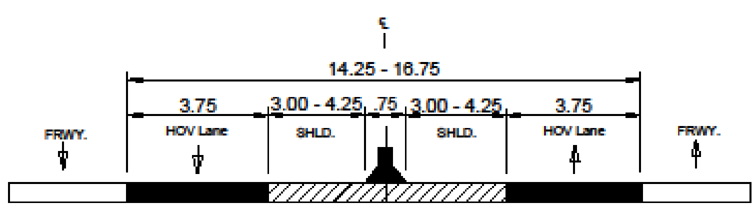
APPLICATION - Reduce shoulder widths, allow retrofit within restricted ROW
- Shoulder width increased at enforcement areas



REDUCED

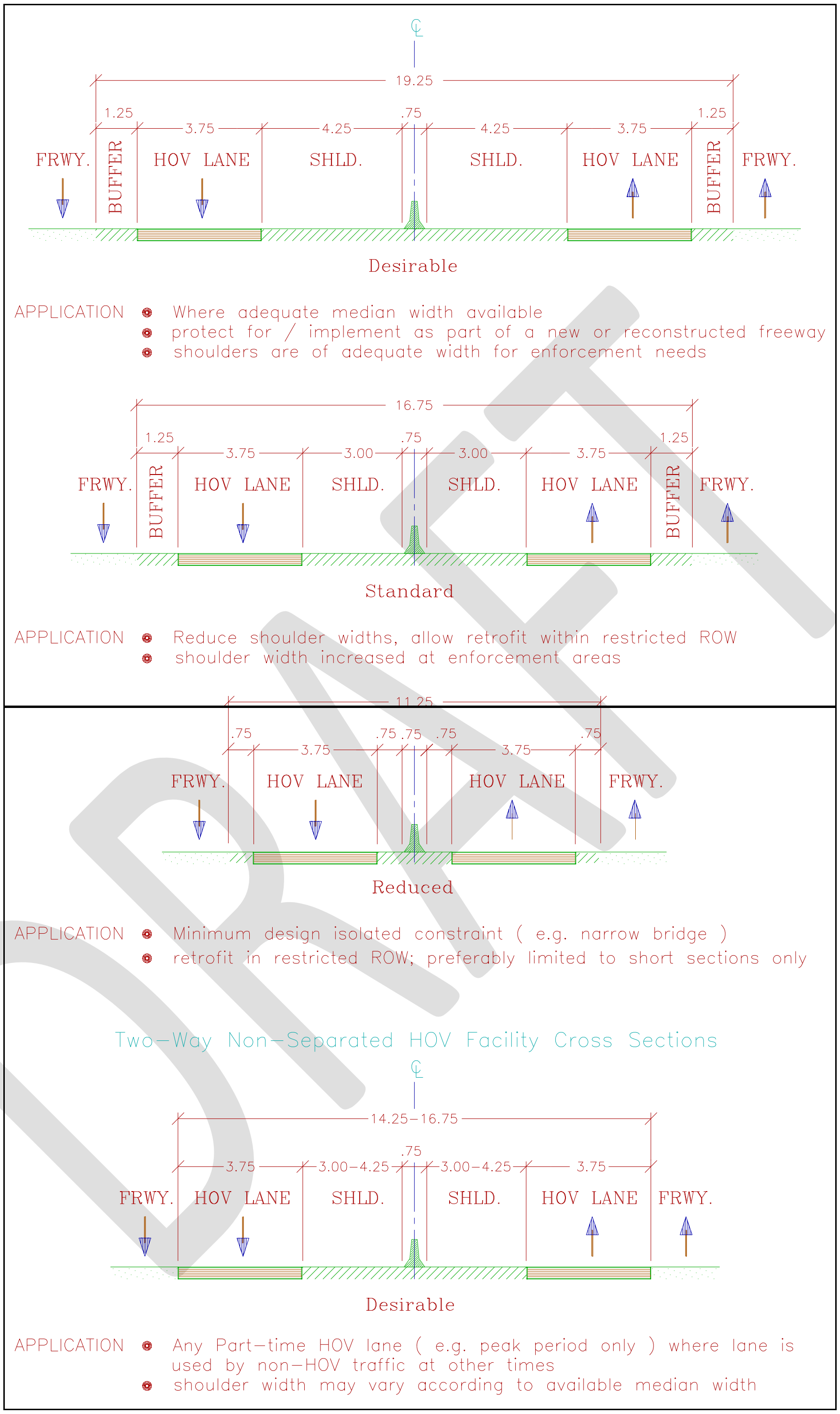
APPLICATION - Minimum design isolated constraint (e.g. narrow bridge)
- Retrofit in restricted ROW; preferably limited to short sections only

Two-Way Non-Separated HOV Facility Cross Sections



DESIRABLE

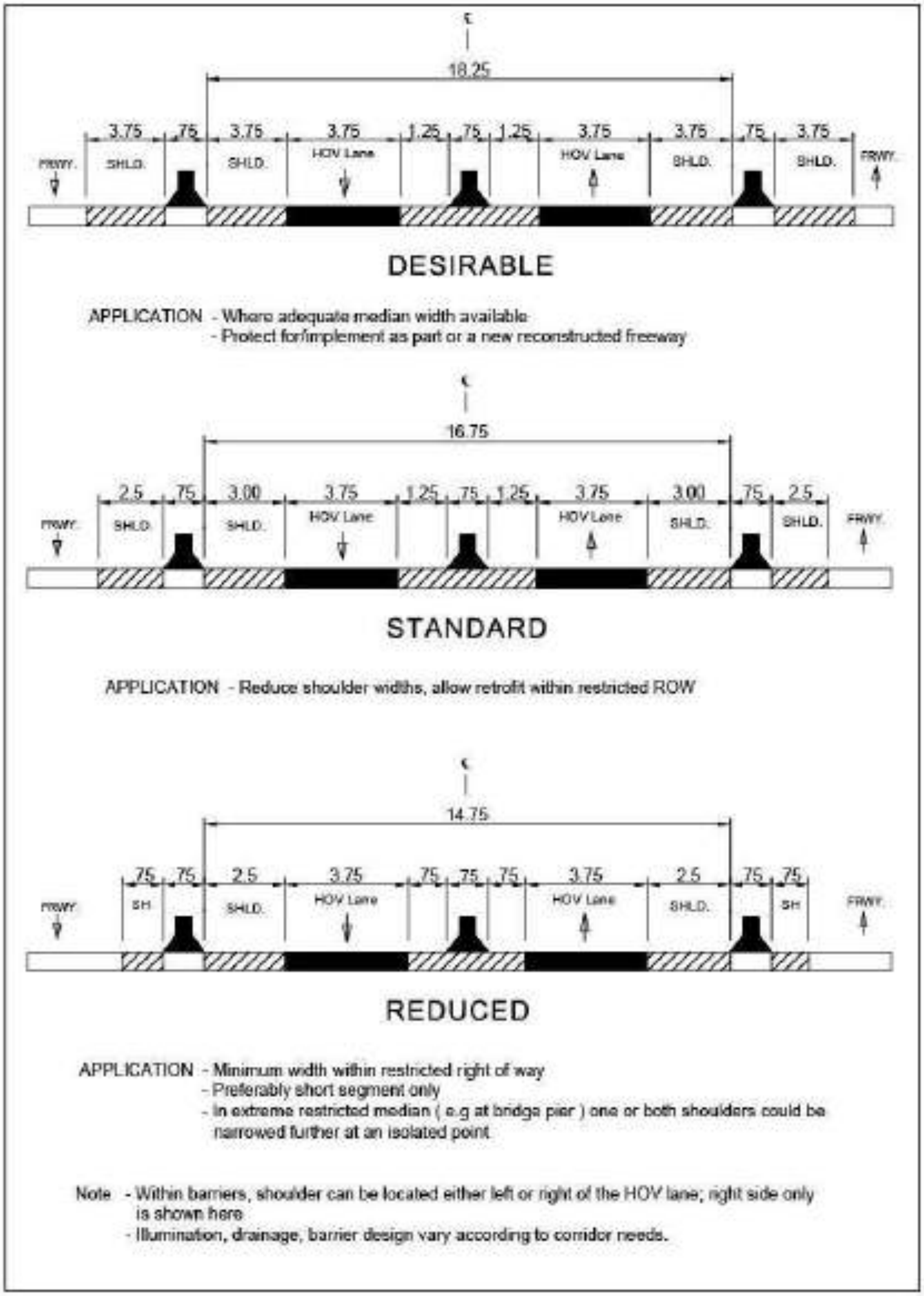
APPLICATION - Any Part-time Hov lane (e.g. peak period only) where lane is used by non-HOV traffic at other times
- Shoulder width may vary according to available median width

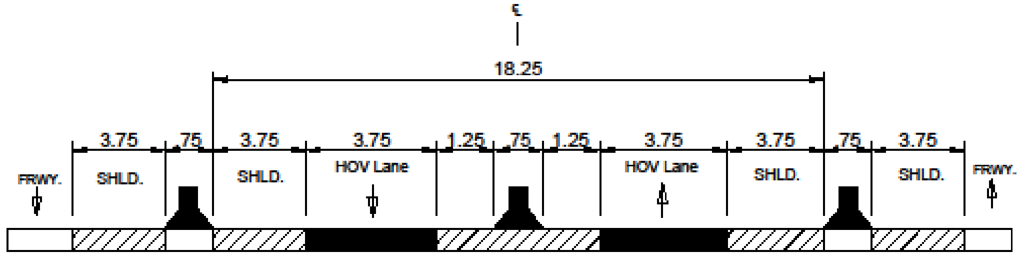


~~**Figure 12.5.3 Examples of Cross Sections of Buffer Separated HOV**~~

Exhibit 12P

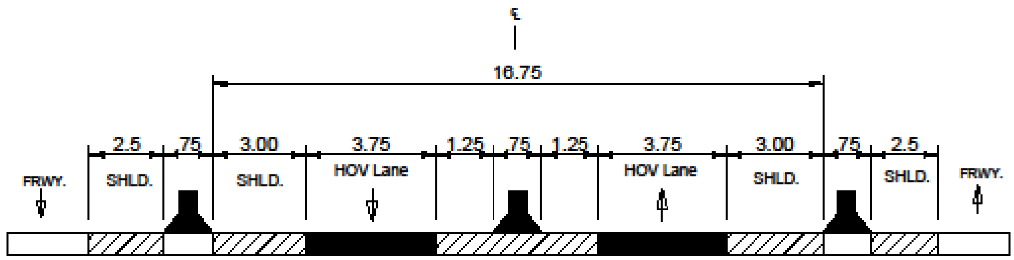
Examples of Cross Sections of Barrier Separated HOV Facility~~and Non-Separated HOV~~


18.25
3.75 .75 3.75 3.75 1.25 .75 1.25 3.75 3.75 .75 3.75
FRWY. SHLD. SHLD. HOV Lane HOV Lane SHLD. SHLD. FRWY.
DESIRABLE
APPLICATION - Where adequate median width available
- Protect for/implement as part or a new reconstructed freeway
16.75
2.5 .75 3.00 3.75 1.25 .75 1.25 3.75 3.00 .75 2.5
FRWY. SHLD. SHLD. HOV Lane HOV Lane SHLD. SHLD. FRWY.
STANDARD
APPLICATION - Reduce shoulder widths, allow retrofit within restricted ROW
14.75
.75 .75 2.5 3.75 .75 .75 .75 3.75 2.5 .75 .75
FRWY SH SHLD. HOV Lane HOV Lane SHLD. SH FRWY.
REDUCED
APPLICATION - Minimum width within restricted right of way
- Preferably short segment only
- In extreme restricted median (e.g at bridge pier) one or both shoulders could be narrowed further at an isolated point
Note - Within barriers, shoulder can be located either left or right of the HOV lane; right side only is shown here
- Illumination, drainage, barrier design vary according to corridor needs.



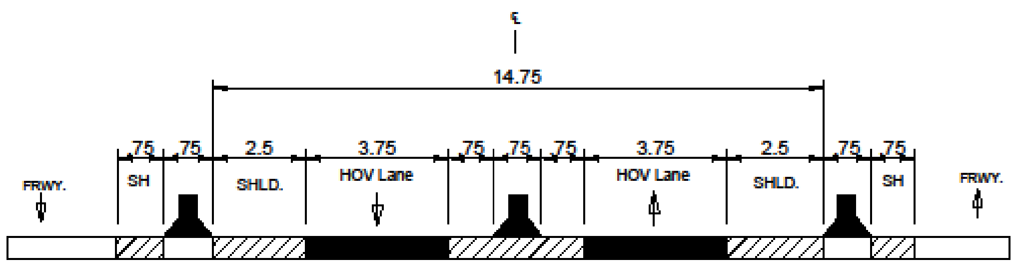
DESIRABLE

APPLICATION - Where adequate median width available
- Protect for/implement as part or a new reconstructed freeway



STANDARD

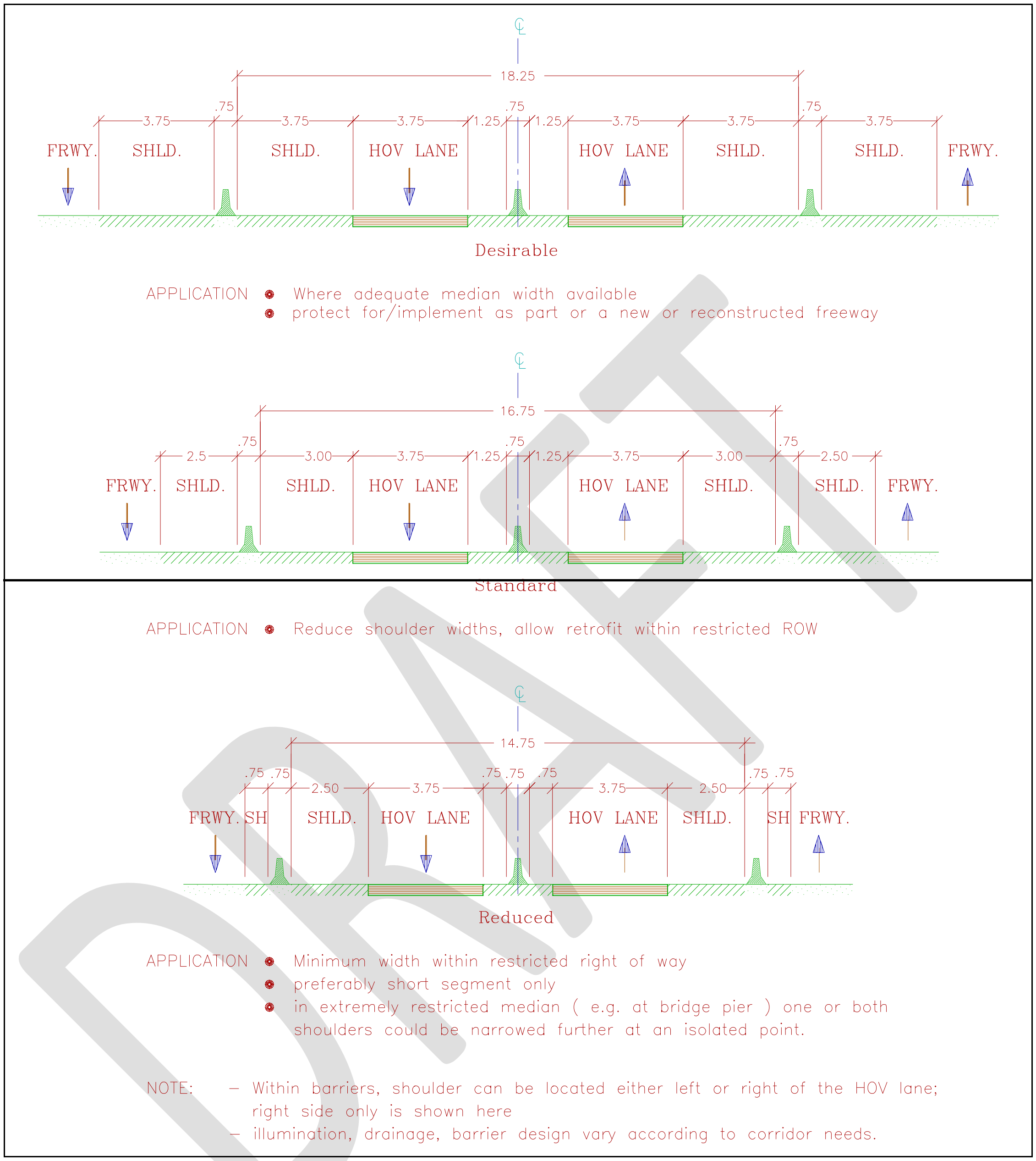
APPLICATION - Reduce shoulder widths, allow retrofit within restricted ROW



REDUCED

APPLICATION - Minimum width within restricted right of way
- Preferably short segment only
- In extreme restricted median (e.g at bridge pier) one or both shoulders could be narrowed further at an isolated point

Note - Within barriers, shoulder can be located either left or right of the HOV lane; right side only is shown here
- Illumination, drainage, barrier design vary according to corridor needs.



~~**Figure 12.5.4 Examples of Cross Sections of Barrier Separated HOV Facility**~~

12.5.1.4 Access and Egress Consideration

Access into and out of a managed lane facility is an important design element for the managed lane facilities. Drivers must be able to make their way safely into and out of the ML. -The location of managed lane access points should avoid creation of short weaving distances between upstream and downstream right-side ramps and left-side managed lane access.- It may be difficult to find appropriate locations for managed lane access on older freeways with frequent on and offramps. -Studies recommended a design domain of 120 m to 500 m per lane change for spacing between general-purpose ramps and managed lane access, depending on traffic volumes and other conditions with 300 m being desirable (300 m is a common recommendation in literature). -These distances are typically applied to passenger vehicles, so the weaving distance provided for buses should be longer (**Exhibit 12S~~Figure 12.5.7~~**).

12.5.1.4.1 Types of Access Configurations

There are 3 types of access configuration (**Exhibit 12Q~~Figure 12.5.5~~**):

- At-Grade Access (Type A)
- At-Grade Ramp Access (Type B)
- Grade-Separated Ramp Access (Type C)

For the first type of At-Grade Access, managed lane traffic enters the general-purpose lanes through a conventional on-ramp from the right. -This access is common for concurrent managed lane facilities. Access between the managed lane and general-purpose lanes is sometimes constrained to specific location, which affects weaving intensity. -This type of access requires a cross-weaving movement through general purpose lanes prior to access point (**Exhibit 12Q~~Figure 12.5.5~~**).

For the second type of At-Grade Ramp Access, traffic weaves across multiple general-purpose lanes but the entrance to or exit from the managed lane is confined to an at-grade on-ramp or off-ramp. -The managed lane operations are impacted by cross-weaving maneuvers from and/or to access points at ramps. -This type of access configuration requires a cross-weaving movement across general-purpose lanes prior to access point and a ramp movement to get from general purpose into the managed lane (**Exhibit 12Q~~Figure 12.5.5~~**).

For the third type of Grade-Separated Ramp Access, the managed lanes access occurs on a grade-separated structure (i.e. flyover, bridge, or underpass). -The operational impact to general-purpose lanes is minimal as cross-weaving movement is eliminated entirely. -This type of access configuration does not require any cross-weaving across general-purpose lanes (**Exhibit 12Q~~Figure 12.5.5~~**).

~~FIGURE~~ Exhibit 12R~~12.5.6~~ includes examples of Ingress / Egress Barrier Separated HOV Facilities and **Exhibit 12T~~Figure 12.5.8~~** illustrates weaving distances at buffer separated HOV facilities as referenced in the Caltrans HOV Guidelines (Caltrans January 2018).- -Further description for HOV/HOT access configuration is outlined in **Section 12.5.2.7**.

Exhibit 12Q
Types of Access Configurations

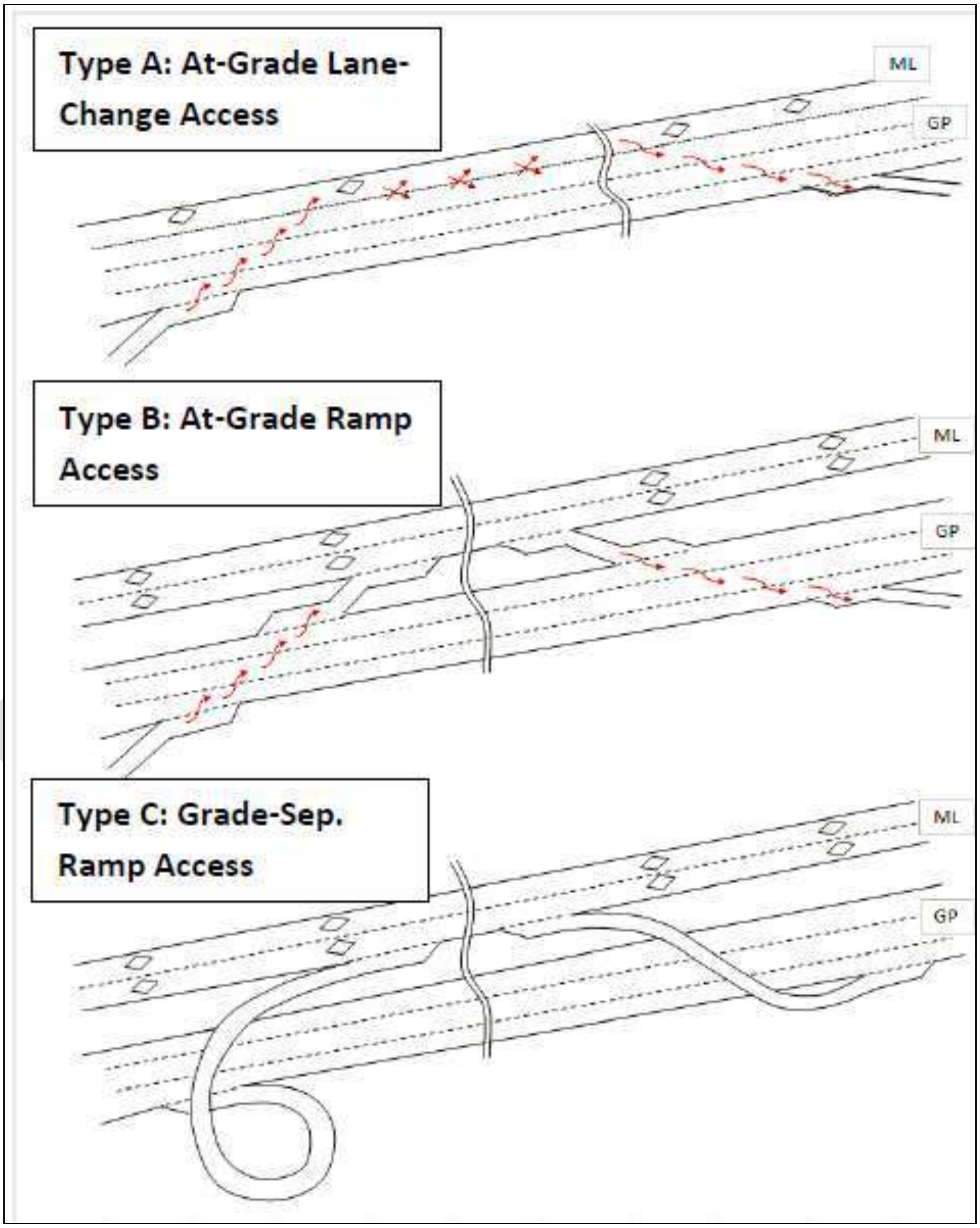
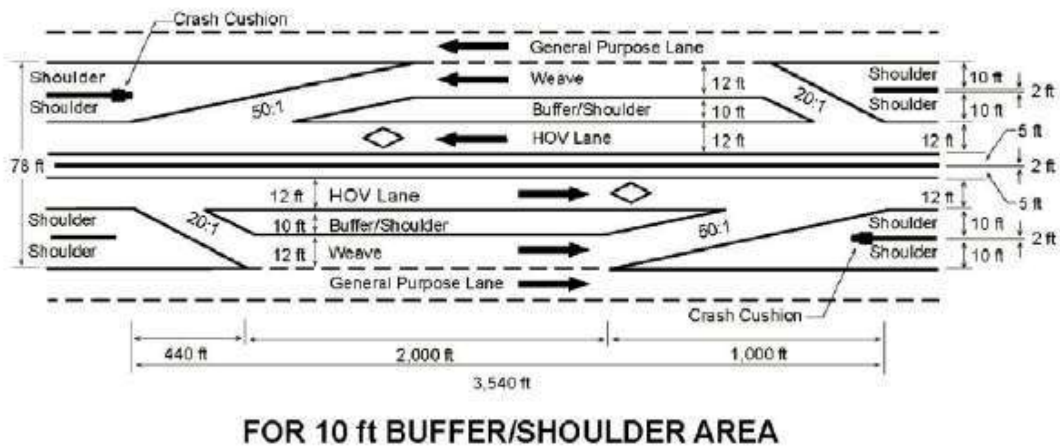


Exhibit 12R

Ingress / Egress Barrier Separated HOV Facilities

Source HOV Guidelines Caltrans January 2018

~~**Figure 12.5.5 Types of Access Configurations**~~



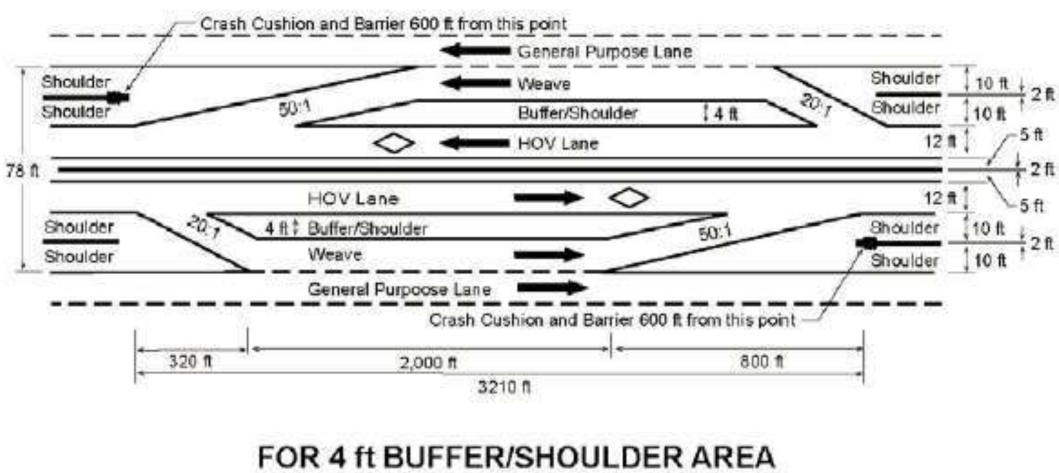


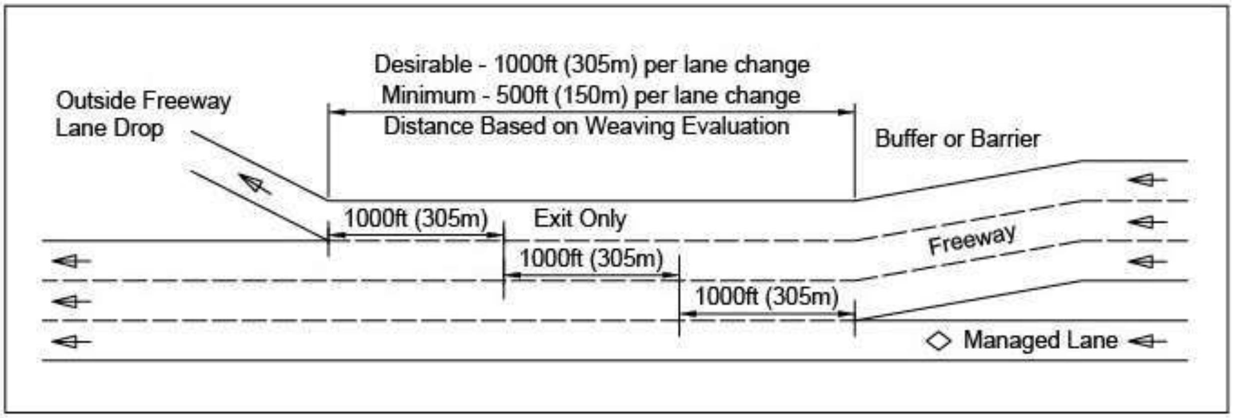
Exhibit 12S

Termination of Managed Lane with 1000 ft (305 m) per Lane Change.

Source NCHRP 815 – Guideline of Implementing Managed Lanes (2016)

~~**Figure 12.5.6 Ingress / Egress Barrier Separated HOV Facilities**~~

~~Source HOV Guidelines Caltrans January 2018~~



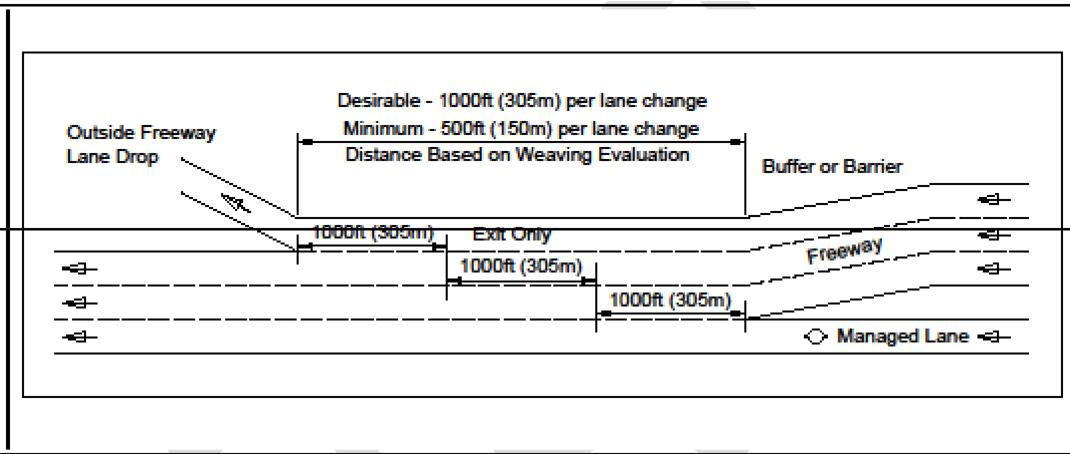
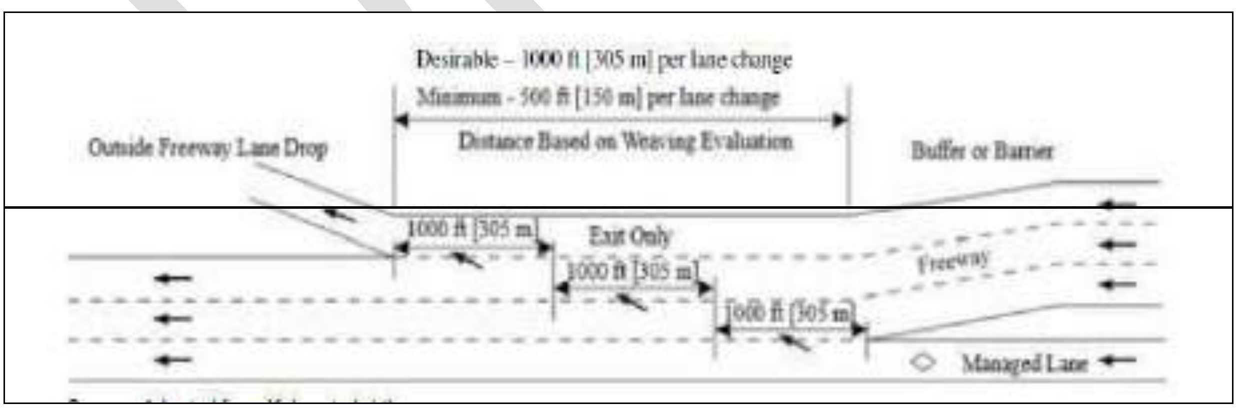


Exhibit 12T

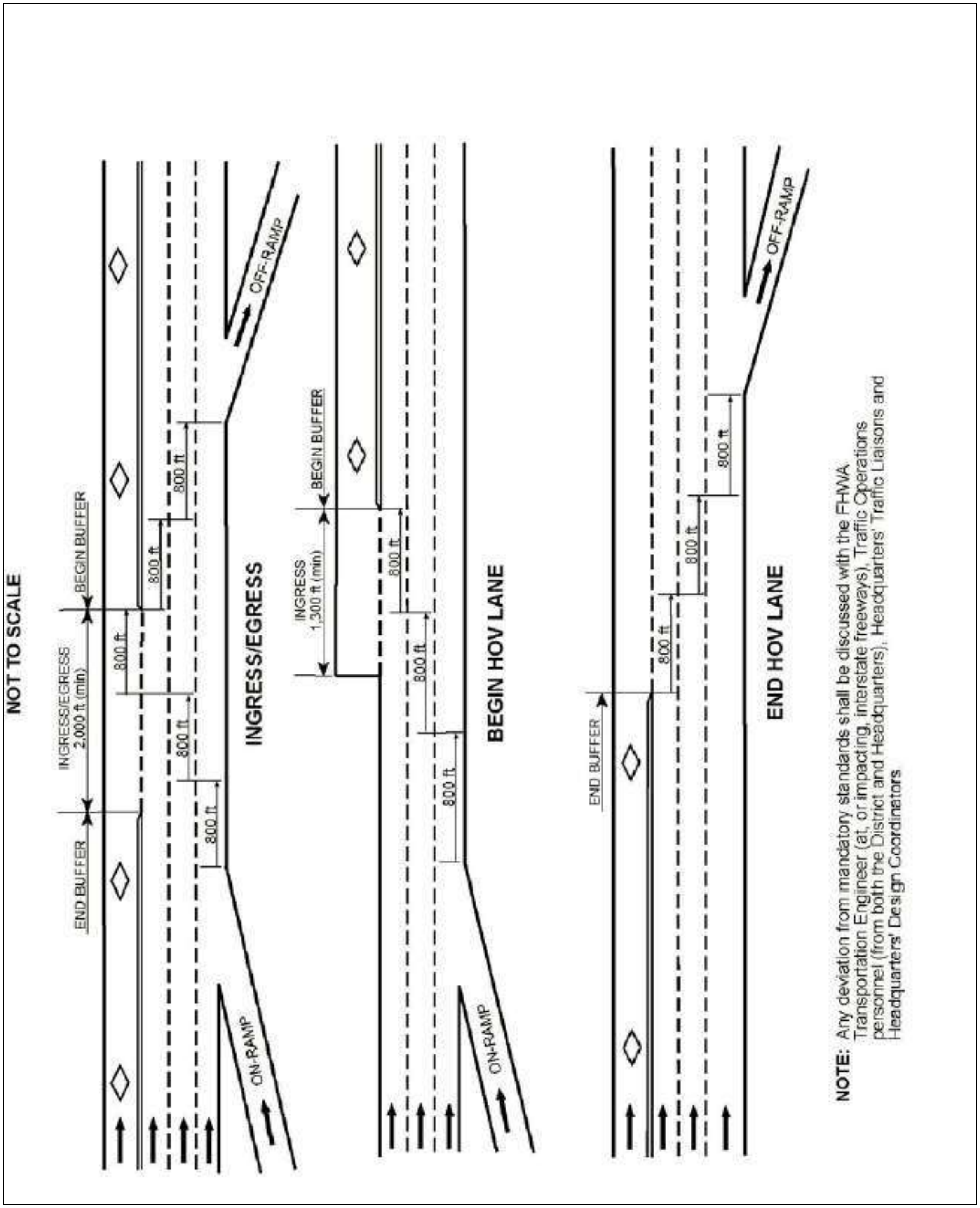
Weave Distance at Buffer Separated HOV Facilities

Source HOV Guidelines Caltrans January 2018



~~**Figure 12.5.7 Termination of Managed Lane with 1000 ft (305 m) per Lane Change.**~~

~~Source NCHRP 815 – Guideline of Implementing Managed Lanes (2016)~~



~~Figure 12.5.8 Weave Distance at Buffer Separated HOV Facilities~~

~~Source HOV Guidelines Caltrans January 2018~~

12.5.1.4.2 Consideration of Limited Access Versus Continuous Access

Provision for intermediate access is typically provided unless a facility is designed to allow access at only the beginning and end.- This is accomplished through either continuous access, in which eligible vehicles may enter the facility at any location, or a limited- or restricted access approach, in which selected locations are designated for ingress, egress, or both.

The choice of access type is based on a general evaluation of performance and management benefits for the entire freeway as well as the capital costs of building and operating the managed lanes. If a proposed access point or series of points causes bottlenecks or does not allow managed lane drivers to use their desired general-purpose entrance and exit ramps, then the access is not serving its purpose and the effects of other factors may not be fully appreciated. This suggests a level of analysis that looks not only at the entire corridor's travel patterns (specifically including the desired origins and destinations for managed lanes users) but also at the immediate area surrounding each proposed access point or driver decision point.

Continuous access and restricted access do not have to be mutually exclusive, in that a managed lane designer does not have to choose either one or the other for the entirety of a managed lane facility. Within a given facility, restrictions on access can be applied to certain parts of the facility while continuous access is provided in other parts of the same facility.

12.5.1.4.3 Frequency of Restricted-Access Points

The defined access points are provided at regular intervals or logical locations; restricted-access points are not intended to serve every general-purpose entrance and exit ramp.- Depending on the purpose of facility, designers would determine where access could be provided.

The location of managed lane access points should avoid creation of short weaving distances between upstream and downstream right-side ramps and left-side managed lane access. It may be difficult to find appropriate locations for managed lane access on older freeways with frequent on- and off ramps. This can be one reason that managed lanes on freeways would operate with more open access, so that weaves are not constrained.

A survey of managed lane practitioners found that spacing for access openings on existing facilities produce a design domain between **1.6 km to 4.8 km** (1 and 3 mi), though the reasons for providing access in a specific location vary, ranging from policy decisions to safety or operational considerations.

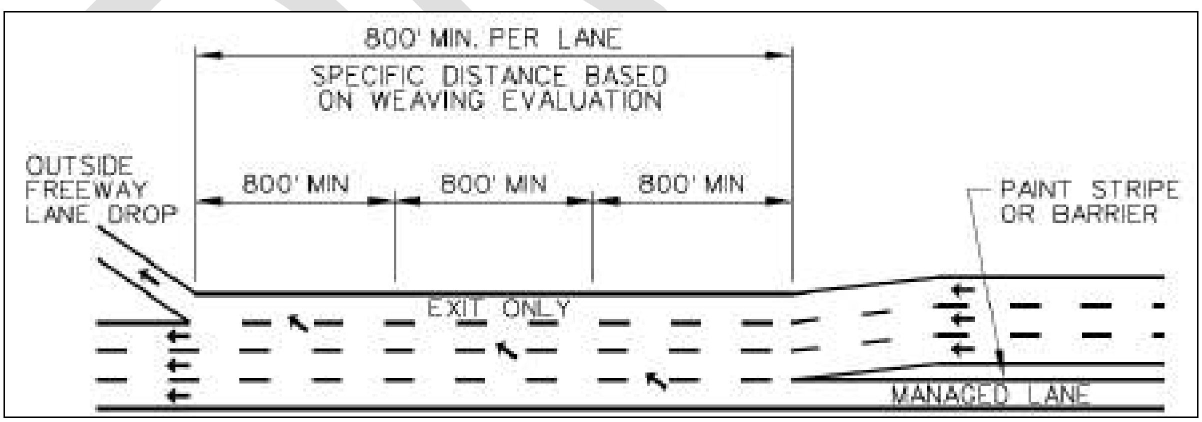
12.5.1.4.4 Beginning and Ending of Managed Lanes

Design for both beginning and termination treatment locations must consider proximity to existing or planned ramps from the right side.- A minimum of 245 m (800 feet) “per-lane change distance” must be provided between ramps and beginning/termination of managed lanes (**Exhibit 12U~~Figure 12.5.9~~**).

12.5.1.4.4.1 Treatment for Beginning of a Managed Lane

Typically, the managed lane begins on the left side of general lane number one with a full width. -For the buffer -separated facility a minimum of approximately 600 m (2000 ft) of dashed white line should be on the right.- The beginning of the buffer should begin no earlier than approximately 250 m (800 ft) distance per lane change required entering managed lane from the nearest on-ramp (**Exhibit 12U~~Figure 12.5.9~~**).

Exhibit 12U
Terminating a Managed Lane as a General Lane



~~**Figure 12.5.9 Terminating a Managed Lane as a General Lane**~~

12.5.1.4.4.2 Treatment for Ending of a~~A~~ Managed Lane

Managed lanes should end in a continuing lane which enables traffic to continue without a merge.- If the managed lane ~~has to~~must merge back into the freeway traffic, a minimum of approximately 600 m (2000 ft) of dashed white line should be provided before the end of the managed lane taper begins.- No less than approximately 250 m (800 ft) per lane change should be provided from the end of buffer to the next off-ramp or connector (**Exhibit 12U**~~**Figure 12.5.9**~~).

12.5.1.4.4.3 Treatment for Barrier Separated Managed Lane

The at grade ingress and egress from general-purpose lanes to a barrier-separated ML facility can be achieved with at grade channelized openings in the physical barriers.- The at-grade opening can be accomplished with the use of a weave lane to assist merging of the ML traffic with the general-purpose lane traffic.- The preferable length of the weaving area for ingress and egress designs is approximately 600 m (2000 ft).

12.5.2 HOV / HOT Lane Design Concepts

The essential principle of a High Occupancy Vehicle (HOV) facility is to give the HOVs priority over non-HOVs from the mixed traffic flow so that they operate in an efficient high-speed manner.- The application of HOV lanes depends directly on traffic demands, physical context, operational circumstances, and planning goals of the corridor under study; the decision depends on detailed corridor-specific analysis, and it cannot be generalized that all freeway HOV lanes in Ontario should be of one type or another.

In this Section, each design concept is outlined, examples of operational applications elsewhere are cited, typical design standards for basic cross-section elements are illustrated, and some comments are made as to appropriate applications in the Ontario context.

12.5.2.1 Concurrent Flow – Median Lane

The most common HOV lane type is the concurrent flow lane, whereby the HOV traffic flows in the same direction as the adjacent general traffic.- Differences in configuration stem from the degree of separation of HOV traffic from adjacent freeway lanes, and the HOV lane's position on either the left (median) or the right side of general traffic lanes.

Median HOV lanes are suited to long commuter trips and express bus services; operational difficulties arise when there are frequent interchanges and a significant amount of HOV weaving between the entrance/exit ramps and the median lane.- In high volume areas such as bus stations and park and ride lots, direct "drop ramps" between the median HOV facility and crossing bridges may be used, "Tee" ramps to/from adjacent transit centres can be introduced, and HOV flyover ramps can be provided between two intersecting HOV routes.

The nature of median HOV lanes varies depending on degree of separation provided from adjacent general traffic lanes by utilization of one of these methods,~~;~~ a physical barrier, a painted buffer zone, or a simple painted line.

12.5.2.1.1 Barrier Separation

Operationally, the most desirable strategy is provision of a continuous physical barrier (e.g. Ontario Tall Wall concrete barrier), with either direct access/egress ramps from flyovers or designated controlled entry zone.

12.5.2.1.2 Buffer Separation

The buffer provides a delineation and controls access between managed lane and general-purpose lanes to improve operations. Having no barrier between the manged and general-purpose lanes, improves maintenance and snow removal operations. The ability to designate managed lane for operation only during peak periods (or other specified times) and allow mixed traffic to use the lane when it would otherwise be under-utilized are also protected by non-separated option.

Experimentation with a variety of buffer widths has led to the conclusion that a **1.25 m** wide painted (double white stripe) buffer between managed lane and adjacent mixed flow lane is a preferred design.- The buffer clearly provides a margin of comfort which reflects typically high-speed differential between the lanes yet minimizes overall cross-section requirements.- It is recommended that a buffer of more than 1.5 m width not be provided, as it could be perceived as a place of refuge for stopped or stalled vehicles, with potential safety consequences.- Cross-sections for buffer ~~-~~separated HOV lanes are shown in **Exhibit 12O~~Figure 12.5.3~~**.

12.5.2.1.3 Non-Separated

Non-separated managed lanes operating in the same direction and immediately adjacent to general-purpose lanes, can be located either to the left (desirable) or to the right of general-purpose lanes. Non- separated managed lanes are normally less expensive and easier to implement, and they provide more opportunity for frequent access.- However, the ease of access could create problems for enforcement and a greater potential for conflicts.

At many locations, managed lanes operate successfully with only a normal (or doubled) dashed white stripe pavement marking as a separator, relying on pavement markings and overhead signage to delineate the managed lane, this non-separated approach is suited to peak period only managed lanes or in severely constrained rights-of-way.- In this situation, managed lane operation will tend to be slower and less relaxing due to driver uneasiness about proximity of slow-moving or stationary traffic and adjacent mixed-flow lane.- This may yield to some reduction in managed lane capacity (**Exhibit 12V**~~**Table 12.5.1**~~), and in the extreme case, may place an upper limit on speed differential between managed lane and adjacent mixed flow lane in the order of 40 km/h.- It is important to note that a managed lane which is utilized during peak periods only and reverts to mixed flow use at other times should appear to be a "typical" lane, with no buffer zone or solid stripe between it and other mixed flow lanes.- **Exhibit 12W**~~**Table 12.5.2**~~ provides potential tradeoffs for contiguous and barrier-separated concurrent-flow lanes respectively.

~~Table 12.5.1~~Exhibit 12V
Width Factors Used in Capacity and Level of Service Calculations

Distance from Edge of Travelled Way to Obstruction (m)	Width Factor* fw (x capacity)	% Reduction in Theoretical Capacity	HOV Lane Separation Characteristic
^{3} 2.0	1.0	0	wide buffer
1.5	0.99	1	proposed 1.25 m narrow buffer Ontario Standard
1.0	0.98	2	
0.5	0.96	4	non-separated lanes 0 - 0.5 m paint line(s)
0	0.90	10	

*** Assumptions**
· 3.75 m wide travelled (HOV) lane
· ~~two~~Two mixed-flow freeway traffic lanes per direction

· Obstruction on one side of HOV lane; adequate shoulder (³ 2 m wide) on other side of lane

~~Table 12.5.2~~Exhibit 12W

Trade-offs for Contiguous Concurrent-Flow Lanes

Suggested Sequence	***Cross-Section Design Change***
1	Reduce the 4.30 m median shoulder (for continuous enforcement) to no less than the desirable criteria. Provide designated enforcement areas instead.
2	Reduce median shoulder to the minimum criteria as per Standards
3	Reduce outside (right) shoulder to a typical minimum width as per Standards.
4	Reduce the median shoulder to 0.6 m. *
5	Reduce the managed lane to 3.35 m. *
6	Reduce general-purpose lanes to 3.35 m, starting from the left and moving to the right as needed. The outside (right) lane is to remain at 3.65 m. *
7	Transition barrier shape at columns to vertical face.
*Requires design exception.	

Source: Nevada Department of Transportation, ML Design Manual December 2013

12.5.2.1.4 Variability

The implementation of managed lanes as added lanes on existing freeways involve, in many cases, geometric compromises to utilize existing structures or minimize impact and cost.- For this reason, a range of alternative cross sections have been illustrated in **Exhibit 12X~~Figures 12.5.10~~** and **Exhibit 12Y~~12.5.11~~** with alternative shoulder widths for barrier separated ML facility and buffer separated ML facility.

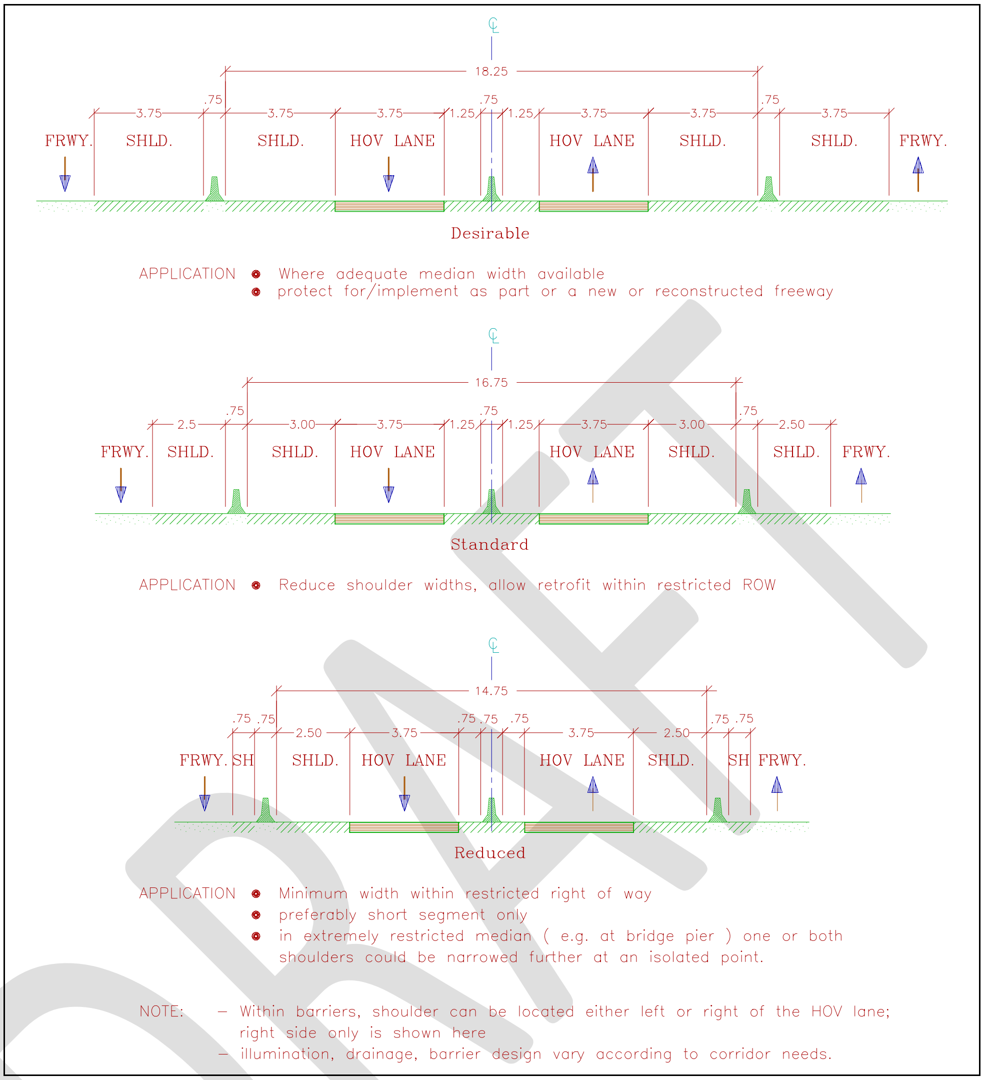
An illustration of a typical constrained situation at a median bridge pier is shown in **Exhibit 12Z~~Figure 12.5.12~~** where it requires alternative cross section for HOV barrier and buffer separation from the general-purpose lane.

When faced with a restricted envelope or section of a corridor within which to retrofit an HOV facility, the designer may be faced to deviate from standards and should consider first the least essential cross-section elements.- **~~Tables 12.5.2~~Exhibit 12W, ~~12.5.3~~ Exhibit 12AA and**

~~**12.5.4**~~**Exhibit 12AB** provides general practice.

HOV lanes are governed by general freeway design standards, and exceptions to the standards will need a sound justification and senior level approval (**Section 12.5.5**).

Exhibit 12X
Two-Way Barrier-Separated HOV Facility Cross-Sections



18.25
.75
3.75
1.25
FRWY.
SHLD.
HOV LANE
HOV LANE
SHLD.
SHLD.
FRWY.
Desirable
APPLICATION
Where adequate median width available
protect for/implement as part or a new or reconstructed freeway
16.75
2.5
3.00
2.50
Standard
Reduce shoulder widths, allow retrofit within restricted ROW
14.75
SH
Reduced
Minimum width within restricted right of way
preferably short segment only
in extremely restricted median (e.g. at bridge pier) one or both shoulders could be narrowed further at an isolated point.
NOTE:
– Within barriers, shoulder can be located either left or right of the HOV lane; right side only is shown here
– illumination, drainage, barrier design vary according to corridor needs.

Exhibit 12Y

Two-Way Buffer-Separated HOV Facility Cross-Sections~~Figure 12.5.10 Two-Way Barrier-Separated HOV Facility Cross-Sections~~

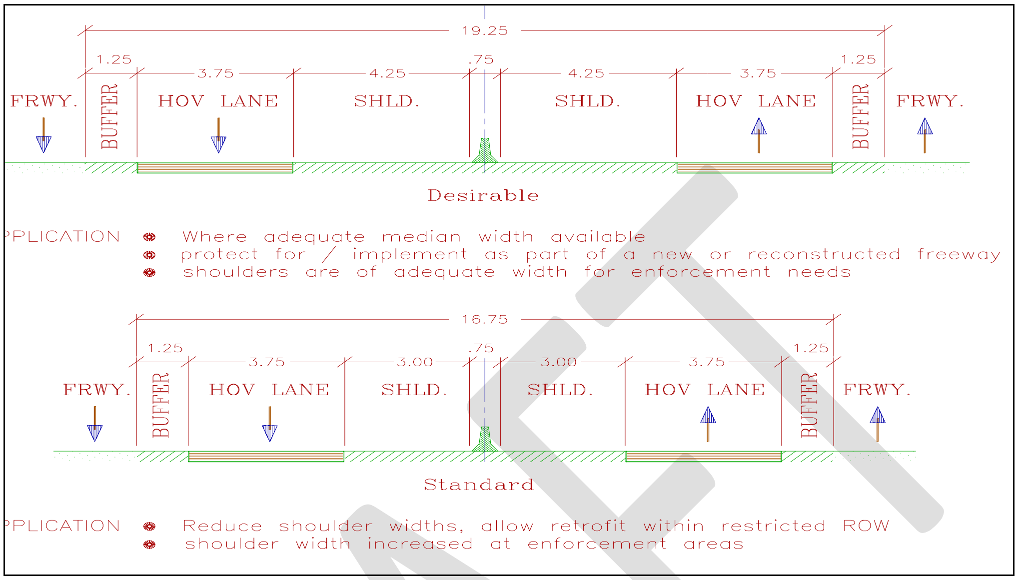
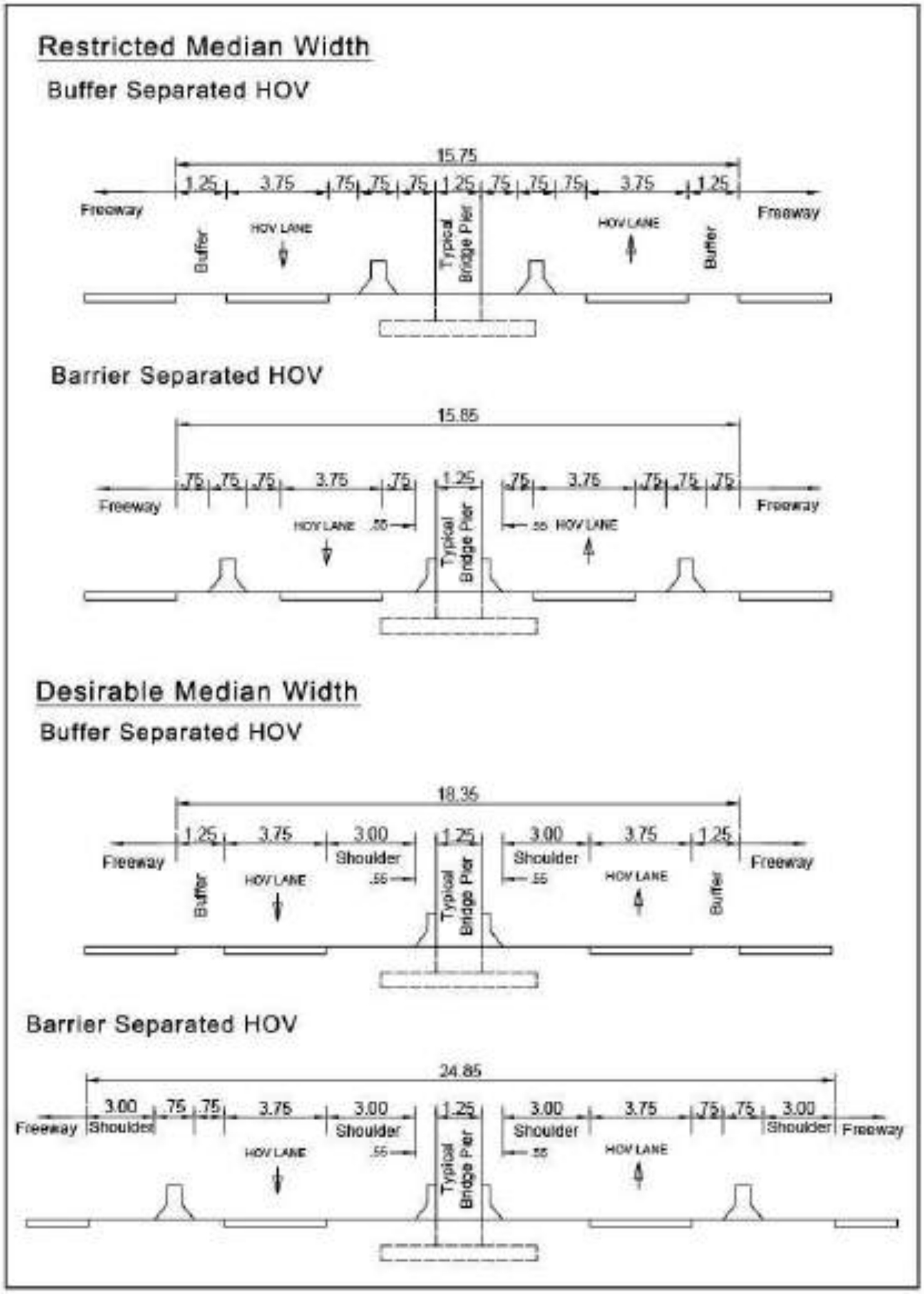
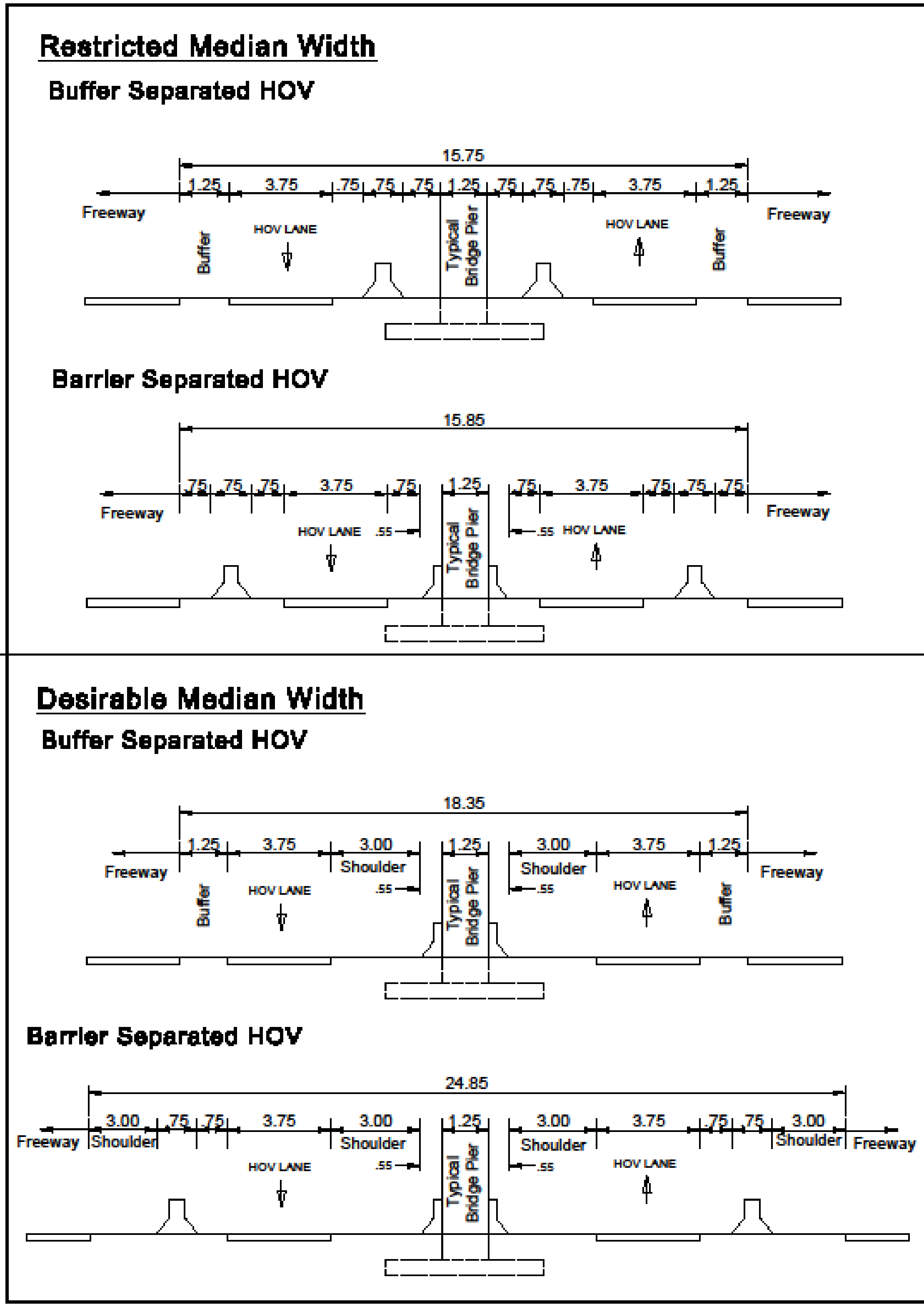


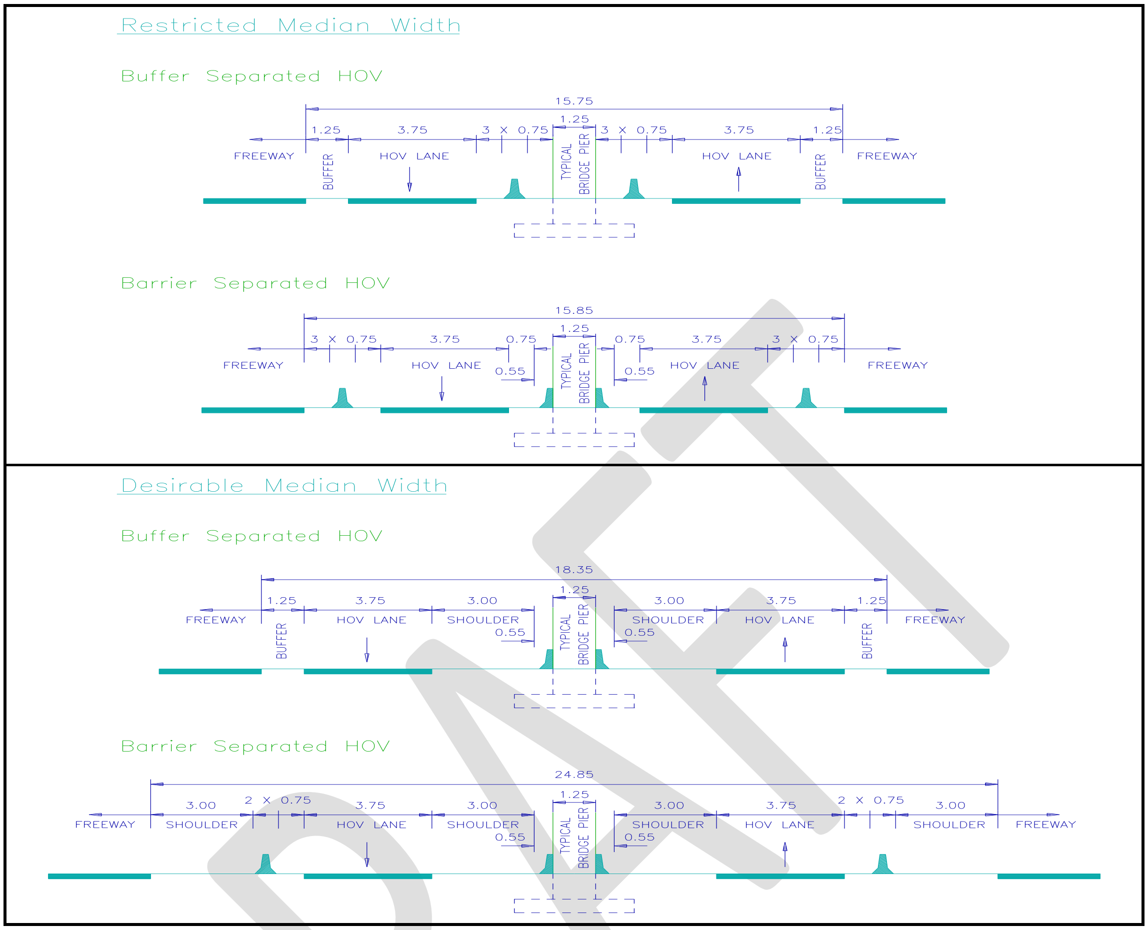
Exhibit 12Z

HOV Lanes at Median Pier

~~**Figure 12.5.11 Two-Way Buffer-Separated HOV Facility Cross-Sections**~~


Restricted Median Width
Buffer Separated HOV
15.75
1.25 3.75 .75 .75 .75 1.25 .75 .75 .75 3.75 1.25
Freeway
HOV LANE
Buffer
Typical Bridge Pier
Barrier Separated HOV
15.85
.75 .75 .75 3.75 .75 1.25 .75 3.75 .75 .75 .75
.55
Desirable Median Width
Buffer Separated HOV
18.35
1.25 3.75 3.00 1.25 3.00 3.75 1.25
Shoulder
Barrier Separated HOV
24.85
3.00 .75 .75 3.75 3.00 1.25 3.00 3.75 .75 .75 3.00


Restricted Median Width
Buffer Separated HOV
15.75
1.25 3.75 .75 .75 .75 1.25 .75 .75 .75 3.75 1.25
Freeway
Buffer
HOV LANE
Typical Bridge Pier
HOV LANE
Buffer
Freeway
Barrier Separated HOV
15.85
.75 .75 .75 3.75 .75 1.25 .75 3.75 .75 .75 .75
Freeway
HOV LANE .55
Typical Bridge Pier
.55 HOV LANE
Freeway
Desirable Median Width
Buffer Separated HOV
18.35
1.25 3.75 3.00 1.25 3.00 3.75 1.25
Freeway
Shoulder
Buffer
HOV LANE .55
Typical Bridge Pier
Shoulder
.55
HOV LANE
Buffer
Freeway
Barrier Separated HOV
24.85
3.00 .75 .75 3.75 3.00 1.25 3.00 3.75 .75 .75 3.00
Freeway Shoulder
Shoulder
HOV LANE .55
Typical Bridge Pier
Shoulder
.55
HOV LANE
Shoulder Freeway



~~**Figure 12.5.12 HOV Lanes at Median Pier**~~

~~Table 12.5.3~~Exhibit 12AA

Guidelines for Restricted Section to Retrofit a Median ML Facility (Concurrent Flow)

Compromise	**ML Lane Type**	
	Two-Way Barrier-Separated	Two-Way Buffer-Separated
First	Reduce left ML lane lateral clearance to no less than 0.6 m	Reduce left ML lane lateral clearance to no less than 0.6 m
Second	Reduce right ML lane lateral clearance to no less than 2.5 m	Reduce freeway right lateral clearance (shoulder) from 3 m to no less than 2.5 m
Third	Reduce freeway left lateral clearance to no less than 0.6 m	Reduce buffer width to no less than 0.3 m
Fourth	Reduce freeway right lateral clearance (shoulder) from 3 m to no less than 2.5 m	Reduce ML lane width to no less than 3.35 m (consider reversing fourth and fifth steps when buses are projected to use the HOV facility)
Fifth	Reduce ML lane width to no less than 3.35 m (consider reversing fifth and sixth steps when buses are projected to use an HOV facility)	Reduce selected mixed-flow lane widths to no less than 3.35 m (leave at least one 3.65 m outside lane for trucks)
Sixth	Reduce selected mixed-flow lane widths to no less than 3.35 m (leave at least one 3.65 m outside lane for trucks)	Reduce freeway right lateral clearance shoulder from 2.5 m to no less than 1.25 m
Seventh	Reduce freeway right lateral clearance shoulder from 2.5 m to no less than 1.25 m	Transition barrier shape at columns to a vertical face or remove buffer separation between ML and mixed-flow lanes.
Eighth	Convert barrier shape at columns to a vertical face.	

Note that this list is provided as ***an example and is not intended to supersede engineering judgment in specific design applications.***

~~Table 12.5.4~~Exhibit 12AB
Pros and Cons of Managed Lane Facility Cross-Section Trade-offs

Design Elements	Pros	Cons
3.75 m travel Lane	- Matches typical guideline for general-purpose travel lanes on freeways - Ample for accommodation of buses and trucks	- May be difficult to achieve in a retrofit without taking width from other elements in the managed lane or general-purpose facilities
3.65 – 3.75 m Shoulder	- Matches typical guideline for general-purpose travel lanes on freeways - Provides refuge space for disabled vehicles - Provides space for enforcement activities - Provides space for temporary storage of snow removed from the travel lane - Provides option for throughput during incidents in the travel lane	- May be difficult to achieve in a retrofit without taking width from other elements in the managed lane or general-purpose facilities
3.35 m travel Lane	- Easier to provide in a retrofit than 3.65-3.75 m lane, though there are safety trade-offs - May be acceptable if associated with a wider buffer	- Narrower than typical freeway lane - Less-than-minimum width in some guidelines; not always allowed or recommended - Associated with higher number of crashes
3.0 – 3.35 m Shoulder	- Can accommodate passenger vehicles and most heavy vehicles - Easier to provide in a retrofit than 3.65 m shoulder	- Narrower than typical freeway shoulder - Reduces the available space to store and/or attend to disabled vehicles and to store snow - Restricts ability of enforcement officers to conduct activities outside of the travel lane
2.4 – 2.7 m Shoulder	- Can accommodate most passenger vehicles	- Not suitable for heavy vehicles - Very restrictive for refuge and

	- Easier to provide in a retrofit than 3.65 m shoulder	enforcement - Minimizes usefulness in snow storage and incident management
Shoulder less than 2.4 m	- Provides a measure of lateral clearance for drivers compared to no shoulder	- Not suitable for heavy vehicles - Not wide enough to store a passenger vehicle without encroaching on the travel lane - Not suitable for maintenance, enforcement, snow storage, or incident management - Can restrict sight distance in curves - Associated with higher number of collisions
1.2 m or wider buffer	- Provides separation between managed lanes and general-purpose lanes - Provides additional accommodation for vehicles to shift laterally within the lane in horizontal curves	- May be difficult to achieve in a retrofit without taking width from other elements in the managed lane or general-purpose facilities - Depending on width, may be seen as an additional travel lane for passenger vehicles or motorcycles without additional delineation or separation devices
Buffer less than 1.2 m	- Provides a measure of separation between managed lanes and general-purpose lanes - Easier to provide in a retrofit than a wider buffer	- Reduces distance between traffic streams that could be traveling at greatly different speeds - May not be allowed in some jurisdictions

Source: Texas A&M Transportation Institute (TTI).

This list provides **an example and it is not intended to supersede engineering judgment in specific design applications.**

12.5.2.2 Concurrent Flow – Right Lane

12.5.2.2.1 Right Lane Use

The location of managed lanes on the outer (right hand) lanes of a freeway can effectively resolve some issues associated with a median managed lane alternative.- However, it poses new operational challenges, particularly at interchanges.- A right-side managed lane conflicts with local on and off-movements with the main lanes, so therefore, either usage of right-side orientations needs to be low to mitigate conflicts, or usage must be restricted to select drivers and vehicles such as buses only. In the context of frequent on-off patterns, right lane managed lane may address the transit needs and short distance trip patterns at lower cost than median managed lanes.- Severe physical constraints, inadequate right-of-way, or structural requirements may effectively preclude a median managed lane, forcing an outside lane option. Another application of right-side managed lanes is a low-cost and easily implemented temporary or pilot project facility, or as an early stage towards a more permanent managed lane.- The most common use of right-side managed lanes has been as a queue bypass for priority vehicles (particularly buses) in situations such as a bridge/tunnel approach, ferry dock, or toll plaza where either a right side or left side managed lane could apply equally well.

For freeway conditions, the right-side managed lane operation is constrained by the interaction between HOVs and non-HOVs at entry and exit interchange ramps. -The most effective right side HOV lanes are those with few vehicles in them; to achieve the person-movement volumes which justify provision of an HOV lane while minimizing the number of vehicles involved, bus-only operation may be the most appropriate designation.- Unless grade separated at the interchange, right-side HOV lanes exhibit lower operating speeds (and Level of Service) than median HOV lanes; the capacity of a right-side HOV lane is correspondingly lower, at approximately **1,100 vehicles/hour** rather than 1,500 vehicles/hour. -There is also greater risk of motorist confusion with respect to signing and pavement markings due to the weaving manoeuvre at ramps.- Right-side HOV lanes have proven to be more difficult to enforce than median facilities, due to frequency of violators claiming that they were bound for the next exit ramp.- With bus-only use however, proper use of the lane becomes easier to enforce.

The right-side managed lane can be separated from adjacent mixed flow lane by either a narrow buffer (±1.25 m) or paint lines; the approach does not lend itself to barrier separation due to the transitions which must be made at interchange ramps.- If the lane is always used by moving traffic (i.e. it does not convert to shoulder use in off-peak periods) a standard permanent shoulder should be provided.- In this respect the right-side managed lane design standards are identical to those for any freeway lane. **Exhibit 12Z** ~~**Figure 12.5.12**~~ illustrates a typical cross-section.

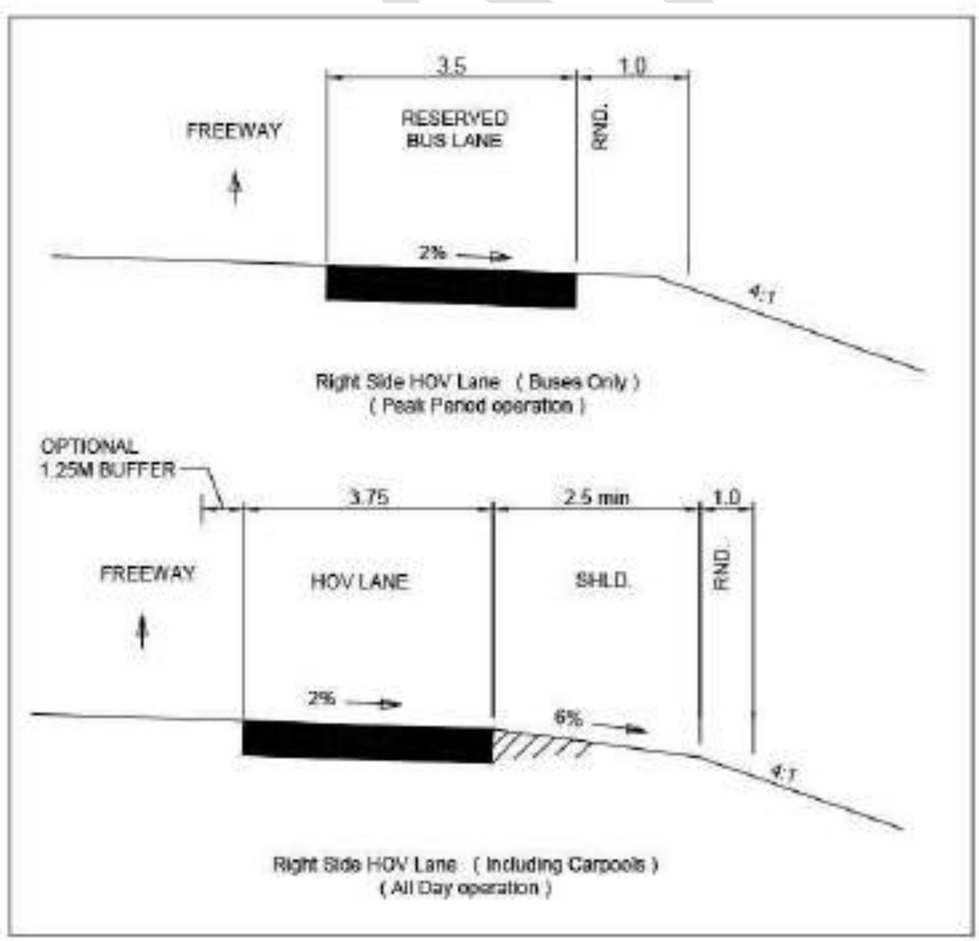
12.5.2.2.2 Right Shoulder Use

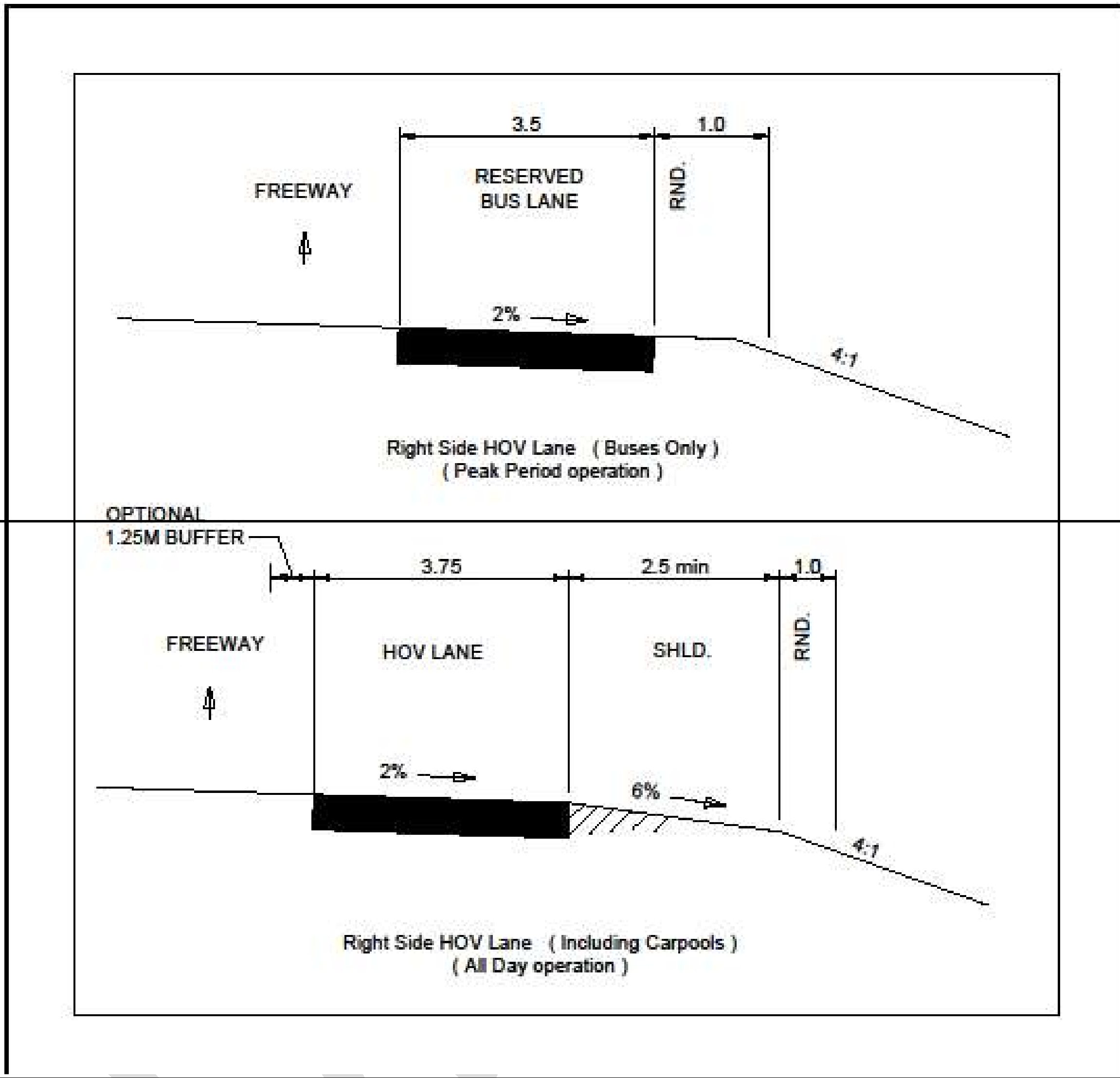
A right shoulder may be utilized as a managed lane on a temporary or peak period basis. Rather than permanently occupying the right lane of a freeway, a right shoulder can provide priority lane when most beneficial and revert to its "typical" usage at other times.
The pavement must be strong enough to allow daily usage by transit vehicles with depth

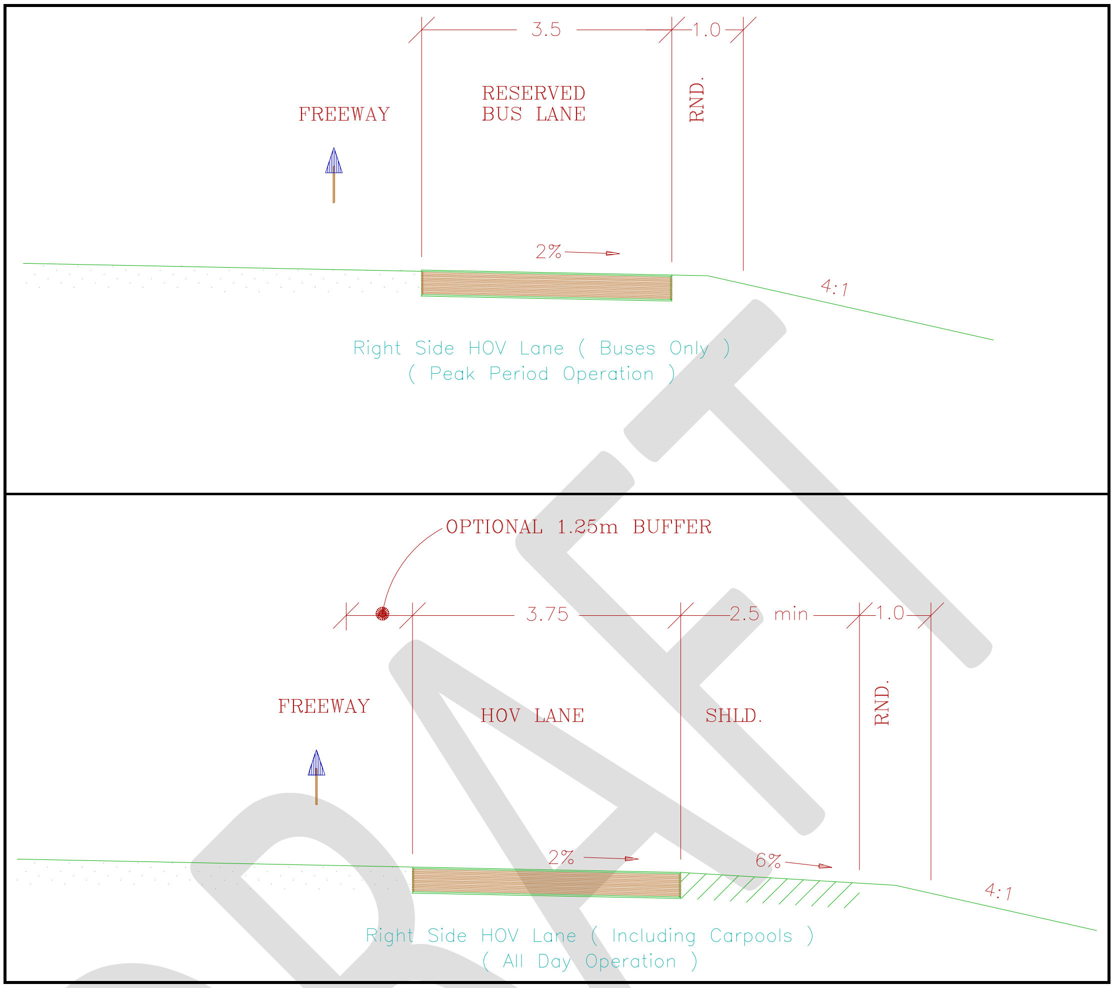
equivalent to adjacent lanes. -For shoulder use by buses only, **3.50 m is the design width**, while if other HOVs are to use the lane an additional 0.35 m in width is recommended (**Exhibit 12AC**~~Figure 12.5.13~~).- Associated with the change in function of the shoulder, requirements should be considered for reinforce, extend, or provide guiderails, since moving traffic would shift 3.5 m closer to any obstacle or slope.

As is the case for any temporary - use managed lane, signage must be frequent, concise, and clear regarding the proper use of the lane.- If the shoulder is to be used for HOVs in peak periods only, the provision of an additional "shoulder" beyond the 3.75 m paved shoulder would be desirable but not essential.- The shoulder could be used by a stopped vehicle in the event of an emergency, in which case the HOVs would have to merge with mixed flow to bypass the obstacle; a premium is therefore placed on the implementation of an effective Incident Management Strategy aimed at removing any stopped vehicles as quickly as possible.

Exhibit 12AC
Right Side HOV Lane




3.5
1.0
FREEWAY
RESERVED
BUS LANE
RND.
2%
4:1
Right Side HOV Lane (Buses Only)
(Peak Period operation)
OPTIONAL
1.25M BUFFER
3.75
2.5 min
1.0
FREEWAY
HOV LANE
SHLD.
RND.
2%
6%
4:1
Right Side HOV Lane (Including Carpools)
(All Day operation)



~~**Figure 12.5.13 Right Side HOV Lane**~~

12.5.2.3 Reversible Flow

A reversible flow HOV lane is suited to a corridor where there is a high directional split in the peak period (at least 65% of all traffic travelling in the peak direction) and is often used in a corridor where extreme physical constraints preclude designation of more than a single lane for HOV use.- A two-lane reversible facility is used to accommodate extremely heavy peak direction demand (potentially both HOV and mixed flow).

A reversible lane must be in the median of the freeway to allow access to it from both directions at different periods of the day.- Reversible HOV lanes, once installed, cannot readily be adapted to other operational approaches, and are only appropriate when corridor demand directionality is a permanent characteristic.

Reversible lanes add additional capacity to the peak flow lanes, which helps to ease congestion and optimize passenger mobility. -However, reversible flow lanes pose a unique set of operational challenges and opportunities. -These lanes work well when isolating managed facility users from general-purpose lanes by use of barriers between the two systems to improve operational performance.- The ability to provide access to/from reversible lane is normally restricted and infrequent; as with any barrier-separated lane, therefore, a premium is placed on focusing carpools and buses at key nodes at either end of the corridor or at a limited number of points along the corridor where access can be provided.

Reversible flow lanes require set hours of operation in each direction.- -Additional operational measures must be put in place to ensure traffic is routed into and out of the facility at set times to ensure maximized flow and standardized periods of operation.- Reversible lanes require additional inputs of signage and safety features to ensure vehicles can easily and safely access the facility during off hours.- Raising public awareness to their operation and safety features should be a prime component of any reversible facility implementation plan.

Specialized signage, access designs, and daily operational requirements are additional factors which should be considered for a reversible lane. -The median location of reversible HOV lanes demands separation of HOV traffic from general freeway flows by physical barriers. Consequently, a shoulder must be provided between barriers in order that the lane not become blocked by a stalled or stopped vehicle.- The provision of direct reversible median drop ramps between crossing roads and the median HOV lane(s) is a typical feature of many reversible facilities.- Recommended cross-sections for reversible HOV lanes are shown in **Exhibit 12AF**~~Figure 12.5.14~~.

As with concurrent flow, a reversible HOV lanes may be applied in extremely constrained retrofit situations, where inadequate width is available for the optimum design.

Reversible flow lanes require additional study to determine the amount of time required to clear out the lanes prior to switching directions compared to bi-directional systems with continuous flow in both directions. Clearance and resetting times vary by corridor length, speed limit and congestion. Efficient planning is necessary to determine system-wide clearance times in multi-facility and radial reversible managed lanes systems to ensure a safe transition for flow from one direction to the other.

Reversible facilities require a signage system to be clearly established to inform travelers of hours of operation for reversible facilities in their direction of travel.- Highly visible gates should be developed and installed to prevent flow from the off-peak direction into the reversible managed facility during periods of opposite flow.

Exhibit 12AE~~Table 12.5.6~~ summarized key advantages and disadvantages of Reversed Managed Lane facilities.

By maximizing the utility of managed lanes, reversible facilities can serve peak demands while keeping costs at a minimum. -While bi-directional facilities may serve off-peak demand in both directions, these facilities require an investment in both directions. -Reversible facilities are less expensive than bi-directional facilities primarily due to the construction of one facility in place of two separate unidirectional facilities.

Reversible Lane Application in Ontario

The applicability of reversible HOV lanes to Ontario freeways appears to be limited, for two main reasons:

- Few Ontario freeways exhibit a directional split as high as 65% during the peak period, particularly when projected over the long term (20 years).
- Most freeway crossing bridges in Ontario have centre piers, conflicting with a centred median lane.- Also, high mast light standards and sign support footings utilize the median.

~~Table 12.5.5~~Exhibit 12AD

Guidelines for Restricted Section to Retrofit a Median HOV Facility (Reversible Flow)

Compromise	Cross-Section
First	Reduce single-lane HOV envelope to no less than 6 m, or two-lane envelope to no less than 8.5 m.
Second	Reduce freeway left lateral clearance to no less than 0.6 m.
Third	Reduce freeway right lateral clearance (shoulder) from 3 m to no less than 2.5 m.
Fourth	Reduce HOV lane width to no less than 3.35 m (consider reversing fourth and fifth steps when buses are projected to use the HOV facility).
Fifth	Reduce selected mixed flow lane widths to no less than 3.35 m (leave at least on 3.65 m outside lane for trucks).
Sixth	Reduce freeway right lateral clearance shoulder from 2.5 m to no less than 1.25 m.
Seventh	Convert barrier shape at columns to a vertical face.

Ontario Examples: Lane controls and no (or minimal) physical separation:

- The **Peace Bridge** between the U.S. and Canada, connecting Fort Erie, Ontario to Buffalo, New York. Three lanes total, all marked reversible, one reversed in the direction of rush hour flow with the possibility of all lanes flowing in the same direction based on traffic needs.
- The **Queenston-Lewiston Bridge** connecting Niagara-on-the-Lake, Ontario to Lewiston, New York. Five lanes total, all marked as reversible, one to four lanes marked daily in

the same direction, depending on traffic needs. In addition to the directional signals, special signals are also fitted to specify what type of vehicle may use the lane.

~~Table 12.5.6~~Exhibit 12AE

Advantages and Disadvantages of Reversible Managed Lane Facility

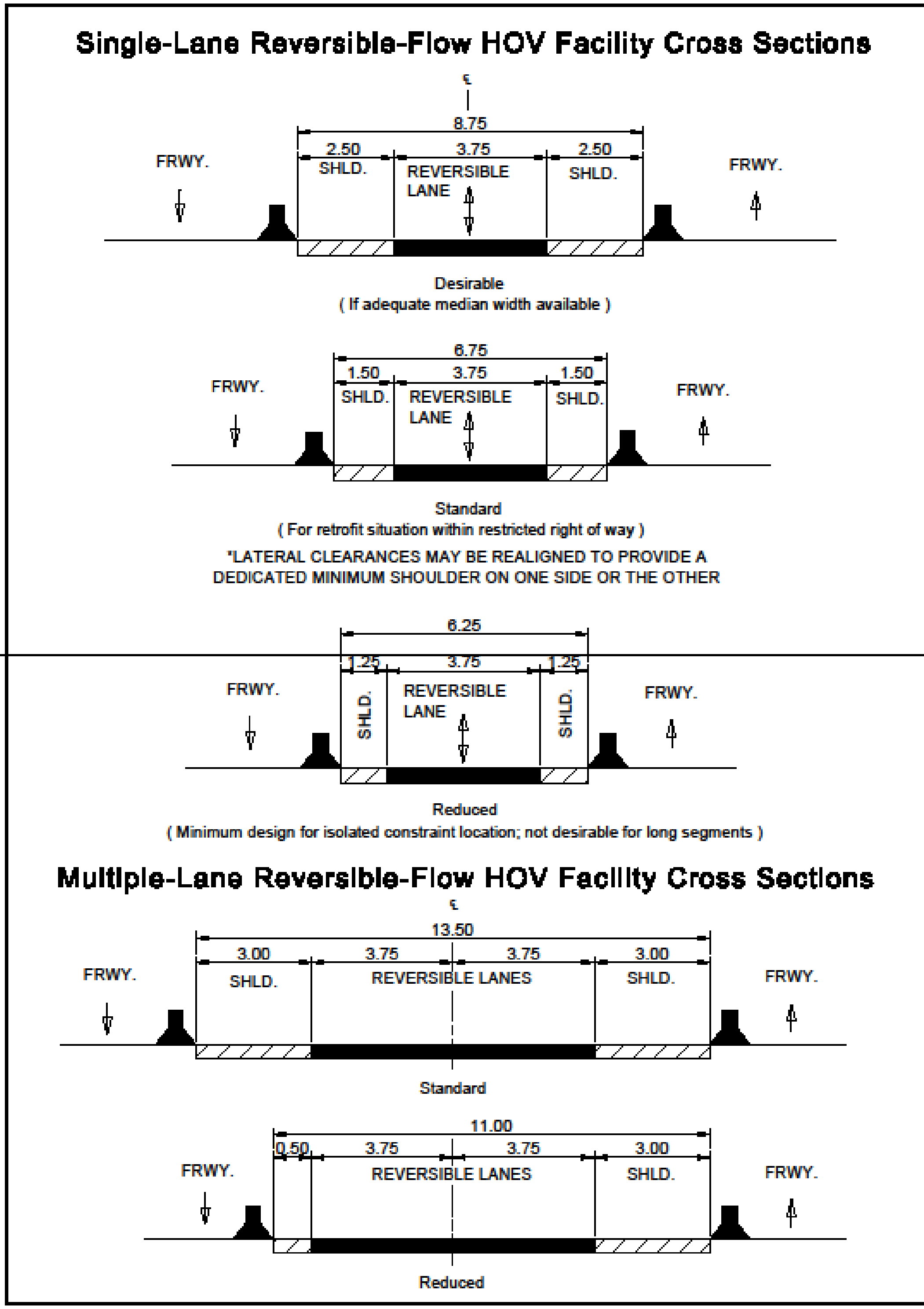
Information Source Georgia Department of Transportation, Jan 2010

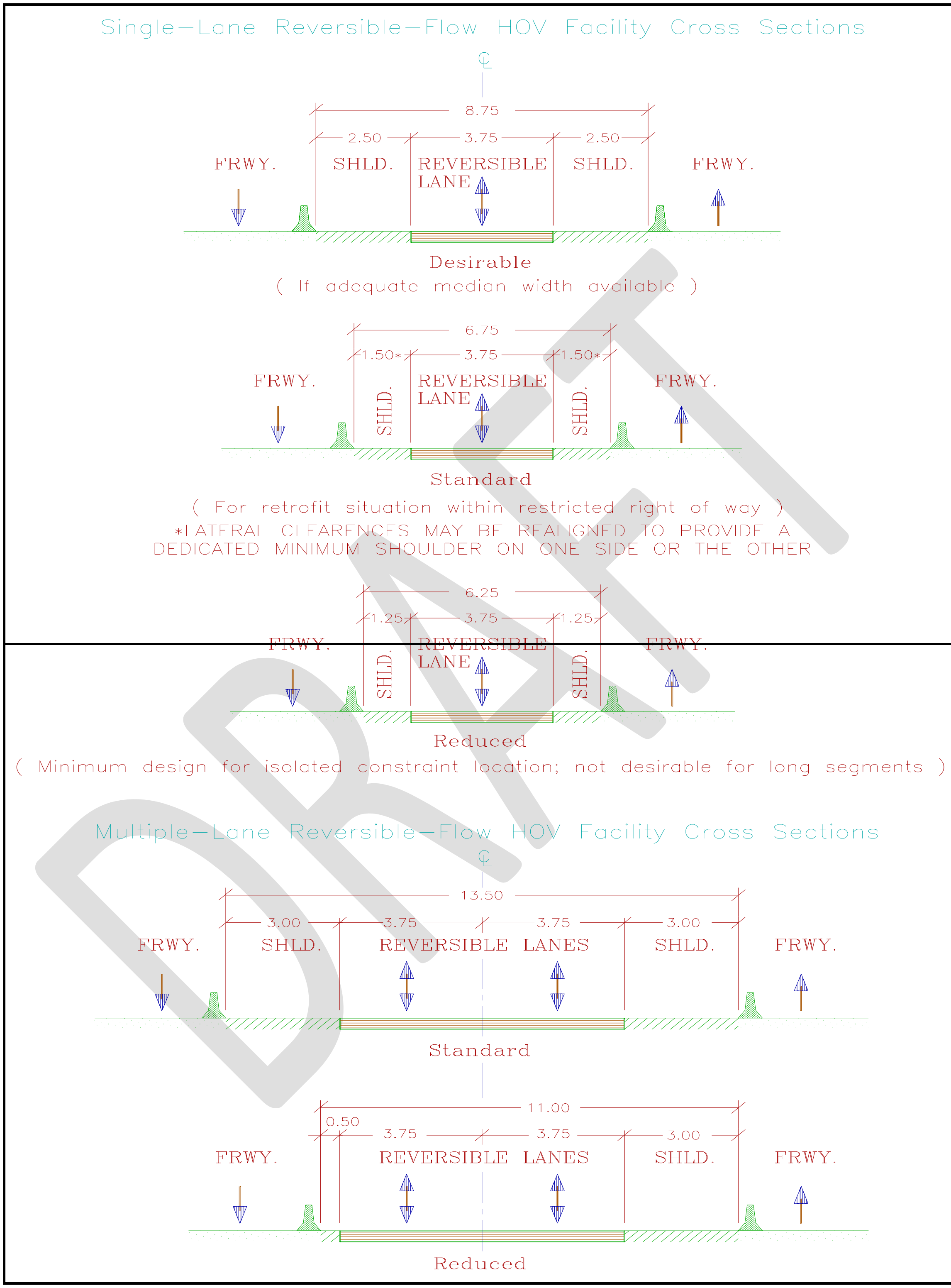
	Operational Issues		**Cost**		**Safety**	
	Pros	**Cons**	**Pros**	**Cons**	**Pros**	**Cons**
Reversible	●Efficient for moving vehicles longer distances ●Isolation from GP lanes improves flow ●Maximizes V/C ratio utility by putting lanes in the direction of greatest flow	●Not well known to drivers ●Complex operations ●Requires studies to determine optimal hours of operation ●Some proportion of demand will not be served ●Less suited to short trips	●Potentially less expensive than bi-directional facility ●May require less ROW ●May require less overpass, bridge and interchange construction	●Trade-off between cost and total access	●Requires a barrier separated system which reduces the risks due to traffic speed turbidity	●Requires additional signage and gates to prevent access to vehicles during off hours ●Requires more enforcement ●Requires extra development to ensure safety at system-to-system interchanges

Bi-Directional	●Can allow for buffer or alternate lane separation ●Can be operational 24hr/day ●Can be designed for short or long trips	●Provides more facility than demand requires in most off-peak hours	●Trade-off between cost and total access	●More expensive than reversible facility ●More overpass bridge and interchange construction often required ●Requires more ROW	●Never utilizes the same corridor for flow in opposite directions	●Does not require barrier systems which can reduce the risk of collision due to traffic speed turbidity
	Transferability		**Environmental**		**Social**	
	Pros	**Cons**	**Pros**	**Cons**	**Pros**	**Cons**
Reversible	●During system-to-system transfers between facilities with similar hours of operation and flow directions, the negative impacts are negligible, but the costs and operational improvemen-ts remain in place	●System-to-system interchanges may require additional engineering due to variations in peak hour directional flow ●Transference onto a radial corridor may not be possible ●Variations in hours of operation can complicate access	●May require less ROW ●May provide air quality improvemen-ts ●May reduce greenhouse gas emissions	●Does not maximize potential air quality benefits from both directions of traffic flow in locations with lower directional splits	●May require less ROW ●May have less impact on neighbouring land uses ●Shorter construction period has less impacts on surroundings	●Provides access in only one direction at a time
Bi-	●No hours of	●System-to-	●Potentially	●May require	●Provides	●May require

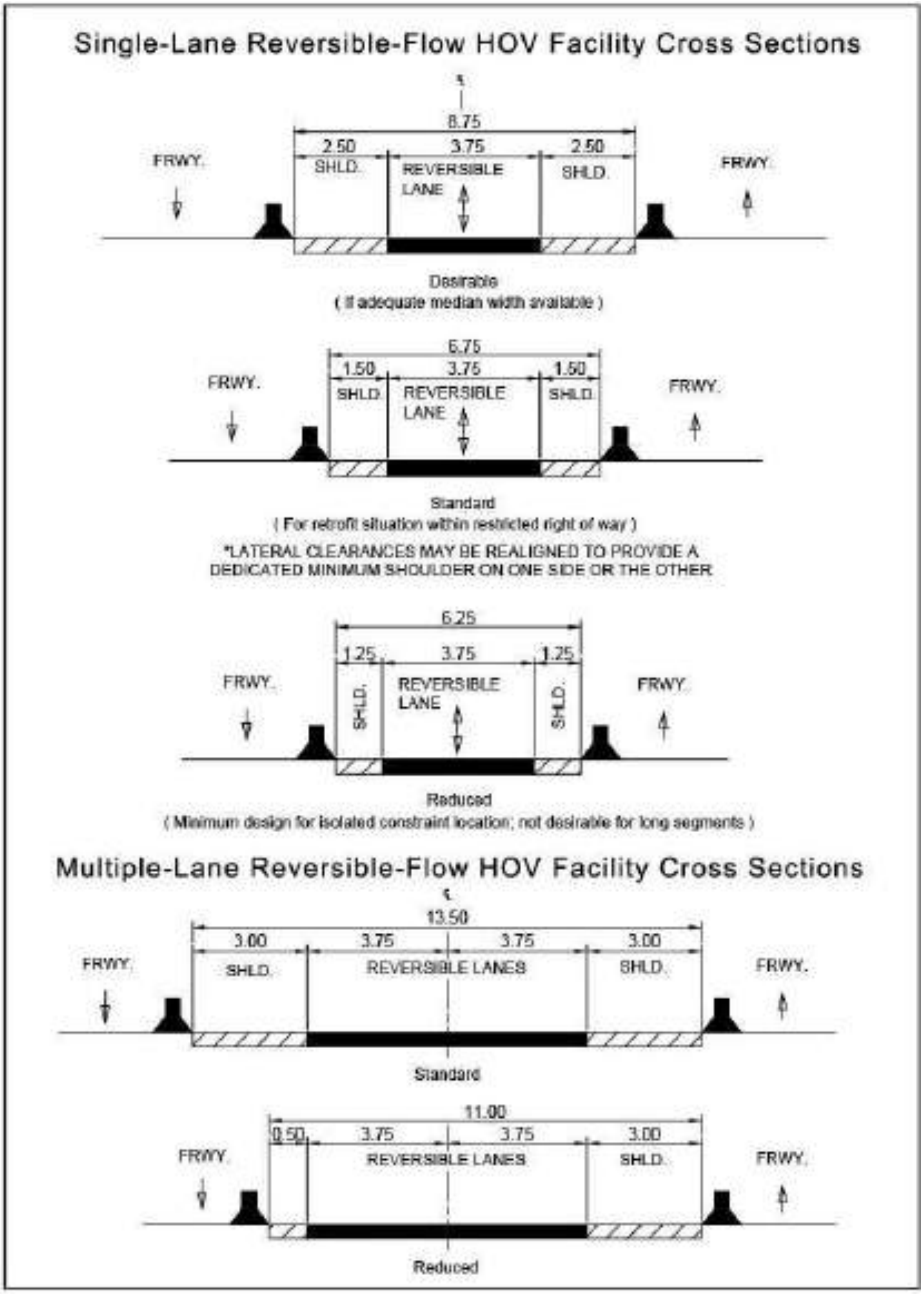
Directional	operation or one-way flows ●Normal routing and directional conditions ● Allows for continued access and transference along the managed lanes regardless of corridor shift	system interchanges may require more system connections than reversible system interchanges	maximizes air quality improvemen-ts ●May reduce greenhouse gas emissions	more ROW	access in both directions at potentially all hours	more ROW ●May have higher impact on neighbouring land uses ●Longer construction periods could lead to adverse impacts on surroundings

Exhibit 12AF
Reversible HOV Lanes


Single-Lane Reversible-Flow HOV Facility Cross Sections
8.75
2.50
3.75
2.50
SHLD.
REVERSIBLE LANE
SHLD.
FRWY.
FRWY.
Desirable
(If adequate median width available)
6.75
1.50
3.75
1.50
SHLD.
REVERSIBLE LANE
SHLD.
FRWY.
FRWY.
Standard
(For retrofit situation within restricted right of way)
*LATERAL CLEARANCES MAY BE REALIGNED TO PROVIDE A DEDICATED MINIMUM SHOULDER ON ONE SIDE OR THE OTHER
6.25
1.25
3.75
1.25
SHLD.
REVERSIBLE LANE
SHLD.
FRWY.
FRWY.
Reduced
(Minimum design for isolated constraint location; not desirable for long segments)
Multiple-Lane Reversible-Flow HOV Facility Cross Sections
13.50
3.00
3.75
3.75
3.00
SHLD.
REVERSIBLE LANES
SHLD.
FRWY.
FRWY.
Standard
11.00
0.50
3.75
3.75
3.00
REVERSIBLE LANES
SHLD.
FRWY.
FRWY.
Reduced



Single–Lane Reversible–Flow HOV Facility Cross Sections
8.75
2.50
3.75
2.50
FRWY.
SHLD.
REVERSIBLE LANE
SHLD.
FRWY.
Desirable
(If adequate median width available)
6.75
1.50*
3.75
1.50*
FRWY.
SHLD.
REVERSIBLE LANE
SHLD.
FRWY.
Standard
(For retrofit situation within restricted right of way)
*LATERAL CLEARENCES MAY BE REALIGNED TO PROVIDE A DEDICATED MINIMUM SHOULDER ON ONE SIDE OR THE OTHER
6.25
1.25
3.75
1.25
FRWY.
SHLD.
REVERSIBLE LANE
SHLD.
FRWY.
Reduced
(Minimum design for isolated constraint location; not desirable for long segments)
Multiple–Lane Reversible–Flow HOV Facility Cross Sections
13.50
3.00
3.75
3.75
3.00
FRWY.
SHLD.
REVERSIBLE LANES
SHLD.
FRWY.
Standard
11.00
0.50
3.75
3.75
3.00
FRWY.
REVERSIBLE LANES
SHLD.
FRWY.
Reduced



~~**Figure 12.5.14 Reversible HOV Lanes**~~

12.5.2.4 Queue Bypass – Main Line

In some circumstances, recurring queues develop on the provincial freeway system; examples include international border crossings/customs areas, toll plazas, ferry docks, exit ramp terminals, or constrained merging areas.- Opportunities may exist to give HOVs "head of the queue" priority treatment through a provision of a short right side or left side lane segment which bypasses the constriction and/or the resulting queue of vehicles.

A short, dedicated lane can be implemented around a point specific traffic bottleneck. This bottleneck may be operational or geometric in nature. The most common queue bypasses exist on approaches to bridges and tunnels, approaches to toll plazas, and metered entrance ramps. The bypass may be functional only for a ~~time~~ period of time that a queue typically forms, and some queue bypasses are now tolled at a differential rate from other lanes if implemented at a toll plaza.

An HOV bypass may be created by widening an existing ramp, constructing a new ramp where right--of--way is available, or reallocating the existing pavement width (provided the shoulders are full depth). Ramp meter bypass lanes may be located on the left or right of metered lanes. Typically, bypass lanes are located on the left side of the ramp (See **Figure 9.17.9**: Left-Turn Slip Around Design – Tangent Alignment of TAC GDG -2017 and **Exhibit 12AG~~Figure 12.5.15~~** below).

Any of the treatments described previously (reversible and concurrent lanes) can be used, in conjunction with a site-specific assessment of constraints and physical opportunities. -Where HOVs are required to merge with or weave across other traffic (e.g., at exit ramp terminals) careful operational review is required.

12.5.2.5 Metered Freeway Entrance Ramps

A key element of many Freeway Traffic Management Systems is ramp metering regulating the rate of vehicle entry onto the freeway.- This process is normally applied only during peak periods on a set of freeway entry ramps, resulting in a queue of vehicles being created on the on ramp upstream of the meter signal.- This peak period recurring queue provides an ideal opportunity for HOV bypass lanes, allowing HOVs to save up to several minutes.- Where a main line freeway bus service exits the freeway to intercept local passengers then re-enters the freeway via metered ramp, a ramp meter bypass lane is essential to avoid repeated delays to the bus.- Ramp meter bypass lanes may be provided in association with, or independent of, mainline freeway HOV lanes.

HOV ramp meter bypass are typically low-volume operations with relatively little risk of conflict between vehicles; HOV-only access ramps could be considered where a two-lane ramp is physically infeasible or if high HOV volumes result in safety concerns that cannot be resolved otherwise.- It is recommended that all metered ramps by provided with HOV queue bypass lanes where physically feasible (**Exhibit 12AH**~~Figure 12.5.16~~).

Exhibit 12AG

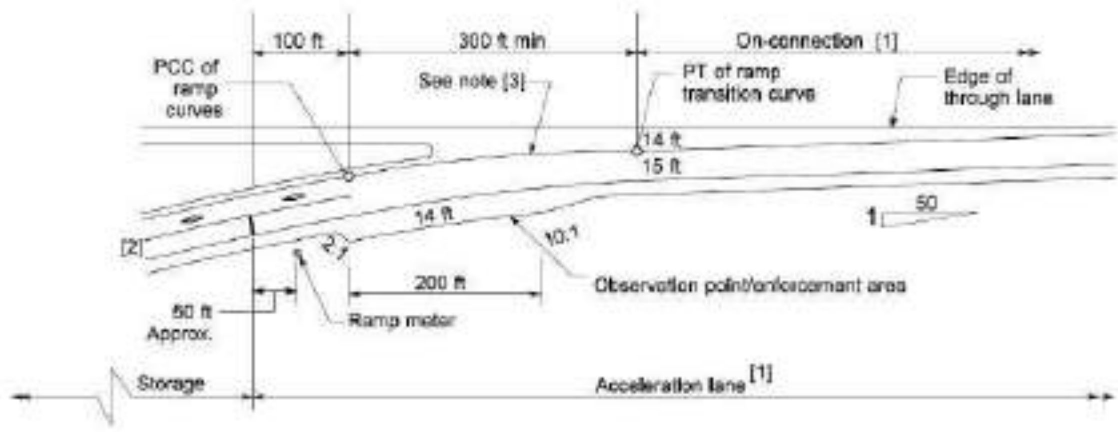
Queue By-Pass Lane- In Ontario a Slip-Around

Exhibit 12AH

Two-lane Ramp Including a Single Lane Ramp and a Single Metered Lane with an HOV Bypass

(*Source: WSDOT Design Manual June 2009)*

~~**Figure 12.5.15 Queue By-Pass Lane- In Ontario a Slip-Around**~~



~~Figure 12.5.16 Two-lane Ramp Including a Single Lane Ramp and a Single Metered Lane with an HOV Bypass (~~*~~Source: WSDOT Design Manual June 2009)~~*

12.5.2.5.1 General

HOV Bypass Design

1. The HOV bypass is designed to operate only during the time when the ramp is being metered. During off peak times, all traffic should use the main portion of the ramp. For this reason, the approach to bypass should be designed such that a conscious effort has to be made by the driver entering the bypass, see **Exhibit 12AI~~Figure~~**~~s~~ **~~12.5.17~~** and **~~12.5.18~~Exhibit 12AJ**.

2. A raised island up to 2.5 m (8 ft) wide with curb shall separate the HOV bypass from the main portion of ramp.

3. Free right turns adversely affect entrances to HOV bypasses.- If practical, designers should consider eliminating the free right turn when an HOV bypass is constructed. Where double left turn lanes (to the on-ramp) and an HOV bypass are present, free right turns shall not be allowed. **Exhibit 12AH~~Figure 12.5.16~~** shows an HOV bypass lane when double left turn lanes are present.

4. The Traffic Office should be contacted for input regarding queue length and storage.

5. If the projected peak traffic storage demand is such that an overflow from the storage area will block the entrance to the bypass lane, the storage length should be increased and additional lane width, striped as a diamond lane, should be provided (**Exhibit 12AI~~Figure 12.5.17~~ note 8**).

6. The minimum recommended length of a ramp is approximately 400 m (1300 ft). This length would allow entering vehicles to approach mainline speeds.

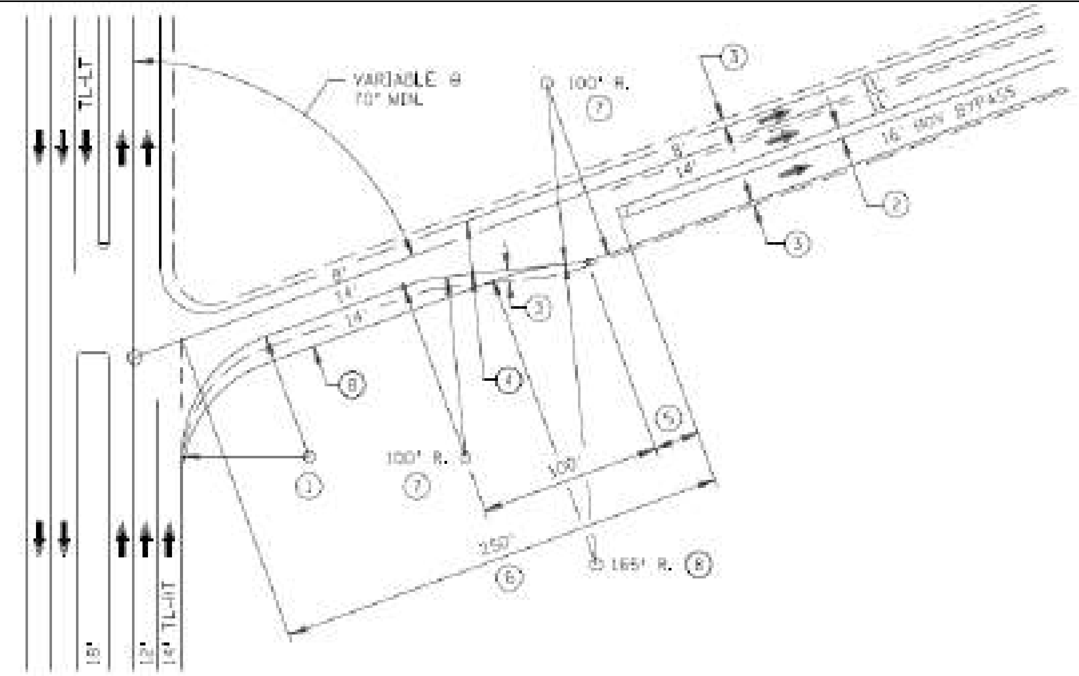
During periods of metering, the left side or outside lane will permit smooth bus re-entry onto entrance ramps from bus interface locations.- During periods of no queues on entrance ramps, buses re-entering from interface locations may turn directly into the right metered lane to avoid possible merging conflicts downstream.

Bypass lanes shall be designed such that the configuration can be easily modified to standard ramp lanes if their use by high occupancy vehicles (HOV's) is discontinued at the interchange.

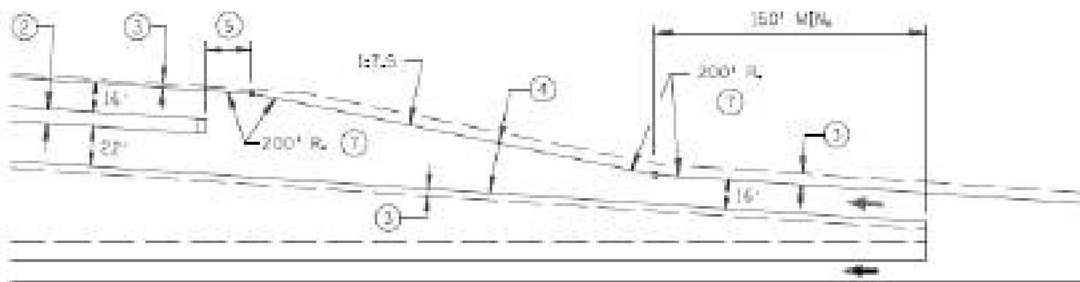
Exhibit 12AI

Ramp HOV Bypass

Source MnDOT Road Design Manual



RAMP H.O.V. BYPASS DESIGN



SYSTEM TO SYSTEM RAMP H.O.V. BYPASS DESIGN

1. SEE CHAPTER FIVE "AT-GRADE INTERSECTIONS" FOR INTERSECTION DETAILS.
2. USE A RAISED ISLAND UP TO 8' WIDE WITH B4 CURB ON ALL RAMPS.
3. FOR RURAL RAMP DESIGN PROVIDE: 6' RIGHT SHOULDER, 4' LEFT SHOULDER AND 2' H.O.V. RIGHT SHOULDER.
4. REPRESENTS B4 CURB LINE (GUTTER) IN URBAN DESIGN OR A STRIPE LINE IN RURAL DESIGN.
5. A TAPER P.I. 25' BACK OF THE RAISED MEDIAN NOSE.
6. 300' DIMENSION WHEN DEVELOPING RAMP TERMINAL WITH H.O.V. BYPASS FOR A DOUBLE LEFT TURNING MOVEMENT.
7. IN RURAL AREAS, THE RADII MAY BE OMITTED.
8. ON RAMPS AND LOOPS, WHEN ADEQUATE MINIMUM STORAGE CANNOT BE PROVIDED, PAVE ADDITIONAL LANE WIDTH AND STRIPE IT AS A DIAMOND LANE TO PROVIDE ADDITIONAL HOV BYPASS LENGTH.

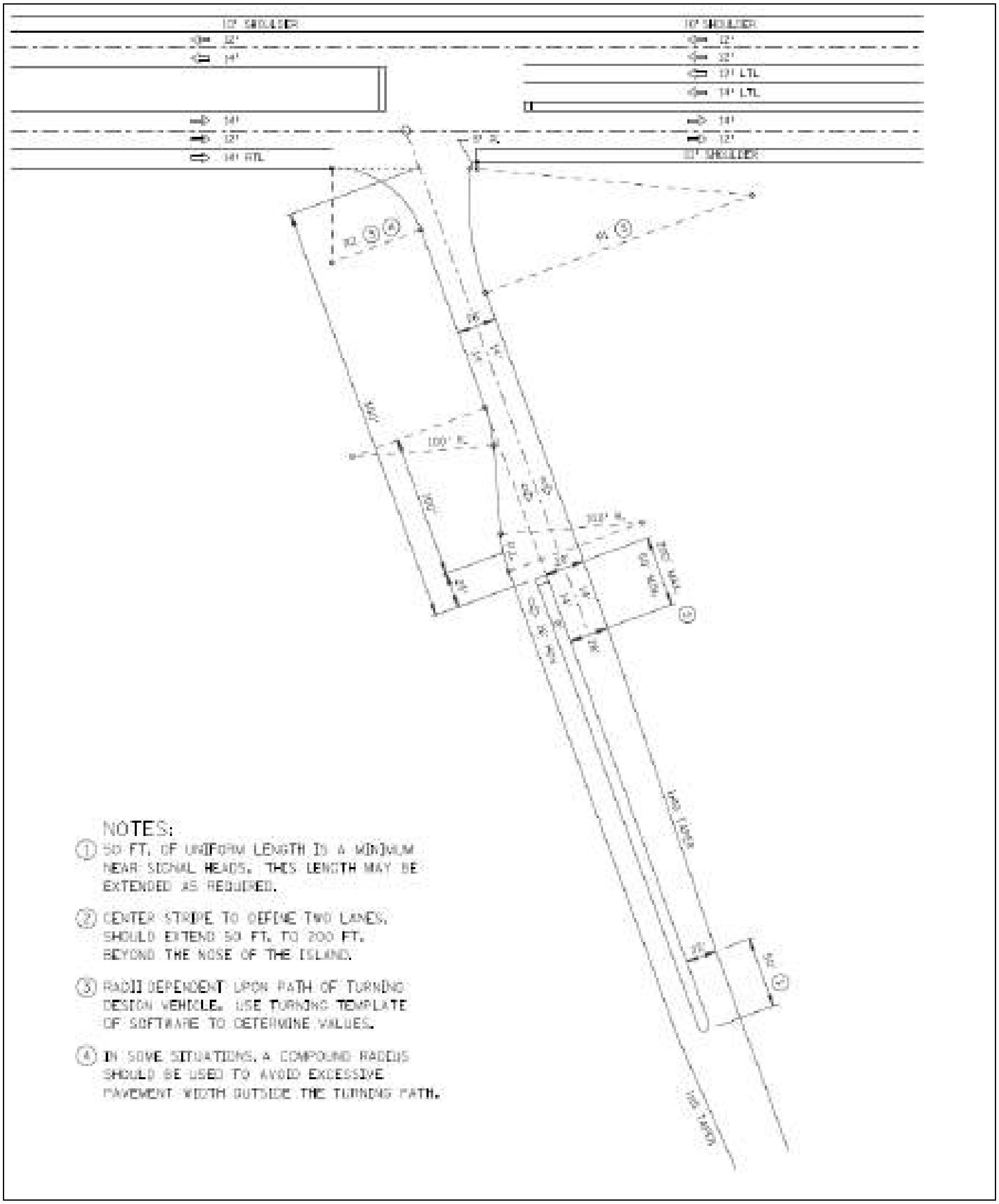
Exhibit 12AJ

Double Left Turn on Ramp with HOV Bypass Lane

Source MnDOT Road Design Manual

~~**Figure 12.5.17 Ramp HOV Bypass**~~

~~*Source MnDOT Road Design Manual*~~



~~**Figure 12.5.18 Double Left Turn on Ramp with HOV Bypass Lane**~~

~~*Source MnDOT Road Design Manual*~~

12.5.2.5.2 Crossing Road Exit Terminal and Transition Zone

Details of exit terminal design at the crossing road, illustrated in **Exhibit 12AK~~Figure12.5.19~~** and **Exhibit 12AL~~12.5.20~~** are found in **Chapter 10**, up to the bullnose.- Downstream of bullnose, a diverging taper shall be introduced on outside or left side of the ramp. -Start of taper should be at the bullnose and the length of taper should be adjusted to minimize the deflections created by the taper. Details of the taper are found in **Chapter 10**.

If more storage for ramp metering is required, then a two-lane crossing road exit may be considered, provided traffic control concerns are addressed, and approval is given by the Traffic Office.

At no point along the ramps shall the offset between the crossing road and the left edge of pavement on the ramp be less than 3.5 m~~etres~~.

12.5.2.5.3 Freeway Entrance Terminal and Transition Zone

Details of entrance terminal design at the freeway, depicted in **Exhibit 2AM~~Figure 12.5.21~~** are found in **Chapter 10**, downstream of the bullnose.

Upstream of bullnose, a merging taper shall be introduced on outside or left side of the ramp no less than 70 m in length measured from the bullnose.- The length of taper should be adjusted to minimize the deflections created by the taper.- It is important that safe merge conditions be designed however ramp metering queue length is diminished as the taper is extended. Location of the metering station is normally dependent on the taper and shall be no less than 100 m from the bullnose. -The parallel lanes of the ramp shall be no less than 30 m between the metering station and the start of taper.

At no point along the ramp shall the offset between the freeway edge of pavement and the left edge of pavement on the ramp be less than 3.6 m with curb and gutter or 4.6 m without curb and gutter.

12.5.2.5.4 Ramp Cross-Section

The entrance ramp between transition zones shall be designed to an ultimate two lanes with shoulders. -Paved shoulder should be provided on the right or inside of the ramp through the freeway terminal transition zone to permit possible merging vehicle runout. -In cases where bypass lanes are not to be constructed initially, grading should be undertaken to satisfy ultimate two-lane design. -Surfacing should be undertaken to provide single lane and appropriate shoulders.

The two-lane ramp shall have a paved width of no less than 7.75 m wide, however design widths indicated in **Chapter 4** should be used depending on radius of inner edge of pavement and traffic condition.

12.5.2.5.5 Safety Measures

A longitudinal barrier (double steel beam or concrete median barrier) shall be located along the outside of an inner loop ramp if unprotected clearance between inner loop and outer loop ramp is less than 10 m. Design of the barrier shall be in accordance with the **MTO Roadside Design Manual**. -An anti-glare screen may also be required.

Exhibit 12AK

"Parclo A" Interchange with Bypass Lanes