CHAPTER G

HOV LANES

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G.1.1 BACKGROUND

G.1.1.1 Introduction

Incorporating high-occupancy vehicle (HOV) facilities into the freeway system is one means of improving the operational conditions on freeways.

Among the many programs, policies, and facilities which can be used to encourage or require improved occupancy rates, the provision of lanes dedicated to use by the preferred vehicle types - High Occupancy Vehicle Lanes - in appropriate locations on provincial freeways can play a major role. The definition of a "High Occupancy Vehicle" may vary according to corridor needs and opportunities, and may range from "buses only" to "all vehicles carrying two or more persons". With no increase in vehicle movement, an HOV lane can carry two or three times as many people as a mixed-flow lane, and at a significantly improved Level of Service. Correspondingly, motorists in current severely congested mixed flow operation could cut their vehicle usage by half or more and have faster, more reliable trips by shifting to HOV use.

The fact that high levels of HOV use have not occurred naturally in response to increasing congestion (in fact, auto occupancy has continuously dropped for over two decades even as congestion has risen) highlights the market-driven nature of HOV facilities. HOV lanes are not simply physical facilities to move large numbers of people; they are agents of change in society, acting to induce travellers to use a more efficient mode than driving alone in a car, thereby producing, on a larger scale, the necessary freeway usage characteristics which will preserve the ability of the freeway infrastructure to accommodate current and future demands.

For Ontario's freeways to shift towards being person movement corridors from their traditional role as conduits for vehicle movement, certain physical and operational changes will be necessary, chief among them the provision on HOV lanes where appropriate.

G.1.1.2 Definition

The definition of a "High Occupancy Vehicle" is a policy decision that can be made on a province-wide, region-wide, or corridor-specific basis. Buses of all types, as well as cars and vans carrying a specified minimum number of persons are normally accepted as HOVs. Some HOV facilities may, for operational or policy reasons, restrict usage to public transit buses only; most freeway-based HOV facilities define eligible usage by two or more, three or more, or four or more persons criteria. A specific province-wide definition of "High Occupancy Vehicle" would not respond adequately to local and corridor needs, and is not recommended.

POLICY

THE PROVINCE SUPPORTS THE CREATION OF HIGH OCCUPANCY VEHICLE (HOV) LANES ON PROVINCIAL HIGHWAYS AND MUNICIPAL ROADS. A CAREFUL EXAMINATION OF THE NEED AND FEASIBILITY OF SUCH LANES WOULD BE NEEDED PRIOR TO THEIR INTRODUCTION IN ANY CORRIDOR.

It is recognized that there is a need to coordinate, plan and develop the HOV lanes in cooperation with appropriate municipalities to ensure proper integration with the current and future transportation system.

It is also recognized that support facilities, programs and incentives are essential for the success of HOV lanes.

G.1.1.3 Goals and Objectives

Any HOV initiative should be considered a subset of a Transportation Demand Management strategy, which is in turn one aspect of the provincial transportation system. Accordingly, the goals and objectives of an HOV incentive program (and its components such as HOV lanes) must be considered in the context of the overall goals of the provincial transportation system.

The provincial HOV policy has the following objectives:

- Maximize the use of existing roads and highways in the face of growing transportation demand.
- Reduce negative environmental effects of automobile commuting.
- Defer the costs for additional roads, highways and transit lines.
- Complement existing and future transit services, e.g. feed existing transit terminals (enhance ridership).

G.1.1.3.1 HOV Program

The goals and objectives of any potential provincial freeway HOV priority program are related to those of the transportation system as a whole. New elements in the system must be considered in both the short term (for initial operation or immediate application) and the long term (as "targets" in growth situations)time frame.

Table G1-1 summarizes the typical HOV goals and objectives relevant to the Ontario situation. Essentially, they are to accommodate growth without increasing congestion, to reduce energy use, and to improve transit efficiency by inducing modal shifts through making travel times shorter and more reliable compared to available non-HOV alternatives. It is important to note that, in areas of growth in demand, HOV strategies may not necessarily lead to a reduction in non-HOV congestion on a particular freeway; latent demand in parallel corridors, trips shifted to "shoulder" periods, and growth in use of all vehicle types will generally fill in any gaps in peak period mixed flow left by shifted HOVs within a short time.

Table G1-1

HOV PROGRAM - TYPICAL GOALS AND OBJECTIVES

Time Frame Focus	Goals	Objectives
Short Term / Corridor-Specific	• improve efficiency, effectiveness, and safety of current operation • ensure improved person-movement capability in corridor • provide for future growth in travel demand • identify strategies and programs which encourage ridesharing and transit use • identify means to reduce pollution and conserve energy, with respect to forecast change in energy use • reflect current and proposed land use plans in corridor	• increase overall corridor vehicle occupancy rates and decrease overall corridor travel time, relative to non-HOV alternative • identify Freeway Traffic Management and Transportation Demand Management initiatives to improve corridor efficiency • be compatible with environmental and energy policies • provide for accommodation of increased travel demand through the provision of preferential facilities in the corridor. • improve travel time reliability • safely operate preferential facilities • implement preferential facilities programs without adversely affecting existing corridor operation • reflect existing market (origin destination) patterns
Long Term / Areawide	• promote personal mobility throughout region • promote increased transit usage • promote improved integration between existing and proposed transportation services and facilities • further promote pollution reduction and energy conservation on a regional basis • support land use planning goals within service area	• increase overall regional vehicle occupancy rates and decrease average freeway system travel time relative to non-HOV alternative • provide facilities / programs which optimize use of the existing and future transportation infrastructure • identify opportunities for intermodal integration between HOV facilities / operations and regional transit systems • identify opportunities for Intelligent Vehicle / Highway System (IVHS) applications • promote concepts / strategies which are compatible with / supportive of a regional HOV program • be supportive of environmental and energy policies • accommodate growth in demand for travel through the provision of preferential facilities on the regional freeway network • identify opportunities for integration of HOV facilities with existing and future development

G.1.2 KEY PLANNING ISSUES

G.1.2.1 The Provision of 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, such as cost, time savings, existing usage, and so on; however, there are also planning goals, environmental requirements, and community interests to be considered.

In this context, the decision to provide an HOV lane can be based on an areawide planning / policy commitment to not encourage growth in single occupancy auto travel, or it can be a site-specific response to a congestion situation where an HOV lane is shown to be a better solution than any other alternative. In reality, there is a balance required between an areawide strategy and the needs and opportunities of a particular corridor.

It may be seen that HOV lanes can in fact be applied in many different situations, for various reasons, and with differing outcomes. The provincial freeway network in Ontario , consists only of QEW and the 400 series highways and in any location where regular recurring congestion occurs (i.e. within and around large urban centres) or is anticipated to occur, it is reasonable to consider the HOV lane option.

G.1.2.2 Freeway Expansion Versus Lane Conversion

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

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

- easily implemented;
- low cost;
- creates greatest HOV incentive (in part through penalizing non-HOV users);
- avoids creation of additional road capacity; and
- avoids community impact of road widening.

The proponency for building new HOV lanes stems from:

- avoids worsening existing congestion;
- minimizes risk;
- can be more readily designed to desirable standards;
- provides long term capacity to accommodate growth;
- realistically reflects current (and foreseeable) patterns of auto use; and,
- based on past experience, is politically / publicly more acceptable.

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

Where possible, the greatest public acceptance is obtained by adding a lane for HOV use rather than redesignating an existing mixed flow lane.

In the short term, it would be a serious mistake to include conversion of an existing congested freeway lane to HOV use as part of an initial or pilot project in Ontario. The resultant impact on mixed flow traffic congestion would, in all likelihood, generate a severe public opinion backlash and diversion to municipal roadways, and would increase, rather than decrease, overall delay, congestion and pollution. These conditions, apart from conflicting with the goals of HOV priority, pose a significant risk of having to abandon the project and the investment in it, and would make it exceedingly difficult to expand the HOV network to the extent necessary to begin producing significant benefits.

It should be noted that the proceeding discussion of freeway conditions does not necessarily apply to urban arterial roads, where heavy transit use / presence, significantly more flexible traffic operations, and community acceptance of transit priority measures may allow greater consideration of lane conversion plans in appropriate corridors.

G.1.2.3 Reserved Bus Lanes Versus Occupancy Rates of 2+ / 3+ Lanes

The establishment of a minimum vehicle occupancy rate for a particular 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 particular lane design. For example, 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) or to a severely restricted number of HOVs (e.g. 4+ designation). 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.

The same conditions apply on the arterial road network, and with the context being significantly different from a freeway setting, the eligibility decision may well vary as a consequence.

An areawide HOV strategy which recognizes these differences and which ensures that a cohesive, functional system develops is needed; consistency is desirable to the extent possible, but just as the freeway system is in many respects fundamentally different from the arterial road network, freeway HOV lanes will not necessarily be consistent in all respects with arterial HOV lanes. It is essential that these differences, where they occur, be communicated effectively to the motorist in general and to all HOV lane users in particular.

G.1.2.4 Use of HOV Lanes by Trucks

As with shared-use vehicles (carpools, buses), trucks have special needs and may warrant preferential treatment in light of their importance to the economy.

An issue which is likely to arise as a consequence is the potential use of HOV lanes by heavy trucks. This has been considered elsewhere, most often with respect to use of HOV lanes during off-peak (i.e. mid-day and overnight) periods by trucks. To date, there has been no implementation of the concept; it has been generally resisted for the following reasons:

- different operational characteristics between HOVs and heavy trucks within a single lane and associated safety issues
- truck travel patterns differ significantly from major HOV patterns in terms of origins, destinations and routes
- degradation of Level of Service offered HOVs, and consequent effect on incentive programs
- incompatible design characteristics for heavy truck use of direct ramps, weaving zones, etc.
- public perception of non-exclusivity of HOV lanes
- confusion regarding lane operation and enforcement

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. This regulation would need to change, for that is exactly where most HOV lanes are likely to be located.

POLICY

IN KEEPING WITH PRACTICE ELSEWHERE, AND WITH REGARD FOR THE CONCERNS NOTED ABOVE, IT IS RECOMMENDED THAT HEAVY TRUCKS NOT BE ALLOWED TO USE HOV LANES.

This recommendation applies to all trucks of more than 6.5m in length, no matter how many occupants it is carrying; a semi-trailer with, for example, a driver and a passenger in the cab will not be eligible to use an HOV 2+ lane.

G.1.3 OPERATIONAL POLICIES

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 the particular facility under study and the area-wide HOV system. The impact of these operational decisions can, in many cases, be greater than the provision of a particular facility on public attitudes towards, and use of, HOVs. The decisions centre on determining the most effective and beneficial use of the HOV facilities available. These involve striking a balance between:

- moving as many people in HOVs as possible;
- avoiding congestion in the HOV lane itself and at its points of interaction with mixed flow lanes; and
- ensuring the lane is adequately used, both relative to a non-HOV alternative and in the view of the public.

G.1.3.1 Eligible Vehicles

In Ontario, it is recommended that eligible vehicle types in HOV lanes and facilities include:

- cars, taxis, motorcycles, light trucks, and vans carrying at least a specified minimum number of people (minimum occupancy rate is addressed in detail in Section G.1.3.2.
- buses of all types, in or out of service
- service and emergency vehicles

Motorcycles should be considered eligible HOVs in Ontario only when carrying an eligible number of people; in particular this means motorcycles could only use 2+ HOV lanes.

Buses contribute substantially to a reduction in single-occupant vehicle travel; the operational efficiency gained in "dead heading" (running empty to a passenger pick up point) direction loads per day. It would be inappropriate (and perceptually inconsistent) to require empty buses to operate in congested mixed traffic lanes. All buses, be they private, public, large, small, scheduled or unscheduled, perform an HOV function; bus use of HOV lanes should not be restricted to public transit buses.

Regarding emergency vehicles, use of the lane by off-duty or unmarked enforcement vehicles would result in public perception of misuse of the lanes and should not be allowed.

G.1.3.2 Vehicle Occupancy

In many respects, the crux 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 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.

Although technological developments which hold the prospect of being able to "fine tune" lane usage are underway, development of a consistent province-wide approach is also required. Consistency in terms of actual HOV definition need not be applied province-wide, however; each HOV treatment should be assessed with regard to consistency in the context of its corridor needs, adjoining HOV systems, and travel/demand patterns.

G.1.3.2.1 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, in order 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 very sensitive to 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 sensitive to 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 in order 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.

G.1.3.2.2 Minimum Lane Usage

The key measure of effectiveness is whether the HOV lane is carrying 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).

G.1.4 ENFORCEMENT NEEDS

HOV lanes, with their usage restrictions and specific operational characteristics, add a new layer of complexity to the road system. Enforcement requirements reflect the need to preserve the function and safety of the HOV facility as well as its public support/acceptance. These enforcement needs are in addition to the normal safety, emergency, and operational duties associated with any urban freeway. Although HOV lanes can, to some extent, be designed to reduce the potential for use by ineligible vehicles, enforcement agencies still need to monitor the following functions:

- vehicle eligibility (occupancy rate, vehicle type)
- safety (particularly lane access/egress)
- traffic operations (speeding, following distance, etc. in both HOV and mixed flow lanes)

When enforcing HOV lane usage, enforcement officers must deal with both drivers who violate the HOV restrictions unwittingly (unaware of signage, unsure of eligibility, etc.) and those who intentionally use the HOV lane in an ineligible vehicle in an attempt to bypass congestion.

Both province-wide and area-wide consistency in these areas will support the effectiveness of any enforcement strategy, and are important in ensuring public awareness, understanding and compliance. In this section, the planning needs of enforcement are outlined; the design of physical facilities related to enforcement activities is dealt with separately in Section G.2.4.4.

G.2 DESIGN GUIDELINES

G.2.1 FREEWAY HOV LANE DESIGN CONCEPTS

The essential principle of a High Occupancy Vehicle (HOV) facility or program is to give the preferred mode (HOVs) priority over non-HOVs from the mixed traffic flow, so that they can operate in an efficient high-speed, unimpeded manner. Different types of HOV lanes are outlined in Figure G2-1.

The application of a particular type of HOV lane will depend directly on the 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.

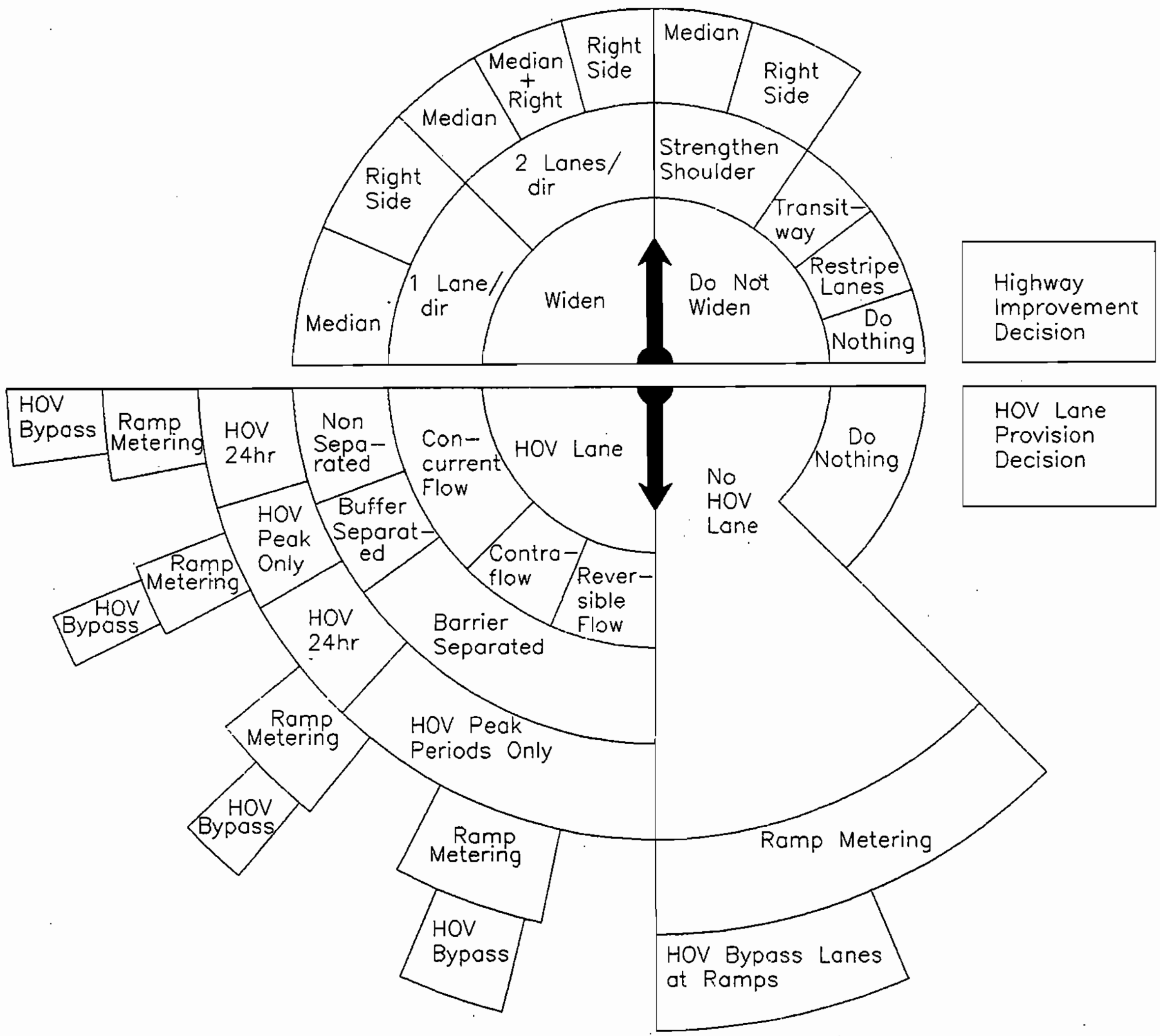


Figure G2-1
HOV Conceptual Alternatives

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 comment as to appropriate applications in the Ontario context are made.

It is important to note that, since HOV lanes are most often implemented after a freeway has been designed and operated for several years, the use of a "standard" design is not always possible. Compromises, constraints, and unique design features are more likely to apply and it is for these reasons that the following pages outline a variety of cross-sections without defining an "MTO standard". The evolution of defined standards will stem from application, experience, and further technical work in Ontario.

G.2.1.1 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 the HOV traffic from the adjacent freeway lanes, and the HOV lane's position on either the left (median) or the right side of the general traffic lanes. In virtually all applications to date, concurrent flow HOV lanes have been provided in both directions of travel, thereby creating a two-way HOV route.

Median HOV lanes, be they concurrent or reversible flow operation, 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 the degree of separation provided from the adjacent general traffic lanes. A physical barrier, a painted buffer zone, or a simple painted line may be used.

a) Barrier Separation

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

Figure G2-2 illustrates recommended cross-sections for barrier-separated median HOV lanes. It may be observed that few urban freeways in Ontario have preserved adequate median width to allow the retrofit of barrier-separated lanes.

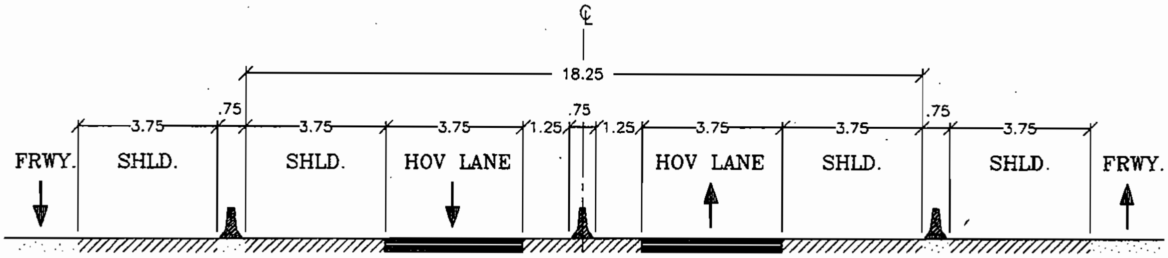
b) Buffer Separation

A more flexible approach is the separation of HOV lanes from general lanes by a painted buffer or line; although less easily enforced and perceived by drivers to be less safe (although, in a number of applications, no significant differences from pre-HOV lane accident rates have been found) the elimination of the barrier reduces right-of-way needs, improves maintenance and snow removal operations, and allows all HOVs access to the lane for at least part of their trip. The ability to designate the HOV 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 is also protected by the non-separated option; barrier-and buffer-separated HOV lanes, on the other hand, invariably operate 24 hours per day in HOV mode.

Experimentation with a variety of buffer widths has led to the conclusion that a 1.25 m wide painted (double white stripe) buffer between the HOV lane and the adjacent mixed flow lane is the preferred design; the buffer clearly separates the HOV lane from adjacent traffic and provides a margin of comfort which reflects the typically high speed differential between the lanes, yet minimizes the overall cross-section requirements. It is recommended that a buffer of more than 1.5 m width not be provided, as it has been shown to be perceived as a place of refuge for stopped or stalled vehicles, with potential safety consequences. Cross-sections for buffer-separated HOV lanes follow in Figure G2-3.

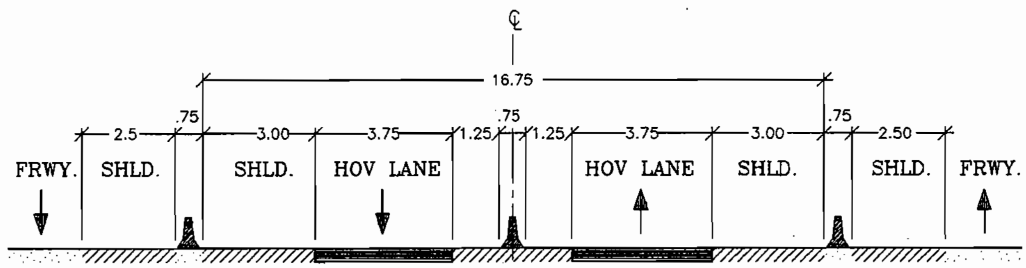
c) Non-Separated

A number of HOV 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 HOV lane, this non-separated approach is suited to peak period only HOV lanes or in severely constrained rights-of-way, but HOV lane operation will tend to be slower and less relaxing due to driver uneasiness about the proximity of slow-moving or stationary traffic and the adjacent mixed-flow lane. This may translate into some reduction in HOV lane capacity (Table G2-1), and in the extreme case, may place an upper limit on the speed differential between the HOV lane and the adjacent mixed flow lane of in the order of 40 km/h. It is important to note that an HOV lane which is used only during peak periods and which reverts to mixed flow use at other times should appear to be a "normal" lane, with no buffer zone or solid stripe between it and the other mixed flow lanes. This factor comes into consideration



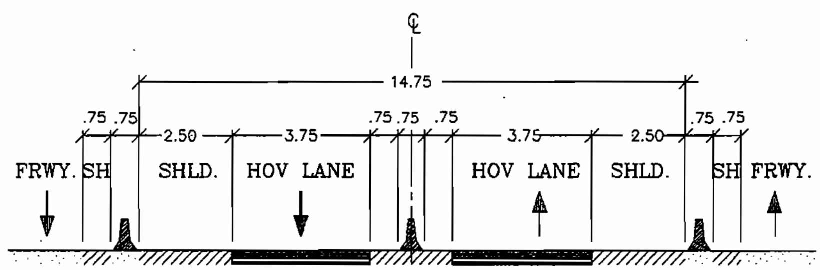
Desirable

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



Standard

APPLICATION
- Reduce shoulder widths, allow retrofit within restricted ROW

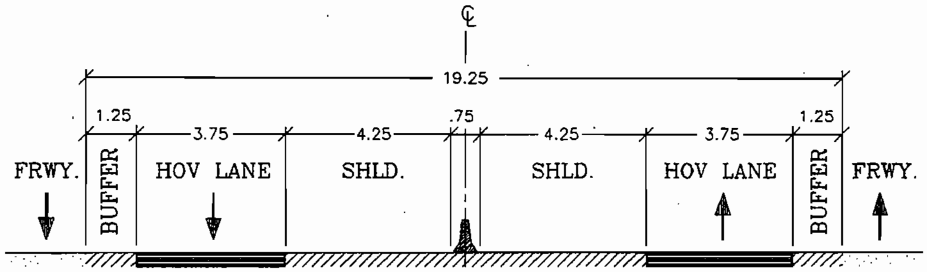


Reduced

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

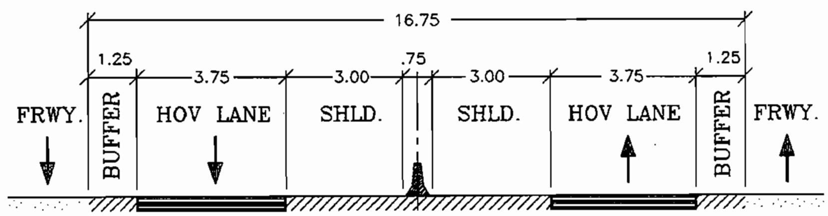
NOTE:
- Within barriers, shoulder can be located either left or right of the HOV lane; right side only is shown here
- illumination, drainage, barrier design vary according to corridor needs.

Figure G2-2
Two-Way Barrier-Separated HOV Facility Cross-Sections



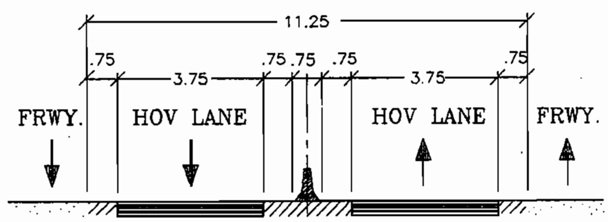
Desirable

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



Standard

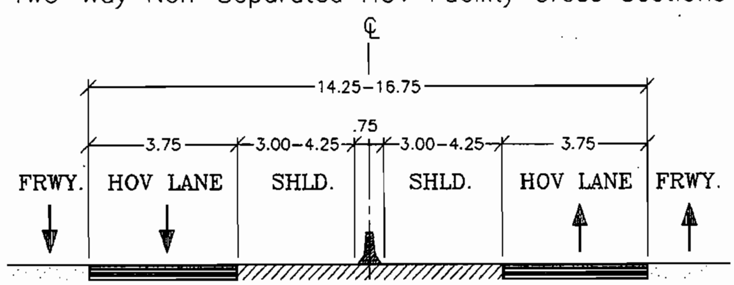
APPLICATION
- Reduce shoulder widths, allow retrofit within restricted ROW
- shoulder width increased at enforcement areas



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 G2-3
Two-Way Buffer-Separated HOV Facility Cross-Sections

with a pilot project, where, it the lane is not well-utilized, it may change from 24 hour to peak-only HOV operation after a trial period.

d) Variability

The implementation of HOV lanes as added lanes on Ontario freeways will involve, in many cases, geometric compromises in order to utilize existing structures or minimize impact and cost. For this reason a range of alternatives have been illustrated in Figures G2.2 and G2.3.

An illustration of a typical constrained situation at a median bridge pier follows on Figure G2-4.

The fact that there is no single design "standard" is a concern (both with respect to freeway planning/design and in the event of legal liability proceedings). In that respect, HOV lanes are governed by general freeway design standards, and exceptions to the standards will need a sound justification and senior level of approval.

When faced with a restricted envelope or section of a corridor within which to retrofit an HOV facility, the designer may compromise on the least essential cross-section elements first. General practice provides the following guidelines:

Table G2-1

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
≥ 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 mixed-flow freeway traffic lanes per direction
- obstruction on one side of HOV lane; adequate shoulder (≥ 2 m wide) on other side of lane

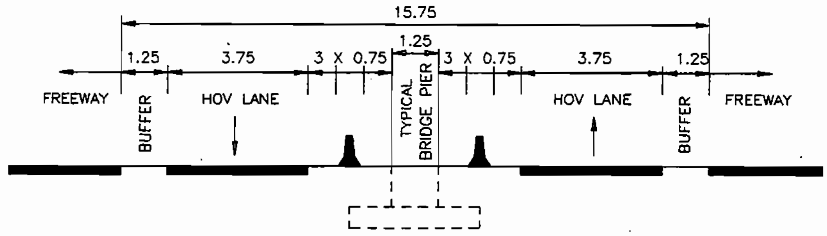
Table G2-2

GUIDELINES FOR RESTRICTED SECTION TO RETROFIT A MEDIAN HOV FACILITY (CONCURRENT FLOW)

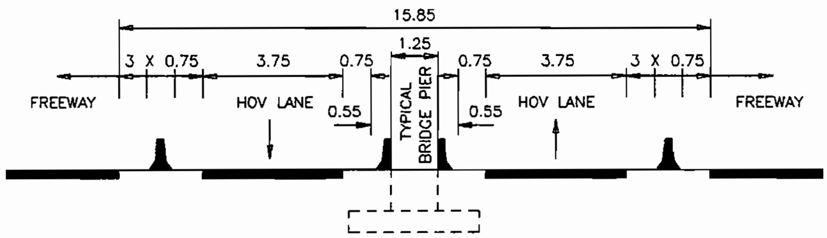
Compromise	HOV Lane Type	
	Two-Way Barrier-Separated	Two-Way Buffer-Separated
First	Reduce left HOV lane lateral clearance to no less than 0.6 m	Reduce left HOV lane lateral clearance to no less than 0.6 m
Second	Reduce right HOV lane lateral clearance to no less than 2.5 m	Reduce freeway right lateral 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 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 HOV lane width to no less than 3.35 m (consider reversing fifth and sixth steps when buses are projected to use the 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 HOV and mixed-flow lanes.
Eighth	Convert barrier shape at columns to a vertical face.	

Restricted Median Width

Buffer Separated HOV

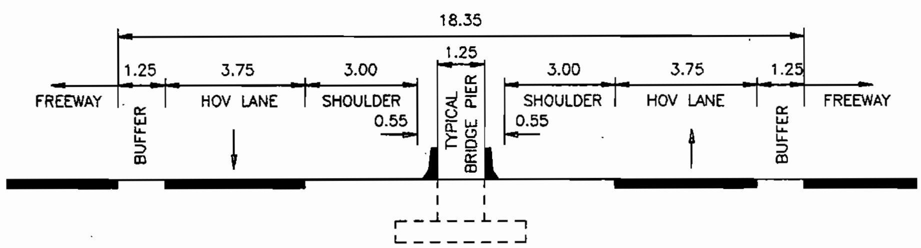


Barrier Separated HOV



Desirable Median Width

Buffer Separated HOV



Barrier Separated HOV

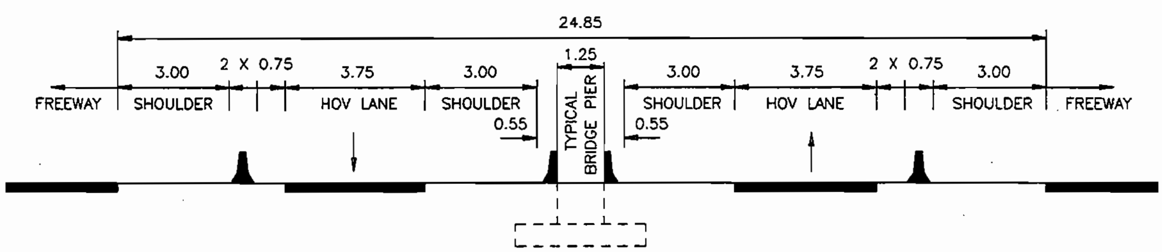


Figure G2-4
HOV Lanes at Median Pier

G.2.1.2 Concurrent Flow - Right Lane

a) Right Lane Use

The location of HOV lanes on the outer (right hand) lanes of a freeway can effectively resolve some of the issues associated with a median HOV alternative. However, it poses new operational challenges, particularly at interchanges. The right lane application has been far less common to date, as major radial corridors have been the first areas to receive attention, but recognition is increasingly being given to the issue of suburban congestion on non-radial routes. Many freeways now exhibit a wide range of trip length, including local (intracity) travel, long-distance commuting, and provincial intercity trips. Multi-nodal origin/destination patterns emerge as urban centres develop and relatively frequent interchanges provide ready access to the freeway.

In the context of such frequent on-off patterns, right lane HOV systems may address the transit needs and short distance HOV trip patterns at lower cost than median HOV lanes. In other cases, severe physical constraints, inadequate right-of-way, or structural requirements may effectively preclude a median HOV lane, forcing a review of outside lane options. Another application of right side HOV lanes has been as a low-cost, easily implemented temporary or pilot project facility, or as an early stage towards a more permanent HOV lane. The most common use of right side HOV lanes, however, 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 HOV lane could apply equally well.

For freeway conditions, right side HOV lane operation is constrained by the necessary 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 1100 vehicles/h rather than 1500 vehicles/h. 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 the 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.

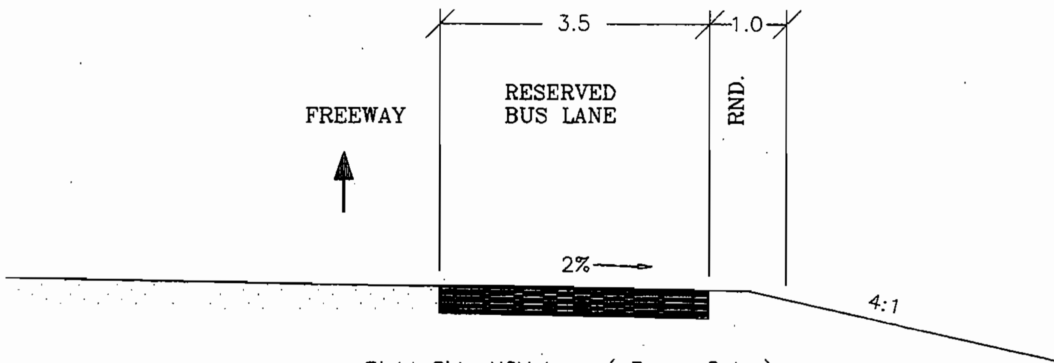
The right side HOV lane can be separated from the adjacent mixed flow lane by either a narrow buffer (1.25 m±) or paint lines; the approach does not lend itself to barrier separation due to the transitions which must be made at interchange ramps. If the lane is used by moving traffic at all times (i.e. it does not convert to shoulder use in off-peak periods) a standard permanent shoulder should be provided. In this respect the right side HOV lane design standards are identical to those for any freeway lane. Figure G2-5 illustrates a typical cross-section.

b) Right Shoulder Use

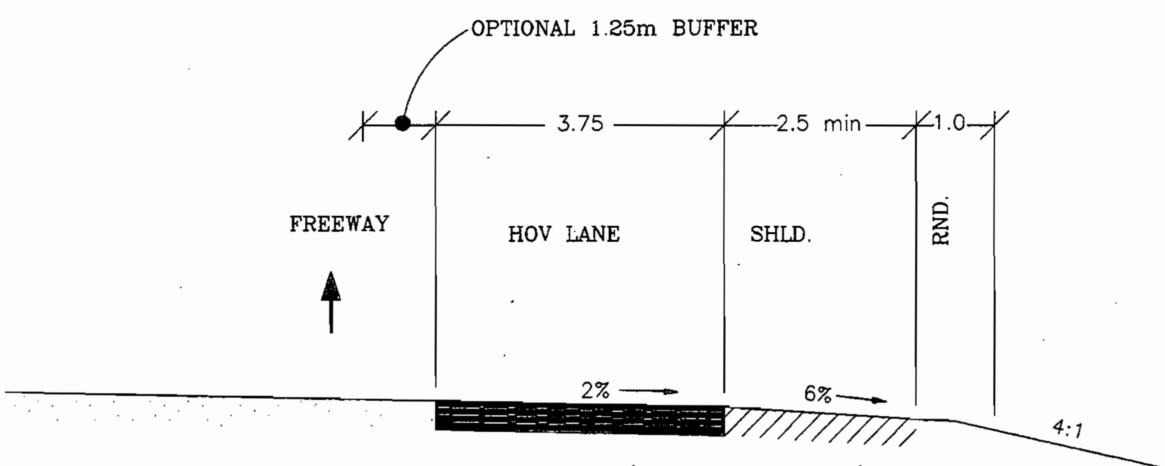
A right shoulder may be utilized as an HOV lane on a temporary or peak period basis. Rather than permanently occupying the right lane of a freeway, a right shoulder can provide HOV priority when most beneficial, and revert to its "normal" usage at other times.

In order to do so, the pavement must be strong enough to allow daily usage by transit vehicles; in practice this means pavement depth equivalent to adjacent lanes. Additional requirements are for adequate width: 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 (see Figure G2.5). Associated with the change in function of the shoulder may be the need to 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 HOV 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.



Right Side HOV Lane (Buses Only)
(Peak Period Operation)



Right Side HOV Lane (Including Carpools)
(All Day Operation)

Figure G2-5
Right Side HOV Lane

G.2.1.3 Reversible Flow

A reversible flow HOV lane is typically applied on a radial downtown-oriented freeway, and operates inbound only during the morning peak period and outbound only in the afternoon peak period. It is suited to a corridor where there is a very high directional split in the peak period (at least 65% of all traffic on the freeway under study travelling in the peak direction) and is often used in a corridor where extreme physical constraints preclude the designation of more than a single lane for HOV use.

In other cases, 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 located in the median of the freeway in order 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 therefore only appropriate when strong corridor demand directionality is a permanent characteristic.

The ability to provide access to/from reversible lane is normally restricted and consequently 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.

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% in 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. High mast light standards and sign support footings also utilize the median.

Specialized signage, access designs, and daily operational needs are additional factors which enter into consideration of 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 the 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 Figure G2-6.

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. In such circumstances, compromises or design elements should follow the following sequence shown in Table G2-3.

Table G2-3

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.

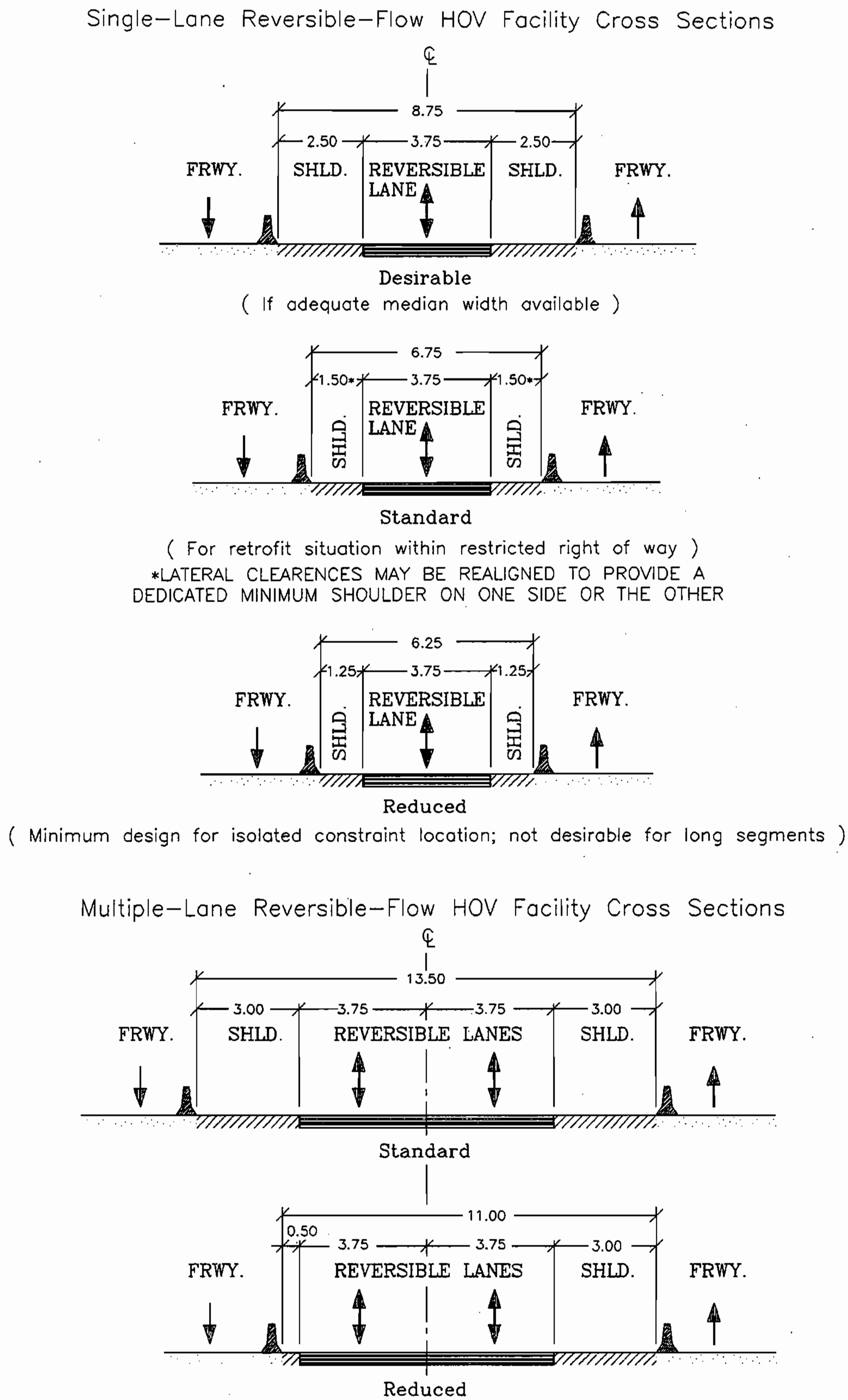


Figure G2-6
Reversible HOV Lanes

G.2.1.4 Queue Bypass - Main Line

In some circumstances, recurring queues develop on or are associated with 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. In terms of time savings and incentive for HOV use, such bypass lanes can be equivalent to several times the length of mainline HOV lane; for example, a 1 km long HOV bypass operating at 60 km/h past a 10 minute standing queue saves the same amount of time as a 13 km long main line HOV lane on a freeway operating at 60 km/h.

Any of the treatments described previously (reversible, concurrent, and contraflow 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.

G.2.1.5 Metered Ramp Bypass Lanes

A key element of many Freeway Traffic Management Systems is ramp metering regulating the rate of entry of vehicles 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 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. In cases 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; Directive B-247 has been issued to ensure the acquisition of adequate property at new freeway interchanges to allow the widened ramps.

G.2.1.5.1 General

POLICY

BYPASS LANES SHALL ALWAYS BE LOCATED ON THE LEFT SIDE OR OUTSIDE OF A PARCLO "A" INTERCHANGE DIRECT OR INNER LOOP ENTRANCE RAMP WHICH IS TO BE METERED, THEREFORE RETAINING CONSISTENCY IN DESIGN WHICH MOTORISTS WILL BECOME FAMILIAR WITH AND DEPEND ON. SEE FIGURE G2-7.

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.

G.2.1.5.2 Crossing Road Exit Terminal and Transition Zone

Details of exit terminal design at the crossing road, depicted in Figure G2-8, are found in Chapter F, up to the bullnose.

Downstream of the bullnose, a diverging taper shall be introduced on the outside or left side of the ramp . Start of taper should be at the bullnose. The length of taper should be adjusted to minimize the deflections created by the taper.Details of the taper are found in Chapter F.

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 Regional 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 metres.

G.2.1.5.3 Freeway Entrance Terminal and Transition Zone

Details of entrance terminal design at the freeway, depicted in Figure G2-9 are found in Chapter F, downstream of the bullnose.

Upstream of the bullnose, a merging taper shall be introduced on the 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 100m 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.

G.2.1.5.4 Ramp Cross-Section

The entrance ramp between transition zones shall be designed to an ultimate 2 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 2-lane design. Surfacing should be undertaken to provide single lane and appropriate shoulders.

The 2-lane ramp shall have a paved width of no less than 7.75 m wide, however design widths indicated in Chapter E should be used depending on radius of inner edge of pavement and traffic condition.

G.2.1.5.5 Safety Measures

A longitudinal barrier (double steel beam or concrete median barrier, shall be located along the outside of an inner loop ramp if the unprotected clearance between the inner loop and outer loop ramp is less than 10m. Design of the barrier shall be in accordance with the "Roadside Safety Manual".

An expanded metal anti-glare screen may also be required.

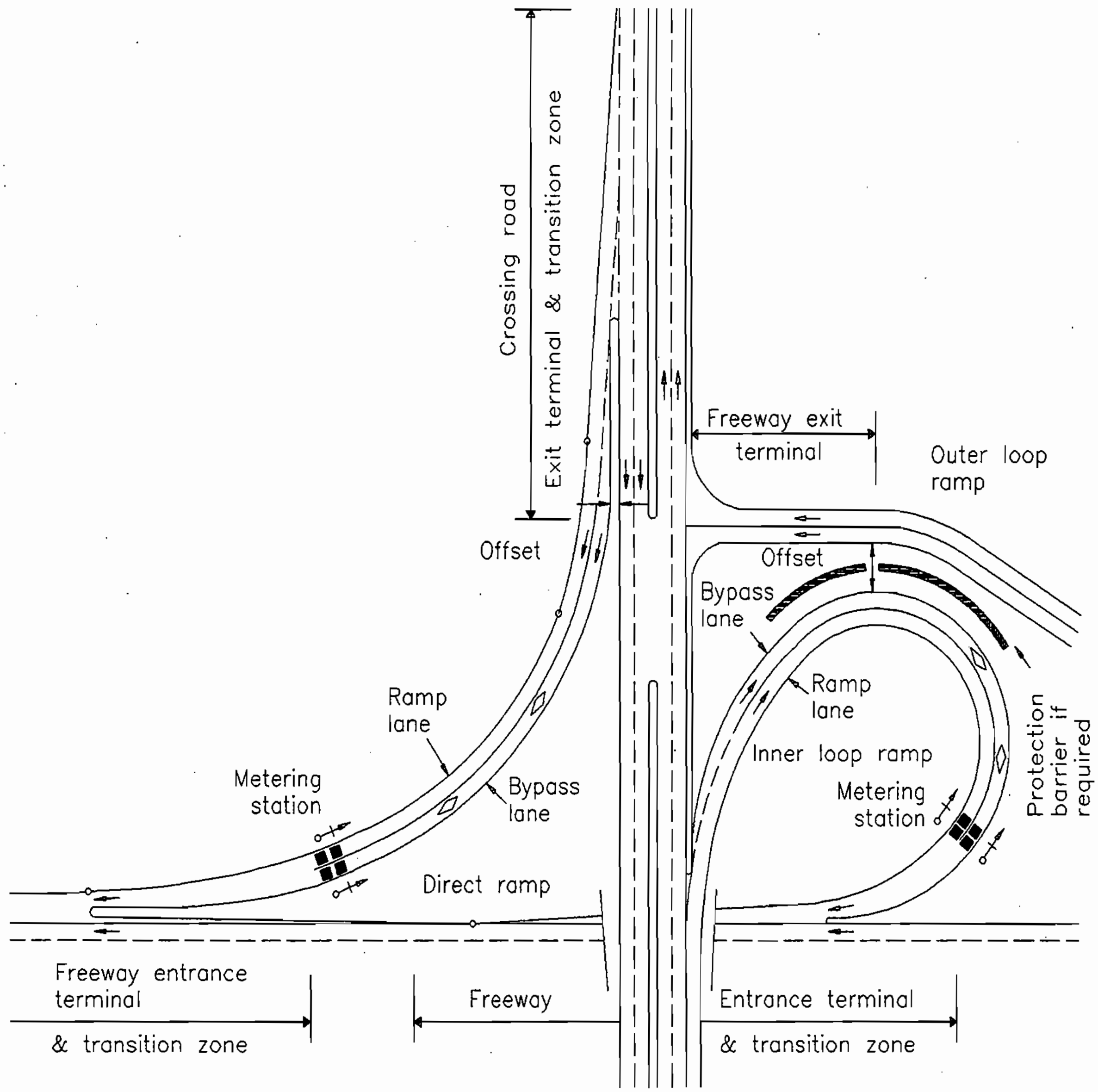


Figure G2-7
"Parclo A" Interchange with Bypass Lanes

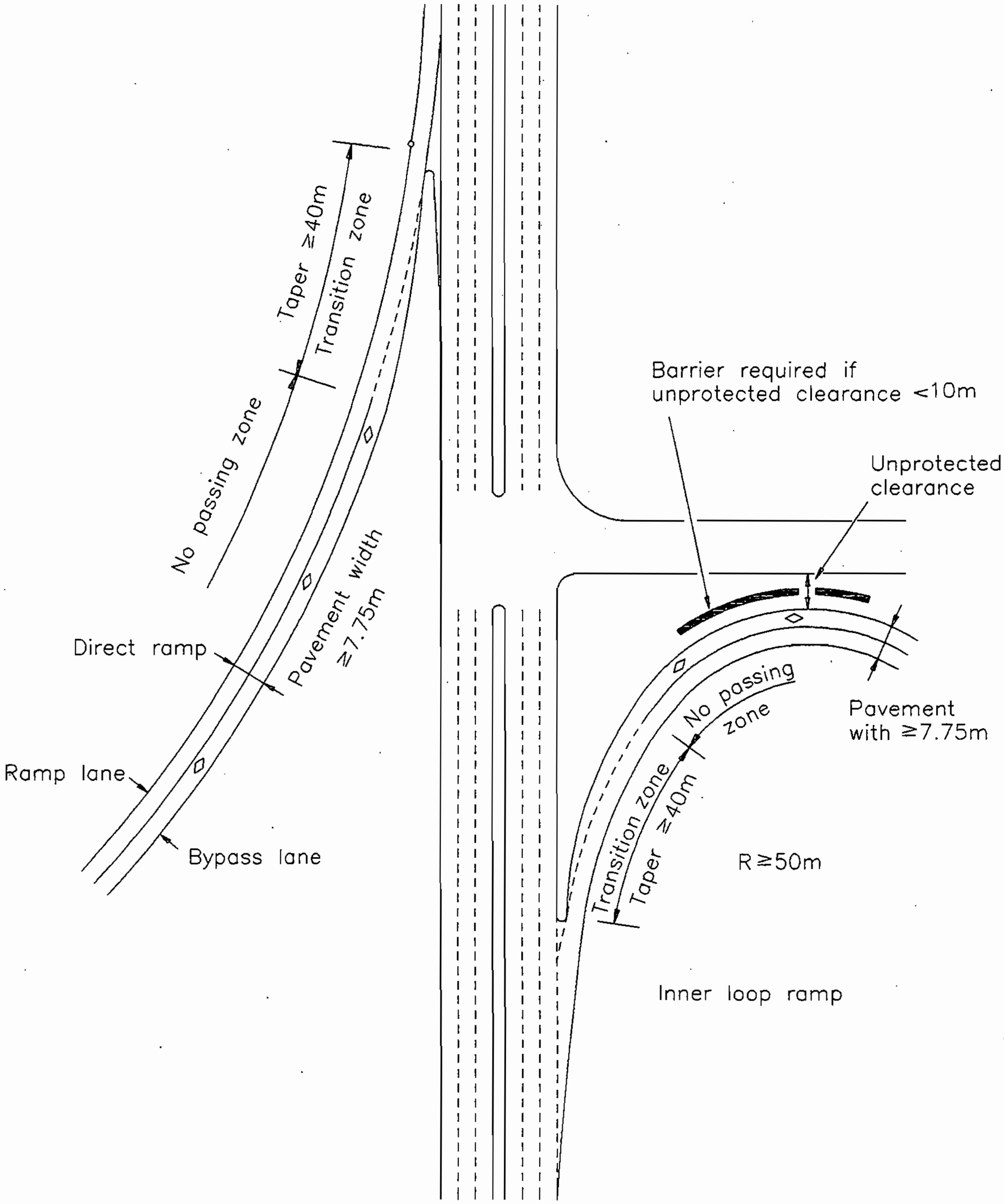


Figure G2-8
Crossing Road Exit Terminals at "Parclo A" Interchanges

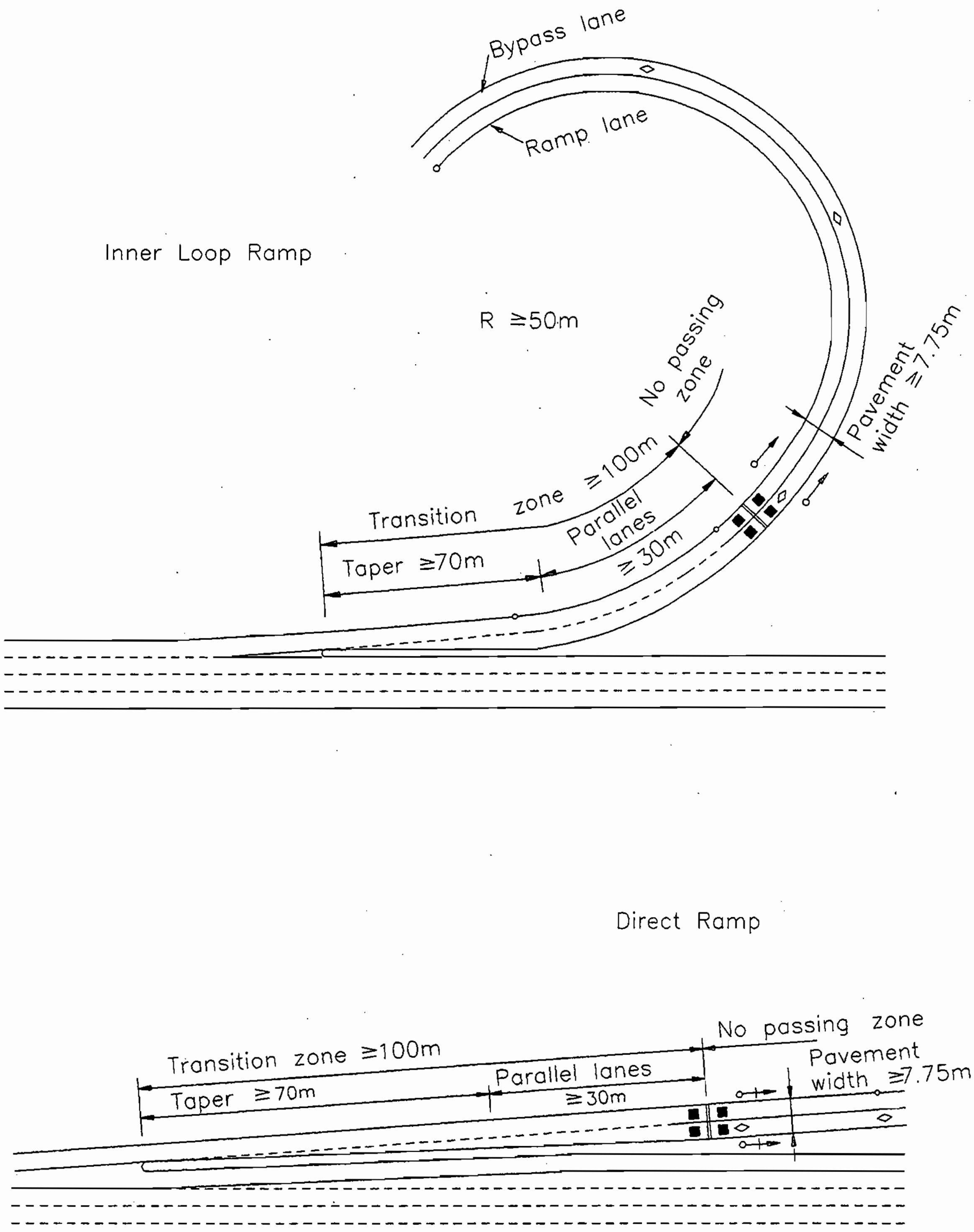


Figure G2-9
Freeway Entrance Terminals with Bypass Lanes

G.2.1.6 Separate HOV Roadway

A separate roadway dedicated to HOV use can be applied where there is a very high volume of HOVs, where a freeway facility is physically incapable of accommodating necessary HOV provisions, where the desired operational characteristics require off-line facilities, or where a barrier-separated exclusive access facility can be provided within a freeway right-of-way.

The Transitways planned to date in Ontario have not considered the potential use of the facility by other HOVs, notably carpools, vanpools and/or taxis. The planning principles for an HOV roadway open to carpools and vanpools would be similar to those used for the Ottawa or Mississauga Transitways but several design details would require modification in order to make the facility safe and suitable for all HOVs. Key design issues have been outlined in Table G2-4.

In addition, the design of stations, access to/from the facility from crossing roads, and the planning strategy for park and ride/park and pool lots would alter.

Since the higher design speed for an HOV facility could act as a significant constraint in this development and design (e.g. a minimum horizontal radius of 650 m is required for 120 km/h operation, while only 250 m radius is required for 80 km/h operation), it must be considered in the local context. Since the intent of the facility is to provide a faster overall trip time for HOVs compared to the mixed flow alterative, use of a higher design speed would be appropriate in an area where the HOV route parallels, or is an alternative to, a freeway; in urban arterial areas, a lower design speed could be used as long as a net benefit still accrued to the HOV user. The reduction of design speed in an area of physically constrained right-of-way may also be acceptable if it were safe and would not eliminate the benefits of HOV.

Table G2-4

KEY DESIGN ISSUES FOR SEPARATE HOV ROADWAYS

Design Element	Busway Standard (Typical)	HOV Standard (Desirable)
Design Speed for Vertical and Horizontal Main Line Alignment	80 km/h	120 km/h
Median Treatment	Solid Painted Line	Physical Barrier
Entrance Ramps	Direct Entry / Intersections	Acceleration Lane / Free Flow

G.2.2 HOV LANE ACCESS/EGRESS PROVISIONS

One of the unique aspects of HOV lane design is the specialized provisions which can be made for access to and from the lane by HOVs. The needs for various access types depend on the traffic patterns and physical opportunities present in a particular corridor under study. They further depend on the HOV lane type being considered and its operational characteristics, Table G2-5 provides a brief overview of the situations in which various access provisions may be considered.

Table G2-5

APPLICATION OF HOV LANE ACCESS PROVISIONS

Access/Egress Type		HOV Lane Type				
		Concurrent Flow				Reversible Flow
		Median			Right Side	
		Barrier	Buffer	Non-Separated		
At-Grade	Continuous (unrestricted)	No	No	Yes	No	No
	Designated Weaving Zone	No	Yes	Yes	Yes	No
	Dedicated Weaving Lane	No	Yes	No	No	No
	Designated Access Point(s)	Yes	No	No	Yes	Yes
Grade-Separated	Direct Ramp From Crossing Road	Yes	Yes	No	No	Yes
	"Tee" Ramp at Off-Line Node	Yes	Yes	No	No	Yes

G.2.2.1 At-Grade Access - Median HOV Lane

For at-grade (weaving) provisions, the following elements may be present:

- no buffer, buffer, or barrier between the HOV and mixed flow lanes
- continuous access, designated weaving zone, or dedicated weaving lane
- one-way weave or two-way (access and egress) weave

Additional factors which affect the type and location of weaving manoeuvre include:

- volume of traffic in HOV lane, in mixed-flow lanes, and performing weaving manoeuvre
- location of the weaving zone relative to right side freeway ramp entrances and exits
- width of buffer or barrier
- number of freeway lanes and Level of Service on mixed-flow lanes
- available cross-section width/configuration
- sight distance
- separate mixed-flow weaving/merging conditions

G.2.2.1.1 Continuous Access

The simplest means of providing access to/from the HOV lane is across a standard or double dashed lane marking from the adjacent mixed flow lane. This is the recommended approach when the HOV lane is used only during peak periods and is open to all users at other times; in such a case, the lane should appear similar to a mixed flow lane and the designation must rely of signage.

If an HOV lane is a permanent installation, it would be preferable to restrict access to designated locations or zones; the lack of acceleration/deceleration areas, the relatively high speed differential between the HOV lane and adjacent traffic, and the improved safety and enforcement characteristics which follow from segregation of the traffic flows militate against the use of continuous access in such a situation.

G.2.2.1.2 Designated Weaving Zone

Where a solid painted line demarcates the HOV lane and where a buffer zone separates the lane from adjacent mixed flow lanes, the recommended strategy is to designate defined zones for access to/from the HOV lane by introducing a dashed pavement marking in an appropriate location.

Figure G2-10 illustrates one application, and provides guidelines regarding weaving zone design and location.

In most circumstances, two-way (access and egress) moves can be accommodated within a weaving area. HOV lane volumes are limited, the number of HOVs entering or exiting the lane at any one point would generally be 500 per hour or less, and in most locations the weaving manoeuvre would emphasize either access or egress; therefore, the risk of the HOV weaving manoeuvre itself operating at a poor level of service is low. If these conditions were not met in a particular case, one-way (access only or egress only) operation could be assessed, but enforcement would be an issue not easily resolved.

The experience to date with design and operation of weaving zones has been that they should be a minimum of 300 m and a maximum of 450 m in length. The guidelines strike a balance between providing adequate merge/diverge length and minimizing the risk/incentive for congested mixed flow traffic to use the HOV lane as a passing lane.

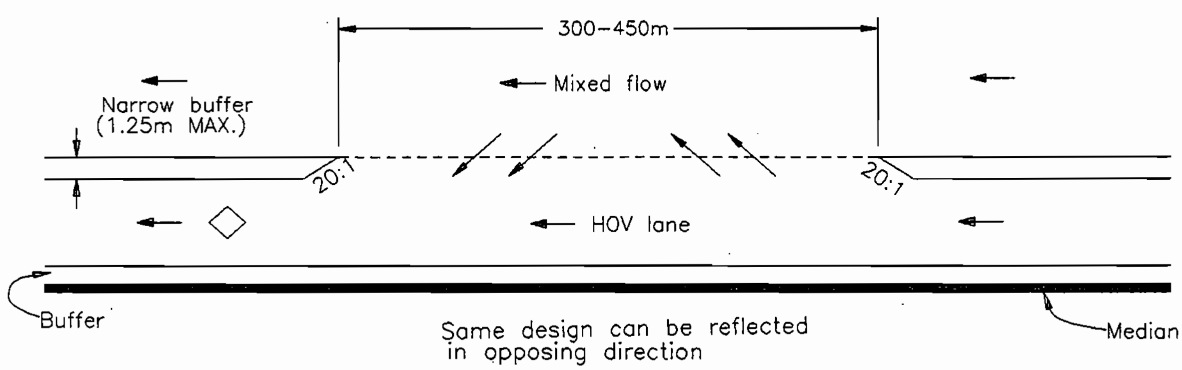


Figure G2-10
Designated Weaving Zone for Buffer Separated HOV Lanes

The location of ingress/egress zones should be subject to careful corridor-specific study, considering HOV traffic origin and destination patterns as well as physical fit and feasibility. It is neither necessary nor appropriate to attempt to serve every freeway entry and exit ramp with an at-grade HOV lane access zone; prime consideration should be reserved for:

- freeway-to-freeway connections
- transit needs
- ramps with a high volume of car/vanpools
- ramps serving major park and ride/park and pool facilities
- isolated interchanges

The placement of an HOV lane weaving zone, apart from responding to travel needs, must consider the weaving condition thereby introduced to the freeway as an HOV entering at a right side ramp weaves across congested mixed flow lanes to access the HOV lane via the weaving zone. A site-specific weaving analysis for a variety of operational situations is required; the "worst case" situation is not necessarily the peak hour, as weaving may in fact be more difficult in the "shoulder" periods where high volumes are combined with high speeds.

As noted above, weaving zone location is flexible, and can be adjusted by simple restriping in response to field observation of traffic operations. As a planning guideline, however, the following guidelines have emerged from experience elsewhere as shown in Table G2-6.

The distances are intended to maintain a Level of Service "D" for the weaving manoeuvre. The greatest distance for an "exiting" weave reflects provisions for buses which find it more difficult (due to visibility) to shift lanes to the right.

In Ontario, two sequential entry ramps from Parclo "A" type interchanges are common; in order for HOVs from both ramps to have the ability to access the HOV lane the weaving zone location should be based on the downstream entry ramp's bullnose.

For a corridor where several interchanges are located, the interchange spacing may determine the location of, and even the ability to provide, weaving zones. If the interchanges are too close together to accommodate the entry weave, weaving zone, and exit weave (i.e. 1000 m - 1800 m between interchange ramp bullnoses, depending on the weaving design), there should not be a weaving zone provided. This will prevent one or the other weaving manoeuvre being "forced" into too short a distance.

For interchange spacing greater than the minimum and up to approximately 2500 - 3000 m, a single weaving zone should be used (if both interchanges serve key HOV routes). Consideration should be given to skewing the weaving zone location within the envelope so as to give greater weaving distance to the higher volume move, or to tying the weaving more closely to the more significant crossing road.

Beyond that spacing, two weaving zones should be provided if both interchanges are to be served.

G.2.2.1.3 Dedicated Weaving Lane

Where there are high volumes (>500 vph) of HOVs seeking to enter or exit a median HOV lane, where a new or reconstructed freeway project offers adequate right of way, or where operational concerns with designated weaving zones are present, consideration should be given to the provision of dedicated weaving lanes. It should be understood that permanent 24 hour HOV lane operation is assumed, for a dedicated weaving lane is not suited to mixed-flow use.

Table G2-6
GUIDELINES FOR HOV LANE WEAVING ZONES

HOV Volumes	No. of Mixed Flow Lanes	Distance from Right Side Entry Ramp Bullnose to Start of Weaving Zone	Distance from Start of Weaving Zone to Right Side Exit Ramp Bullnose	
			"Must Exit" at Bullnose	"Choice" at Bullnose
< 250 vph	2	300 m	600 m	400 m
	3	400 m	600 m	400 m
250 - 500 vph	2	400 m	800 m	600 m
	3	500 m	800 m	600 m

The basic parameters regarding length and location relative to interchanges are similar to those for a designated weaving zone, as outlined in the previous Section G.2.2.1.2. An illustration of a dedicated weaving lane follows in Figure G2-11.

By providing a clearly defined area where acceleration or deceleration to match the speed of the merging traffic can occur safely and without interference a dedicated weaving lane provides the optimum conditions for at-grade access to a buffer-separated median HOV lane. Within a single corridor, access types could include both zones and lanes, applied as appropriate relative to the HOV and mixed flow traffic conditions and demands. The addition of a weaving lane can force the realignment of the mixed flow lanes if in a retrofit (narrow median) situation; the associated costs and impacts may be significant.

Dedicated weaving lanes are less flexible than other at-grade options and should be considered carefully in the case of a "demonstration project" or a lane where uncertainty regarding demand is present; it may be more appropriate to begin with a weaving zone and upgrade to a dedicated lane if and as needed, based on operational experience. Similarly, such lanes could be protected for in new highway construction but applied with care.

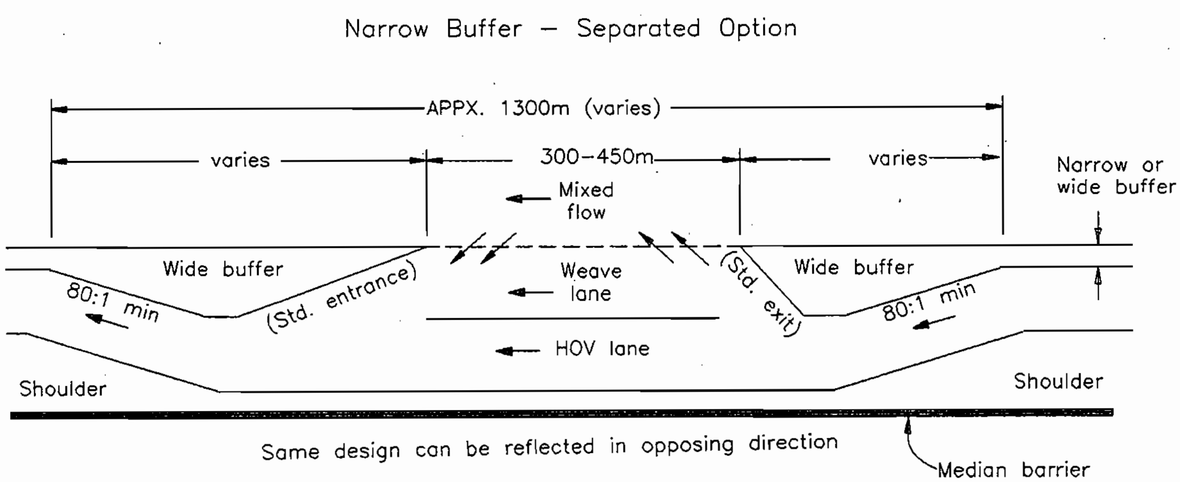


Figure G2-11
Dedicated Weaving Lane for Buffer-Separated HOV Lane Access

G.2.2.1.4 Designated Access Point

In Figure G2-12, it was pointed out that access to a barrier-separated HOV lane was best provided by designated access points rather than by weaving zones along its length (since the latter inherently involve elimination of the barrier for several hundred metres).

A designated access point therefore tends to be at the end of an HOV lane or at a key point such as a freeway-to-freeway interchange. Such a design is usually site-specific; typical layouts are shown on Figure G2-12.

Key issues are signage (to ensure HOVs know of the lane and non-HOVs don't enter in error), safety (the introduction of a barrier between two concurrent flow lanes is a concern), and enforcement (a pull-over shoulder, with (preferably) the ability to return the ineligible vehicle to mixed flow traffic should be located downstream of the entry point).

G.2.2.2 At-Grade Right Side HOV Lane

The provision of access and egress for right side HOV lanes is relatively simple, yet the operational issues which arise are complex and potentially unacceptable in their impact. The issues are mainly a result of the need for mixed flow vehicles entering or exiting the freeway at interchanges to cross the HOV lane to/from right side ramps. While there are several ways of resolving the resultant weaving conflict, the costs and impacts involved may negate whatever gains the HOV lane is intended to provide.

Examples of such measures include:

- grade separation with entry ramps: high cost and conflict with short term / temporary right side opportunities;

- consolidation of entry ramps (e.g. merging loop and direct on ramps to a single freeway entry point): focuses traffic to create an even more severe weaving condition;

- ramp metering: must occur corridor-wide and has minimal impact on hourly volume;

- restriction of HOV lane usage (by raising minimum occupancy rates, bus-only designation, etc.): conflicts with goal of moving more people more conveniently and with minimum acceptable lane usage criteria; or

- provision of adequate specialized merge / weave area: potential physical impact on interchange, structure, and area.

Due to these concerns, right lane application to date has been restricted to areas where there are no such conflicts, to low-volume Reserved Bus Lanes, or to locations where both HOV lane volumes and interchange ramp volumes are relatively low.

A design which provides for the weaving of entering or exiting traffic across the HOV lane (and which, in the process, allows HOV access / egress) is shown in Figure G2-13, based on the layout of a typical urban Parclo "A" type interchange in Ontario. Basic signage, lane lengths, and lane marking concepts are shown; development of more detailed design standards is required.

In some cases, a right side HOV lane can still be effective if it does not pass through an interchange (thereby avoiding the issue of conflict). A bus-only lane, for example, which is used by buses which exit and re-enter the freeway at each interchange via a transit interface or by bases which travel only between interchanges, can provide a queue-jump time saving / reliability function for hundreds of users at little cost. Such a lane would physically appear little different from an auxiliary lane or paved shoulder, with the exception of a solid paint lane line, a buffer zone (if 24-hour operation), and special signage. Access / egress would occur on the interchange ramps, as shown in Figure G2-14.

G.2.2.3 Grade Separated Access

As described in Section G.2.2.1, reliance on at-grade access for median HOV lanes poses several operational issues and may place constraints on the effectiveness and attractiveness of an HOV lane. Furthermore, in some locations the high demand, the freeway / interchange configuration, or physical constraints may virtually preclude use of at-grade measures.

If grade separated access / egress provisions can be well-located, physically feasible, and cost-effective with respect to the demands placed on them (and relative to viable alternatives), they can provide many benefits:

- high capacity
- good level of service
- safety
- control / management of traffic flow
- time savings / HOV priority
- reliability
- elimination of the need for at-grade weaving zones / lanes
- enforceability
- visible HOV priority, with marketing / public impression benefits.

Grade separated access ramps take two basic forms: "drop ramps" from crossing roadways, and "Tee ramps" serving adjacent off-line nodes. Other unique configurations may occur at freeway-to-freeway interchanges; they are discussed in Section G.2.2.5.

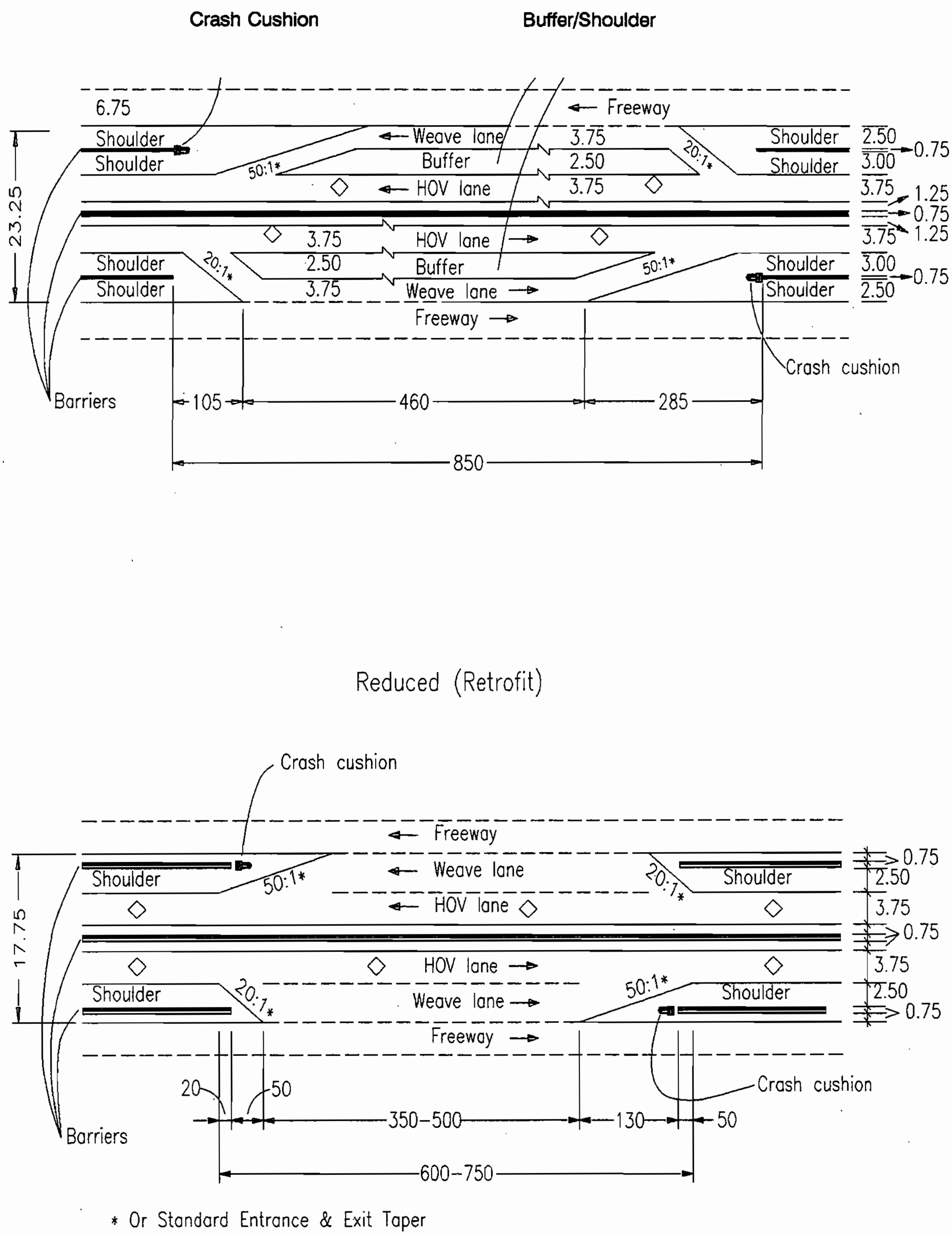


Figure G2-12
Dedicated Weaving Lane for Barrier-Separated HOV Access

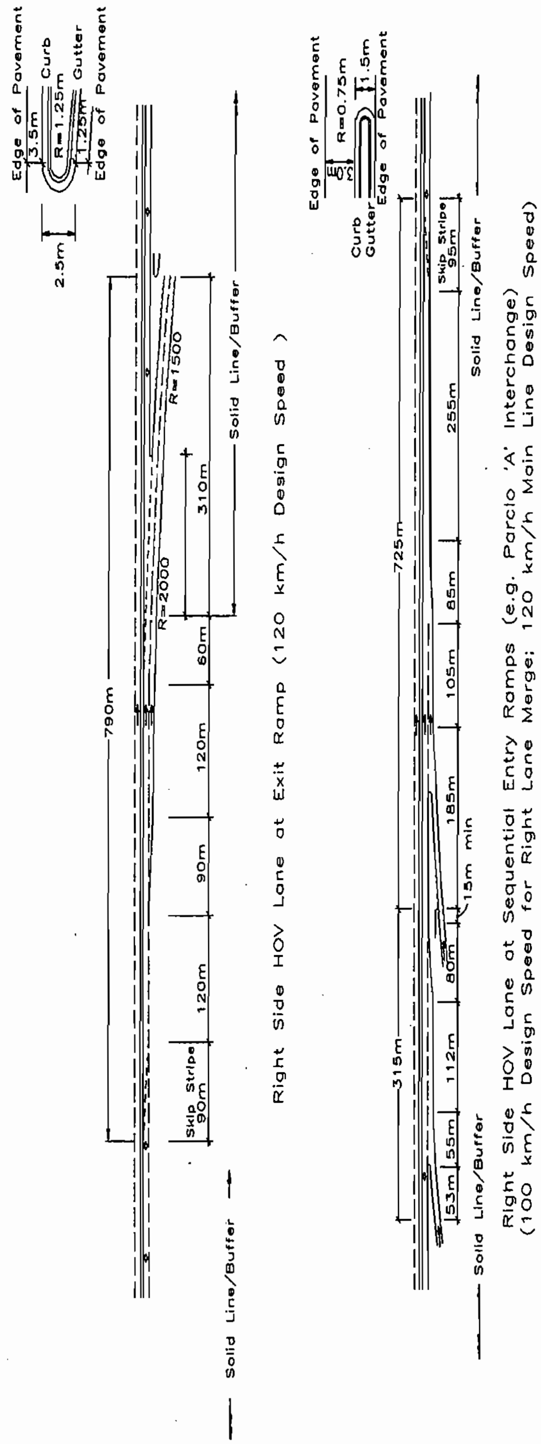


Figure G2-13
Right Side HOV Lane Through Treatment at Interchange Ramps

G.2.2.3.1 Direct Ramp From Crossing Road

A direct ramp may be two-way, one-way or reversible, and may feed either a buffer separated or barrier-separated median HOV lane. As with any HOV infrastructure investment, operational decisions must be made and committed to prior to considering a direct ramp; if the HOV lane is only to operate during peak periods, or if it is a "test case" which may be abandoned after a trial period, direct ramps should not be provided. On the other hand, the initial success of a "test case" may in fact depend on the presence of a direct ramp to resolve operational issues or to allow service to a major HOV generator. Since the costs of a direct ramp may range from $2 million to upwards of $5 million, this decision must be carefully considered.

Figure G2-15 illustrates a general design outline for a two-way ramp; Figures G2-16, G2-17, G2-18 and G2-19 following show typical cross-sections for various median widths ranging from "optimum" to "minimum", for two-way and single lane (reversible) ramps respectively. Finally, Figure G2-20 provides examples of direct ramp applications.

A key issue in consideration of a direct ramp is whether the crossing roadway already has an interchange with the freeway. In many retrofit situation, a major centre for HOV generation will already be served by an interchange. While the provision of a direct ramp in such a situation may not be desirable, it could be essential or it may be the best of the available alternatives. Figures G2-21, G2-22, and G2-23 outline the implications and configurations of several such design situations, using interchange layouts typically found in Ontario. The operational analysis of the arterial roadway and the ability to provide adequate vehicle storage and/or signal operation to allow the introduction of a new intersection will generally be the key determinants of the feasibility of the concept. Several structural issues are posed as well by the introduction of a new mid-span connection; rather than raising the direct ramp on a structure per se, it would generally be preferable to provide a walled ramp of earth fill, thereby reducing costs and structural complexity at the ramp's upper end.

Another important factor is the ability, at an existing structure, to widen the freeway to allow the new median lanes (two ramp lanes, two main line HOV lanes, and associated shoulders) while maintaining the pre-existing number of lanes through the available span opening.

For these reasons, it is often preferable to, where possible, introduce direct HOV ramps only at either a new / future crossing road or at an existing structure with an adequate span and no other interchange ramps. In such a case, an integrated design, or at least protection for later introduction of a direct ramp (through adequate deck width for mid-span turning lanes, etc.) would yield benefits.

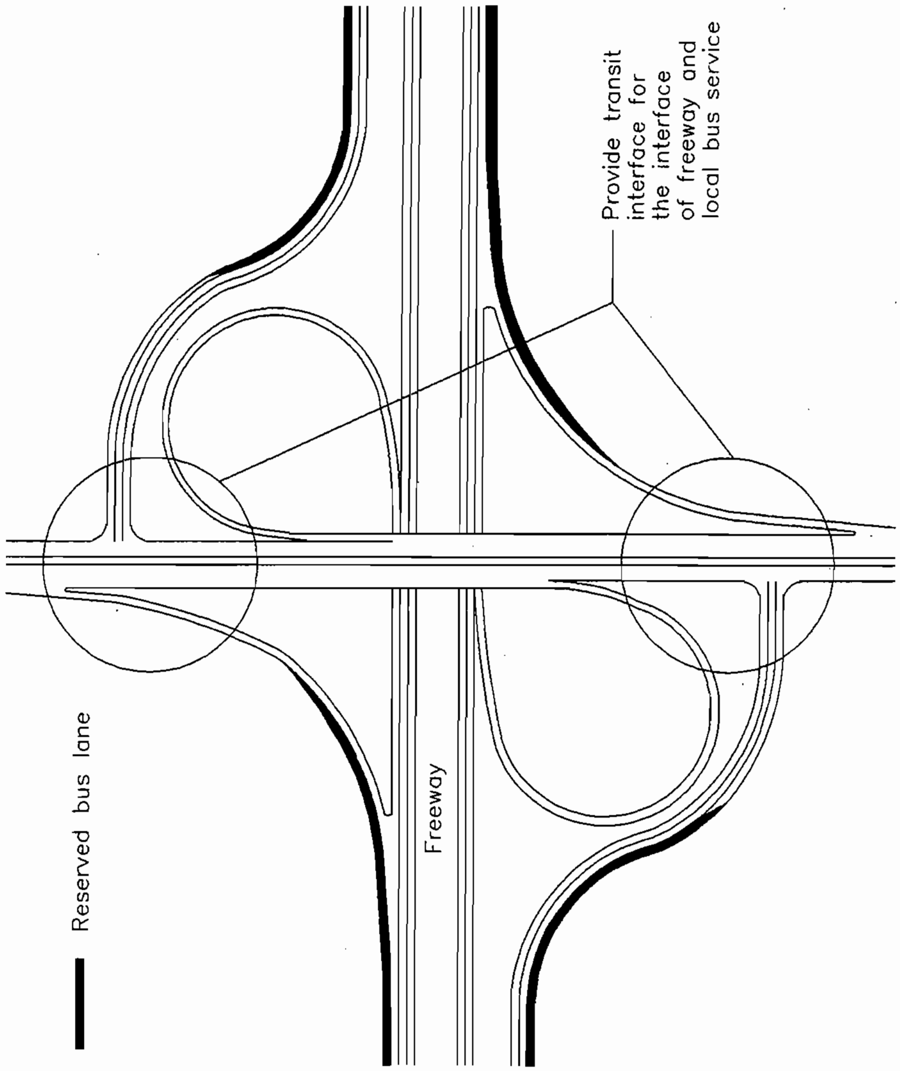


Figure G2-14
Right Side HOV Lane Access/Egress at Interchange Ramps

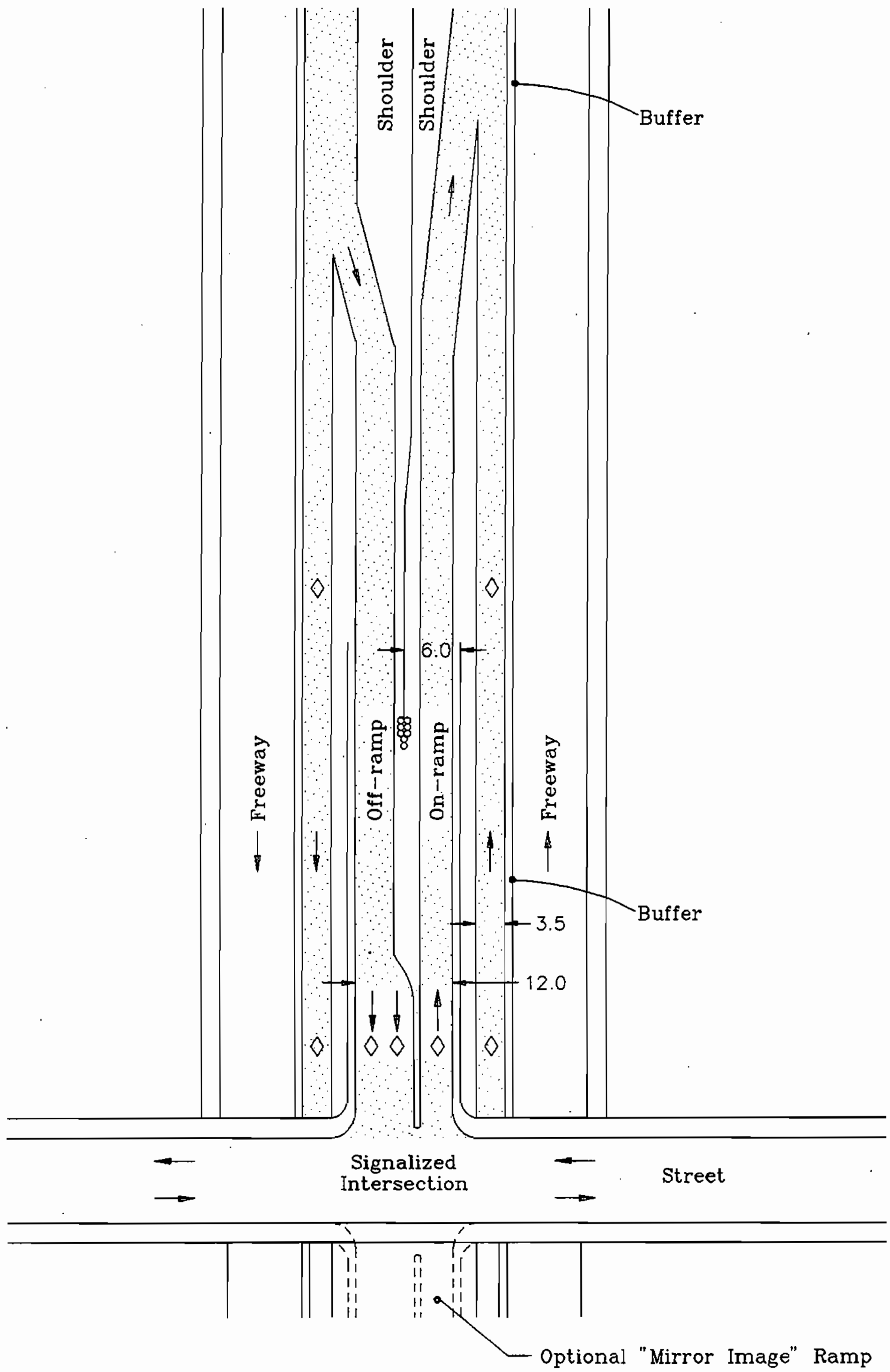
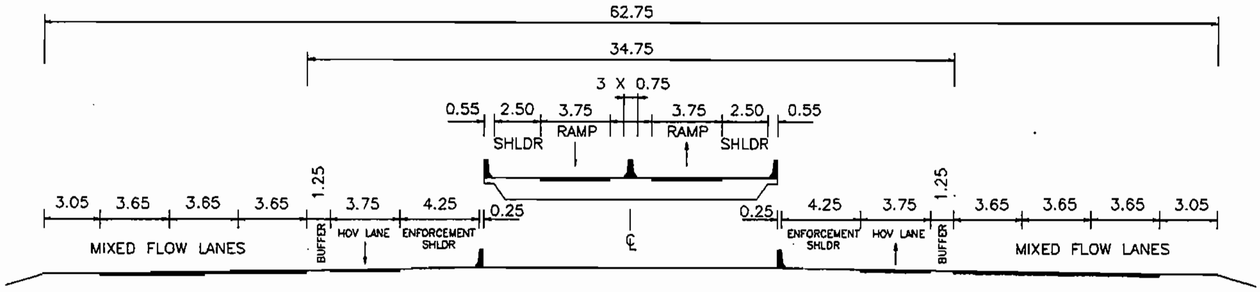
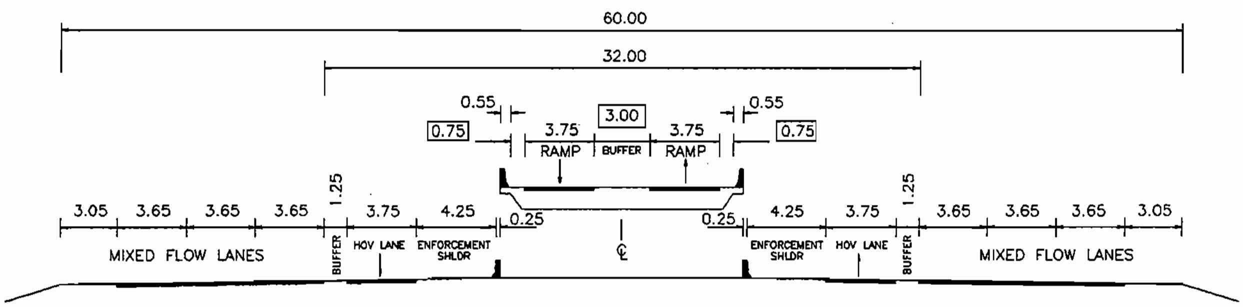


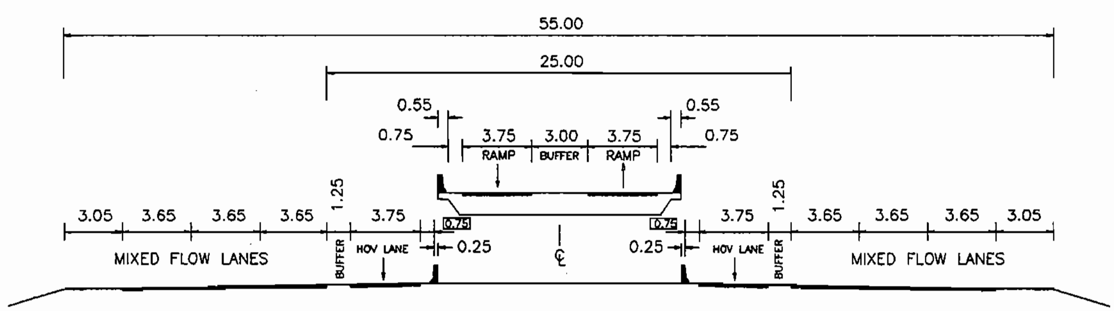
Figure G2-15
Two-Way Median Ramp for a Buffer-Separated HOV Facility



Concurrent Flow HOV Lanes with 2–Way Ramp Access/Egress (standard)

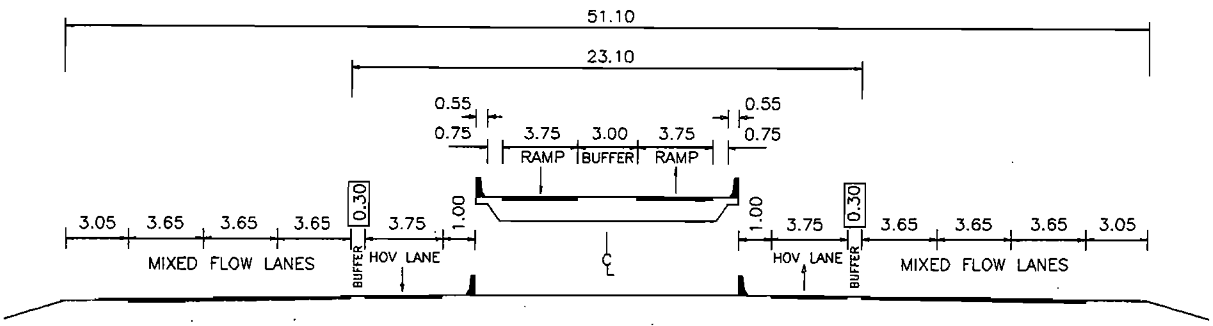


2–Way Ramp Access/Egress (Reduced)

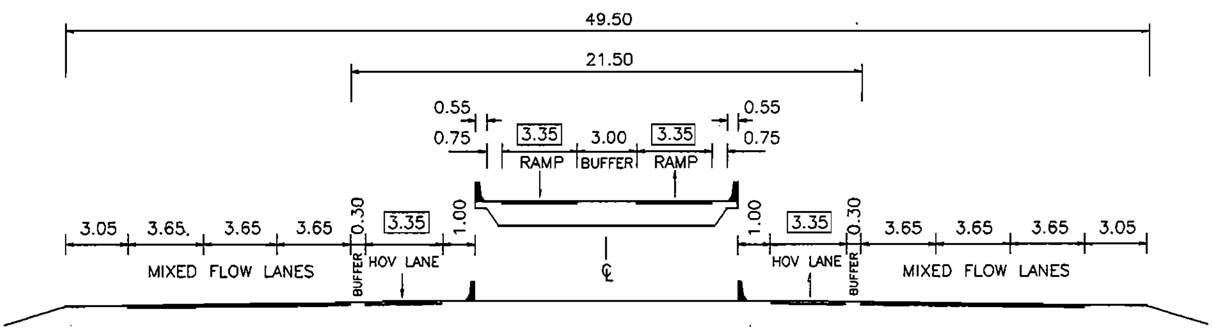


Reduced Left HOV Lane Lateral Clearance

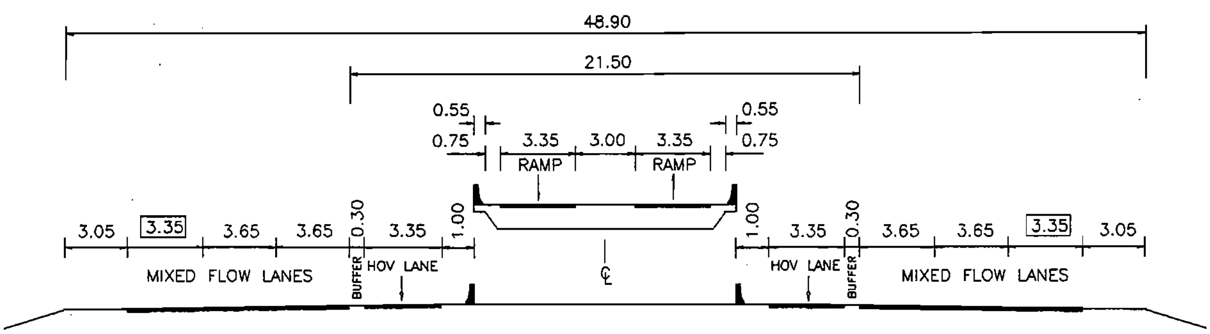
Figure G2-16
Median HOV Two-Way Ramp Cross-Sections



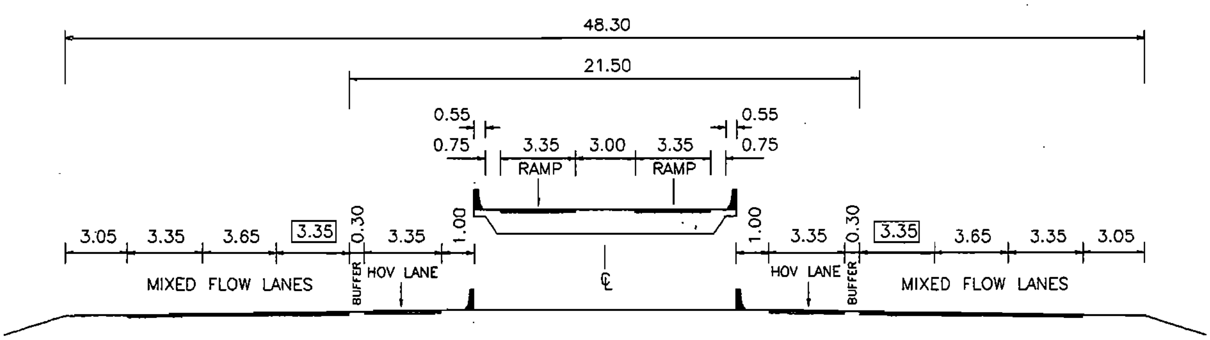
Reduced Buffer Separation



Reduced HOV Lane Widths

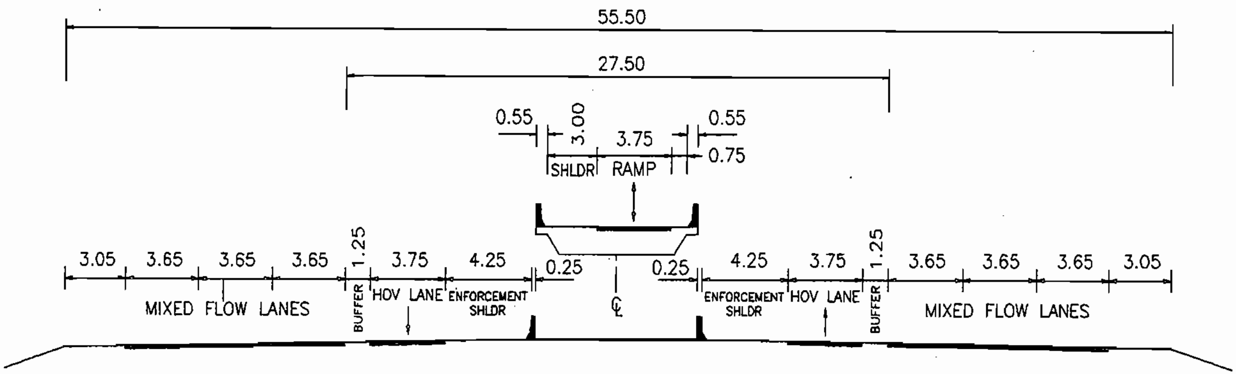


Reduced Mixed Flow Lane Widths (1 lane per direction)

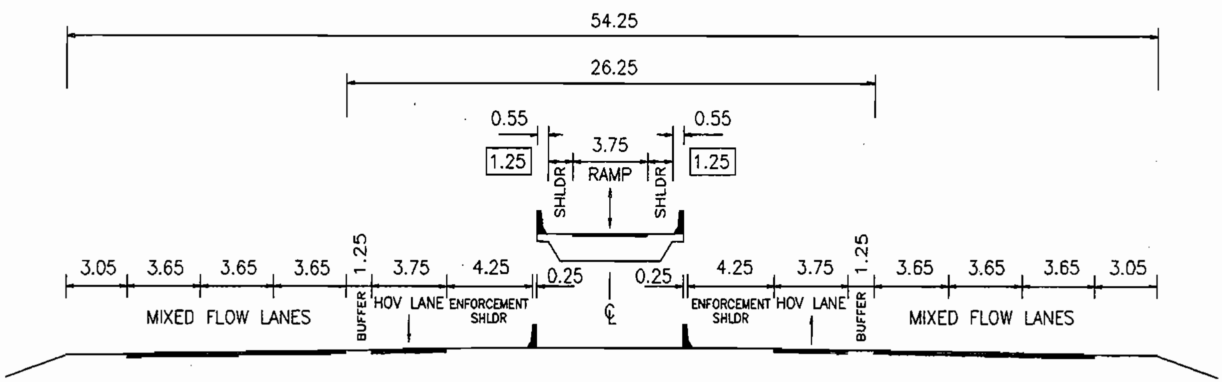


Reduced Mixed Flow Lane Widths (2 lanes per direction)

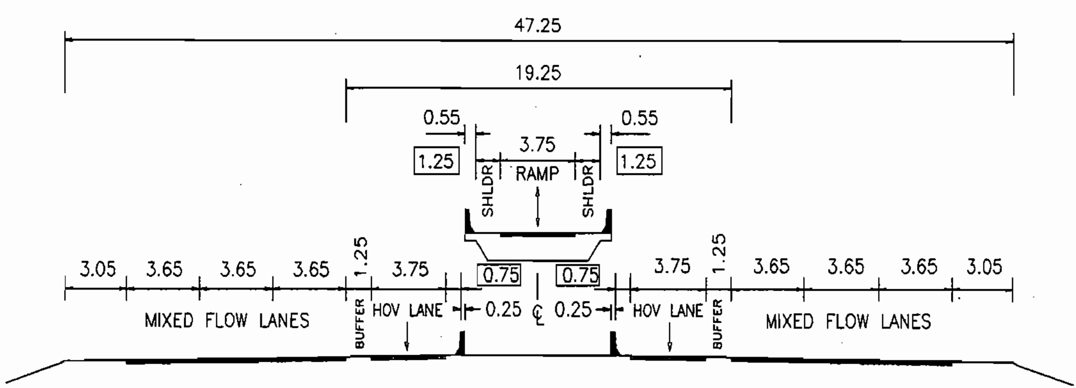
Figure G2-17
Median HOV Two-Way Ramp Cross-Sections



Concurrent Flow HOV Lanes with Reversible Ramp Access/Egress(standard)



Reversible Ramp Access/Egress(reduced)



Reduced Left HOV Lane Lateral Clearance

Figure G2-18
Median HOV Reversible Ramp Cross-Sections

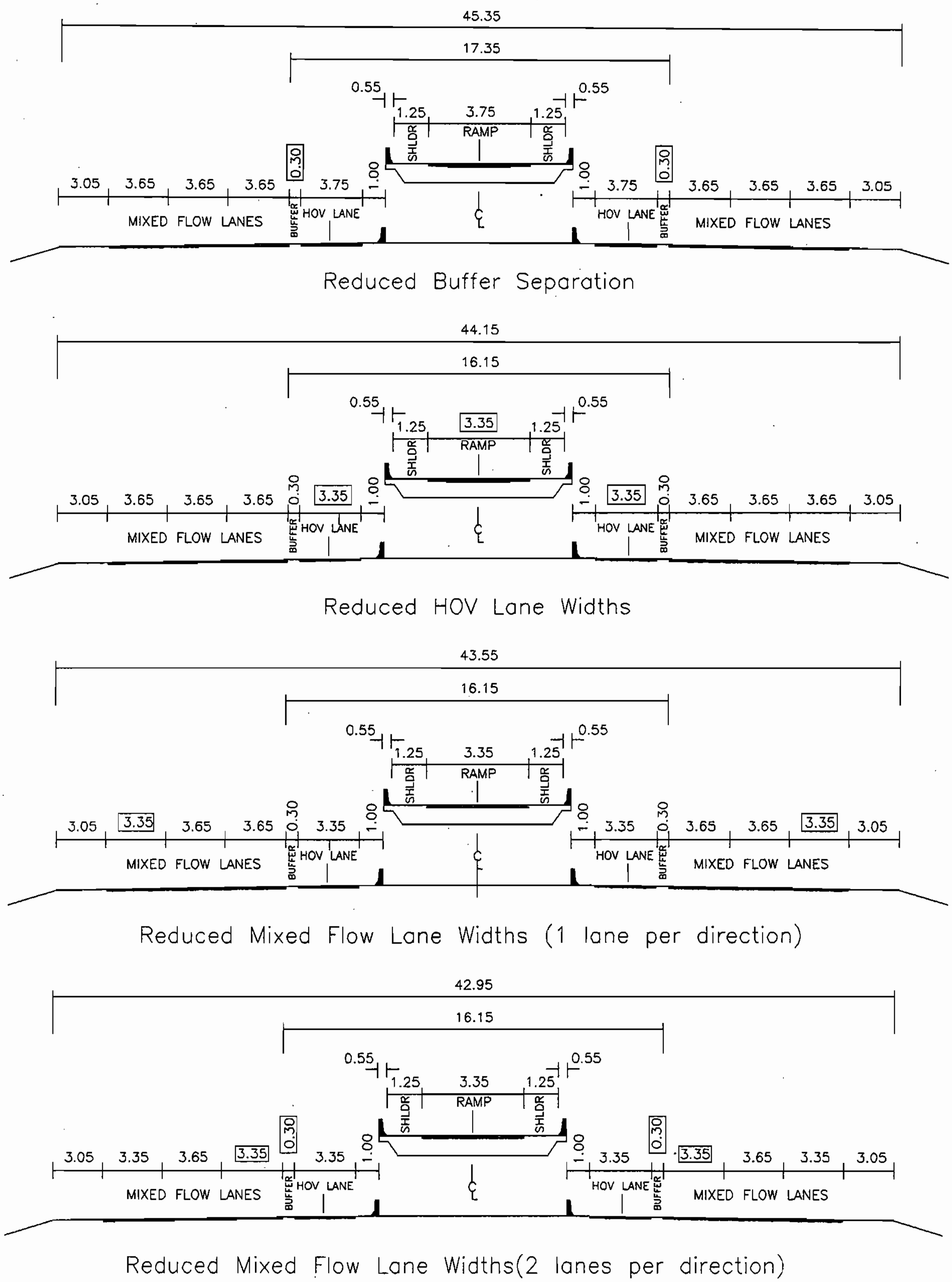


Figure G2-19
Median HOV Reversible Ramp Cross-Sections

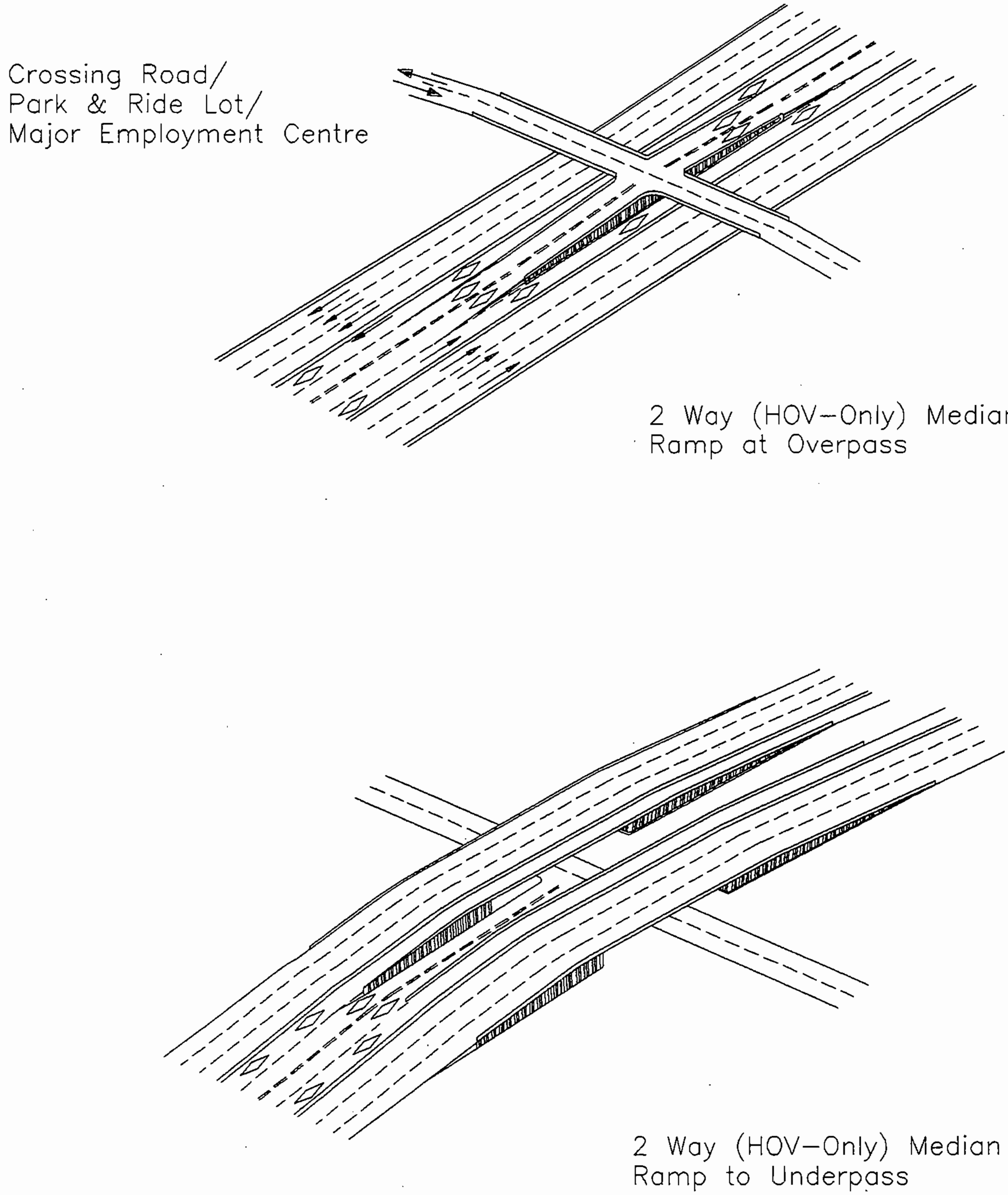
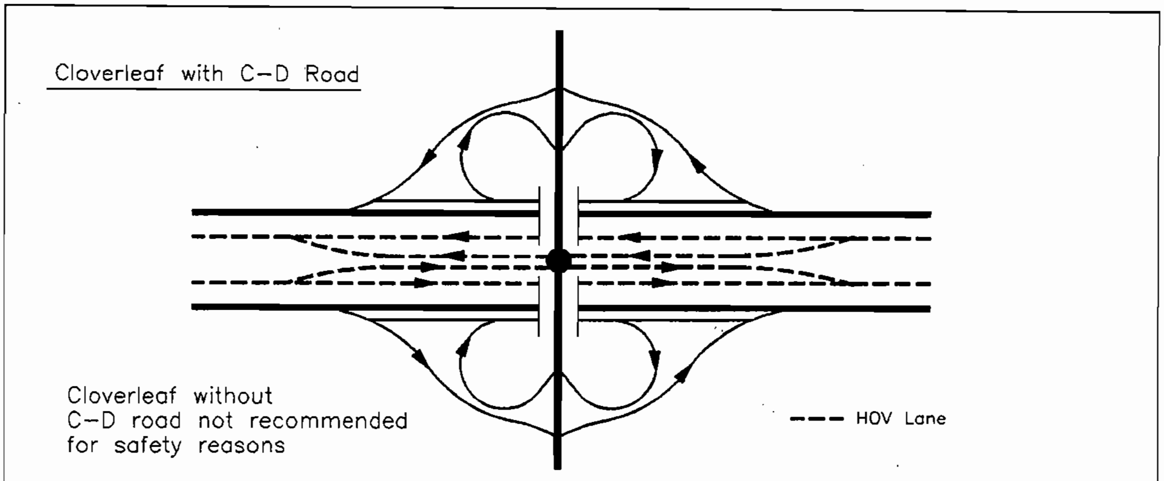
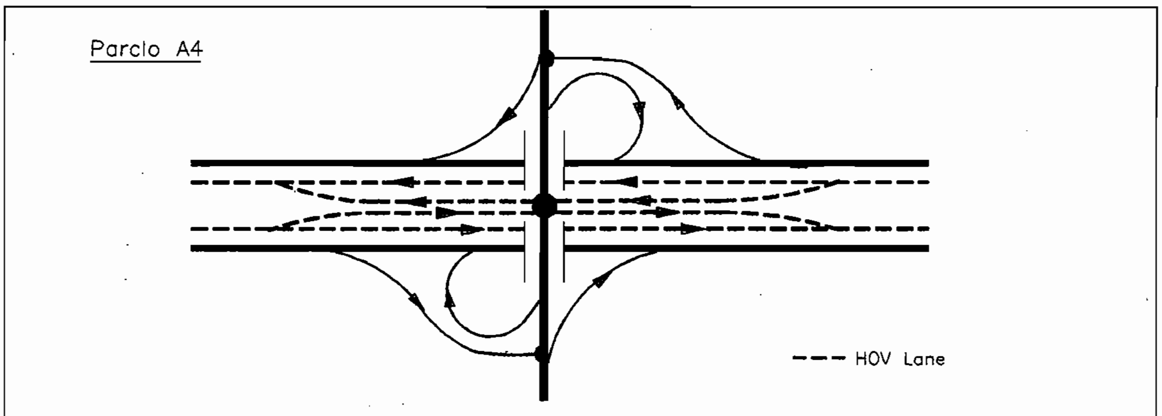


Figure G2-20
Direct Median Ramp at Crossing Roads



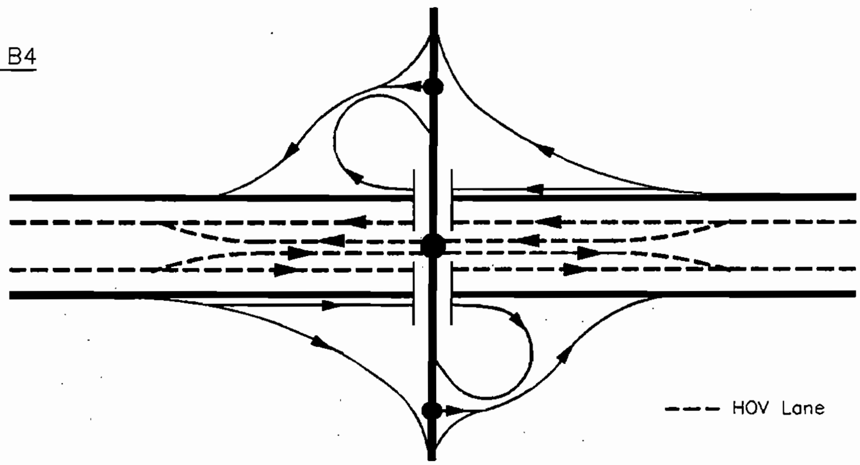
BENEFITS	DISADVANTAGES	APPLICATIONS
Free flow of most freeway and arterial traffic. Minimum impact on arterial operation. Can prioritize HOV signal without synchronization problems.	Difficult to retrofit to parclo interchange due to property and structural requirements. Potential weaving concerns on C–D road and arterial. Higher cost for arterial structure.	New interchange plans where property available. Low – moderate volume interchanges. High volume directionally skewed "tidal flow" interchanges where entry/exit weaving is minor.



BENEFITS	DISADVANTAGES	APPLICATIONS
Conventional interchange layout. Can be readily retrofit to existing I.C. No weaving Moderate cost Allows HOV service/interface in existing demand corridor.	Signal synchronization on arterial is key issue. Turning moves and queue storage on bridge structure (esp. if retrofit).	Retrofit to existing parclo interchange if traffic conditions on arterial permit. New interchange plans, esp. if one signal can be eliminated.

Figure G2-21
HOV Direct Ramp/Interchange Combinations

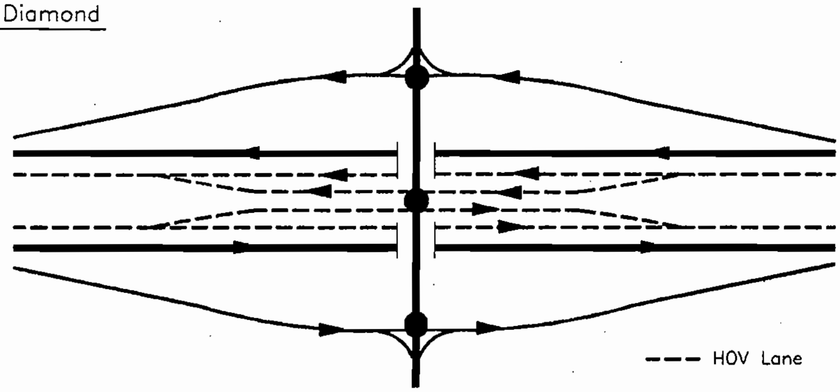
Parclo B4



BENEFITS	DISADVANTAGES	APPLICATIONS
If mixed flow left turns to entry ramps physically protected, layout has a maximum of two stops and less synchronization need.	Weaving between arterial HOV's and loop traffic. "Unexpected" signal for free – flow loop move. Left turns and queues conflict with through arterial traffic; parclo 'A' removes conflict.	Retrofit to existing parclo 'B' interchange. New freeway where property/ environmental constraints preclude parclo 'A' and where traffic patterns permit.

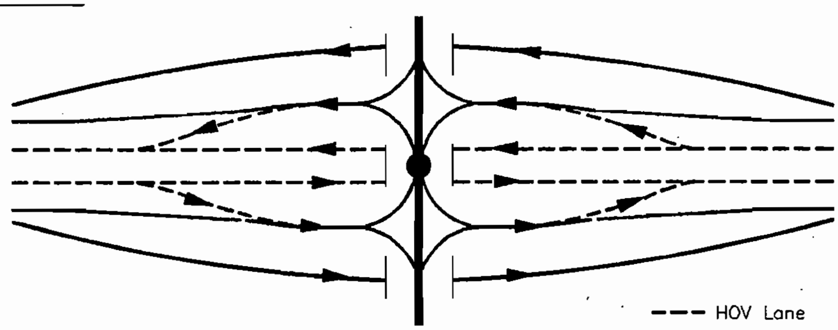
Figure G2-22
HOV Direct Ramp/Interchange Combinations

Simple Diamond



BENEFITS	DISADVANTAGES	APPLICATIONS
Minimal right of way requirements. Efficient transit interface opportunity. Can be retrofit in constrained area. Conventional freeway operations.	Signal synchronization and vehicle storage made difficult by signal proximity. Additional left turns introduced on arterial(compared to parclo).	Where signal synchronization can be accomodated either by operational measures or by adequate intersection spacing. In constrained right of way where access is essential.

Point Diamond



BENEFITS	DISADVANTAGES	APPLICATIONS
Right of way requirements minimized. Can be retrofit in constrained area. Single signal on arterial; synchronization not an issue. Freeway buses can interface with arterial buses by using freeway – grade bus turnouts.	Heavy demand on single intersection. Weaving/merging on ramps. Double ramp structures required. Unconventional left side freeway exits/entrances.	Where traffic conditions/demands on arterial allow effective signal operation. In severely constrained corridor where access is essential.

Figure G2-23
HOV Direct Ramp/Interchange Combinations

G.2.2.3.2 Ramps to Parallel Routes / Off Line Nodes

In circumstances where there is no reasonable way to provide HOV lane access at a major node through use of an existing structure, or where no structure exists or is otherwise planned, a new HOV-only crossing structure may be provided. Such ramps are likely to be costly, but can be designed to optimum standards and, if serving a major HOV generator or providing an essential link, may be as, or more, cost-effective than available alternatives. In some cases, a single direct ramp alone could provide the 5 - 10 minutes time savings needed to begin inducing new HOV trips. Such ramps may also eliminate an otherwise unacceptable at-grade weaving operation.

Since these ramps tend to be site-specific in design, there are few HOV-related guidelines to offer; they will have cross-sections and design criteria identical to mixed flow ramps. Figures G2-24 to G2-28, provide examples of situations and possible design applications at Parclo "A" interchanges.

G.2.2.4 Terminal Points

G.2.2.4.1 Start of HOV Lane

An HOV lane should start as a new lane on the left side of the left-most mixed-flow lane. Entry to the HOV lane should require conscious movement by HOVs; the HOV lane should not begin as a direct continuation of a mixed flow lane from which non-HOVs are directed to exit. Consistency with intermediate weaving zones should be maintained: a 300 - 450 m long dashed white line located at least 300 - 550 m (as appropriate depending on HOV volume and freeway width) downstream of the nearest right side freeway entry ramp bullnose should be used to designate the access area. A dedicated weaving lane is not required for this entry-only manoeuvre, although consideration should be given to protecting the ability to provide such a lane if the HOV lane is to be extended upstream in the future.

G.2.2.4.2 End of HOV Lane

The preferred means of terminating an HOV lane is as a direct continuation into a free flow mixed-flow lane. If the HOV lane must physically end, a left side lane drop after a minimum 750 m (1000 m desirable) merging zone is adequate. Alternatively, the right side mixed flow lane could be dropped at an interchange or downstream of the end of HOV designation on the left lane. If possible, the lane drop should be located in an area where a high-volume right side mixed-flow ramp relieves traffic volumes on the freeway. The introduction of mainline congestion due to merging HOV lane traffic is to be avoided; if queuing occurs in the area of the lane drop, HOVs should get "head of queue" treatment if possible.

As with any weaving zone, a minimum of 200 m per lane change should be provided between the end of the buffer / barrier and the next downstream right side exit ramp. A dedicated weaving lane is not needed for this egress-only move, however, future downstream extension of the HOV lane may warrant protection for the ability to later provide the extra lane.

G.2.2.5 Freeway-to-Freeway Interchanges

For HOVs to transfer between freeway corridors, mixed flow ramps must generally be used, along with appropriately located weaving lanes / zones. If there are HOV lanes in both freeway corridors, an ultimate network plan may warrant provision of a direct HOV-only ramp between the two, as shown in Figure G2-29.

Due to the complexity of most freeway-to-freeway interchanges, only one or two such HOV-only moves can be provided within the interchange itself. There may be a restricted design speed on the HOV ramp in order to retrofit it into the area; it would obviously be preferable to protect for such a connection in the design stage.

Another impact is that, in order to introduce the ramp, the freeway main lines may need to be widened or "bulged" around the ramp terminus. As with any such complex situation, the design solution will be site-specific.

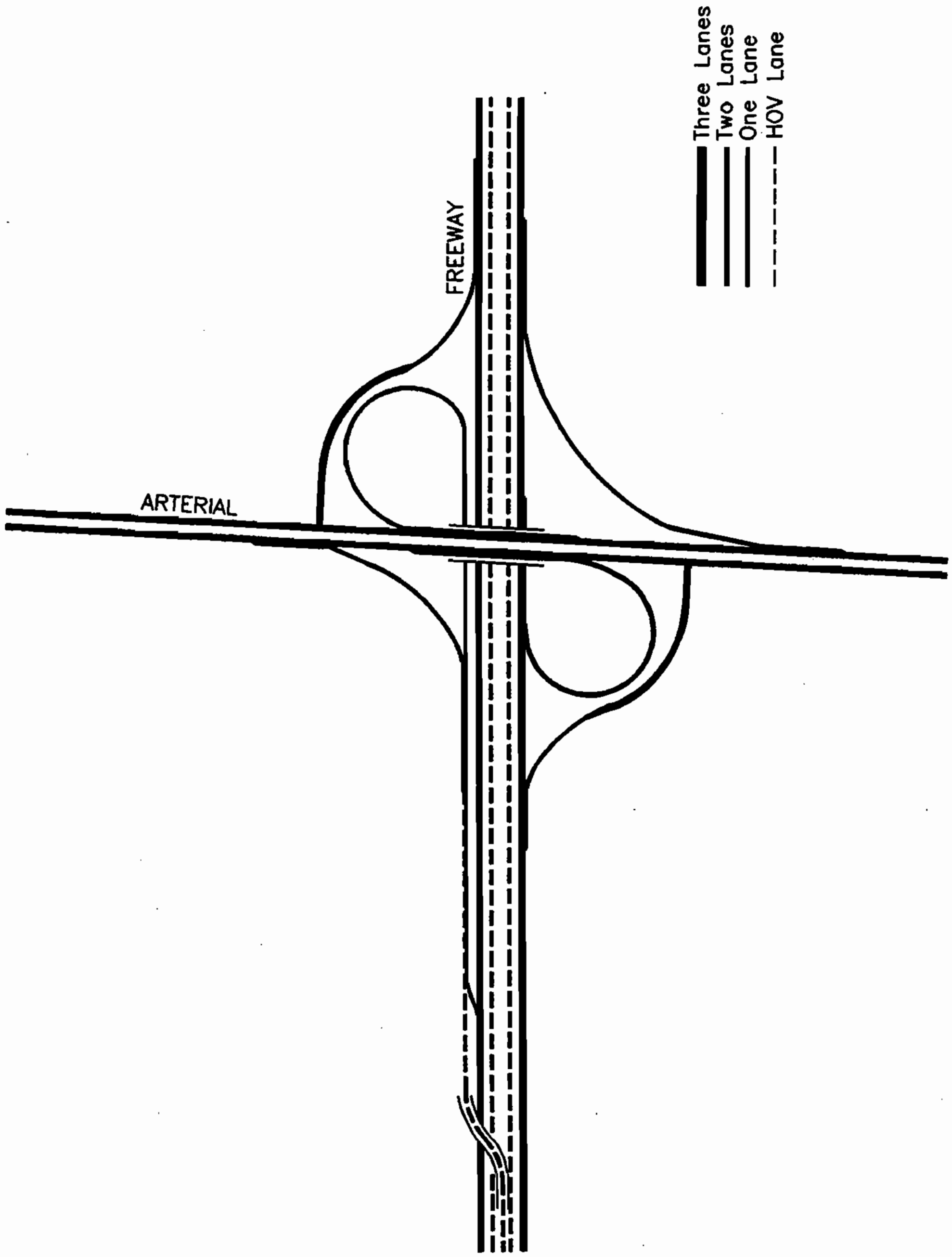


Figure G2-24
Direct Ramp from Parclo "A" Entry Ramp to Median HOV Lane

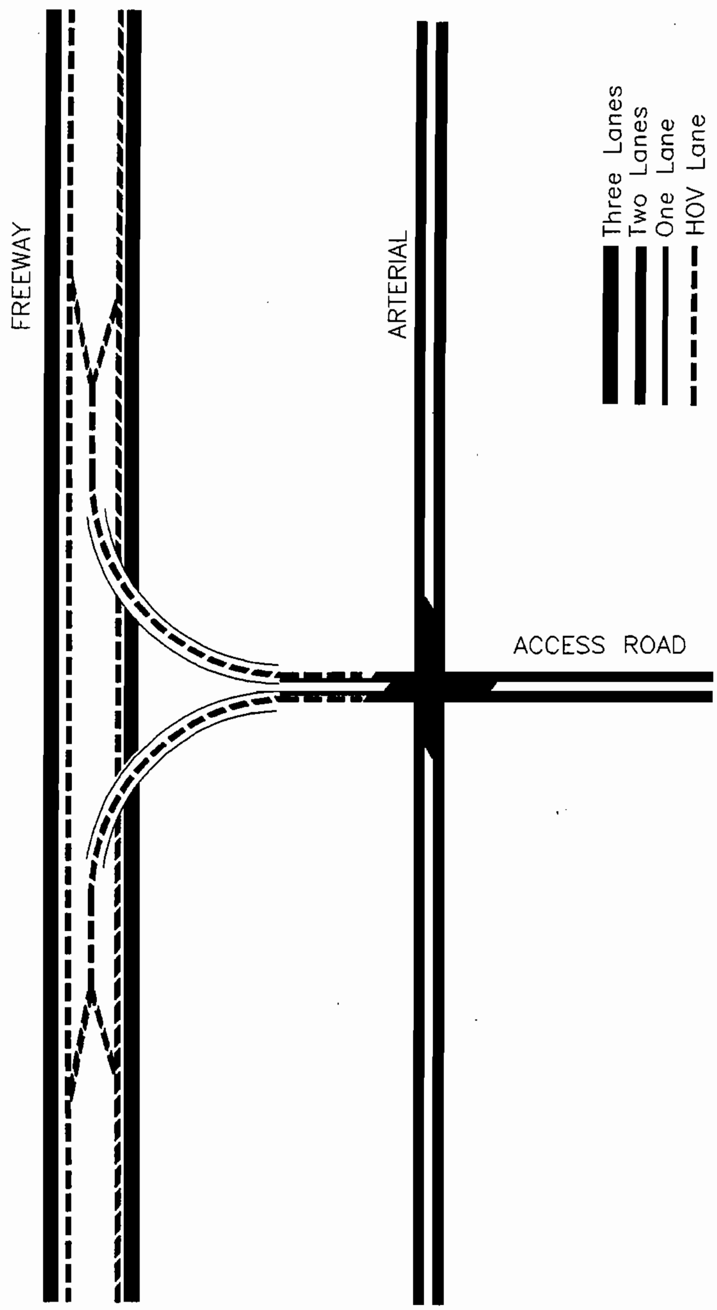


Figure G2-25
In/Out Ramp Between Median HOV Lane and Off-Line Activity Centre

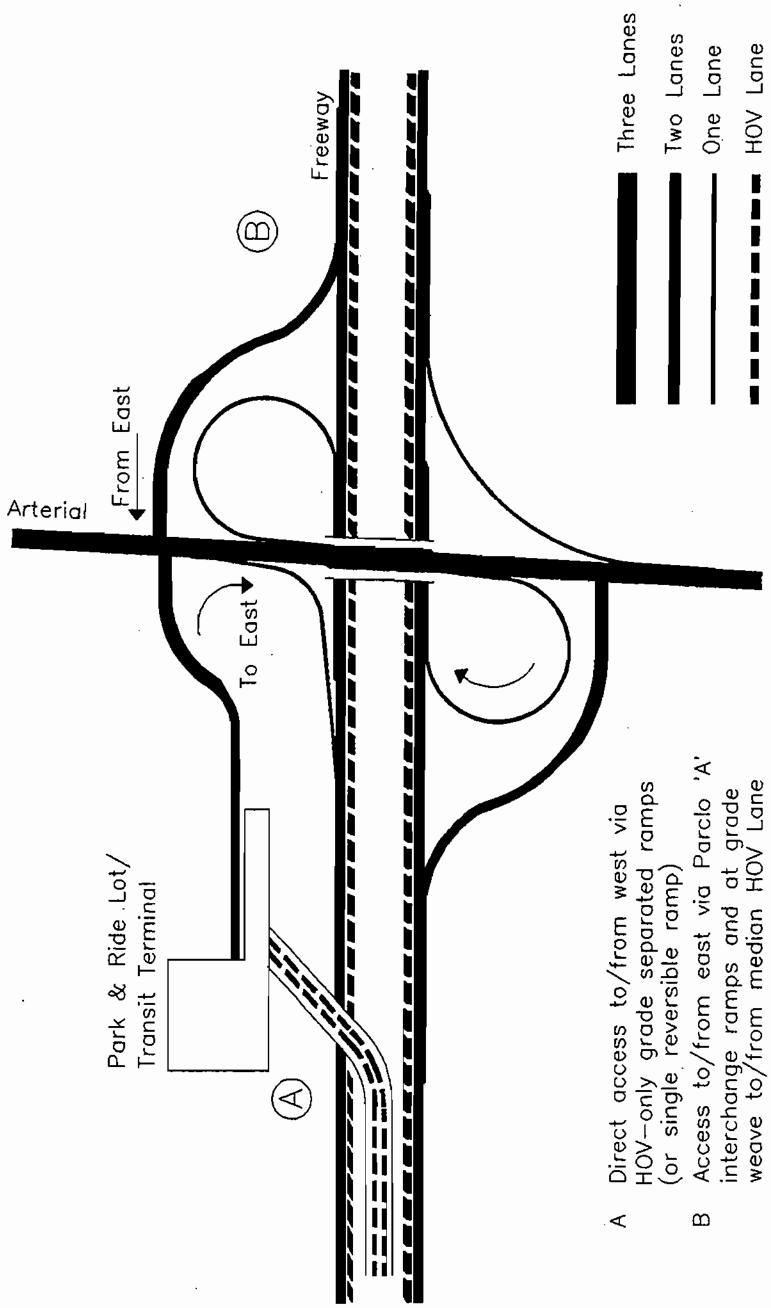


Figure G2-26
Direct Ramp to Off-Line Parking/Transit Node at "Parclo A" Interchange

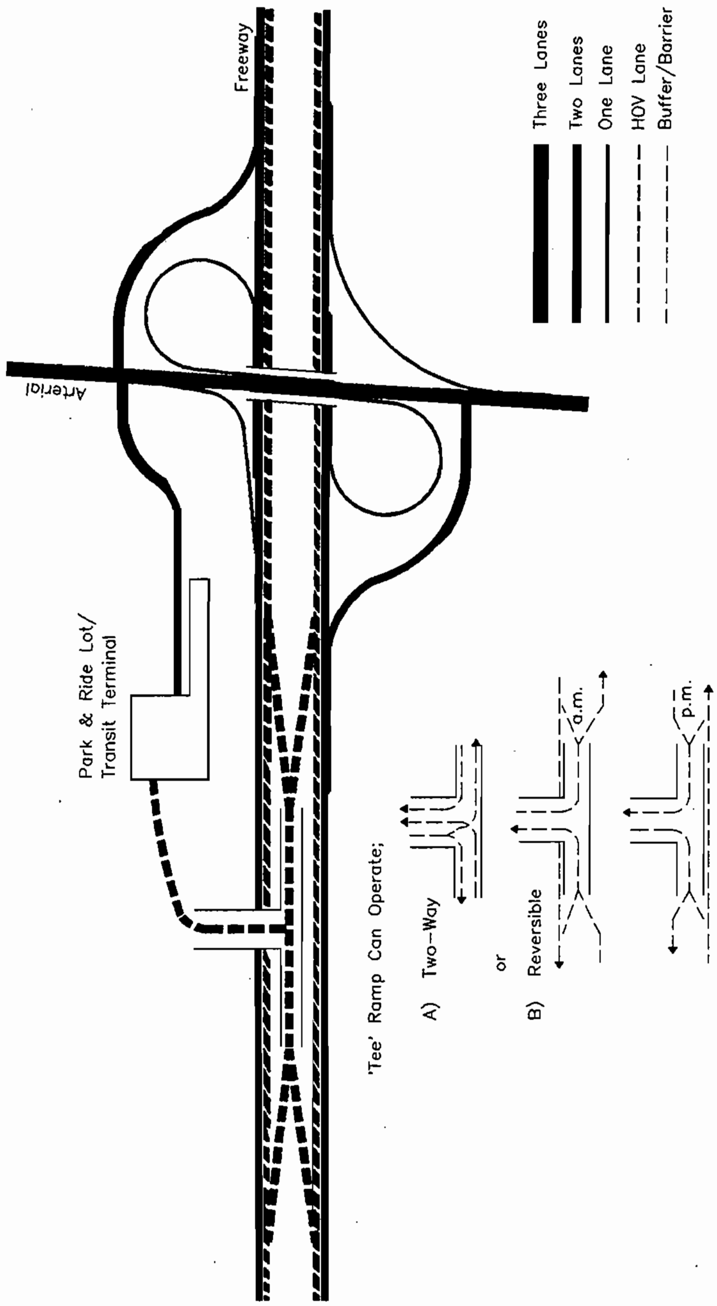
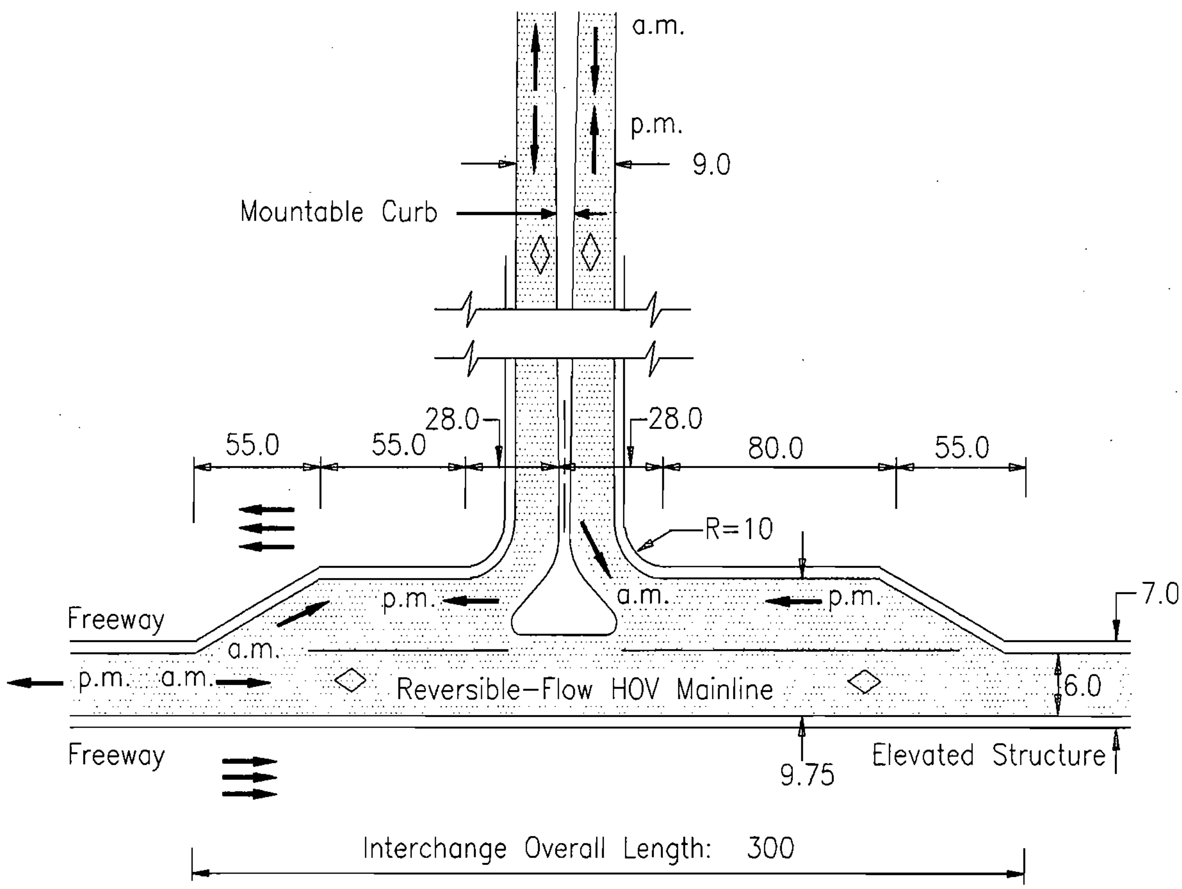


Figure G2-27
"Tee" Ramp for Direct Access Between Median HOV Lane and Off-Line Facility



"Texas Tee" Ramp Configuration, Single-Lane Reversible-Flow HOV Facility

Figure G2-28
Reversible Median "Tee" Ramp

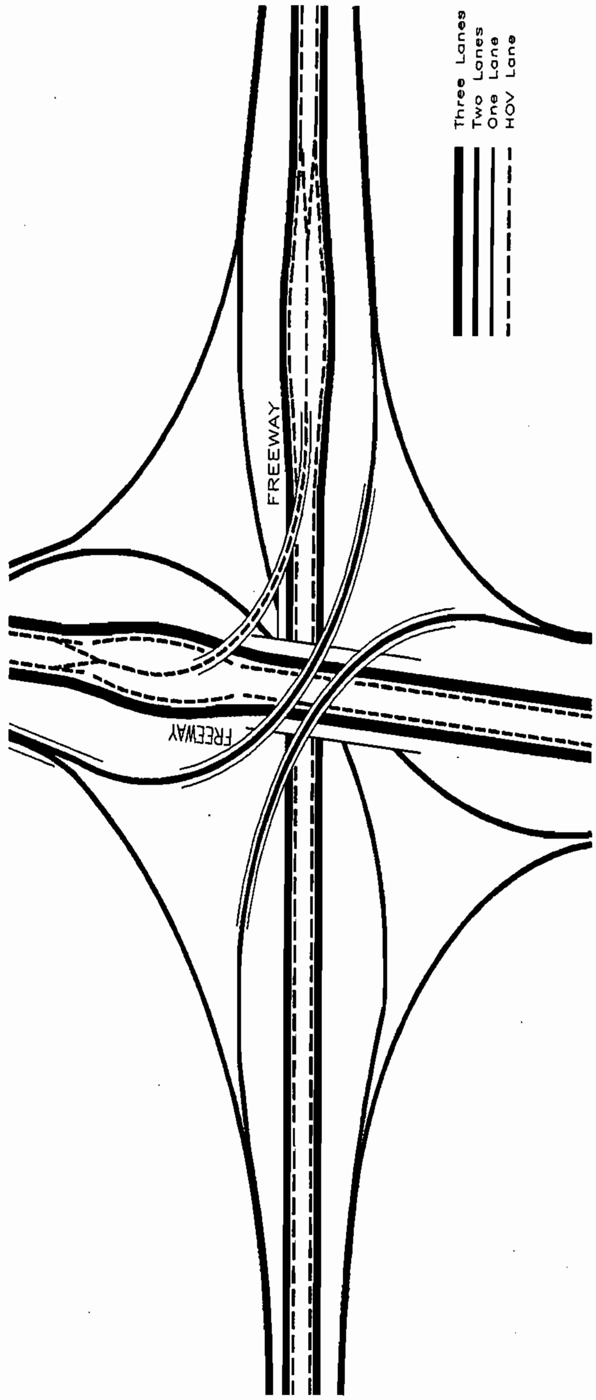


Figure G2-29
Freeway-to-Freeway Interchange with Direct HOV Lane Connection (Major Move Only)

G.2.3 TRANSIT FACILITIES

The provision of transit stations where passengers and/or buses may gain access to the HOV lanes is essential in corridors where transit service forms a significant element of the HOV lane user market. Such facilities may be as simple as a bus bay and shelter on a right side HOV lane or as complex as a multi-level multimodal transportation gateway astride the freeway. The standards for transit stations in the HOV context are still evolving, and in any case will tend to be site-specific and not readily standardized in application.

In this section, the transit interface facilities are shown mainly for illustrative purposes, indicative of the full range of opportunities which may be available. Facility types covered include:

- On-Line
    - median
    - right side

- Off-Line / Interchange
    - interface at Parclo A interchanges
    - Transitway stations
    - Park and Ride lots

G.2.3.1 On-Line Stations

One of the most difficult tasks facing the planner of an HOV facility is to reconcile its inherent tendency to be more beneficially located in the freeway median with the need for excellent transit vehicle and passenger access through interface with crossing roads. The goal is to allow express (through) buses to use the HOV lane without having to divert off line to pick up passengers, and for local transit users to gain direct access to the lanes without having to weave across congested mixed flow traffic.

The optimum solution may be to provide a transit station, elevated (or depressed) at the cross street level, with direct HOV lane access / egress ramps. There are two fundamental drawbacks, however: the physical requirements of such a facility (if feasible) are significant, leading to high cost and potentially enormous retrofitting problems; and a passenger interface in the middle of a freeway presents a generally hostile environment to the passenger, particularly for the desired walk-in movement from surrounding development, for example in winter conditions. Such a facility may also be unable to address the Park and Ride or Park and Pool components of the HOV market.

Some examples of median on-line HOV transit stations exist and many concepts have been developed for such facilities but in the Ontario context it must be considered an unlikely scenario for actual for actual application except possibly for local-express passenger transfer in a non-retrofit situation. Figure G2-30 illustrates a typical median on line HOV transit station.

The provision of bus bays on right side HOV lanes exhibits significantly greater potential for utility, reasonable cost, and attractiveness (and indeed the potential for good local transit interface is a significant portion of the rationale for right side lane application. See Figure G2-31.

Right side HOV lane bus bays are suited to locations between interchanges, at simple crossing structures, or at major employment of residential focal points for simplicity of access and operation; if an interface is needed at an interchange, the operational and physical requirements alter so significantly as to require special consideration, and a simple bus bay is generally not feasible.

G.2.3.2 Off-Line / Interchange Interfaces

Most of the users of a freeway HOV facility will access the freeway corridor from the crossing arterial road system, and most major arterials have interchanges with the freeway. The need to transfer passengers to the HOV express services, for local buses to access the HOV lane, and for mixed flow traffic to use the interchange ramps efficiently and safely all conflict at the typical Ontario Parclo "A" type interchange. As noted in Section G.2.4.1, significant constraints are placed on the median interface concept, and bus bays for right side HOV lanes are most appropriately located in mid-interchange positions.

The most common alternative, and one which is essentially impossible to use by median HOV lane express buses, is the provision of bus interface opportunities at the ramps of Parclo "A" interchanges. At Parclo "A" type interchanges, the stopping of local buses on the cross road within the interchange area poses unacceptable safety and operational impacts.

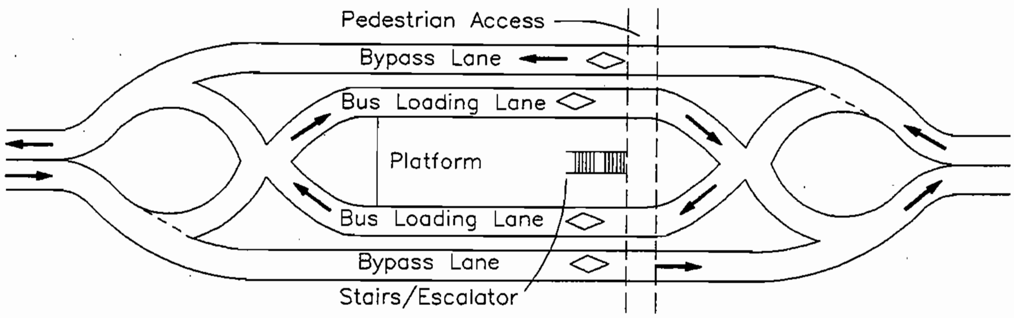
Configurations for three interface types are shown in Figures G2-32, G2-33 &G2-34.

Standards have yet to be developed for "B" type interchanges or other variations found on the Ontario freeway system. It should be noted that such interfaces are well suited to interchanges with ramp metering and accompanying HOV Bypass Lanes, although there are some implications as to the location of the bypass lane (e.g. on the left side of a metered entry ramp for a Parclo "A" layout) and for property requirements. The design standards are already applied on new Ontario freeways in urban areas with respect to property acquisition needs.

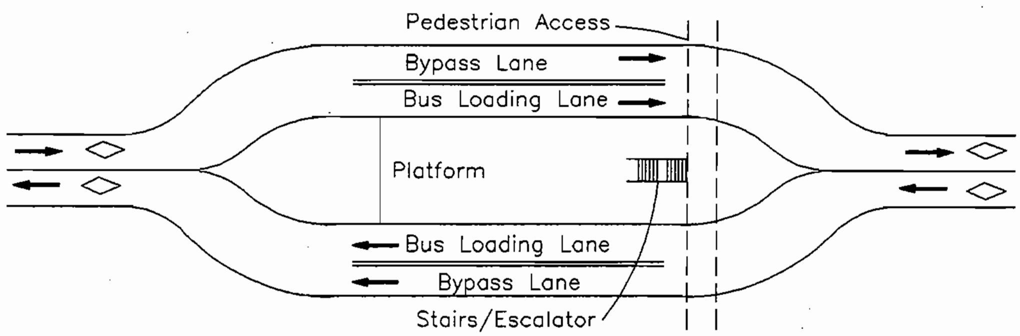
An interchange type which is well suited to off-line transit interface is the full diamond layout, however,

CENTER PLATFORM

A) Regular Two-Way Flow (Cross-Over Required)



B) Reverse "English Style' Flow



SIDE PLATFORM

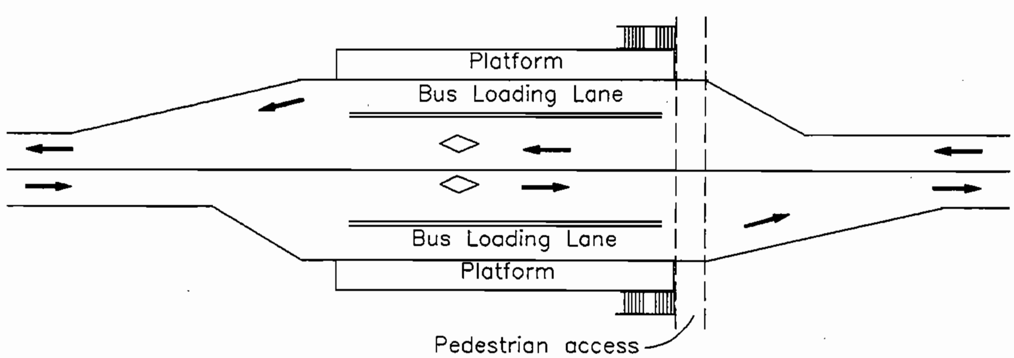


Figure G2-30
Median On-Line Transit Station

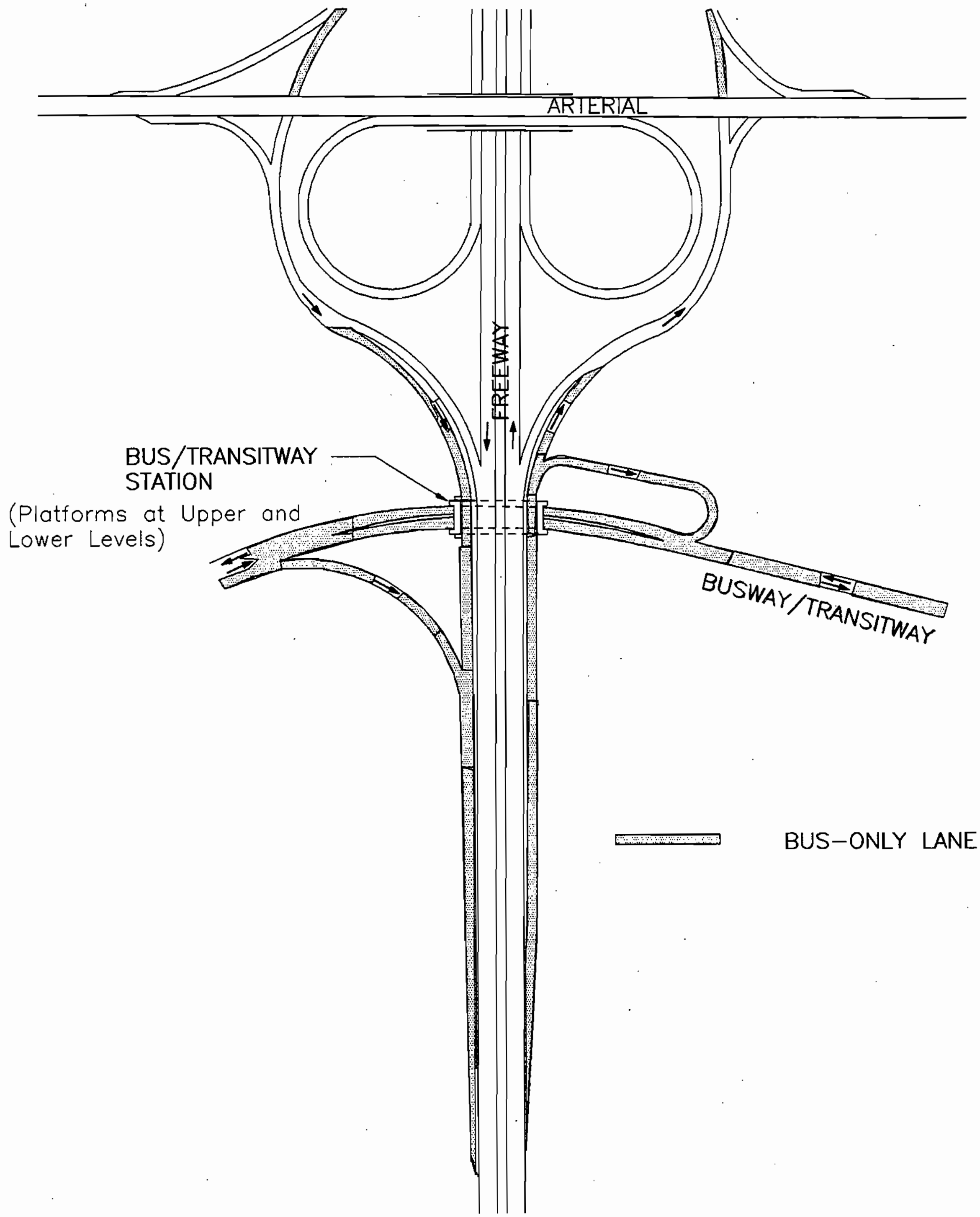


Figure G2-31
On-Line Transit Stop for Right Side RBL

such configurations are rare in Ontario. If a new freeway is being planned with HOV priority in mind, traffic patterns at each interchange should be examined closely to determine the need for a "Parclo A" type interchange and the traffic signal impact if one or both of the inner loops were to be replaced by left turns or other substitutes. If less than 100 vehicles in the peak hour are projected to use the loop ramp, it may be possible to accommodate those vehicles by a left turn at the off ramp terminus signal, thereby freeing up significant flexibility for HOV interface options, as well as property which could be used for a Park and Ride lot or transit facility. There may be retrofit opportunities at some interchanges in proposed HOV corridors.

Rather than attempting to accommodate all of these conflicting demands at a Parclo "A" interchange (which is a complex enough operating entity as it is), it may be more appropriate to group Park and Ride, Park and Pool, local-express transit interface, and walk-in transit facilities all in a single dedicated off-line station linked with the HOV lane, either by direct ramp to the adjacent freeway median or by slip ramp to / from a right side facility. The provision of a direct ramp requires cost-effectiveness justification in the form of significant demand levels (provided by the large multi-purpose HOV lot). It may be considered that a transit interface facility as shown in Figure G2-33 is capable only of accommodating walk-in and transfer passengers from the arterial route; the Park and Ride market and Park and Pool HOV formation would still have to be addressed in other ways. Under these circumstances, the provision of a dedicated multi-purpose HOV centre at key points in an HOV lane corridor should be seriously considered as significant ancillary features to the HOV lanes themselves.

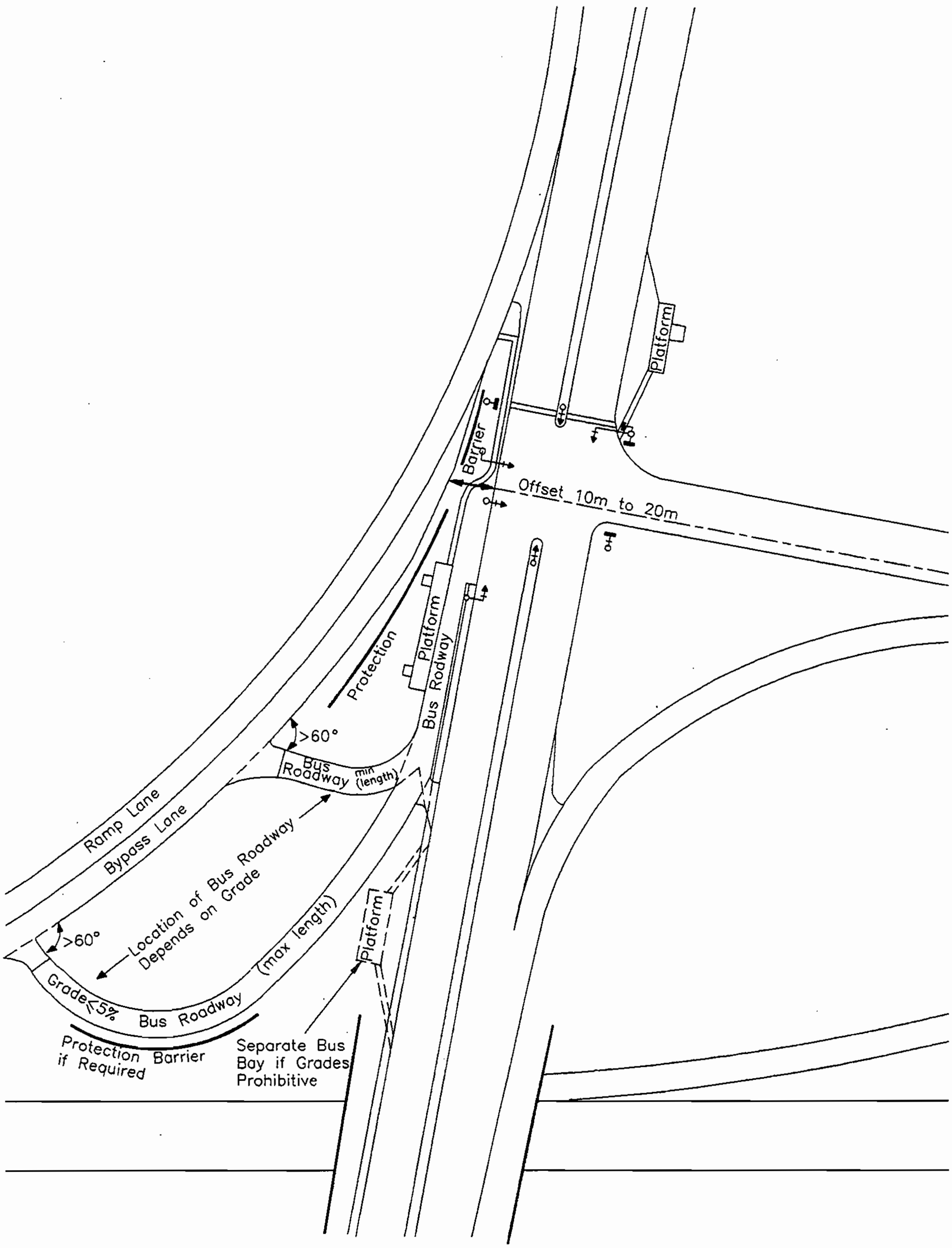


Figure G2-32
Freeway Interchange Bus Interface TYPE I

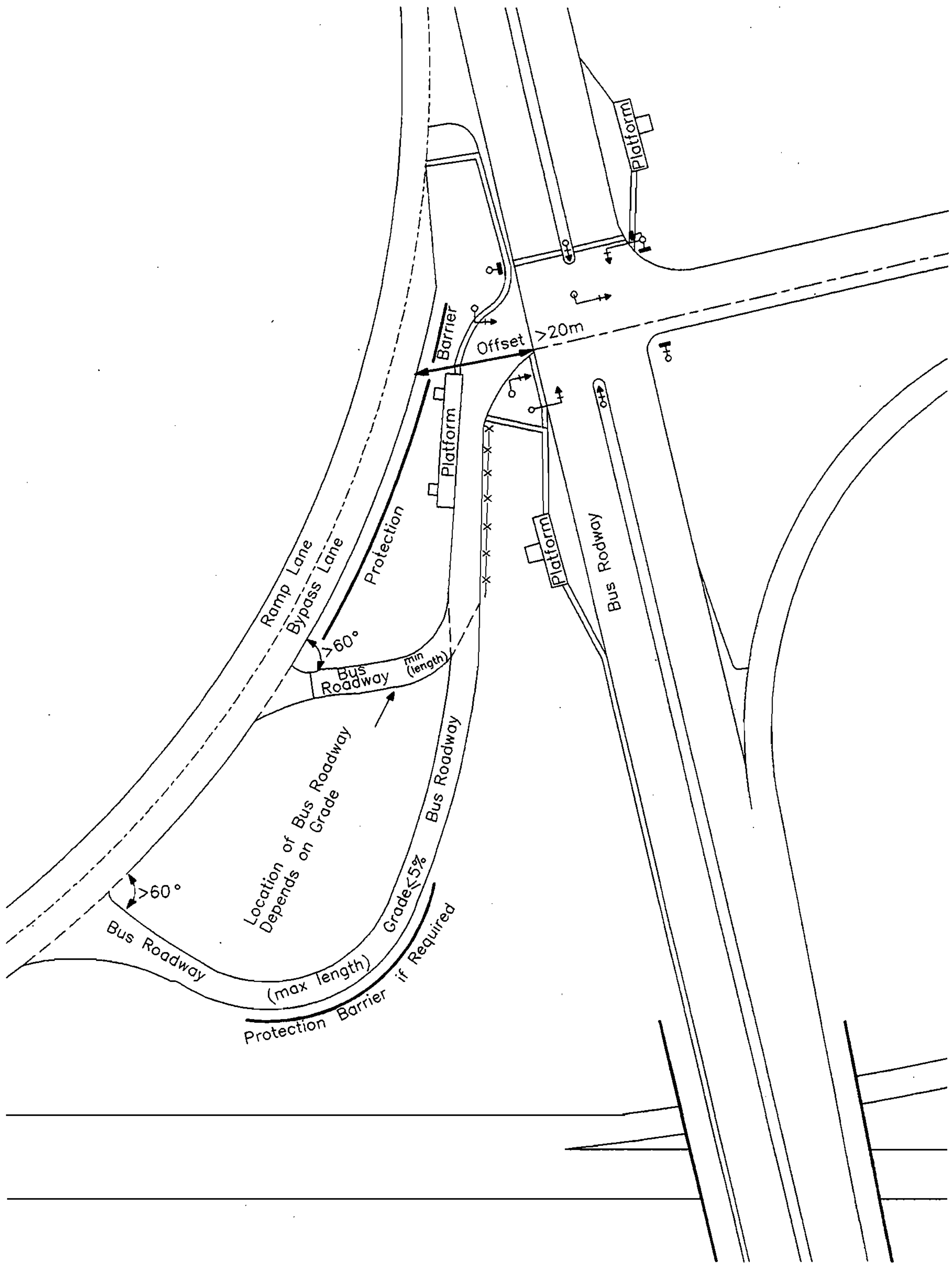


Figure G2-33
Freeway Interchange Bus Interface TYPE II

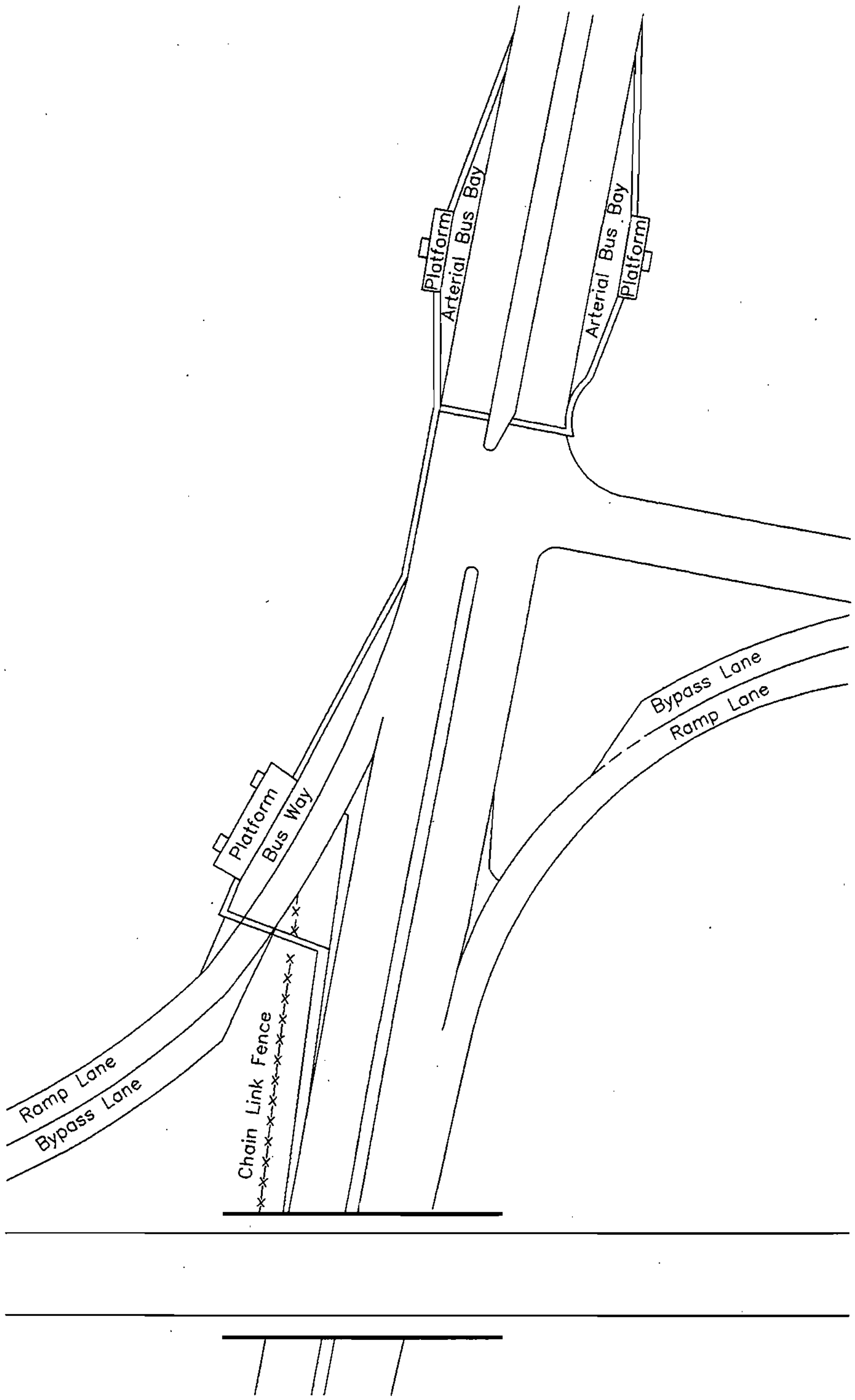
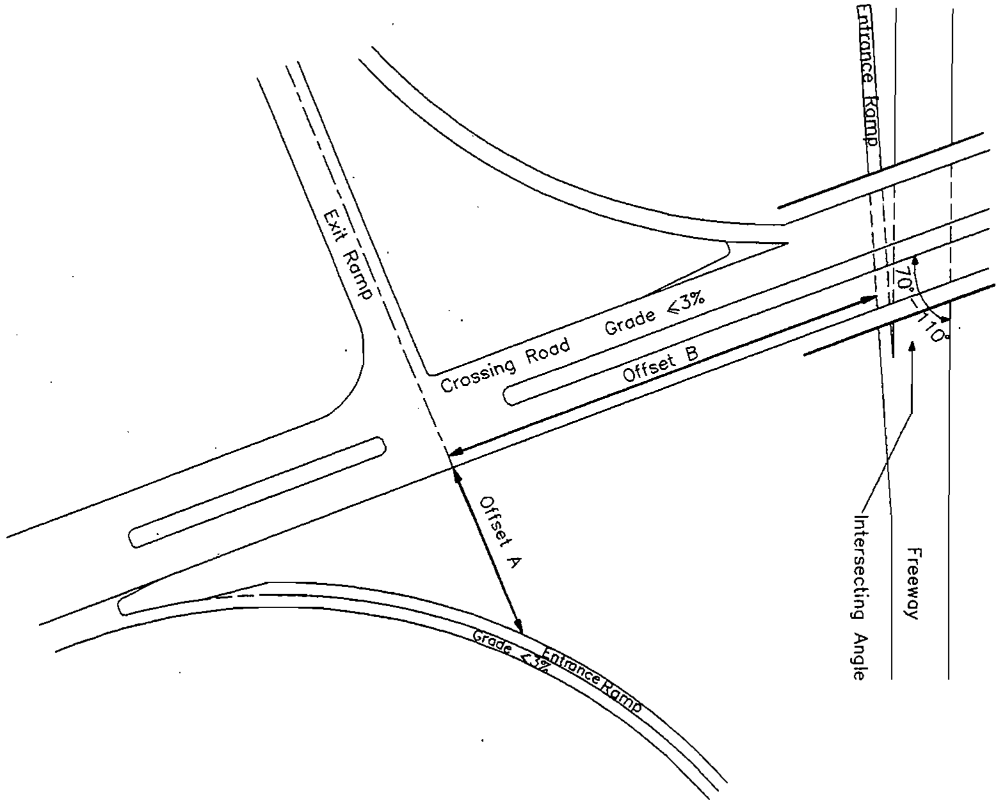


Figure G2-34
Freeway Interchange Bus Interface TYPE III



GUIDELINES

STEP 1

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

STEP 2

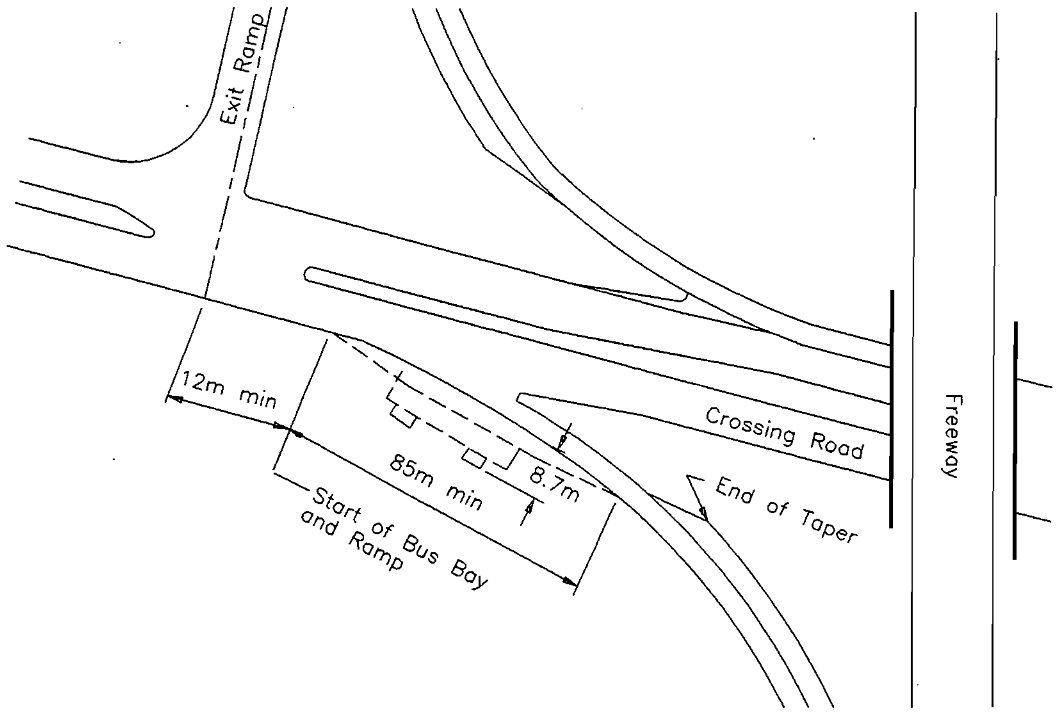
- if "OFFSET A" is >20 m then "OFFSET B" must be ≥ 100 m to provide TYPE II interface.
- if "OFFSET A" is 10-20 m and intersecting angle is ≥ 90° then "OFFSET B" must be ≥ 140 m to provide TYPE I interface with or without local bus exit
- if "OFFSET A" is 10-20 m and intersecting angle is < 90° then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

STEP 3

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

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

Figure G2-35
Interface of Freeway and Local Bus Services at "Parclo A" Interchanges (TYPE I & II)



GUIDELINES

STEP 1

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

STEP 2

- locate the downstream end of the bus bay 85.0 m along the ramp from the start of the curve on the arterial
- ensure that the downstream end of the bus bay is adjacent to or upstream of end of taper/start of the bypass lane (the point at which 2 vehicles can travel side-by-side)
- ensure that buses turning left from the freeway exit ramp can manoeuvre into the bus bay at an appropriate approach angle.(A minimum distance of 12 m from bus turning lane to start of bus bay)
- for the length of the platform provide an offset from edge of ramp of 8.7 m.

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

Figure G2-36
Interface of Freeway and Local Bus Services at "Parclo A" Interchanges (TYPE III)

G.2.3.3 Bus Interface at Parclo "A" Interchanges

Five parameters are used to define the Type I and II bus interface space requirements:

- offset from crossing road at exit ramp to direct entrance ramp with by-pass lane (if required)
- offset from exit ramp along crossing road to edge of pavement at freeway or inner loop entrance ramp
- intersection angle of the roadways
- grade of the crossing road
- grade of the direct entrance ramp.

Two parameters are used to define the Type III bus interface space requirements:

- Length along the direct entrance ramp, between the start of the bypass lane (the point at which 2 vehicles can travel side-by-side) and the upstream end of the bus bay.
- Offset from the edge of the entrance ramp which will accommodate the bus bay and the platform area and a bus shelter.

These guidelines should be appropriate for most applications, however, if conditions are restricting then a layout of the interface should be undertaken using the Design Standards.

G.2.3.3.1 Selection of Interface Type

1. Interface Type I

   In cases where an offset between the Freeway exit terminal and entrance ramp of 10 - 20 m is provided, develop crossing road profile and entrance ramp profile to permit possible implementation of Type I Freeway Interchange Bus Interface (Figure G2-32) with:

   (i) a bus platform length of 35 m;

   (ii) a bus roadway at a 0.5% longitudinal grade between the crossing road and the downstream end of the platform;

   (iii) a bus roadway at a grade of no more than 5% with appropriate vertical transition curves between the platform and the freeway entrance ramp;

   (iv) in cases where the climbing grade of the crossing road permits it, a bus roadway at a grade of not more than 5% with appropriate vertical transition curves between the platform and the re-entry point at the crossing road; or,

   (v) in cases where the climbing grade of the crossing road does not permit local bus re-entry onto the crossing road, a separate local bus bay to be located along the crossing road before the crossing road structure.

2. Interface TYPE II

   In cases where an offset between the Freeway exit terminal and entrance ramp of at least 20 metres is available, develop crossing road profile and entrance ramp profile to permit possible implementation of Type II Freeway Interchange Bus Interface (Figure G2-33) with:

   (i) a bus platform length of 35 metres;

   (ii) a bus roadway at a 0.5% longitudinal grade between the crossing road and the downstream end of the platform; and

   (iii) a bus roadway at a grade of no more than 5% with appropriate vertical transition curves between the platform and the freeway entrance ramp.

3. In cases where an offset of less than 10 m is provided between the Freeway exit terminal and entrance ramp, develop a Type I Freeway Interchange Bus Interface as per #2 above at a point downstream of the Freeway exit terminal where necessary offset is available.

4. In cases where the crossing road exit terminal is downstream of the Freeway exit terminal.These guidelines suggest that in circumstances of new design, an offset of at least 20 m is sufficient to provide a Type II Bus Interface and possibly a Type I Bus Interface. If property limitations or the skew of the crossing road to the freeway is such that an offset of 10 - 20 m results, then a Type I Bus Interface is appropriate with or without a separate local bus bay depending on local conditions. If the offset is less than 10 metres then a Type I Bus Interface is still appropriate but it must be located downstream of its normal position where sufficient offset is available. If the Freeway entrance ramp is accessed downstream of the Freeway exit ramp then a new design is required which is not yet developed.

5. Interface Type III

   This additional geometric design standard provides guidance in providing for an interface at Parclo "A" Interchanges which are configured such that the freeway direct entrance ramp is located downstream along the crossing road from the exit ramp terminal.

   This Type III bus interface which is most suitable to this interchange configuration is indicated in Figure G2-34.

G.2.3.3.2 Operational Considerations

(i) Interface TYPE I and II

Bus access to the bus interface will be from the exit ramp left-turn lane in situations where the exit ramp terminal at the crossing road is 2 lanes.

Bus access to the bus interface will be from the center freeway exit ramp either/or turn lane in situations where the freeway exit ramp terminal at the crossing road is 3 lanes. Location and alignment of the bus interface entrance shall be designed such that conflicts between turning traffic in adjacent lanes is avoided.

Buses will access the bus roadway and stop at one of two possible bus platforms at the interface.

Buses can proceed through the interface platform area at speeds not exceeding 35 km/h which has been established as reasonable from the point of view of manoeuvrability, safety and costs.

During unmetered times of the day, buses will likely enter directly into the main traffic flow from the bus roadway.

Passengers will access the bus interface by either transferring from local transit or walking in from the crossing road.

Access will be directly to the platform since fares will likely be collected on-board the buses. Platform access can be at either end or along its length.

(ii) Interface TYPE III

As with all freeway bus operations, bus access to the Type III interface will be from the exit ramp left turn lane in situations where the exit ramp terminal at the crossing road is only 2 lanes.

Bus access to the Type III bus interface will be from the centre freeway exit ramp either/or turn lane in situations where the freeway exit ramp terminal at the crossing road is 3 lanes. Location and alignment of the Type III bus interface entrance shall be designed such that conflicts between turning traffic in adjacent lanes is avoided.

Buses will access the Type III interface at the freeway entrance ramp terminal and stop at one of two possible bus platforms.

Buses will exit from the platforms directly onto the ramp when there is a suitable break in traffic flow. If there is a bypass lane and a metered lane on the ramp and if metering is in operation then the bus may move left into the bypass lane without undue weaving difficulties. At such time that metering is not in operation then the bus may stay in the main flow of traffic.

Passengers will access the Type III bus interface by walking from local bus bays on either side of the arterial or by crossing the freeway entrance ramp from the other side of the interchange.

Passenger access to buses will be uncomplicated since fares will likely be collected on-board the buses and not at turnstiles at the ends of the platforms. This allows platforms to be accessed from the ends or along its length. If the access is along its length then additional offset from the ramp will be required.

G.2.3.3.3 Staging Considerations

Integration of the bus system with the ultimate rail system has been considered and it is anticipated that bus interfaces will be operational during the integration process.

Transitway sections between interchanges will ultimately be linked together with grade-separated structures, however at an interim measure, at-grade bus crossings could possibly be developed. This condition may have traffic operational improvements or geometric design provisions then it may be possible to utilize the initial bus interfaces to facilitate transfers between local buses and freeway buses. The Type I Bus Interface however does not permit left turns into the bus roadway from the crossing road due to its inherent design characteristics.

Full development of transit service staging should be undertaken during preliminary design activities for the transitway.

If at-grade bus crossing impacts are minimized through traffic operational improvements or geometric design provisions then it may be possible to utilize the initial Type III bus interfaces to facilitate transfers between local buses and freeway buses during the interim time frame.

G.2.3.3.4 Design Standards - General

The design should consider desirable alignment elements which improve passenger ride, such as reducing sags, crests and directional changes while moderating costs.

Design of Bus Interfaces should consider:

- safety
- capital costs
- alignment
- intended operation
- impact on crossing road and bus roadway access/egress locations

Design speeds shall be 35 km/h on bus roadways and platform areas.

G.2.3.3.5 Horizontal Alignment

Sufficient sight distance shall be provided for buses on the bus roadway such that drivers can maintain safe and efficient operation of the vehicles. Minimum stopping sight distance must be provided at egress to the freeway entrance ramp.

Passing sight distance does not apply since no passing will occur on the bus roadway except the passing of stalled or immobile vehicles.

The bus roadway shall be on tangent through the platform area.

Minimum edge of pavement radii for the B-12 design vehicle are as follows:

Stop Condition (0 - 15 km/h)	Radii: 18 m
Yield Condition (15 - 25 km/h)	Radii: 20 m

Note that on a four lane roadway with a 15 m radius, buses use both lanes when making a right turn.

G.2.3.3.6 Vertical Alignment

The maximum gradient on the bus roadway shall not exceed 5%, as depicted on Figures G2-32 and G2-33.

The minimum gradient on the bus roadway should be no less than 0.5% at platforms to permit positive drainage.

The design parameter for crest curves and sag curves on the bus roadway shall remain above a minimum K = 4 m for crest and K = 8 m for sag curves (at 40 km/h).

G.2.3.3.7 Turning Vehicle Paths

The Design Vehicle dimensions shall be used to ensure that highway buses can manoeuvre easily on bus interface sites. The highway bus type B-12 shall be the design vehicle for all bus interface layouts. This design vehicle will accommodate standard Buses. For reference of design vehicles see Chapter E, Section E.5.

A clearance of at least 1.0 m should be provided between the line given by the Design Vehicle Turning Radius and any fixed object that a bus could collide with.

There are two paths for the design vehicle, as follows:

Stop Condition

The vehicle commences a turn from a stationary position (e.g. from bus platform on bus roadway).Stop condition reflects the treatment for stop sign control where the access road joins a two-lane roadway, using the 15 m turning radius design vehicle template.

Yield Condition

The vehicle commences a turn at speeds between 15 and 25 km/h (e.g. downstream of platform along bus roadway). Yield condition reflects the treatment for signal control where an access road joins a two-lane roadway, using the 20 m turning design vehicle template.

G.2.3.3.8 Safety and Security Measures

Chain link security fencing shall be provided as required to encourage safety and pedestrian control in the bus interface area.

Fencing may be replaced by longitudinal traffic barrier with aluminum pedestrian barrier affixed to the top or fencing affixed to the top of a retaining wall if so required.

Longitudinal traffic barrier shall be installed along Freeway traffic entrance ramps where safety is at risk due to vehicles accidentally veering towards pedestrian areas of the interface.

Longitudinal barrier shall be installed if the unprotected clearance between the bus roadway and the freeway edge of pavement is within 10 m.

Such barrier shall be located in accordance with the "Roadside Safety Manual".

Provisions are to be made for access by emergency vehicles, including fire trucks and ambulances. Designated fire routes, no parking zones, etc., shall meet municipal approval, although emergency vehicles will generally use bus roadways.

G.2.3.3.9 Interface Location

Interfaces at interchanges shall be located as closely as practicable to crossing roads of suitable geometrics and ridership potential.

Pedestrian walk distances shall be minimized between local and freeway buses.

G.2.3.4.0 Platform Facilities

Standardized bus interface designs shall be provided if practical.

Geometric design provisions at bus interfaces should allow for platforms to be 35 m long, 4 m wide and the bus platform level should be 150 mm above the bus pavement level.

Satellite shelter pads should be provided for along the platform such that a 1.2 m by 3.65 m shelter (approximate dimensions) could be constructed.

Lighting of the bus roadway, and the platforms, and of sidewalks and shelters should be integrated with that of the ramp and crossing road. Under pavement crossings should be provided accordingly.

G.2.3.4.1 Local Bus Facilities

Where freeway bus interfaces are located adjacent to crossing roads, the municipality may request that bus bays for local service be provided, particularly if the interface cannot accommodate local bus facilities. Bus bays will assist the through traffic movement and reduce the accident-prone weaving movement on four and six-lane roads.

The location and dimensions of the bus bay must be reviewed with the transit authority to ensure that the location suits their operations. It will also require a careful site review to ensure that conflicts with driveways or other topographic features are minimized, and that the location is approved by the municipality. Typical configurations are provided on Figure G2-39.

Care must be taken in the bus bay design allowing sufficient entrance and exit lengths to discourage serious disruption of traffic movement in the adjacent lanes. Both Standard and some models of Articulated Buses (B-12) should be accommodated in bus bay design.

Local buses travelling in one direction on the crossing road may be provided with bus stopping privileges at freeway bus platforms for Type I interfaces where the offset between the crossing road and the freeway entrance ramp permits it and where the grade differential is small. This arrangement provides optimum passenger transfer potential between buses. Under favourable circumstances local buses then re-enter the crossing road upon leaving the interface.

Buses which may wish to turn left from the crossing road into the bus interface will be able to do so only at Type II interfaces. Type I interfaces do not provide sufficient area in which to turn a bus from that position.

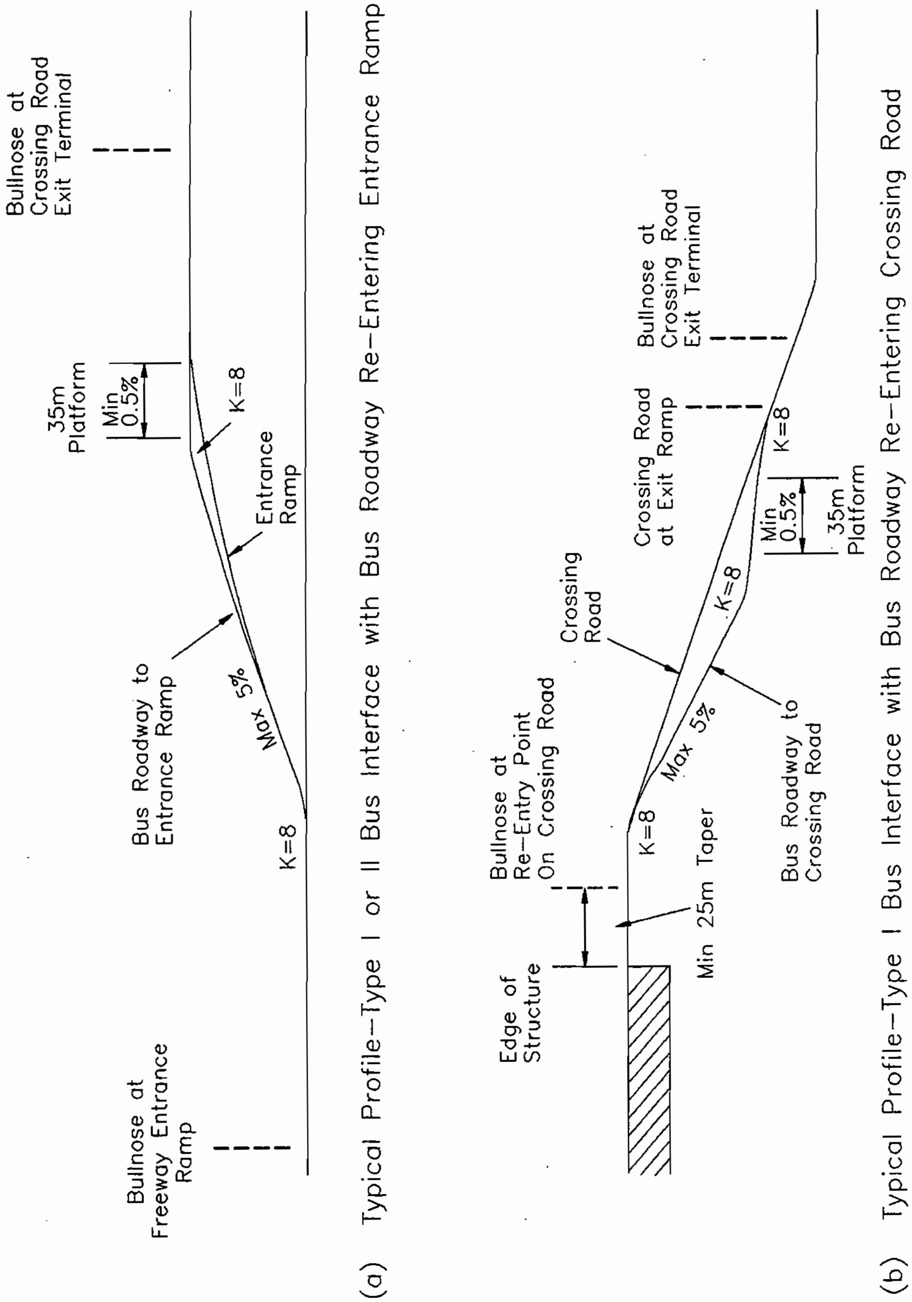
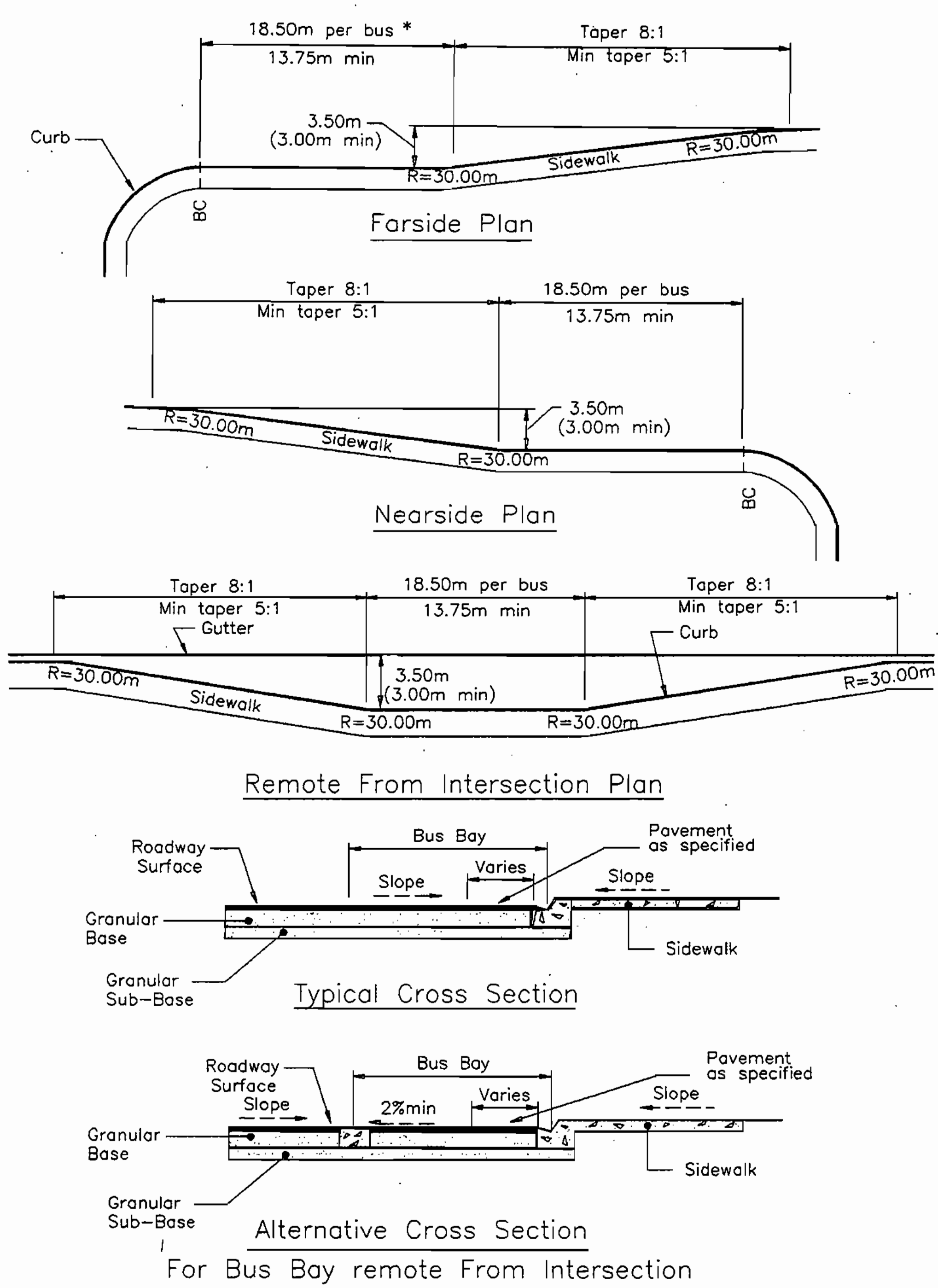


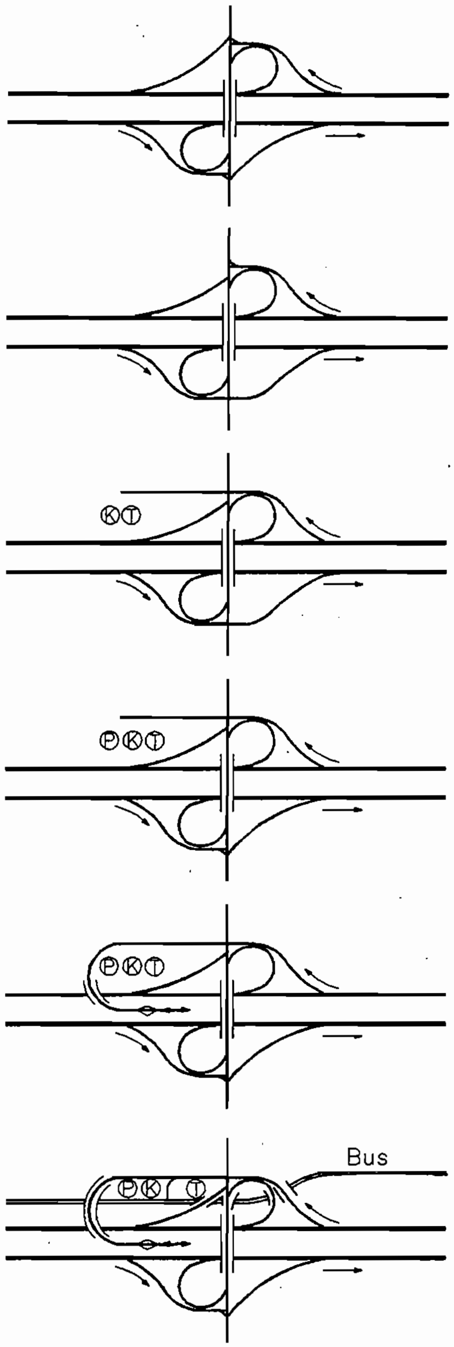
Figure G2-37
Typical Profile of Interchange with Bus Interface TYPES I, II &III



Notes:

- Careful analysis of the crossfall and gutter shall be made to ensure proper drainage.
- This standard is applicable for design speeds of 70km/h or less.
- * To accomodate articulated buses.

Figure G2-38
Arterial Bus Bays



① Existing Interchange

② Construct Transit Interface

③ Introduce Off–Line Stop, Kiss+Ride

④ Add Parking

⑤ Add Direct Ramp To HOV Lane

⑥ Add Bus Only Transitway

Figure G2-39
Staged Development Transit Station

G.2.4 FREEWAY TRAFFIC OPERATIONAL AND SAFETY SYSTEMS

G.2.4.1 FTMS Applications and Overview

Freeway Traffic Management Systems (FTMS), as practised in Ontario, are identified by the name COMPASS and consist of four basic systems, each with a distinct function and set of subsystems. Table G2-7 summarizes the systems.

The Vehicle Detector, Closed Circuit Television and Changeable Message Sign subsystems are now in operation in Burlington, Mississauga, and Toronto, while expansion plans include Ottawa-Carleton and other urban corridors in the Greater Toronto - Niagara area. Ramp metering and Arterial Advisory (Blankout) Sign subsystems operate in one corridor each. Additional subsystems such as Lane Control Signs, advanced Arterial Advisory Signs, Highway Advisory Radio, and Ramp Meter Bypass Lanes are in various stages of planning.

Advanced technological concepts such as in-vehicle navigation systems, automatic toll payment, and automatic traffic information systems are also in the early stages of international research and development. Together with the FTMS strategies now in place, they form an "Intelligent Vehicle / Highway System", or IVHS, which would be expected to evolve over the coming years (and decades) towards general use on Ontario's highways.

In addition to the electronic and physical systems in place, FTMS includes plans and procedures to ensure a rapid, co-ordinated response to incidents among Police, Emergency Services, FTMS and MTO Maintenance staff.

For several reasons, High Occupancy Vehicles and their facilities are among those segments of the highway system which exhibit the greatest potential for FTMS/IVHS related applications and benefits:

- The intent of FTMS is to make the highway system operate more efficiently, more safely, and with less congestion; these goals are shared with HOV applications.

- FTMS/IVHS strategies are normally applied in those corridors exhibiting significant recurring congestion, in order to maximize potential benefits; these are also conditions suited to HOV application.

- HOVs are a small portion of the transportation system, yet carry a disproportionate number of people; they are thus suited to pilot project application with maximum initial impact.

- An HOV lane has the potential to operate with great flexibility and maximum efficiency through increased awareness of mixed flow conditions and flexible electronic signage and gate controls; HOV lanes could thus theoretically operate only when and as needed to avoid congestion, for example at various points throughout the day or with varying minimum occupancy rates depending on the overall freeway level of service. However, if not tied to a schedule, enforcement and driver expectations could have problems due to inconsistency.

- An HOV lane is in most cases a more controlled environment than several mixed flow lanes, and is used by a select group of vehicles (no trucks); management of the flow within the lane to achieve optimum efficiency will be far easier than application of IVHS on a large scale to the entire freeway system.

- One of the major HOV-related issues at present is the determination of vehicle eligibility (i.e. occupancy); advanced registration and/or electronic monitoring techniques hold some promise to resolve this problem.

- Ramp metering, and preferential treatment of HOVs at metered ramps, holds significant potential to become more efficient and effective, with monitoring and control of upstream lane volumes and gap availability.

- IVHS plans are likely to be fist applied to buses and commercial fleets before extending to the entire automotive spectrum; since bus use is a major factor in achieving the potential of an HOV facility, any technique which improves bus service is supportive of the HOV concept.

- Ridesharing and transit information will become more readily available and accurate, thereby making HOV use and carpool formation more convenient.

In summary, HOV facility and operation will potentially be among the most significant and easily-applied components of an advanced Traffic Management/IVHS plan for a freeway corridor. It may also be noted that, if an FTMS/IVHS application is effective in reducing congestion in a corridor, it will be diminishing one of the strongest incentives to use HOVs. However, since HOV use is itself one of the most effective means of reducing congestion, it is essential that HOV operation maintain a good level of service and that use of HOVs - both carpools and buses - be made as convenient and attractive as possible.

TABLE G2-7

FREEWAY TRAFFIC MANAGEMENT SYSTEMS

System	Subsystem	Functions
Monitoring	Vehicle Detector Station Closed Circuit Television	• Real-time speed and volume monitoring • Incident detection and confirmation • Data collection
Advisory	Chargeable Message Signs Lane Control Signs Arterial Advisory Signs Highway Advisory Radio	• Provision of information to motorists, both on the freeway and prior to freeway entry. • Management of traffic during congestion, incidents, or maintenance activities.
Management	Ramp Metering Ramp Metering Bypass Lanes Ramp Closure Gates	• Control flow rate of vehicles entering freeway. • Preferential treatment of designated vehicles at metered ramps. • Closure of key ramps if needed due to incident or maintenance. • Co-ordination with Police, Emergency crews, Maintenance Operations staff and Municipal traffic, control centres, to ensure a rapid, co-ordinated response to incidents and congestion.
Communications and Control	Control Cabinets Communications Cable District Traffic Operations Centre	• System control • Data processing • Linkage to external offices

G.2.4.2 Incident Management

As essential element in a Freeway Traffic Management and Operations plan is Incident Management, both in reducing the risks of disruptive incidents occurring and in minimizing the consequences of incidents of traffic flow when they do occur. Since two of the key features associated with HOV priority treatments are travel time improvement and reliability, incident management plays a major role in HOV system operations.

Typical non-recurrent incidents include traffic accidents, disabled vehicles, spilled loads, driver gawking, and adverse weather conditions. Other irregular activities which may affect flow include freeway maintenance (including snowplowing) and construction while unusual situations such as traffic diversion from blocked parallel routes, VIP transfers, and larger scale emergencies can also occur. Together, all these departures from "normal" operation may represent the cause of up to 60% of the delay experienced on freeways in Ontario's urban areas.

An Incident Management Strategy, involving defined actions and responsibilities, should be developed for a corridor prior to the introduction of HOV lanes; involved agencies should include the MTO, provincial/regional police, all emergency service providers, tow truck operators, and the affected municipalities.

Freeway Traffic Management System (see Section G.2.4.1) can play a large role in identifying and removing incidents while informing area motorists of the situation; some HOV-specific design features related to incident management are also appropriate:

- adequate shoulder width, continuous throughout HOV project, for both HOV and mixed flow lanes (see Section G.2.1 for relevant design guidelines).
- widened shoulders where necessary for enforcement purposes (Section G.2.4.4).
- physical barriers between opposing traffic flows and, where adequate right-of-way exists, between adjacent HOV and mixed traffic lanes.
- adequate geometric provisions for lane access, egress, and termination.

Barrier-separated HOV lanes have been shown to have lower accident rates than adjacent mixed flow lanes, and to have a lower rate than non-barrier-separated lanes.

Given that an HOV lane's effectiveness is predicated on a fast, reliable travel time, and that during peak periods it will carry a disproportionate number of persons, there is some justification to developing an incident management strategy which places highest priority on maintaining smooth HOV lane operation.

In the extremely unusual event of emergency or construction conditions requiring use of the HOV lane by non-HOVs (e.g. during closure of the mixed flow lanes), consideration should be given to maintaining HOV priority to the extent possible, and to ensuring that the facility is operationally compatible (e.g. reversible lane) with the demands being placed on it. Limiting such use to off-peak periods, and using temporary or electronic signage to define the condition is highly desirable.

G.2.4.3 Signage

Clear, concise communication of HOV-related facilities and regulations to all freeway users is a substantial challenge. In addition to the normal entry, exit, and directional signage associated with any freeway lane, the specification of: a) vehicle eligibility; and, b) time of HOV lane operation are required. Furthermore, the dynamic nature of many HOV applications provides opportunities for use of changeable signs.

The accepted symbol for designation of HOV-related signage is a white elongated diamond outline on a black background. Use of the symbol for other purposes should not be allowed.

G.2.4.3.1 Pavement Markings

Use of standard pavement markings and colours is recommended for HOV facilities: white for concurrent flow and yellow for lines separating opposing flows; solid stripes where vehicles are not permitted to cross and dashed stripes where crossing is allowed.

A buffer zone between a concurrent flow HOV lane and a mixed flow lane should be delineated by solid white stripes. If no access restrictions are placed on the HOV lane or if it reverts to mixed flow usage during part of the day, elimination of the buffer and use of standard white dashed striping should be used; in such a case, lane designation will rely entirely on signage.

In the Ontario context, writing on the HOV lane pavement (e.g. "BUSES AND CARPOOLS ONLY") is not recommended. Use of the diamond symbol as a pavement marking would be appropriate, however, only for full-time HOV lanes.

G.2.4.4 Enforcement Facilities

There are three major requirements for enforcement-related facilities associated with a freeway HOV/Bus lane:

- a place to observe traffic operations and lane violators;
- a place to pull over violators (preferably incorporating a means of sending apprehended vehicles back into the mixed flow); and
- a safe refuge for accident/incident investigation.

In addition to these specific features dedicated to enforcement use, the design of the priority lane itself can affect the violation rate, and in the level of enforcement effort and associated facilities required. A contraflow lane dedicated to bus-only operation, for example, will by its very nature attract fewer violators than a non-separated concurrent flow lane, and could be considered virtually self-enforcing.

For the purpose of both operational safety and ensuring the use of the priority lane only by eligible vehicles, there are benefits from limiting or controlling the access to the lane. Even in the case of non-separated concurrent flow facility, marking the pavement so as to focus transfer moves to limited zones can minimize unexpected moves. For barrier-separated priority lanes, provisions for enforcement should be focused on the entry points, allowing the apprehension and removal of ineligible vehicles before the lane is used.

For reversible flow HOV lanes, a moveable physical barrier is required at each end of the priority section to preclude any vehicle gaining access to the lane in the wrong direction. In association with such moveable barriers there is normally a pocket area suited to use by enforcement vehicles for observing entering traffic. A pair of enforcement officers, with one observer and one downstream officer to pull over the observed violator, if effective in this situation.

A second situation in which a stationary observation and enforcement position is effective is immediately downstream of a ramp meter or queue bypass. Both non-HOV queue jumping and ramp metering violators can be enforced in this way, although the latter requires the provision of a meter signal head that is visible to the enforcement officer.

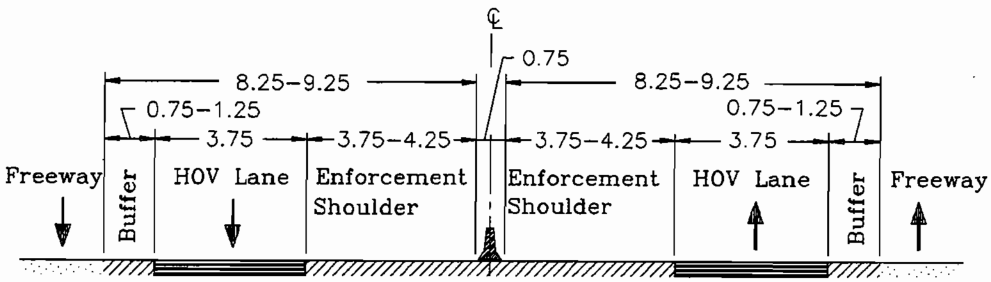
All enforcement shoulders or zones should be at least 4 m wide (5 m preferable) in order to allow safe movement within the area; length, including access and egress tapers, should be designed in accordance with the entering and exiting vehicles speeds. The optimum design is a full width breakdown shoulder extending the length of the facility; where adequate right-of-way is not available, periodic shoulder widening to the necessary width is required (in concurrent flow median lanes the widened shoulders can alternate between one direction and the other within a constrained width median). Enforcement areas should not take the form of a wide buffer between HOV and mixed flow traffic. One effective deterrent to would-be violators can be the provision of a turnaround, if space is available, to release the apprehended vehicle in the opposite direction.

Examples of recommended practice for concurrent flow HOV lane enforcement areas follow in Figure G2-40. Enforcement zones for other types of HOV application (reversible flow, ramp meter bypass, etc.) can be developed in a site-specific manner.

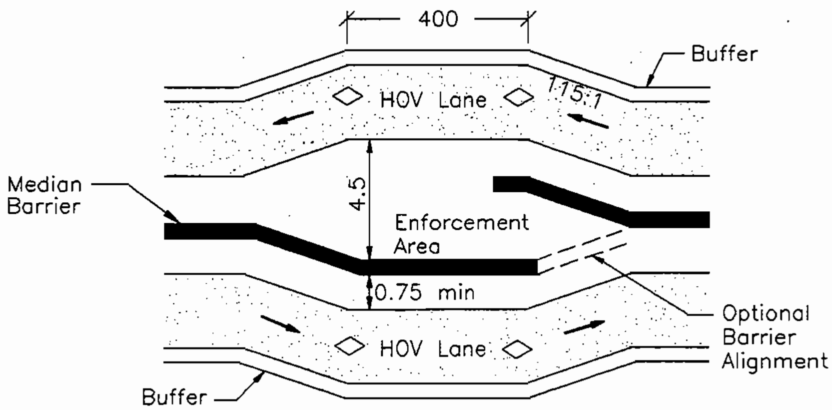
G.2.4.5 Illumination

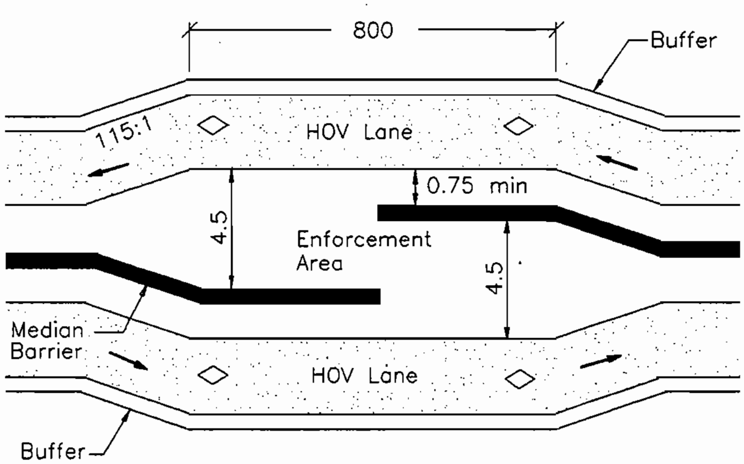
As with any other freeway element, safety of operation is essential for an HOV lane. Particularly with barrier-separated facilities, the use of lighting at access and egress locations is desirable. The presence of lighting in corridors where Closed Circuit Television monitoring is used as an element in a Freeway Traffic Management System aids in monitoring and in the management of incidents.

The most significant HOV-related illumination requirement is the provision of adequate lighting in enforcement areas to allow monitoring of vehicles occupancies (recognizing that peak periods during the winter months occur during darkness in Ontario). HOV ramp meter bypass lanes and HOV lane access zones, are key locations in this regard.



High–Speed Enforcement Areas along Two–Way Buffer–Separated HOV Facilities





Typical Layouts for Designated High–Speed Enforcement Areas

Figure G2-40
High-Speed Enforcement Areas

G.2.4.6 Maintenance

The ability to carry out regular freeway maintenance activities in a matter which ensures the safety of maintenance crews and minimizes disruption to traffic flow should not be affected by the presence of an HOV facility. Some HOV designs have inherent additional operational costs; the daily placement of barriers or pylons on contraflow lanes, for example, or the shifting of barriers to allow reversible operation.

The presence of adequate shoulders, use of advance signage (including Chargeable Message Signs), and restriction of activities to off-peak periods are typical effective strategies.

In Ontario, the removal of snow from the freeway system is a crucial maintenance activity; in this respect, concurrent flow non-barrier-separated facility design is favoured over barrier-separated lanes. In the presence of barriers, the consideration of the reduction of shoulder width in constrained areas from a standard 2.5 - 3.0 m should take into account snowplowing and snow storage needs. The use of a reduced shoulder for an extended length is highly undesirable, and should only be considered if an acceptable snow removal strategy can be applied.

Assigning a high priority to HOV lanes for both snow removal and litter removal is desirable, given that the lanes rely on smooth peak period operation to carry a disproportionate share of freeway users.

In the long term, HOV lane pavement resurfacing or reconstruction can be a significant challenge; again, non-barrier-separated lanes are more flexible, in that the adjacent freeway lane can be designated for HOV use on a temporary basis during the construction period. If the work can be accomplished on a weekend (in the nearly three days between the Friday and Monday peak period peak direction flows) it would be desirable to do so, and to limit the impact on peak period peak direction weekday HOV flow.

For reversible lanes, and in particular those with heavy volumes of buses, wheel rutting in the single lane can develop over time to create a problem, especially when combined with snowplowing and reconstruction constraints as cited above. The pavement of such a facility should be designed for strength and longevity.

Since HOV lanes are located in either the median or right side lanes, maintenance of a clear path for surface water drainage across the lane is essential; in the case of barrier-separated lanes, drainage slots in the base of the barrier are required.

G.3 HOV PRIORITY PROGRAMS

HOV lanes should be implemented with other programs, policies, and incentives designed to encourage HOV use. The portion of a commuter trip on a provincial freeway is only a small component in an overall decision-making process which encompasses a choice of mode, choice of route, choice of travel time, and trip segments on other roadways leading to and from the freeway. All of these other aspects can and should be influenced in order to achieve the goal of using fewer vehicles to move more people.

A wide variety of incentive measures are available to make an HOV trip faster more convenient, less costly, and more desirable; in many cases, each individual incentive measure generates only a small part of the overall incentive required in order to induce modal shift. It is therefore important that as many of these elements as possible be put in place and work together to achieve the overall goal. Formation of a coalition of HOV practitioners is recommended in each urban area, to ensure that a coordinated areawide strategy is developed and applied.

Four areas of practice are highlighted:

1) Travel Demand Management
2) Parking
3) Transit Operation
4) Marketing

The role of the employer is providing both incentives and a workplace environment which supports the use of shared ride/transit modes is emphasized, as are the benefits which may result in the way of reduced parking needs, property development bonuses, and employee productivity/morale.

Establishment of park and ride lots well-served by transit; carpool parking lots with amenities such as lighting, phones, newspaper boxes, and transit service; and priority parking for carpools within large parking areas (both by fee and location) is recommended. Joint use of parking areas such as those of churches, cinemas, sports complexes, and shopping centres for carpool lots can be pursued. Ridematch programs and "guaranteed ride home" plans are effective HOV incentives.

Transit operators need to take advantage of HOV "expressways" by providing express service, new routes, and coordinated services. Their involvement throughout the HOV facility planning and design process is essential. HOV marketing can be initiated by using the base awareness and staff already in place for transit marketing. The education of the public and the generation of public support for HOV lanes (by both users and non-users) is essential; an HOV lane has to be "sold" like no other freeway lane does.

CHAPTER J

MISCELLANEOUS

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J.1 DETOURS

J.1.1 INTRODUCTION

J.1.1.1 Purpose

The guidelines contained in this section have been developed to provide a uniform set of metric standards or courses of action for the design and construction of detours which will provide for a safe and uninterrupted flow of traffic.

POLICY

AT THE PRE-DESIGN STAGE THE PLANNING AND DESIGN SECTION SHOULD HAVE EXECUTIVE APPROVAL ON ALL DETOUR PROJECTS AFTER CONSULTATION WITH THE REGIONAL TRAFFIC SECTION, CONSTRUCTION OFFICE AND ENVIRONMENTAL SECTION.

J.1.2 Design Considerations

POLICY

SAFETY SHOULD BE THE FIRST CONSIDERATION OF THE DESIGN. ALTHOUGH IT IS DESIRABLE TO MINIMIZE COSTS, THIS SHOULD NOT BE DONE AT THE EXPENSE OF SACRIFICING SAFETY BY REDUCING GEOMETRIC STANDARDS TO AN UNACCEPTABLE LEVEL. COST BY ITSELF SHOULD NOT BE A LIMITING FACTOR.

The traffic demand is an important consideration and the traffic volume, expressed as AADT, or DHV, a primary factor in determining the detour design speed. Most detours are in use during the summer months and it may be more appropriate to use the SADT for determining the detour design speed.

A limiting factor to the detour design speed selection may be the available sight distance. This should be addressed at the Pre-Design stage and decided by mutual agreement of all the sections and/or Offices involved.

When designing a detour, the classification of the approach roadway must be taken into consideration and will also be one of the factors used to determine the detour design speed. Once selected the horizontal and vertical alignment will be based directly on the detour design speed. The cross sectional elements will be influenced by the detour design speed.

The duration for which a detour is in operation is also a consideration and has an influence on the geometric standards to which it is constructed. Research indicates that if a detour is to be operational for more than one season, it should be constructed to normal geometric standards.

Short term detours on low volume facilities may be better accommodated on local roads (off-site detour) and this option should be investigated.

Surprise elements caused by the construction traffic should be eliminated as much as possible. Create an environment as nearly as possible like that of the approach highway, but if differences cannot be avoided, then the differences must be clearly visible to the motorist.

Produce a physical facility that will induce any driver to take the proper action which makes it possible for the vehicles to react as intended. These guidelines are intended to be flexible enough so that regional variations can be incorporated into the design. Any major deviation from these guidelines should be individually documented in the Design Criteria.

J.1.2 DETOUR DESIGN SPEED

The detour design speed is a primary control and will influence the design of the detour in both the horizontal and vertical planes. The following are guidelines for the selection of a detour design speed:

High volume highways

- above 6000 AADT or 600 DHV; detour design speed should remain the same as the approach roadway for high design speeds and may be reduced for lower design speeds.

Low volume highways

- below 6000 AADT or 600 DHV; detour design speed may be reduced for all approach roadway design speeds.

A consistent design speed is desirable throughout the detour section.

Recommended detour design speeds are shown in Table J1-1.

Any deviations from a high or low volume threshold (6000 AADT or 600 DHV) must be justified in the Design Criteria. Drivers will not significantly reduce their speed in a detour unless they clearly perceive the roadway situation hazardous. Therefore, whenever feasible, design for speeds vehicles will travel, not the speeds one hopes they will travel. Design speed should not be significantly lower than what drivers will reasonably expect or tolerate.

The introduction of a lower design speed should not be affected abruptly but over a sufficient distance to permit drivers to change speed gradually before reaching the section of highway with a different design speed. A transition section for a speed reduction should be provided whenever the reduction is 20 km/h or more. The transition section should reduce speed in 10 km/h increments. The regional Traffic Section should review the selection of the detour design speed.

Table J1-1
Recommended Detour Design Speed Reductions

(i) High Volume Highways							
Highway Design Speed (km/h)	60	70	80	90	100	110	120
Recommended Reduction (km/h)	20	20	10	10	10	0	0
Detour Design Speed (km/h)	40	50	70	80	90	110	120
(ii) Low Volume Highways							
Highway Design Speed (km/h)	60	70	80	90	100	110	120
Recommended Reduction (km/h)	20	20	20	20	20	20	20
Detour Design Speed (km/h)	40	50	60	70	80	90	100

Note:
A maximum reduction of 30 km/h may be used for low volume highways, but must be justified, in terms of cost and safety, in the Design Criteria.

J.1.3 GEOMETRIC ELEMENTS

The geometric elements of a detour are critical for its safe traffic operation.

The horizontal and vertical alignment will be based directly on the detour design speed and the cross sectional elements will be influenced by the detour design speed.

The horizontal and vertical alignment deviations from standard as described in Sections C.3.4.5 and C.4.4.6 must not be applied to detours. See Table J1-2 and J1-3.

J.1.3.1 Horizontal Alignment

J.1.3.1.1 Minimum Stopping Sight Distance

Use the detour design speed and table C2-1 to set minimum stopping sight distances for detours. However, at the approach end to the detour, the minimum stopping sight distance should correspond to the highway design speed.

J.1.3.1.2 Minimum Radii

Use the detour design speed and Table C3-3 to obtain the minimum radius of curvature for a detour.

J.1.3.1.3 Transition Curves

Simple spirals, reverse spirals and simple curves are the most common methods used to provide a transition on detours. Since many factors will influence the type of transition curve which can be applied, each detour should be evaluated to determine the the best possible method to use in order to provide a smooth and safe transition.

J.1.3.1.4 Tapers

The Ontario Manual of Uniform Traffic Control Devices, Division 5, Temporary Conditions, should be consulted to provide proper taper lengths when required.

J.1.3.1.5 Traffic Diversions (Lane Shift)

When it is necessary to shift lanes through a construction area, it is essential that the re-alignment of the travelled lanes are designed for the safe movement of traffic at a reasonable speed. The use of reverse circular curves with or without spirals is recommended.

(i) Procedure

The minimum horizontal alignment control for a diversion on a tangent section of roadway is obtained by the use of an appropriate correlation factor (L/S) given in Table J1-4.

The steps involved in determining the minimum length of the diversion and the required radius of the reverse circular curves are:

1. Establish the detour design speed and the required lateral lane shift (S).
2. From Table J1-4, using the detour design speed obtain the minimum L/S factor and determine the length of the shift (L). This length multiplied by 2 will result in the total length of the diversion.
3. From Figure J1-1, using the L/S factor and the required lateral shift find the appropriate radius for the reverse circular curve.

It should be noted that this length and radius is a minimum and for longer duration detours on high speed roadways the desirable length should be longer. Ideally, these curves would have, in addition, the appropriate spiral curves. When curves with spirals are designed, the appropriate radius and spiral parameter values have to be determined individually.

The range of radii curves in Figure J1-1 is based on limiting values for the rate of roadway cross-fall of **- 0.02** m/m.

J.1.3.2 Vertical Alignment

J.1.3.2.1 Grades

Grades on a detour section should not differ from those normally used in highway design. Try to keep the grades as close as possible to the existing highway grades. Check the available stopping sight distance to correspond to the approach highway design speed. Refer to Tables C4-1, C4-2 and C4-3 for standard maximum grades.

J.1.3.2.2 Vertical Curves

Use the detour design speed and Tables C4-6 and C4-7 to obtain the minimum crest and sag vertical curves value, K.

J.1.3.2.3 Pavement Edge Drop-Offs

During paving or milling operations both longitudinal and transverse stepping or edge drop-offs usually occur, producing different elevations between adjacent roadway surfaces.

The maximum difference in elevations should be:

- For longitudinal edge drops between lanes and transverse steps created during milling or paving operations, no elevation difference greater than 40 mm may be left unprotected without ramping; a slope of 10:1 must be used.

J.1.3.3 Cross Sectional Elements

J.1.3.3.1 Lane Widths

Try to maintain approach lane widths. For design speeds, ≥80 km/h, lane width of the detour should be consistent with the width of the approach roadway.

In situations where it is not possible to include shoulders, the minimum lane width should be increased to allow more tolerance for trucks.

A detour section which expects a high composition of truck traffic should provide an additional width of pavement on curves to ensure adequate clearance between opposing trucks on undivided facilities; see Section D3, Pavement widening on Curves.

For design speeds, <80 km/h, the lane width may be reduced. Recommended minimum lane widths:

- High volume facilities 3.25 m
- Low volume facilities 3.00 m

Refer to Tables J1-2 and J1-3.

J.1.3.3.2 Shoulder Widths

Try to maintain approach shoulder widths.
For design speeds, ≥80 km/h the shoulder width of the detour should be consistent with the shoulder of the approach roadway.

For lower design speeds, <80 km/h, the shoulder width may be reduced.

Recommended minimum shoulder width for both high volume and low volume facilities is 1.0m plus 0.5m rounding. However, a minimum width of 2m plus 0.5m rounding would be desirable, especially on longer detours, to allow for emergency stops.

Refer to Tables J1-2 and J1-3 for shoulder widths as a function of the detour design speed. As the length of a detour increases, the probability of a vehicle requiring an emergency stop also increases. If shoulders are eliminated, the vehicle will be forced to stop in the travel lane, resulting in increased traffic congestion and potential rear-end accidents. Thus, the non-use of shoulders on detours should be avoided.

J.1.3.3.3 Cross-fall and Superelevation

The pavement and shoulder cross-fall for a detour should remain unchanged from the approaching roadway, unless a change can be justified.

Maximum rate of pavement super-elevation for a detour is 0.06 m/m. Refer to Section D.4 for details.

Table J1-2
Detour Design Guidelines for High Volume Highways

Highway Design Speed (km/h)	60	70	80	90	100	110	120
Recommended Reduction in Design Speed (km/h) *	20	20	10	10	10	0	0
Detour Design Speed (km/h)	40	50	70	80	90	110	120
Minimum Lane Width (m) **	3.25	3.25	3.50	3.50	3.50	3.75	3.75
Minimum Width of Usable Shoulder (m) ***	1.00	1.00	2.00	2.00	2.00	3.00	3.00
Maximum Grade %	12	8	6	5	4	4	3
Minimum Radius of Curvature (m)	55	90	190	250	340	525	650
Maximum Superelevation %	6	6	6	6	6	6	6
Minimum Stopping Sight Distance (m)	45	65	110	135	160	215	245
Minimum Vertical Curve Value K Crest	4	8	25	35	50	90	120
Sag	8	12	25	30	40	50	60

Table J1-3
Detour Design Guidelines for Low Volume Highways

Highway Design Speed (km/h)	60	70	80	90	100	110	120
Recommended Reduction in Design Speed (km/h) *	20	20	20	20	20	20	20
Detour Design Speed (km/h)	40	50	60	70	80	90	100
Minimum Lane Width (m) **	3.00	3.00	3.25	3.25	3.25	3.50	3.50
Minimum Width of Usable Shoulder (m) ***	1.00	1.00	2.00	2.00	2.00	2.00	2.00
Maximum Grade %	12	12	8	6	6	6	6
Minimum Radius of Curvature (m)	55	90	130	190	250	340	420
Maximum Superelevation %	6	6	6	6	6	6	6
Minimum Stopping Sight Distance (m)	45	65	85	110	135	160	185
Minimum Vertical Curve Value K Crest	4	8	15	25	35	50	70
Sag	8	12	18	25	30	40	45

Notes:

* Design speed reduction should not exceed 20 km/h.

** Pavement widening warants should be considered.

*** Minimum shoulder width 1.00 metres + 0.5 metres rounding.

Table JI-4
MINIMUM L/S FACTORS

	DETOUR DESIGN SPEED							
km/h	60	70	80	90	100	110	120	130
L/S	12	16	19	23	27	31	36	42

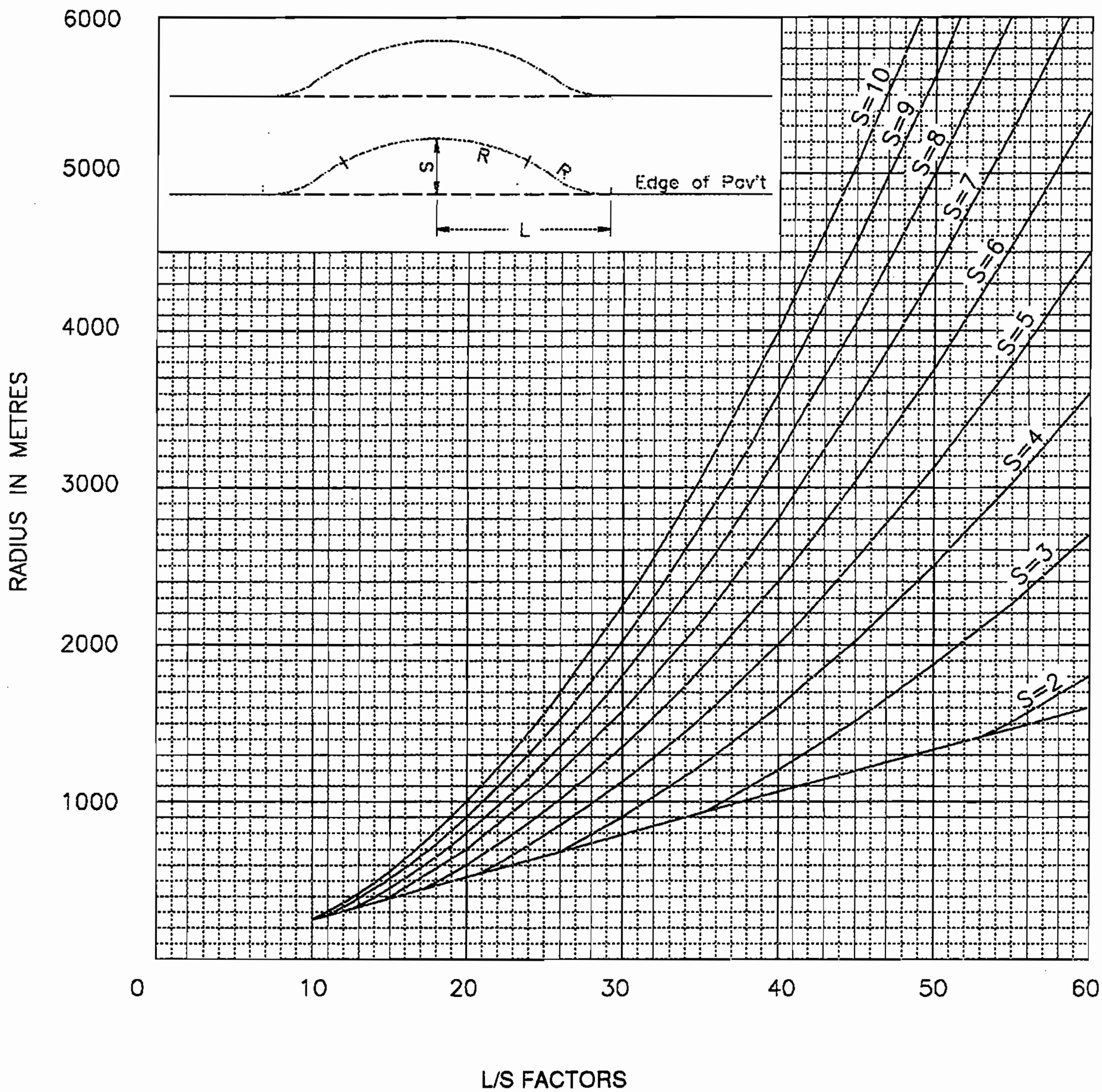


Figure J1-1
Relation Between Radius Of Diversion And L/S Factors For Lateral Shift

J.1.4 GENERAL CONSIDERATIONS AND ADDITIONAL SOURCES

J.1.4.1 Monitoring Of Detour Operation

Construction staff should provide comments and recommendations once the detour is constructed. These comments should be documented and submitted to Regional Planning and Design Offices.

J.1.4.2 Informing The Public

Advanced notice to the emergency services, transportation companies and public, giving the location and dates that a detour/construction zone will be in effect can help ease traffic congestion through the detour/construction zone.

A motorist who is warned in advance will be more tolerant of delays and inconveniences. The motorist will also be more alert and responsive to construction zone control. Refer to the Ontario "Manual of Uniform Traffic Control Devices", Division 5, for specific details.

J.1.4.3 Records

Regional Planning and Design Offices should keep separate records for detours outlining the elements of the design including the detour design speed.

J.1.4.4 Traffic Control Devices

The Ontario "Manual of Uniform Traffic Control Devices", especially Division 5, Temporary Conditions, should be used to provide proper guidelines for the signing and delineation of detours. Adequate signing and traffic control devices for detours is an essential part of the overall detour operation. Appropriate traffic control devices are required to ensure that the detour operates safely and efficiently.

J.1.4.5 Traffic Barriers And Hazard Protection

The `TRAFFIC BARRIER MANUAL' should be consulted to provide Ministry policies, warrants and guidelines for the barrier selection criteria and installation of temporary systems.

J.1.4.6 Hydrology

For hydrology and drainage considerations the Regional Structural and/or Planning and Design Sections should be contacted for any recommendations related to the design of the detour.

J.1.4.7 Geotechnical

The Regional Geotechnical Section should be consulted to provide recommendations regarding granular depths, suitable fill material and pavement depths for detours.

J.1.4.8 Lighting

Sufficient lighting should be provided and maintained throughout the detour section, see "Electrical Engineering Manual", Vol 1, Electrical Design.

J.2 CLIMBING AND PASSING LANES

J.2.1 DESIGN OF TRUCK CLIMBING LANES

J.2.1.1 General

When the need for a truck climbing lane is warranted based on the criteria detailed in Section B.4.4.1.1, the vehicle performance on grade graphs (speed-distance curves) are used to determine the location of the additional lane.

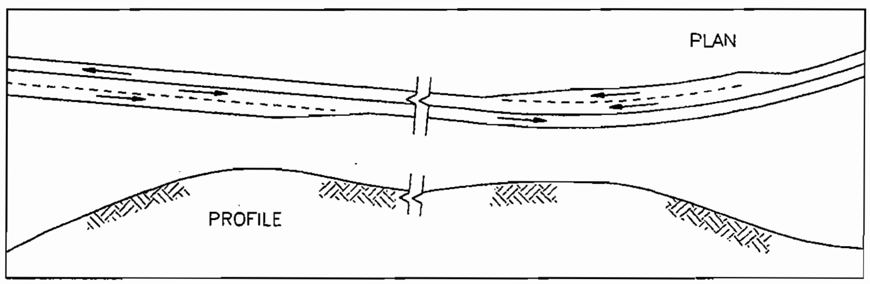
Speed reduction is used to locate the beginning and end of the climbing lane from the graphs for the appropriate vehicle.

Climbing lanes are designed independently for each direction. Depending on the profile and horizontal alignment conditions, they may or may not overlap, as shown in Figure J2-1.

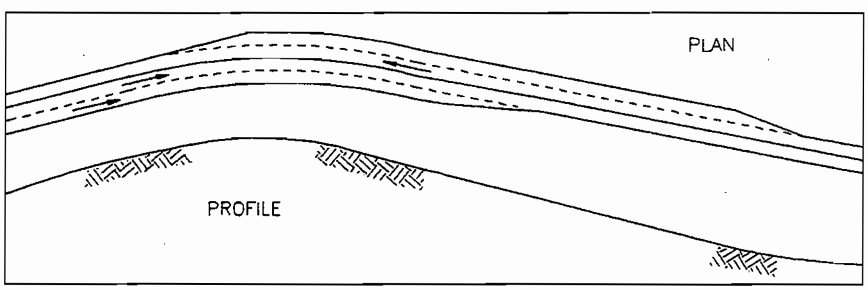
The end of a climbing lane should not be designed in advance of an intersecting sideroad or large commercial entrance.

The acceleration section of the climbing lane should be extended to provide adequate operational sight distance and/or to extend the lane to the minimum length.

This section summarizes typical design and cross-section elements and provides guidelines for the procedure of designing climbing lanes.



Climbing Lanes
–A–



Climbing Lanes Overlapping on Crest
--B–

Figure J2-1
Sample Locations for Climbing Lane Sections on 2-Lane Highways

J.2.1.2 Design Elements of Climbing Lanes

When designing a climbing lane representative truck weight-to-power ratio has to be selected and the appropriate vehicle performance on grade graphs utilized.

Vehicle performance on grade graphs are available in Appendix.

The performance graphs are for the "typical" entry speed of 90 km/h and are for 60, 120, 180 and 210 kg/kW vehicles. If these do not well represent the situation under consideration, graphs for different entry speeds and different power to weight ratios are included in report TDS-90-12, Appendix B, available from the Research and Development Branch.

When using these graphs, the lane should begin at the point at which the speed drops to 15 km/h below the operating speed, (critical length of grade), and continues until the speed increases to within 15/km/h of the operating speed.

POLICY

THE MINIMUM LENGTH OF A CLIMBING LANE IS 1500 m, INCLUDING TAPERS.

A direct taper is placed at the entrance to and exit from the climbing lane:

- Entry taper - 80 m minimum
- Exit taper - 180 m minimum.

The standard visibility distance to the mid point of the exit taper is 450 m and the minimum visibility distance is 200 m.

POLICY

THE MINIMUM WIDTH OF TRUCK CLIMBING LANES IS 0.25 m LESS THAN THE ADJACENT THROUGH LANE AND A MINIMUM OF 3.25 m.

Shoulder widths for truck climbing lanes are the same as the shoulder width on the typical cross-section for the roadway but may be reduced to 1.0 m where the cost of maintaining the shoulder is prohibitive, in which case the shoulder should be fully paved.

An example of application of the performance graphs to determine the location of the beginning and end of a climbing lane is shown in the following sub-section.

J.2.1.3 Example of Truck Climbing Lane Design Procedure

- 2-lane highway with a posted speed of 90 km/h,
- Representative Design Vehicle of 180 kg/kW, *
- Composite grade:

  0% approach;

  +2% for 500 m;

  +3% for 700 m;

  -1% for 800 m.

Determine the climbing lane location from the appropriate speed distance graph in the Appendix.

When using the graphs, vertical curves are generally ignored and speeds are usually taken from the graphs on the assumption that the vehicle travels in a straight line from one point of grade intersection to the next.

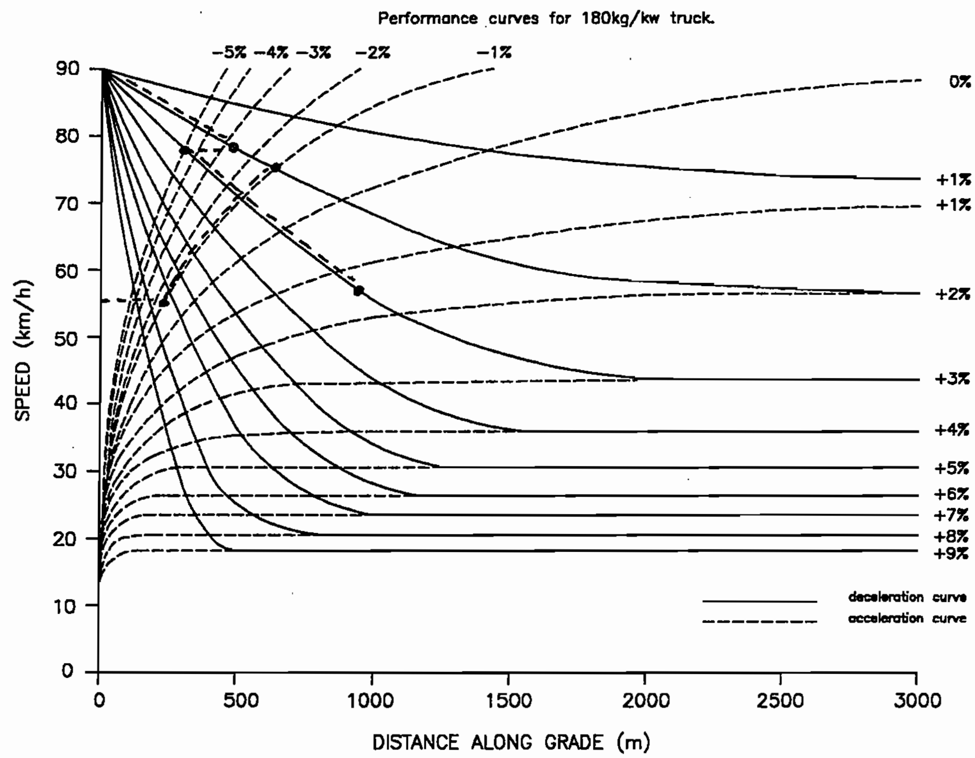
Following the dotted line on the deceleration graph the truck approaches the +2% grade at 90 km/h and does not drop speed to 75 km/h until approximately 85 m into the +3% grade. The truck speed further decreases on the +3% grade for 615 m dropping to approximately 55 km/h. At this point, transferring the speed to the acceleration graph, the truck begins to accelerate on the -1% grade for 400 m until it reaches 75 km/h; representing the end of the climbing lane, where the heavy vehicles regain speed to the extent that the speed differential is not higher than 15 km/h.

When the determined length of the additional lane is less than the minimum standard length of 1500 m it is recommended to increase the length at the end of the climbing lane as shown in Figure J2-2.

* Weight-to-power ratio = kg/kW (kg =0.4536 lb)

Weight-to-horsepower ratio = lb/hp (hp =0.7457 kW)

Example:



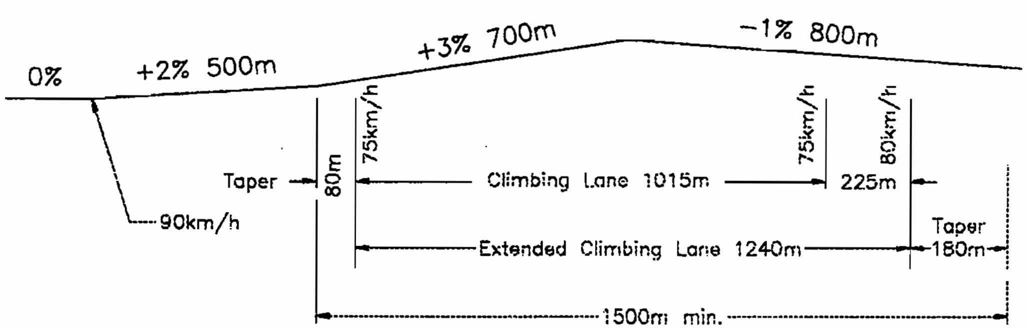


Figure J2-2
Truck Climbing Lane Location

J.2.2 DESIGN OF PASSING LANES

J.2.2.1 General

When limited opportunities for safe passing manoeuvres on two-lane rural highways impede traffic operations and safety problems arise, the need for a passing lane is considered. Section B.4.4.2 details the operational analysis for the warrants of a passing lane based on the available Assured Passing Opportunity (APO).

J.2.2.2 Passing Lane Location

The value calculated for lane frequency is a guideline as to what would be desirable spacing for a system of passing lanes. However, most times it will be quite difficult to maintain this spacing because of the roadway geometry and roadside development. The following are supplemental guidelines for the placement of the auxiliary lanes:

POLICY

PASSING LANES SHOULD NOT BE CONSTRUCTED OPPOSITE EACH OTHER, LEAVING THE IMPRESSION OF A STAGE DEVELOPMENT FOR A FUTURE FOUR-LANE HIGHWAY.

- The policy on two staggered three-lane sections versus one four-lane section is to use three-lane sections for all passing lanes on all highways. Exception to this policy will occur if the ultimate facility is to be a four-lane undivided highway Any overlapping of adjacent three-lane sections in opposite directions should be noted in the Design Criteria.
- Passing lanes should not be constructed on long tangent sections as passing opportunity already exists in these areas, thus maximum benefit would not be derived from such a placement. The passing lane may also restrict passing in the other direction.
- Lanes constructed on long horizontal or vertical curves, with inadequate POSD, Passing Opportunity Sight Distance, will have a greater perceived benefit to drivers.
- Passing lanes should not be built near four-lane sections which effectively serve the same purpose or prior to towns or reduced speed zones where platoons will rapidly reform.
- In sections where grades exist but truck climbing lanes are not warranted, any passing lanes which are warranted will function more effectively by being located on the significant grades due to the greater speed differentials.
- Passing lanes should not be constructed in areas with restricted roadway width, i.e. bridges.
- Turning movements within a passing lane section should be kept to a minimum and also, if possible, high volume intersections and driveways should be avoided when passing lanes are constructed. If necessary , separate left turn lanes should be constructed to separate traffic flows.
- A greater benefit will be derived when passing lanes are constructed after a section of no passing rather than one in which passing is allowed.
- When all of the above factors have been taken into account, the passing lane should be located where the minimum feasible construction cost occurs.

J.2.2.3 Design Elements of Passing Lanes

The required length of a passing lane to allow a platoon of vehicles to overtake a slow moving vehicle depends on the number of vehicles in the platoon, Q, and the average speed of passing vehicles. The relationship between passing lane length, average speed of passing vehicles and platoon length is shown in Figure B4-5.

POLICY

THE MINIMUM AND MAXIMUM LENGTHS ARE 1500 m AND 2000 m ESPECTIVELY, INCLUDING TAPERS.

A direct taper is placed at the entrance to and exit from the passing lane:

- Entry taper - 80 m minimum
- Exit taper - 180 m minimum.

The interval (frequency) between successive passing lanes is influenced by driver frustration and economic constraints. To minimize frustration, the interval should be as short as possible. This frustration can be minimized by advance signs indicating the location of the next passing lane.

Lane Frequency (LF) can be calculated, see Section B.4.4.2.2. The formula based on length of platoon and selected length of passing lane, provides an acceptable gap between passing lanes.

Lane width for passing lanes and width of adjacent shoulders are given in D.2.3 and D.5.3.

APPENDIX

Speed-Distance Curves

The appendix contains speed-distance graphs for typical design vehicles' performance on grades, see Figure J2A-1 to J2A-4. If these do not satisfactorily represent the situation under consideration, graphs for different entry speeds and different power to weight ratios are included in report TDS-90-12, Appendix B, available from the Research and Development Branch.

The performance curves are based on the Society of Automotive Engineers recommended truck performance functions.

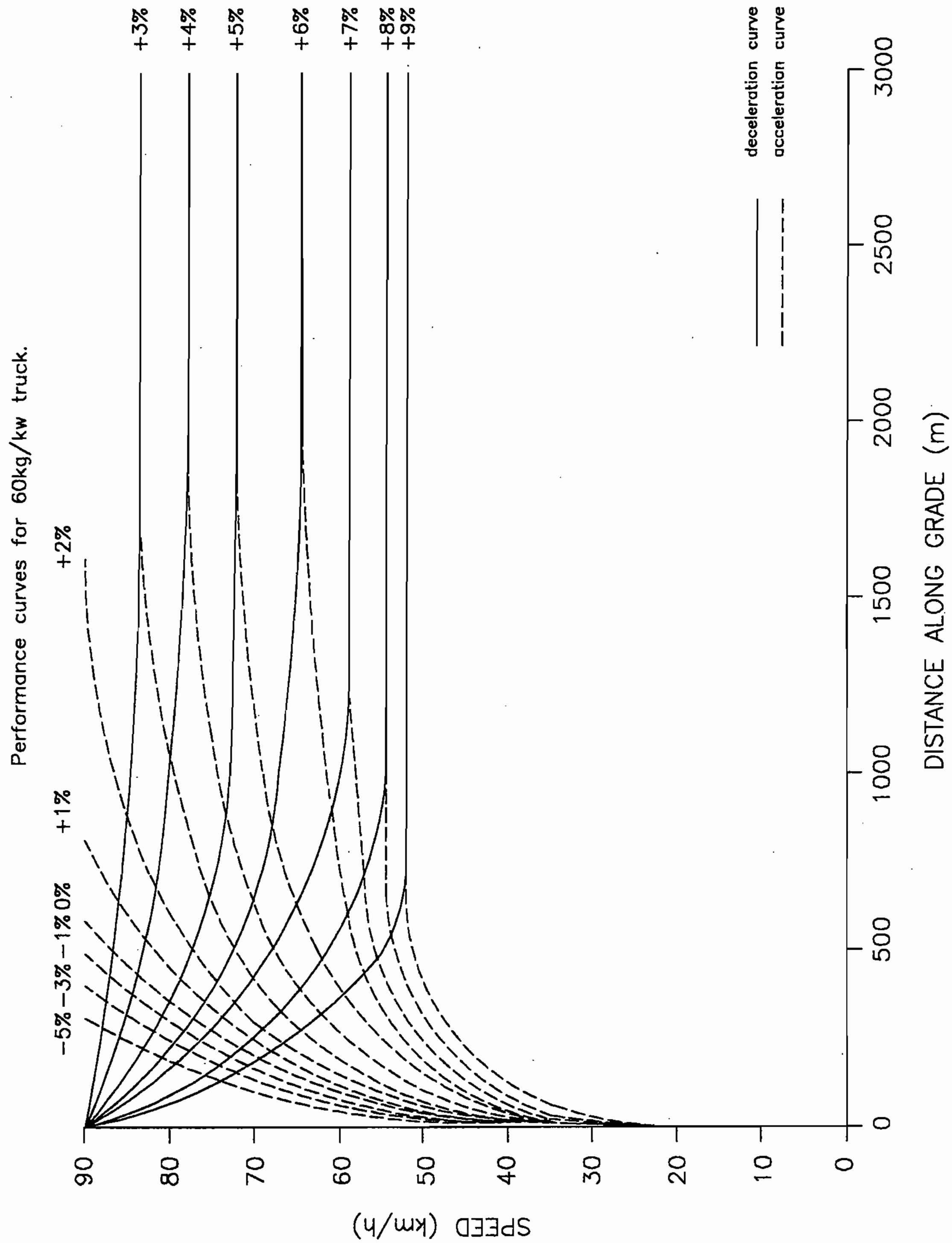


Figure J2A-1
Performance Curves for 60 kg/kW Truck.

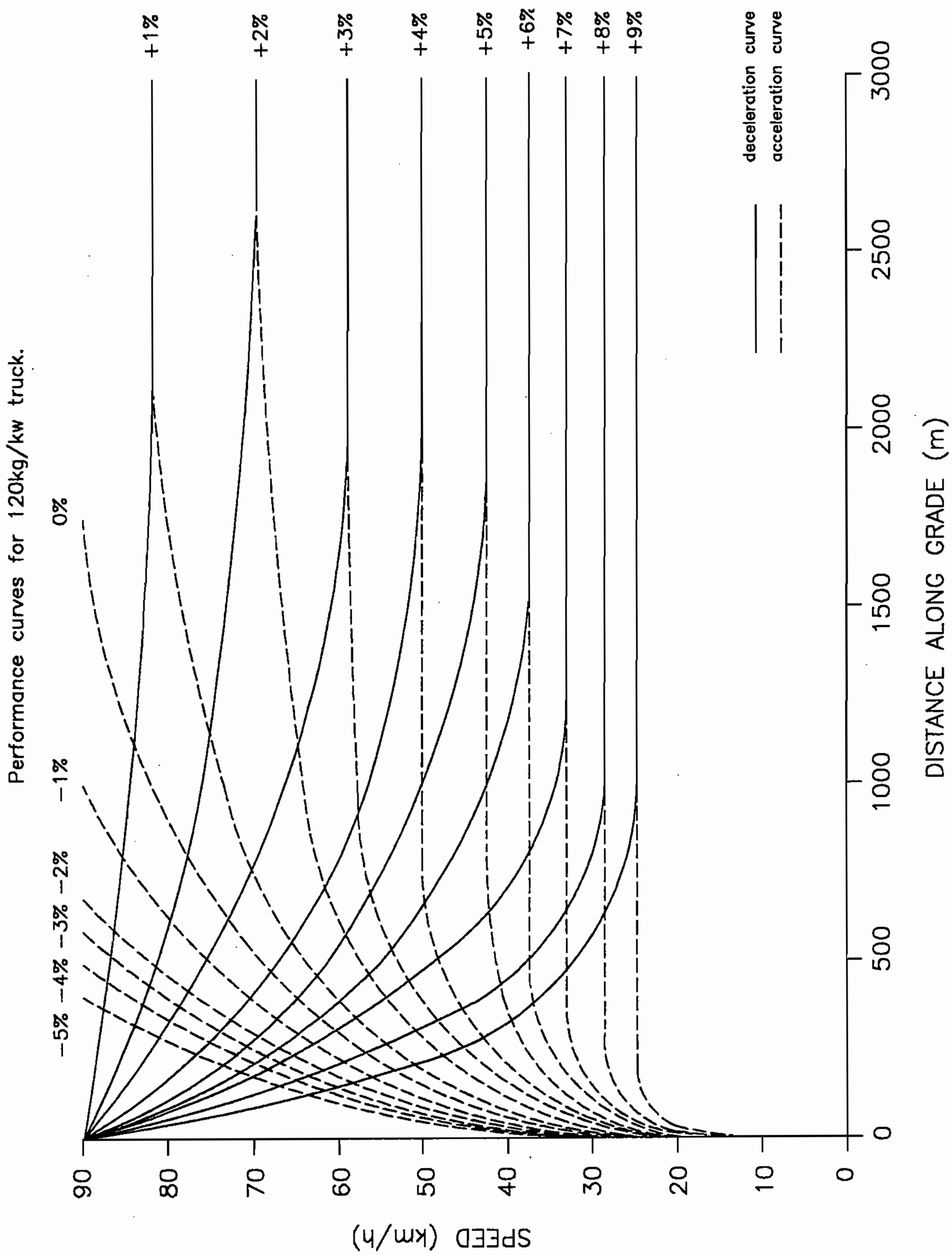


Figure J2A-2
Performance Curves for 120 kg/kW Truck.

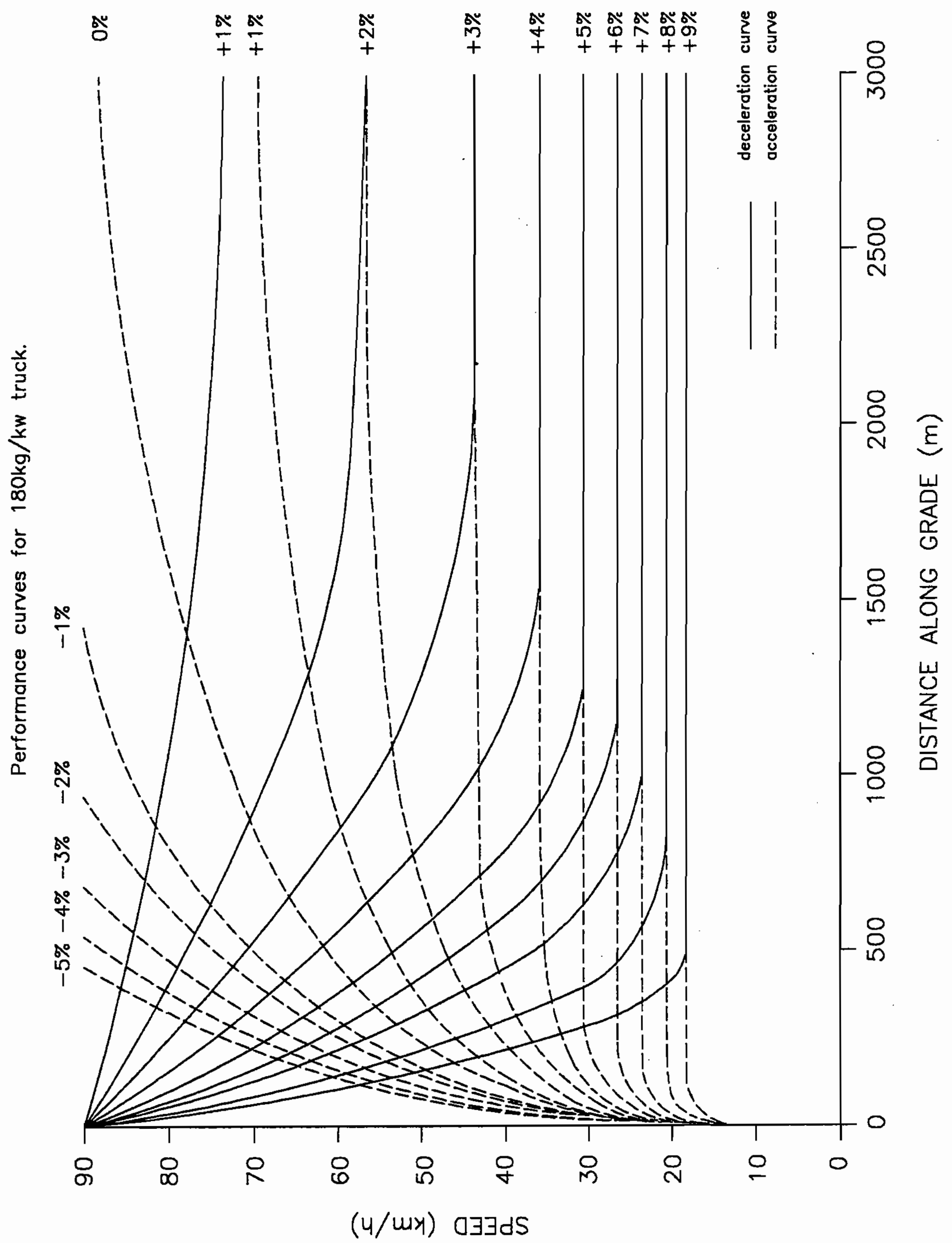


Figure J2A-3
Performance Curves for 180 kg/kW Truck.

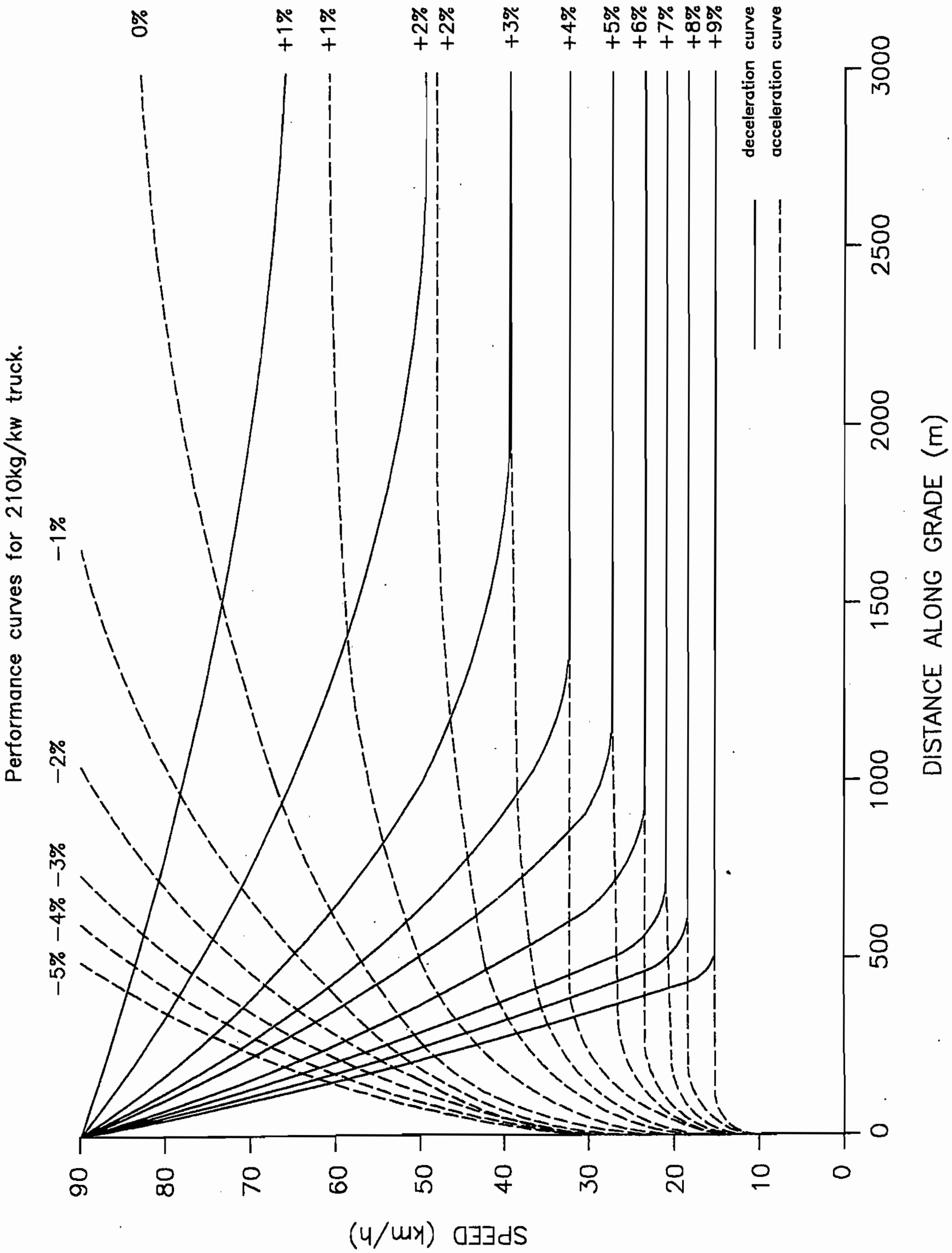


Figure J2A-4
Performance Curves for 210 kg/kW Truck.