DESIGN BULLETIN #84/2014

Considerations for Selection of Freeway Over/Under Configuration at Service Interchanges

Summary

The Department has accepted the attached document, Considerations for Selection of Freeway Over/Under Configuration at Service Interchanges. The purpose of the document is to provide increased guidance to Engineers and Planners and promote a more consistent design philosophy on Alberta Transportation's interchange projects. The document provides a discussion on the selection of either the *freeway over* or *freeway under* configuration of service interchanges and a preferred practice on Alberta Highways.

Scope

The document includes a discussion of the four possible vertical configurations at an interchange. These configurations are differentiated by whether the major roadway (normally a freeway) crosses over or under the minor roadway and whether the interchange is in cur or fill, as follows:

- Case I: freeway under, interchange in cut
- Case II: freeway under, interchange in fill
- Case Ill: freeway over, interchange in cut
- Case IV: freeway over, interchange in fill

The discussion covers safety and operational considerations, economic considerations, and social/community impacts. Advantages and disadvantages for each case are listed. Considering all these factors, Case II is the preferred practice where topography is not a major influence in design. Engineers and Planners working for Alberta Transportation should clearly outline a rationale for deviating from the Case II design.

Effective Date

November 10, 2014

Contact

Contact: Jarret Berezanski (780 415-1252) or Julian Macdonald (780 643-0798),
Major Capital Planning, Alberta Transportation.

Attachments

- Alberta Transportation, Considerations for Selection of Freeway Over/Under Configuration at Service Interchanges, September 2014.

Recommended:	Approved:
Original memo signed by *Jarret Berezanski*	*Original memo signed by* *Moh Lali*
_______________________ Jarret Berezanski, P. Eng. Director, Major Capital Planning	_______________________ Moh Lali, P. Eng. Executive Director, Technical Standards Branch

Considerations for Selection of Freeway Over/Under Configuration at Service Interchanges

1.0 Preamble

This document provides a discussion on the selection of either the *freeway over* or *freeway under* configuration of service interchanges and a preferred practice on Alberta Highways. **Service interchanges** are defined as interchanges in which only one of the interchanging roadways is considered as a high speed, free-flow roadway through the interchange area (either a freeway or expressway). The crossing roadway would be a lower class roadway which permits at-grade intersections.

Factors to consider in the selection of the vertical configuration of service interchanges include safety, operations, economics, social considerations, and topography. The following discussion considers the first four of these factors and the preferred practice is applicable in locations where topography is not a major influence or constraint in the interchange design. A detailed engineering study including but not limited to life-cycle cost analysis over the long term should be conducted to justify interchange designs which deviate from the preferred practice.

2.0 Vertical configuration of service interchanges

There are four generalized cases of vertical configuration at service interchanges as shown in **Figure 1**. These cases can be described in several ways. Case I and Case II involve the freeway passing underneath the crossing roadway (*freeway under configuration*), which can be alternately described as the crossing roadway passing over the freeway (*crossroad overpass configuration*). Case I and Case II are differentiated by the profile of the freeway relative to the elevation at the ramp gores at either end of the interchange (which would normally be coincidental with the natural ground level). Case III and Case IV involve the freeway passing over the crossing roadway (*freeway over configuration*), which can alternately be described as the crossing roadway passing under the freeway (*crossroad underpass configuration*). Similar to Case I & II, Case III and Case IV are differentiated by the profile of the freeway relative to the elevation at the ramp gores at either end of the interchange. Vertical configurations which are designed between the extremes of Case I and Case II, or between the extremes of Case III and Case IV are also possible, depending on site-specific conditions. For example, in the *freeway under configuration*, the crossing roadway could be partially elevated above the natural ground level with the freeway partially depressed below the natural ground level. Such configurations would possess traits of both Cases to a certain degree. These traits are described in this document.

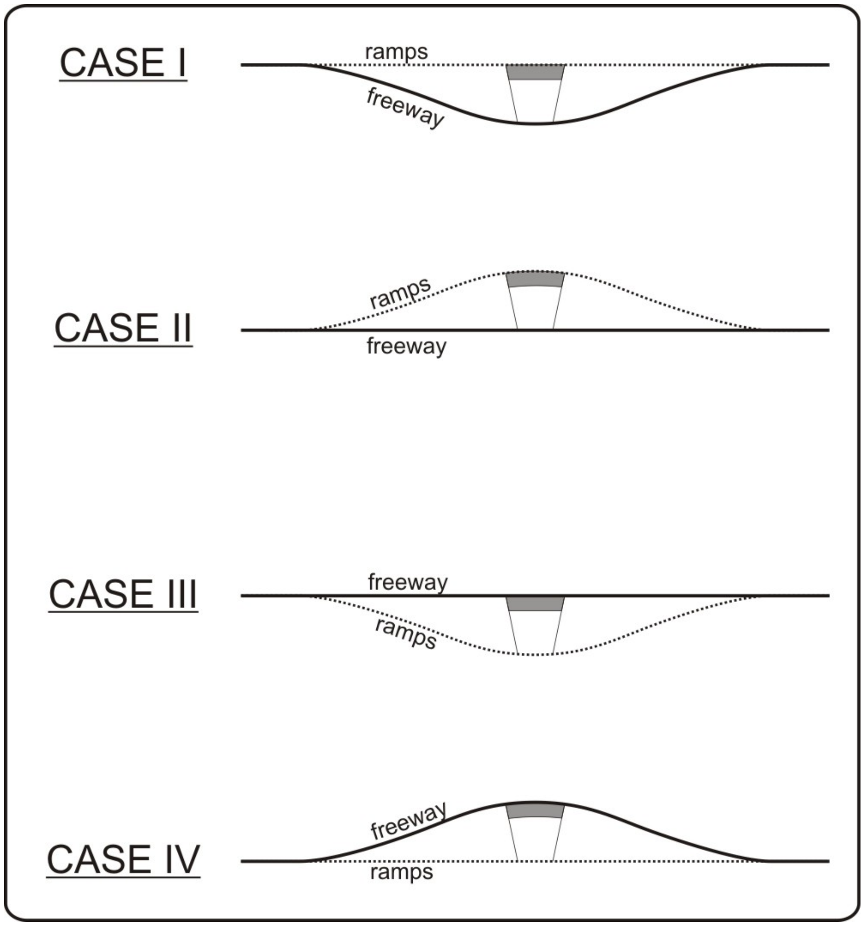


Figure 1 - Vertical configurations at service interchanges*

3.0 Safety and operational considerations

3.1 Effect of grade

Ramps at service interchanges serve to transition vehicles between the lower speed crossroad and the higher speed freeway, requiring vehicles to accelerate when entering the freeway and decelerate when exiting the freeway. Due to gravity, the direction of the ramp grade (negative or positive) will either serve to help or hinder acceleration and deceleration over the length of these ramps.

* Ramp profiles shown assume diamond type ramps in all quadrants of the interchange. Ramp profiles for partial interchanges or interchanges with loop ramps may differ from the figure. The relative vertical position between the freeway mainline and the bridge structure defines the Case.

For Case II, exit ramps occur on upgrades and entrance ramps occur on downgrades. This assists vehicles in decelerating along exit ramps and accelerating along entrance ramps[1,2,3], allowing for smoother operation and potentially (depending on the ramp configuration and design speeds) shorter ramps. Conversely, for Case III, vehicles on the entrance ramp must work against gravity in accelerating uphill, and extra braking is needed to decelerate downhill on exit ramps. This increases stopping distance, which may surprise some drivers as they reach the end of the ramp.

3.2 Sight distances at ramps and gores

The view the freeway driver has of the upcoming exit ramp gore, the view of the ramp geometry, and the view of the ramp terminal intersection where the ramp meets the crossroad all provide the driver with critical visual information in order to anticipate and smoothly transition from the higher speed freeway onto the lower speed crossroad, and vice-versa. Providing sufficient decision sight distances through these areas assists merging drivers, exiting drivers, and drivers on the freeway mainline, helps reduce the number of sudden or erratic manoeuvers, and leads to overall improved safety and operation of the interchange.

The *freeway under configuration*, in particular Case II, provides sight distance advantages as follows:

- For drivers exiting the freeway, the view of the exit ramp gore from the freeway is usually superior[1,3] due to the sag curve at the beginning of the exit ramp followed by an upgrade as the ramp rises from freeway level.
- For vehicles entering the freeway, most (or all) of the entrance ramp is visible due to the ramp downgrade followed by a sag curve at the freeway entrance gore. This gives an entering driver a commanding view of the freeway and the upcoming merge area. This situation is much preferred to Case III in particular, which can have restricted sight distance at the freeway entrance gore due to the ramp upgrade followed by a crest curve.

3.3 Sight distances at ramps terminal intersections

For service interchanges, sight distances at the ramp terminal intersections must also be considered. This is particularly important at stop-controlled junctions where intersection sight distance is critical to the operation of the intersection. The *freeway under configuration* (Case I & II) is preferred as there tends to be less visual obstructions such as bridge piers, and retaining walls, which are characteristic of the *freeway over configuration* (Case III & IV)[1]. Case I offers the best sightlines due to the fact that the crossroad remains at-grade through the interchange area. For Case II, intersection sight distances are dependent on the gradeline of the crossroad. For example, a steep grade combined with a sharp crest curve through the overpass can result in restricted intersection sight distances for vehicles attempting to turn left or right from the ramp terminal intersection. Caution must also be used in designing bridge parapets and barrier systems (such as high tension cable barrier, guardrail, etc.), particularly at unsignalized ramp terminal intersections, so as to minimize any visual obstructions. Roundabouts at the ramp terminal intersection may significantly reduce the sigh distance requirements in all cases.

3.4 <u>Bridge operational safety</u>

Bridge structures along roadways introduce a number of safety and operational issues which tend to be compounded with higher speeds and higher traffic volumes. For these reasons the *freeway under configuration* (Case I & II) has a number of safety and operational advantages due to the fact that the bridge structure is located along the crossroad which carries relatively lower volumes at lower speeds. Specific bridge related issues which can be minimized with the *freeway under configuration* include:

- Collisions related to preferential icing on the bridge deck going from unfrozen roadway surface to possibly icy bridge surface.
- Braking and acceleration which occurs along the freeway at the crossing area of cloverleaf and partial-cloverleaf interchanges (see **Figure 2**). Braking on the freeway occurs in advance of "B-loops" which are located beyond the bridge structure while acceleration occurs on the freeway following "A-loops", which join the freeway prior to the bridge structure. Areas where braking and acceleration or where changes in direction occur (while merging, diverging, and weaving) tend to aggravate bridge icing safety issues. It is generally preferable that this braking, weaving, and acceleration not occur on a bridge structure at freeway speeds.

3.5 <u>Freeway geometry</u>

The use of either the *freeway over* or *freeway under configuration* is fundamental to the development of the freeway alignment through the service interchange area, particularly when curvilinear freeway alignments are necessary. Bridge structures tend to increase the risk of barrier related collisions and other loss of control incidents, particularly in Alberta's winter climate conditions where preferential icing can. Introducing curves in these locations further increases driver workload and increases the risk of loss of control incidents. To minimize these occurrences, it is desirable that bridges only be used in combination with straight (tangent) sections of the roadway alignment. Where the roadway alignment design necessitates bridge structures on curves, these should be located close to the centre of the curve so as not to include spiral or superelevation transition sections. Due to these limitations, with the *freeway under configuration*, there is more flexibility in designing the freeway alignment, which, when design tradeoffs are necessary, takes precedence over the alignment of the crossroad.

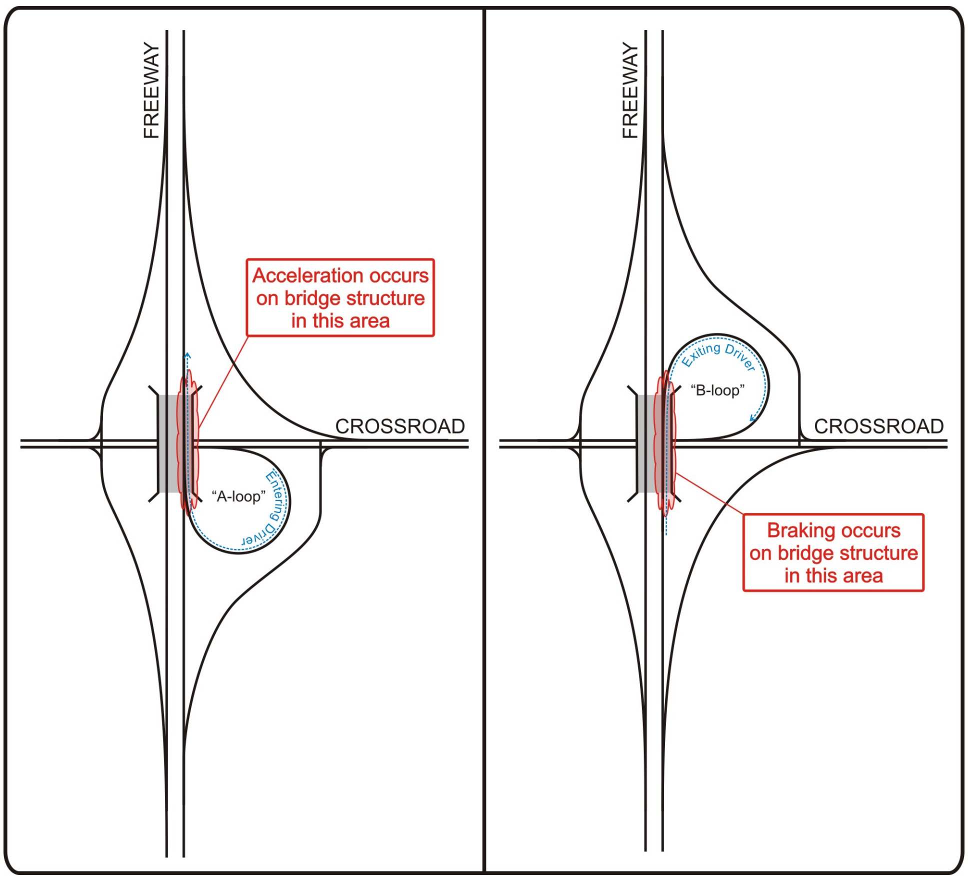


Figure 2 - Location of vehicle acceleration and braking on "A-loop" and "B-loop" interchanges

3.6 <u>Roadside design</u>

Alberta Transportation aims to provide a barrier-free environment along provincial highways wherever practical. This is accomplished by ensuring obstacles such as piers and retaining walls are located sufficiently away from the edge of the roadway (outside the “clear-zone”) so that an errant vehicle has the opportunity to recover.

Lateral barriers such as guardrail can often be avoided in the *freeway under configuration* by designing sufficient lateral offset distance under the structure to ensure that all obstacles are located outside the clear zone. Lateral barriers will be required on the crossroad overpass; however, it desirable that these barriers be located on the relatively lower speed and lower volume roadways.

3.7 <u>Other design considerations</u>

3.7.1 Utilities

If the freeway is situated within a transportation and utility corridor or the freeway alignment is otherwise parallel to a linear underground utility, it may be prohibitive to excavate below grade. Case II and Case IV, where all roadways are situated at or above ground level, are likely to better accommodate existing parallel underground utilities.

3.7.2 Drainage

Interchanges with portions of roadway below the natural ground level (Case I and Case III) will require special systems to ensure that water can be drained properly and not accumulate on the roadway surface. It is particularly critical that proper drainage be achieved in Case I, where the freeway is below the natural ground level, as the freeway should be planned to the highest level of flood control possible in order that it remain in operation during emergencies[4]. Accommodating proper drainage is usually more difficult in Case I due to the larger volume of cut below the natural ground level. If the freeway must pass over the crossroad, troublesome drainage problems may be reduced by elevating the freeway without altering the crossroad grade[3] (Case IV).

3.8 <u>Other operational considerations</u>

3.8.1 Bridge visual impact

The *freeway under configuration* requires that a bridge structure cross the freeway. Although subtle, the visual cue provided by a looming overpass structure along a freeway:

- Alerts the driver to the possible presence of an interchange, offering the driver more time to determine whether it is the desired exit and to make appropriate lane changes and adjustments in speed to take the exit[1,2,3].

- Assists the long distance driver on a rural freeway, who may experience boredom or tiredness, to remain alert, by offering a change of scene and tend to break the monotony of an unchanging roadway section[1].

3.8.2 Staging

Where a new freeway is to be constructed crossing an existing roadway, Case IV will cause fewer traffic disturbances and a detour during construction is usually not needed.[3] With the *freeway over configuration* (Case III or Case IV) there is also an opportunity to phase-in construction of diamond interchange ramps while incurring minimal throw-away costs at final construction (Figure 3). This is accomplished by first building the interchange ramps in their final configuration, providing temporary additional capacity on these ramps if needed, to accommodate through traffic. The freeway overpass is then constructed at a later time with minimal disruption to the crossroad below or to through traffic.

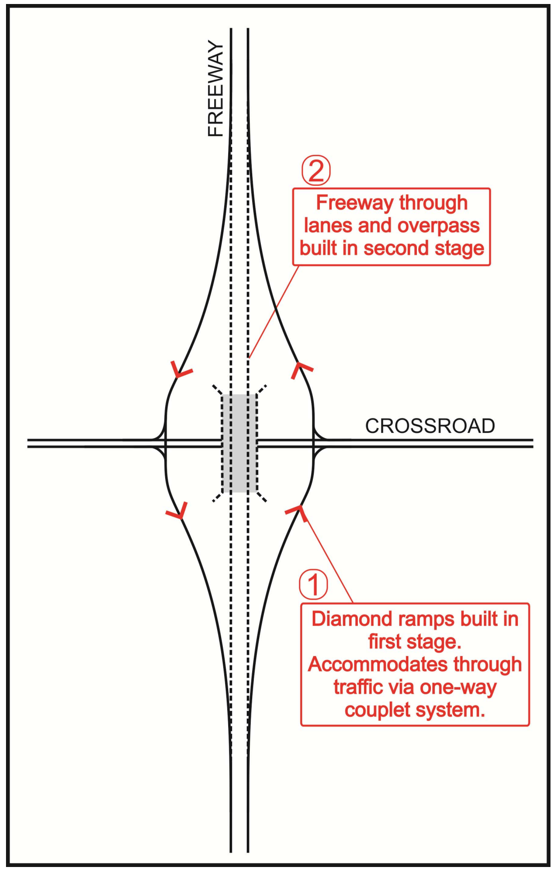


Figure 3 – Staged construction of a diamond interchange (Case III and IV)

On the other hand, when a new interchange is added to an existing roadway (either a freeway or an expressway or arterial roadway which is being upgraded to a freeway), Case II is least disruptive, as the gradeline of the existing roadway does not need to be altered.

3.8.3 Maintenance and reconstruction

The *freeway under configuration* provides better opportunity to perform maintenance, rehabilitation, reconstruction, or expansion activities on the interchange bridge structure(s) without diverting or interfering substantially with freeway traffic flow[3]. Bridge maintenance and reconstruction activities for the *freeway over* *configuration* on the other hand would normally require either partial interference with traffic flow or in the worst case, total closure of the roadway. This is a significant operational and safety issue as the freeway is generally high speed and volumes typically increase with time. In winter, Case I can also produce increased snow removal efforts. With the other cases, the freeway is exposed to the wind, lessening the amount of accumulation.

3.8.4 Overdimensional load accommodation

The *freeway over configuration* is advantageous if the freeway is a high load corridor as there is no vertical clearance limitation[3]. Whereas, in the *freeway under configuration*, special provisions are required in order to accommodate high loads, particularly at non *diamond*-interchanges. This could include additional ramps or median crossings so that the high loads are able to “bypass” the bridge structure. Conversely, the *freeway under configuration* accommodates heavy loads without the need to strengthen the bridge structure, and special provisions are required in order to accommodate heavy loads along the freeway in the *freeway overpass configuration*.

4.0 <u>Economic considerations</u>

The *freeway under configuration* has economic benefits (as compared to the *freeway over configuration*) attributable to the initial and life cycle cost of the bridge structure(s) at the interchange. This is because the width of the freeway would normally exceed that of the crossroad, particularly in rural areas, equating to less total bridge deck area. Furthermore, to achieve the required centerline-to-centerline separation between carriageways, costs normally dictate two separate structures for the *freeway over configuration*. There are also savings due to significantly less earthwork with the *freeway under configuration*[2,3]. User cost savings are also apparent in the freeway-under configuration as there are fewer impacts to the flow of vehicles on the freeway during maintenance and reconstruction activities. Case IV can be an economical solution when a new freeway is constructed crossing several existing roadways. In this case right-of-way requirements can be reduced by keeping the crossroads at-grade. Case I and Case IV will incur higher user costs due to the undulating gradeline on the higher traffic volume roadway.

5.0 <u>Social / community impacts</u>

The *freeway under configuration* provides important social benefits which are particularly important in urban areas and in rural or semi-rural areas where interchanges are situated adjacent to development. These benefits are a result of the freeway being at ground level (Case II) or below ground level (Case I) which results in:

- Less visual impact[1], particularly for Case I where the freeway is entirely out of view from the surrounding area. Case II can be further mitigated with the use of berms.
- Less noise impact to surrounding areas[1,3], particularly for Case I. Case II can be mitigated further with the use of berms adjacent to the freeway.
- For Case II, less truck noise due to gentler acceleration on the entrance ramps (downgrades) and gentler braking on the exit ramps (upgrades)[1].

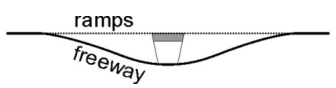
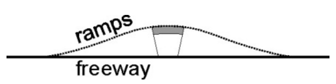
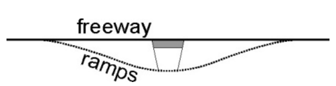
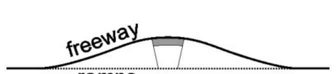
6.0 Preferred practice

A summary of the advantages and disadvantages of each of the four interchange vertical configurations is provided in **Table 1**. It can be seen that there are numerous safety, operational, economic, and social benefits to providing the *freeway under configuration*, particularly when the freeway remains at ground level with the crossroad elevated above the under-passing freeway (Case II). **Case II is therefore the preferred practice** for service interchanges on Alberta highways, where topography is not a major influence. Designs which deviate from this practice should be supported through an engineering study outlining the reasons why Case II configuration is not appropriate and rationale for the proposed alternate configuration.

References

1. Geometric Design Guide for Canadian Roads, Transportation Association of Canada, 1999
2. Freeway and Interchange Geometric Design Handbook, Institute of Transportation Engineers, 2005
3. A Policy on Geometric Design of Highway and Streets, American Association of State Highway and Transportation Officials, 2011
4. Design Bulletin #16 “Drainage Guidelines for Highways under Provincial Jurisdiction in Urban Areas”, Alberta Transportation, 2007

Table 1: Advantages and disadvantages of each vertical configuration Case

	Ramp grade	Sight distances - ramps and gores*	Sight distances - ramp terminal intersections†	Bridge operational safety	Freeway geometry	Roadside design	Other design considerations	Other operational considerations	Construction staging and maintenance	Economic considerations	Social / Community
CASE I 			Best sightlines at ramps terminal intersections.	High speed / high volume road users protected against potential preferential bridge deck icing safety issues.	Greater flexibility in freeway geometry.	Lateral barriers along the freeway can be avoided by designing sufficient lateral offset distance under the structure.	Potential for conflicts with utiltiies crossing the freeway. Proper drainage of the freeway lanes can be difficult to achieve.	Precence of an overpass alerts the freeway driver to a possible upcoming interchange. Heavy loads can be accomodated along the freeway without requiring structural strengthenin Increased snow removal efforts.	Better opportunity for bridge structure maintenance, reconstruction, or expansion without diverting freeway traffic.	Lower structural costs, higher earthwork costs. Higher user costs due to the undulating gradeline on the higher traffic volume roadway.	Least visual and noise impact of the freeway where the freeway is entirely out of view from the surrounding area.
CASE II  Preferred	Exit ramps on up-grades and entrance ramps on downgrades. This assists in vehicle deceleration along the exit ramp and acceleration along the entrance ramp.	Best view of the exit ramp from freeway. Most (or all) of the entrance ramp is visible.	Sight distance dependant on gradeline of crossroad.	High speed / high volume road users protected against potential preferential bridge deck icing safety issues.	Most flexibility in freeway geometry.	Lateral barriers along the freeway can be avoided by designing sufficient lateral offset distance under the structure.		Precence of overpass alerts the freeway driver to a possible upcoming interchange. Heavy loads can be accomodated along the freeway without requiring structural strengthening.	Better opportunity for bridge structure maintenance, reconstruction, or expansion without diverting freeway traffic. Least disruptive when adding an interchange to an existing freeway.	Least costly (less bridge deck area and earthworks).	Least truck noise due to gentler acceleration on the entrance ramps and less braking on the exit ramps. Ramps tend to block some of the freeway visual and noise. Noise impact to surrounding areas can be further mitigated with the use of berms adjacent to the freeway.
CASE III 	Exit ramps on downgrades and entrance ramps on upgrades. This hampers vehicle deceleration along the exit ramp and acceleration along the entrance ramp.	Reduced sight distance on the entrance and exit ramps. View of entrance gore area can be hidden from view. Exit ramp may be hidden from view until driver reaches the exit gore.	Obstructions at the ramp terminal intersections (bridge piers, guardrails, retaining walls, etc.) can impair sight distance.	Bridge deck on higher volume / higher speed roadway increases potential for safety issues related to preferential bridge deck icing. This is compounded at cloverleaf or partial cloverleaf interchanges where braking, acceleration, and weaving occurs on strucure.	Bridge structure limits freeway alignment options. Curves on structure should not include spiral or superelevation transition sections. Tangent sections are preferred.	Lateral barriers are required along the freeway on structure. Wider shoulders are required to meet shyline offset distance requirements for high-speed freeway.	Potential conflicts with utilties parralel to the freeway.	High-load vehicles accomodated along the freeway without having to rely on the ramps or other bypass routes.	Better construction staging opportunities as interchange can be phased with minimal throw-away costs.	Higher user costs during maintenance and rehabilitation of the bridge structures.	Visual and noise impact to surrounding areas can be mitigated with the use of berms adjacent to the freeway.
CASE IV 			Obstructions at the ramp terminal intersections (bridge peirs, guardrails, retaining walls, etc.) can impair sight distance.	Bridge deck on higher volume / higher speed roadway increases potential for safety issues related to preferential bridge deck icing. This is compounded at cloverleaf or partial cloverleaf interchanges where braking, acceleration, and weaving occurs on strucure.	Bridge structure limits freeway alignment options. Curves on structure should not include spiral or superelevation transition sections. Tangent sections are preferred.	Lateral barriers are required along the freeway on structure. Wider shoulders are required to meet shyline offset distance requirements for high-speed freeway.		High-load vehicles accomodated along the freeway without having to rely on the ramps or other bypass routes.	Less disturbances to existing surface roadways. Better construction staging opportunities as interchange can be phased with minimal throw-away costs.	Can be less costly in urban areas when crossing multiple existing roadways. Higher user costs due to undulating gradeline on higher traffic volume roadway. Higher user costs during maintenance and rehabilitation of the bridge structures.	High visual and noise impact of the freeway.

*Sight distances along the entry and exti ramps, and at exit and entry ramp gores along the freeway

†Intersection sight distances at the intersections between the interchange ramps and the cross street

NOTE: Case II is preferred when topogrophy is not a major influence or constraint in the interchange design