**Decision Sight Distance for Freeway Exit Ramps – a Road Safety Perspective**

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**Abstract**

Design guidelines/standards and subsequent project design criteria generally stipulate that Decision Sight Distance (DSD) be provided at freeway exit terminals. In most such guidelines the DSD is to be measured to a low point on the highway at the bullnose. However, achieving DSD for exit ramps is not always realistic. Vertical and horizontal curves, the presence of retaining walls, cut slopes and other structures and fixtures present challenges that may require major design modifications (and therefore costs).

This paper examines the theoretical foundation used to derive the DSD, and reflects, from a safety perspective, on whether the DSD, as defined in current design standards is appropriate and considers the implications of deviating from those standards.

The paper covers a literature review of relevant design guidelines and reviews human factor parameters used to derive the DSD and positive guidance principles. The paper also examines the concept of nominal and substantive safety, which is fundamental to the topic of "departure from standards". On that basis, the paper concludes whether the DSD to an exit ramp, as currently defined, is truly relevant in all cases to driver's decision-making process. Improvements and modifications to the current DSD requirements are recommended.

**Decision Sight Distance Criteria at Exit Ramps in Ontario**

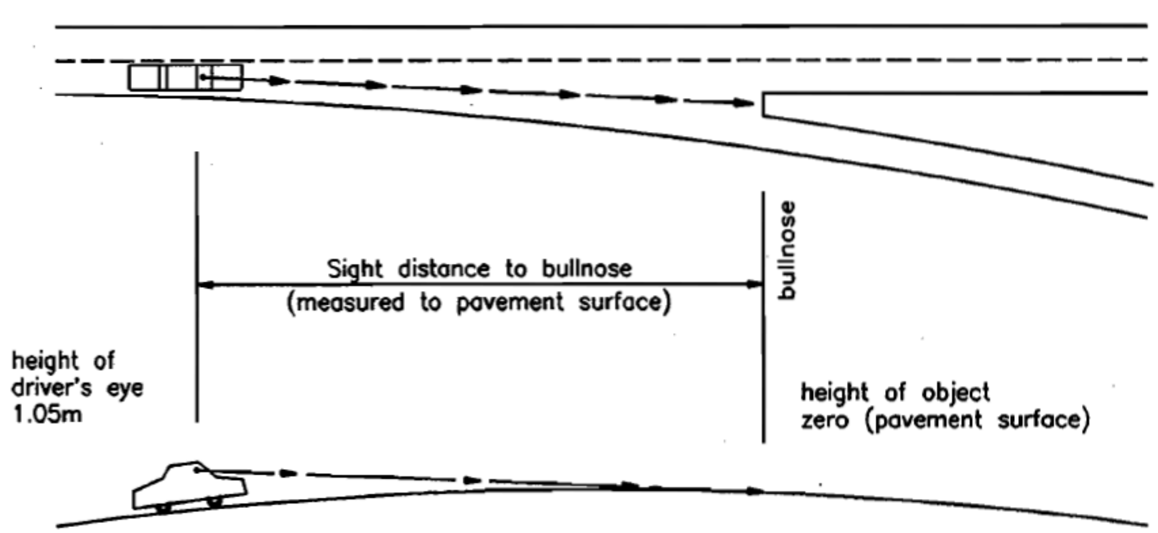
In Ontario, decision sight distance (DSD) requirements are defined in the Ministry of Transportation Ontario (MTO) criteria detailed in the Geometric Design Standards for Ontario (MTO Guide) (1), Section F.5.3.6 – Sight Distance at Exit Terminals (SDET). It is noted that the MTO Guide does not use the industry standard terminology of "Decision Sight Distance", although the technical foundation appears to be similar.

The MTO Guide specifies a range of "desirable" SDET as a function of design speed and the MTO Guide further defines the fashion of measuring SDET. Accordingly, the SDET is to be measured from an eye height of 1.05 m to a height of object height of 0.00 m (pavement surface). This is amplified in the text, where it is stated *"it is desirable for the driver to see the pavement surface at the bullnose"*. The MTO Guide indicates that the vehicle's position from which SDET is to be measured is in the shoulder lane. The MTO definition of the SDET is illustrated in Figure 1.

**Figure 1 MTO Sight Distance at Exit Terminals (1)**

SIGHT DISTANCE AT EXIT TERMINALS

| Design Speed km/h | 60 | 70 | 80 | 90 | 100 | 110 | 120 |
|---|---|---|---|---|---|---|---|
| Sight Distance to Bullnose, m | 170 to 230 | 200 to 270 | 240 to 310 | 270 to 350 | 300 to 390 | 340 to 430 | 370 to 470 |



However, achieving DSD for exit ramps is not always realistic. Vertical and horizontal curves, the presence of retaining walls, cut slopes and other structures and fixtures present challenges that may require major design modifications (and therefore costs).

The MTO Guide does not provide any rationale or source for its definition for the SDET values. It is somewhat evident that the values used in the MTO Guide originate from industry standard manuals, primarily the AASHTO Green Book (2) and the TAC Geometric Design Guide (4). The various values associated with the DSD/SDET from AASHTO, TAC and MTO are summarized in Table 1.

**Table 1 Decision Sight Distance***

| Design Speed [km/h] | AASHTO 2011 (3) | | | TAC (4) | | | MTO (1) |
|---|---|---|---|---|---|---|---|
| | C | D | E | C | D | E | At Exit Terminals |
| 50 | 145 | 170 | 195 | 145 | 160 | 200 | |
| 60 | 170 | 205 | 235 | 175 | 205 | 235 | 170-230 |
| 70 | 200 | 235 | 275 | 200 | 240 | 275 | 200-270 |
| 80 | 230 | 270 | 315 | 230 | 275 | 315 | 240-310 |
| 90 | 270 | 315 | 360 | 275 | 320 | 360 | 270-350 |
| 100 | 315 | 355 | 400 | 315 | 365 | 405 | 300-390 |
| 110 | 330 | 380 | 430 | 335 | 390 | 435 | 340-430 |
| 120 | 360 | 415 | 470 | 375 | 415 | 470 | 370-470 |
| 130 | 390 | 450 | 510 | 375 | 415 | 470 | n.a. |

Notes: * For MTO GDSOH, Sight Distance at Exit Terminals
Avoidance Manoeuvre C: Speed/Path/Direction change on rural roadway
Avoidance Manoeuvre D: Speed/Path/Direction change on suburban roadway
Avoidance Manoeuvre E: Speed/Path/Direction change on urban roadway

There are some notable differences between the MTO Guide and the AASSHTO Green Book / TAC Geometric Design Guide, as follows:

- Both the AASHTO Green Book and TAC Geometric Design Guide provide some further rationale for the use of DSD and the derived values. This is useful in understanding the foundation and implications of design decisions with respect to sight distances.

- The eye height and object height used for determining the sight distance in the AASHTO Green Book is 1.08 m and 0.60 m (taillights) respectively, while the TAC Geometric Design Guide suggests 1.05 m and 0.15 m (Table 1.2.5.1) respectively; MTO Guide, however, requires that it is desirable that drivers see the pavement surface at the bullnose (i.e. object height equal to zero).

- TAC Geometric Design Guide does not prescribe the location of the vehicle from which the sight distance is to be measured; AASHTO Green Book suggests that, "*the sight distance on the freeway preceding the approach nose of an exit ramp should exceed the minimum stopping sight distance for the through traffic design speed, desirably by 25 percent or more. Decision sight distance, as discussed in Section 3.2.3, is desired where practical.*" (3)

- Both the AASHTO Green Book and the TAC Geometric Design Guide provide discrete values for DSD (rather than a range). Both also define five categories of manoeuvres, including differences between urban, sub-urban and rural conditions. This does not necessarily reflect a better level of accuracy (in this respect the MTO guide provides more flexibility), though the reader may be led to believe so.

**Definition of Decision Sight Distance**

The TAC Geometric Design Guide does not formally provide a definition of the DSD, however, the values contained in the TAC Geometric Design Guide is copied from the 1994 AASHTO Green Book (2). The 1994 AASHTO Green Book defines the DSD as:

> *The distance needed for a driver to detect an unexpected or otherwise difficult-to-perceive information source or condition in a roadway environment that may be visually cluttered, recognize the condition or its potential threat, select an appropriate speed and path, and initiate and complete the manoeuvre safely and efficiently.*

The 1994 AASHTO Green Book definition was modified from a 1975 publication on positive guidance by Alexander and Lunenfeld (5) which defined DSD as:

> *The distance at which a driver can detect a signal (hazard) in an environment of visual noise or clutter, recognize it (or its threat potential), select appropriate speed and path, and perform the required action safely and efficiently is called decision sight distance.*

Thus, it can be seen that the origin of the DSD came from positive guidance principles. It is therefore important to understand the definition of positive guidance. Alexander and Lunenfeld provides an operational definition of positive guidance as follows:

> *Any information carrier, including the highway, that assists or directs the driver in making speed or path decisions provides guidance information. Positive guidance information is provided when that information is presented unequivocally, unambiguously, and conspicuously enough to meet decision sight distance criteria and enhance the probability of appropriate speed and path decisions.*

Based on the definition of positive guidance, it appears that by applying proper positive guidance to the highway features, DSD criteria could be met. The 1975 positive guidance publication suggested that guide signs have two characteristics that make them candidates for the location of positive guidance information: their size (large) and their placement (overhead). Furthermore, the publication suggested that information on such signs is conspicuous and can be designed to meet DSD criteria.

**Derivation of the DSD**

According to the AASHTO Green Book, the DSD is derived from empirical data. For the avoidance manoeuvres a pre-manoeuvre time is increased above the brake reaction time for stopping sight distance to allow for drivers additional time to deal with the hazard. For stopping manoeuvres the braking distance from the design speed is added to the pre-manoeuvre component, while the braking component is replaced in speed/path/direction change manoeuvre with a manoeuvre distance based on manoeuvre times. As this paper is dealing with vehicles deciding to exit the mainline, the DSD in question would be related to the speed/path/direction change manoeuvre.

The manoeuvre times are based on research by McGee (6) in 1978. The research was conducted in two phases. In phase 1, a model of the hazard-avoidance process was formulated to be used as a basis for quantifying DSD, and preliminary DSD values were developed based on the average times for the elements of the model derived from literature sources. In the 2nd phase, 19 subjects drove an instrumented vehicle through eight typical highway situations to validate the preliminary DSD values. The sample size used by this study appears to be very limited, and it is unclear whether the AASHTO Green Book took this into account in adopting the values for use in determining the DSD.

Olson (7) had an insightful discussion on DSD and the McGee study. According to Olson, the McGee study's recommendation essentially formed the basis of the DSD values as presented in the AASHTO Green Book. The total time needed for DSD is divided into three categories: "detection and recognition", "decision and response initiation", and "manoeuvre" times. The McGee recommendations are summarized in Table 2.

As evident from Table 2, it can be deduced that the AASHTO Green Book used the minimum values of the various speeds (10.2 s and 11.2 s) and applied it to the rural road category (Avoidance Manoeuvre C); while applying the maximum values (14.0 s and 14.5 s) and applied it to the urban road category (Avoidance Manoeuvre E). The suburban category (Avoidance Manoeuvre D) ended up with intermediate values.

**Table 2 Time Values (seconds) for DSD for Various Speeds (6)**

| Design Speed (mph) | Detection and Recognition (s) | Decision and Response Initiation (s) | Manoeuvre (Lane Change) (s) | Total |
|---|---|---|---|---|
| 30 | 1.5-3.0 | 4.2-6.5 | 4.5 | 10.2-14.0 |
| 40 | 1.5-3.0 | 4.2-6.5 | 4.5 | 10.2-14.0 |
| 50 | 1.5-3.0 | 4.2-6.5 | 4.5 | 10.2-14.0 |
| 60 | 2.0-3.0 | 4.7-7.0 | 4.5 | 11.2-14.5 |
| 70 | 2.0-3.0 | 4.7-7.0 | 4.0 | 10.7-14.0 |

The 3.0 seconds used for the detection and recognition phase is very conservative and a more recent study by Finnegan and Green (8) suggested a value of between 1.0 and 1.5 s. According to Olson (7), the "decision and response initiation" time corresponds to the portion of the lane change time prior to the actual manoeuvre. The numbers recommended by McGee (4.2 to 7.0 s) is somewhat more conservative than the numbers (3.7 to 6.6) from Finnegan and Green. The "manoeuvre" time, which is the last category in Table 1, which McGee et al recommended to be 4.5 s (except for the highest speed), which is three times the amount given by Finnegan and Green (1.5 s). The Finnegan and Green study suggested a total time of 8 seconds (rounded) to change lanes.

Another human factors book (9) by Dewar and Olson cited a more recent study by Lerner et al. The Lerner study focused on the "decision and response initiation" time, and the results ranged between 1.60 to 6.99s. Dewar and Olson concluded that this result is reasonably close to the values given in Finnegan and Green.

It can be seen that the values used in the AASHTO Green Book is therefore between 20 and 70 percent higher than the order-of-magnitude of the time required to change lanes.

Dewar and Olson concluded the perception-response time is highly variable. The perception response time depends largely on the intensity of the stimulus, the amount of information that the driver is required to process and the complexity of the decision making process. Other factors that can affect perception-response time include expectancy, fatigue, use of chemicals (i.e. alcohol, certain drugs, etc… age and sex. However, Dewar and Olson did not provide any definitive numbers to use under various situations. According to Dewar and Olson, there is no data to support this decision. Dewar and Olson recommended that the assessment should be based on a specific set of facts and decide whether there was anything that would likely affect one or more stages of perception-response, and is a vast improvement over attempting to use one number or even a range of numbers for all situations encountered.

As such, driver expectancy is one important factor that can be influenced by roadway design especially when the DSD criteria is not met. Alexander and Lunenfeld defined driver expectancy as follows:

*Driver expectancy relates to the readiness of the driver to respond to events, situations, or the presentation of information. It is primarily a function of the driver's experience. If an expectancy is met, driver performance tends to be error free. When expectancy is violated, longer response time and incorrect behaviour usually result.*

It can be infer from the discussion above that the DSD values specified in the current highway design manuals are meant to be a guidance only. In situations where the DSD cannot be met, mitigating measures would involve the clear conveyance of simple information to meet driver expectancy. More importantly, the use of guide signing is the foundation of positive guidance to convey such messages to meet driver expectancy and DSD criteria.

**Case Study of a Freeway in Ontario**

The decision sight distance available at all the bull-noses at exit terminals was reviewed for a freeway in Ontario.

Sight distances were measured on both the horizontal and vertical alignments using the criteria set forth in the MTO Guide for SDET. Of note is the requirement prescribed by the MTO Guide that the position of the vehicle from which the distance is measured is in the right lane. However, in most instances in this project the right lane along the freeway is a "weaving" lane. This is relevant to the extent that it would be assumed that vehicles in such lane are either "leaving" the lane or have purposely accessed the lane to exit the highway. It follows that drivers should have already perceived the impending exit well before the point of measurement or it would have been too late for them to take such decision. That is, if it is assumed that SDET as defined is a significant criteria in driver decision.

The horizontal and vertical sight distances available at all the bullnoses at exit terminals were compared to the values contained in the MTO Guide in Table F5-2. The designed (or achieved) values that are below the suggested are highlighted. It should be mentioned that the MTO would suggest that in urban conditions the higher values should be applied. The designed values were also compared to the TAC Geometric Design Guide / AASHTO Green Book for suburban conditions, manoeuvre D. Suburban values were selected, as the highway is mostly a depressed highway that is not subjected to the visual clutter of a typical urban area. These values seem to fall in the middle of the MTO range, which seems logical.

A total of eight exit ramps were evaluated, and the results found that 3 exit ramps did not meet the MTO Guide distances, and one exit ramp met the DSD specified by the TAC Geometric Design Guide / AASHTO Green Book, but is less than the upper limit in the MTO Guide. The sight distance restriction at the exits and the reasons for not meeting the SDET are summarized below.

**Exit Ramp 1:** horizontal sight distance restricted by the lateral presence of an MSE wall and the road curvature (R=900 m).

**Exit Ramp 2:** vertical sight distance restricted by the vertical curve over an overpass structure.

**Exit Ramp 3:** vertical sight distance constrained by vertical curve over a large hydraulic structure. Achieved value meets TAC/AASHTO DSD value, but less than MTO upper limit.

**Exit Ramp 4:** horizontal sight distance restricted by road side barrier on the exit ramp and road curvature.

**Observations on the Findings**

The sight distances achieved at ramps Exit Ramps 1 and 2 are significantly lower than the upper values in MTO Guide. When compared with the TAC Geometric Design Guide /AASHTO Green Book, the sight distances are also lower by approximately 30%.

At Exit Ramp 1, drivers travelling in the shoulder lane could detect the start of the taper for the gore area at a distance of approximately +/- 350 m from the bull nose as drivers would be able to detect the exit ramp from the pavement markings.

At Exit Ramp 2, while the required sight distance to the bullnose is not achieved, drivers should be able to better detect the presence of the exit ramp as it rises quite rapidly from the mainline.

At Exit Ramp 3, the achieved sight distance falls in the middle of the range in the MTO Guide and equal the value suggested by the TAC Geometric Design Guide / AASHTO Green Book. The sight distance achieved should be considered as meeting the standard requirements.

At Exit Ramp 4, the achieved sight distance is close to the lowest value in the MTO Guide, but lower than the value in the TAC Geometric Design Guide / AASHTO Green Book.

At all remaining exit terminals the stopping sight distances achieved or exceed the requirements in the MTO Guide and the Geometric Design Guide / AASHTO Green Book.

**Commentary and Discussion**

It would be rather simplistic to suggest that for the exit ramps where SDET (or DSD) is not achieved the design team should modify the geometry and the roadside, so it does. While this may be the case, and the design team should be better equipped to answer this question, it seems that there are serious site constraints that have already limited the design and such a suggestion may not respond to the realities of the project. A minor exception may be at Exit Ramp 4 where a relocation of the road side barrier may result in sufficient sight distance to meet the MTO criteria.

There are other mitigating measures that could be considered, and some will be discussed further in this paper. However, as "meeting the standards" seems to be a requirement, "departure from standards" should require further justification.

From a road safety perspective, there are two questions that require consideration: a) is not meeting the standard, as defined in a guide (MTO or TAC) of significant concern?; and, b) if so, are there mitigating measures that can be implemented to address these concerns. This is the same concept of "nominal and substantive safety", fundamental to the topic of "departure from standards" and the mitigations. Hauer (10) has extensively discussed the nominal and substantive safety concept. "Nominal safety" is achieved by meeting or exceeding the standard and "substantive safety" is quantifying the safety implications of a "departure from standards".

A detailed literature search has concluded that there is no "substantive safety" evidence to be found regarding sight distance in general, and SDET/DSD in particular, i.e. there is no data to estimate or evaluate the expected safety performance of a roadway due to a change in the sight distance (including Stopping Sight Distance). For example:

> *1994 AASHTO Green Book (Page 265, 3rd Paragraph) – The major control for safe operation on crest vertical curves is the provision of ample sight distances for the design speed; while research has shown that vertical curves with limited sight distance do not necessarily experience safety problems, it is recommended that all vertical curves should be designed to provide at least the stopping sight distance shown in Exhibit 3-1. Wherever practical, liberal stopping sight distances should be used. Furthermore, additional sight distance should be provided at decision points.*

This would also indicate difficulties in defining "nominal safety" and, indeed, the literature search was not useful in shedding additional light on this subject.

While the criteria presented in the MTO Guide, which states "Sight distance, greater than minimum stopping sight distance, is required for the driver to make a series of decisions, and execute the manoeuvre safely" is universally accepted, there is only minimal validation for the values suggested in any of the mentioned design guides.

Perhaps the larger problem is “sight distance to what?” or where is the information presented to the driver in order to make such series of decision. The MTO Guide suggests that visibility forward should be to the pavement, while the TAC geometric Design Guide / AASHTO Green Book suggests some low point ahead, just above the road surface. In other words, the information required by drivers to “make a series of decisions, and execute the manoeuvre safely” is somewhere lower than the driver’s eye, towards the road surface. While this may be appropriate for various elements of the road, it is questionable if this can hold true, for freeway exit ramps in particular.

Intrinsic to the concept of “nominal standards” is the assumption that they equally apply to most, and preferably to all the drivers on a given facility. From a road safety perspective this is an important assumption and indeed, most design parameters meet this concept.

Focussing on freeway exit ramps only, sight distance, as defined and measured in the design guides reviewed, seems to be a conspicuous exception. It is highly unlikely, if at all possible, that each and every driver on the highway can “enjoy” and make use of so defined SDET/DSD in order to obtain sufficient information for the decision making process. As with many other “standards”, “measured sight distance” assumes that no other obstacles, except road fixtures, are impeding the driver’s sight, or in other words, the highway is assumed to be empty as viewed on a plan. While on two-lane rural roads, which were the basis of the development of the sight distance concepts, the leading car can benefit from availability of sight distance to a low point on the road, on multi-lane highways this is practically unattainable.

Further, even if this was not the case, visibility to such low points seems irrelevant given that an exit ramp is a “destination” and that the physical bullnose alone would contain little or no useful information to drivers such that he or she can “make a series of decisions”. This information should have been available well before the bullnose is in sight, and the series of decisions already initiated.

Drivers’ visual capabilities to see objects at distances specified are often neglected in design standards (not to mention other visibility factors such as luminance contrast, colour, contrast, ambient luminance level, and glare). As highlighted in NCHRP Report 400 (15), in Swedish Design Standard (12), for example, issues related to object recognition was addressed by defining object height and a visibility angle. As concluded, under bright light conditions, part of obstruction must be covered by at least 1 degree of arc angle so that a driver with 20/20 static visual acuity can perceive it as an object if that is an object the driver is looking for. While evaluating drivers’ visual limitations within stopping sight distance model for 1980 NAASRA, McLean (13) concluded that taking into consideration by driver’s encountered environmental conditions, 5 degrees of arc would be a minimum angle to perceive an object on the roadway surface. McLean pointed out that in order to be perceived by a driver from the distance of 65 m, an object must be at minimum 100 mm above the line of sight; to be detected from a distance of 130 m, an object must be at minimum 200 mm above the sight line. As it is summarized in (15), however, based on daytime visual capability studies conducted by Ketvirtis and Cooper (14), regardless of contrast, at 90 km/h speed

*The drivers do not have visual capabilities to recognize objects that are less than 300 mm in height at or beyond stopping sight distance.*

…

*The findings from nighttime visual capability studies suggest that a substantial proportion of the driving population are not able to detect or recognize hazardous objects in the roadway at the AASHTO minimum stopping sight distance for a driver traveling at 90 km/h (131 m). The only exception to this statement is when the object is externally illuminated or retro reflective, that is, has vehicle tailing or side reflectors.*

For a long time 300 mm had been height of the object to which stopping sight distance was measured and crest vertical curve K-parameters determined in AASHTO standards. Based on research by Fambro, D. B., K. Fitzpatrick, and R. J. Koppa (15), 600 mm height of the hazard is adopted the Green Book editions after 1994:

*The selection of a 0.60 m object height was based on research indicating that objects with heights less than 0.60 m are seldom involved in crashes (15). Therefore, it is considered that an object 0.60 m in height is representative of the smallest object that involves risk to drivers. An object height of 0.60 m is representative of the height of automobile headlights and taillights. Using object heights of less than 0.60 m for stopping sight distance calculations would result in longer crest vertical curves without a documented decrease in the frequency or severity of crashes (15). Object height of less than 0.60 m could substantially increase construction costs because additional excavation would be needed to provide the longer crest vertical curves.*

In AASHTO standards, the very same rational and 600 mm hazard-height criterion was recommended for decision sight distance.

Thus, from a road safety perspective, the availability of such sight distances to low points presents a paradox (especially if it is a low contract pavement surface, as required by MTO GDSOH). Drivers will have the least sight distance when they need it most, i.e. in high exposure and risk conditions presented by high traffic flows, and will have the most sight distance when, from a safety perspective, they need it least. The margin of error in low traffic flows is significantly larger and the consequences of an errant manoeuvre are lessened. To illustrate, consider the SDET at this exit ramp, where the "measured nominal values" are met or exceeded. Figure 2 illustrates the driver's view to the exit ramp bull-nose at LOS B-C, and Figure 3 illustrate the driver's view to the exit ramp bull-nose at LOS C-D. When measuring from the inside lane to the bullnose the driver's eye sight "crosses" all traffic lanes. For a driver to actually see and benefit from the available sight distance, all the traffic lanes should be void of traffic, a most unlikely scenario. So while the "nominal values" were achieved, from a road safety perspective, the objectives are not. Figure 4 illustrates the driver's view of the exit ramp bull-nose in plan view at various levels of service for urban and rural conditions. Figure 5 are photographs of freeway exit ramps taken at 370m and 470m upstream of the exit bull-nose.

**Figure 2 Driver's View of Bull-nose from 470 m Distance (LOS 'B-C')**

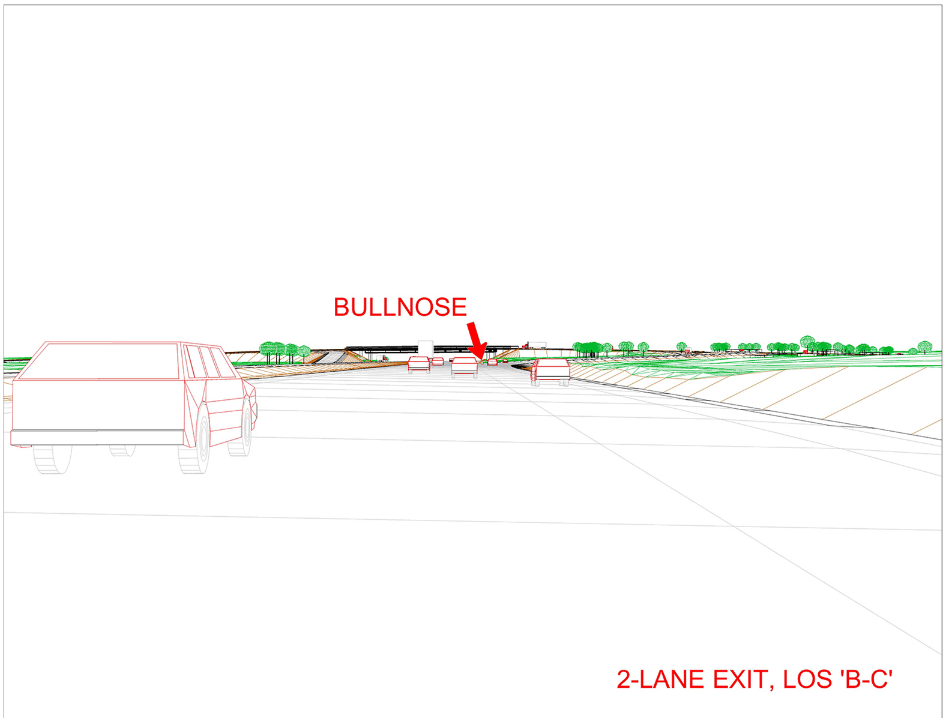



**Figure 3 Driver's View of Bull-nose from 470 m Distance (LOS 'C-D')**

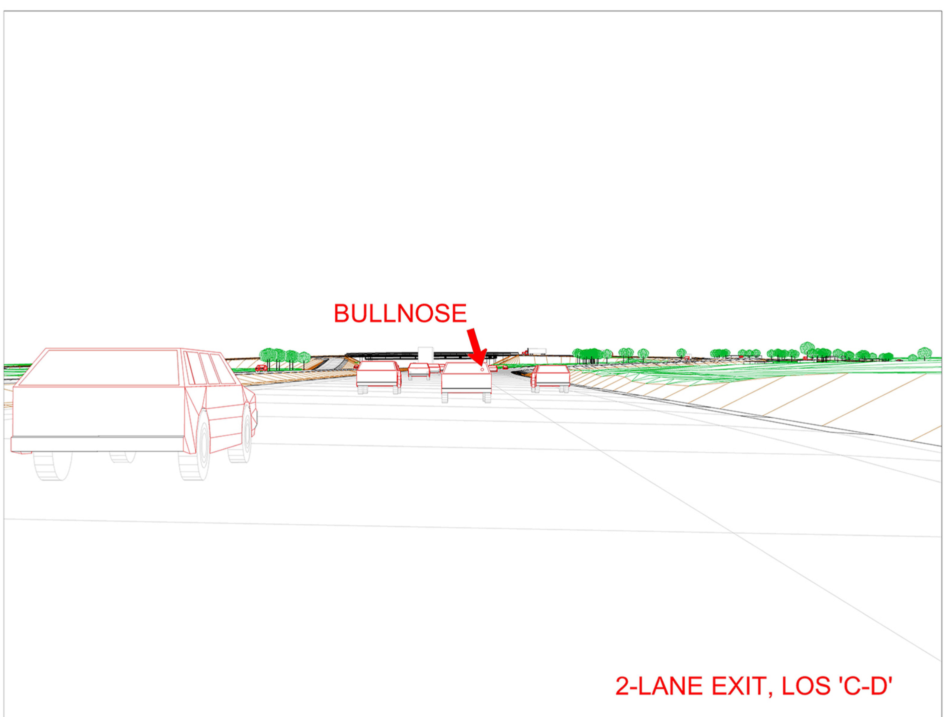


**Figure 4  Driver's View of Exit Ramp Bull-nose, Plan View**

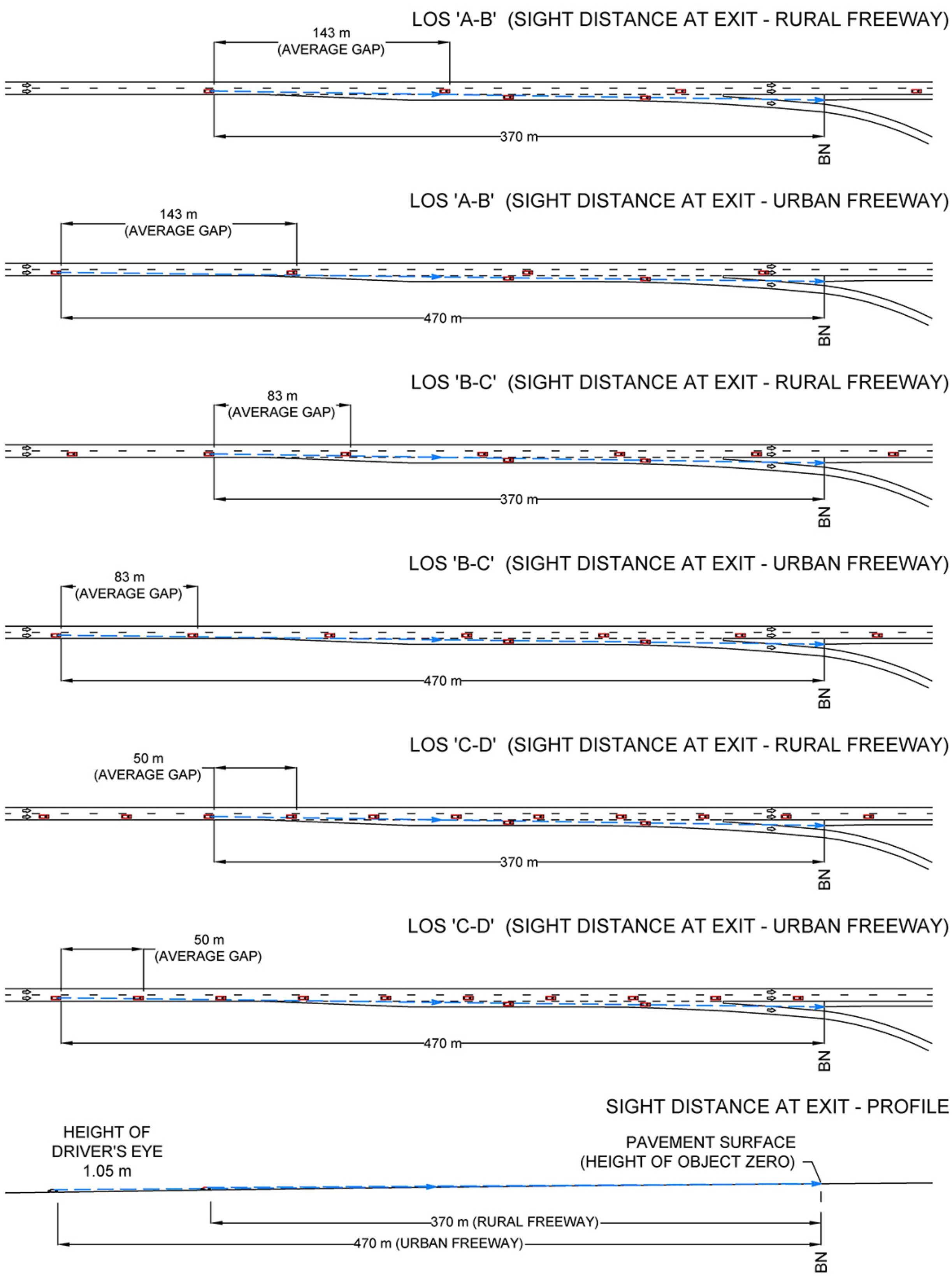
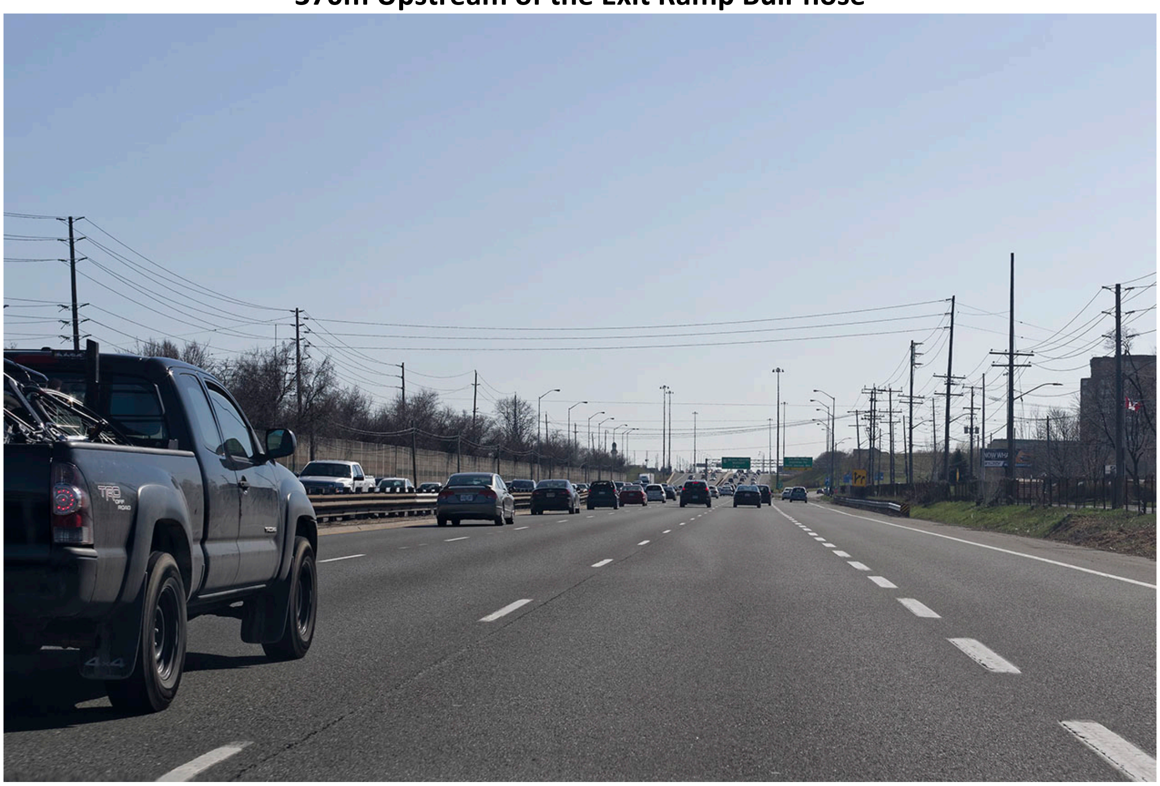


**Figure 5 Photographs of Freeway Exit Ramps**

**370m Upstream of the Exit Ramp Bull-nose**



**470m Upstream of the Exit Ramp Bull-nose**

An additional issue with the methodology of measuring SDET is the vehicle location. In the MTO Guide, the vehicle is assumed to be in the shoulder lane. However, if that vehicle is exiting, the driver would have the least complex manoeuvre to execute. Drivers in the inside lanes are faced with more complex decisions but would have the least available sight distance to the decision point.

As such, it is important to understand that while meeting the SDET as defined by the MTO Guide may satisfy “nominal standard”, the resultant impact on the safety performance of the exit terminal is largely unknown and unquantifiable.

The MTO Guide’s definition of the SDET should be considered as a guiding principle, however, the designer should also interpret the SDET/DSD as measured to the various highway features that provide clues to the drivers as they are approaching an exit ramp. The physical bull nose is one such feature, and other highway features such as guide signing, pavement markings, highway geometrics such as horizontal and vertical profiles and the presence of a ramp are additional visual clues to the drivers wanting to exit the mainline. For example, the beginning of the exit ramp taper and the associated signage that is visible to approaching drivers can clearly indicate to drivers the beginning of the exit.

In conclusion, and specifically, though perhaps not exclusively, for exit ramps, it seems that meeting the “nominal values” for SDET/DSD as defined by the MTO Guide, may be of little relevance and benefit from a road safety perspective. Quoting from "A Users' Guide to Positive Guidance" 3rd Edition, September 1990, FHWA Report No. FHWA-SA-90-017:

> *Decision sight distance is used to determine the adequacy of forward sight distance to a hazard and/or to position highway information when there is insufficient sight distance.*

If one substitutes DSD with SDET and taking into account that “universal” sight distance to an exit cannot be available in the current context, the only logical outcome is a recommendation that **<u>all exits</u>** should be appropriately signed and that the critical signs be located at the SDET (or DSD) and that the “measured values” should be to an object height that ensure that most, if not all drivers can detect, and that this object (signs) contains the necessary information for drivers to “make a series of decisions, and execute the manoeuvre safely”. It is conspicuously noted that the MTO guide signs manual (10) on advance guide sign adheres to these principles.

**Mitigation Measures**

A number of mitigating measures can be considered to mitigate the SDET/DSD restrictions:

- Increase radii of horizontal curves
- Improve vertical curvature

- Increase shoulder width (lateral clearance)
- Remove sight line obstruction
- Reduce posted speed limit
- Provide positive guidance measures, e.g. signing (freeway turn-off signs, exit signs, hazard markers, delineators, etc.)

Given the project constraints and the complexity of some constructions, it appears that the first three mitigation measures would usually require significant changes to the designed geometry that may not be feasible or cost-effective for most of the locations. Nonetheless, the designer should always be encouraged to maximize sight distance through minor geometric modifications if possible, for example, by local modifications to the cross sectional elements (i.e. shoulder widths) to increase the sight distance available.

Another possible measure is to reduce the posted speed limit. The effectiveness of this measure will, however, largely rely on the compliance of drivers to the posted speed limit and the level of enforcement that is sustainable for good speed compliance. As it is concluded in Human Factors for Road Systems (16), "When available, actual operating speed should be used instead of design speed to help determine needed sight distance".

Irrespective, it is essential that **all exit ramps** should be appropriately signed and that the critical signs be located at the SDET (or DSD) distance from the exit terminals.

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