Sight Distance

General

A driver needs adequate sight distance along a roadway to make safe and efficient decisions. Several types of sight distance are discussed in this section:

- **Stopping sight distance** – The distance traveled in the time it takes a driver to recognize an object ahead, decide to stop, and then stop their vehicle.
- **Decision sight distance** – The distance traveled in the time it takes a driver to recognize an object ahead, decide whether to stop their vehicle or change their path, and then make the maneuver.
- **Intersection sight distance** – The time gap acceptance distance needed for a driver to enter an intersection.
- **Passing sight distance** – On two lane roadways, passing sight distance contributes to the determination of No Passing Zones.

Quick Tips:

- Stopping sight distance should be provided throughout the entire length of the roadway.
- For sag vertical curves, a design exception is required for curves that meet passenger comfort criteria, but do not have a fixed lighting source.
- Refer to Table 8 for guidance on which type of sight distance applies and the boundaries.

Stopping Sight Distance

Stopping sight distance (SSD) is the length of roadway ahead that is visible to the driver. This distance allows a driver to see an object in the roadway and stop their vehicle before colliding with the object. A roadway should be designed to provide continuous stopping sight distance throughout the route.

A formal design exception is required wherever stopping sight distance cannot be provided.

SSD consists of two components:

1. Brake reaction distance – The distance a vehicle travels from the moment a driver spots the object until the driver applies the brakes.
2. Braking distance – The distance a vehicle travels from the moment the brakes are applied until the vehicle comes to a stop.

Combining these yields the following equation:

$$SSD = 1.47Vt + 1.075\frac{V^2}{a} \quad \text{(Equation 6D-1\_1)}$$

where:

SSD = stopping sight distance, ft

t = break reaction time, 2.5 s

V = design speed, mph

a = deceleration rate, 11.2 ft/s^2

(Reference: Equation 3-2 AASHTO Greenbook, 2011)

Table 1 provides minimum SSD derived from Equation 6D-1_1, although greater lengths are desirable.

Table 1: Stopping Sight Distance on Level Roadways.
(Source: Table 3-3 AASHTO Greenbook, 2011)

design speed (mph)	brake reaction distance (ft)	braking distance on level grade (ft)	stopping sight distance	
			calculated (ft)	design (ft)
25	91.9	60.0	151.9	155
30	110.3	86.4	196.7	200
35	128.7	117.6	246.3	250
40	147.0	153.6	300.6	305
45	165.4	194.4	359.8	360
50	183.8	240.0	423.8	425
55	202.2	290.3	492.5	495
60	220.5	345.5	566.0	570
65	238.9	405.5	644.4	645
70	257.3	470.3	727.6	730
75	275.7	539.9	815.6	820

Stopping Sight Distance Adjustment for Grade

Vertical grades greater than 3% affect the braking distance component of stopping sight distance. On upgrades, braking distance decreases. On downgrades, braking distance increases. Most roadways are traversed in both directions; therefore, a vertical grade for one direction of travel increases the needed stopping sight distance, while decreasing the needed stopping sight distance for the other direction of travel. In most cases the available sight distance on downgrades is greater, so adjustments to the sight distance values shown in Table 1 are not normally needed for downgrades. Exceptions are one-way roadways and roadways with independent vertical alignments.

The following equation can be used to determine the needed SSD on downgrades:

$$d_B = \frac{V^2}{30[(\frac{a}{32.2}) - G]} \quad \text{(Equation 6D-1\_2)}$$

where:

d_B = braking distance on grade, ft

V = design speed, mph

a = deceleration, 11.2 ft/s^2

G = grade, $\frac{rise}{run}$, ft/ft

(Reference: Equation 3-3 AASHTO Greenbook, 2011)

This is added to the distance traveled during brake reaction time (1.47Vt) to determine stopping sight distance.

Example Problem 6D-1_1, Determining Stopping Sight Distance on Grade

Stopping Sight Distance for Trucks

Trucks are heavier than passenger cars; therefore, they need a longer distance to stop. The values shown in Table 1 do not consider the physical characteristics of trucks, such as weight. However, adjustment factors for trucks are not necessary. Drivers in trucks are able to see farther down the road because the driver is at a higher elevation above the roadway surface, thus increasing the available sight distance. The increase in the height of the driver offsets the need for additional braking distance resulting from the truck's weight.

Decision Sight Distance

Decision sight distance (DSD) provides drivers approaching changes in the roadway environment, such as intersections, interchanges, or areas where the roadway turns as shown in Figure 1, time to recognize the change and decide to either change their vehicle path, reduce their speed, or stop their vehicle.

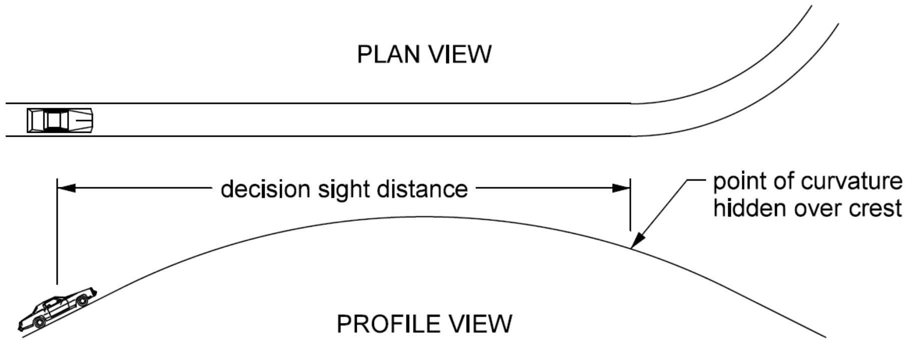

Figure 1: Illustration showing decision sight distance.

Low Speed Environments

Providing stopping sight distance on roadways in a low speed environment is usually sufficient. Roadways in low speed environments are usually affected by visual noise from competing sources such as roadway elements, traffic, traffic control devices, and advertising signs. This visual noise makes it difficult for drivers to perceive a hazard and decide to change their path. As a result, most drivers will stop. In addition, the alignment and roadway cross-section are restricted in urban areas due to constraints in the roadside, which makes providing decision sight distance difficult.

High Speed Environments

Providing decision sight distance in high speed environments is desirable. More freedom exists to adjust the alignment or cross-section in a high speed environment. If the alignment or cross-section cannot be adjusted, the decision point should be relocated, for example moving an exit gore that is hidden over a crest vertical curve to a point upstream of the high point.

The AASHTO Greenbook provides decision sight distance based upon design speed and various avoidance maneuvers for rural and urban roadways. The Department prefers to use avoidance maneuver C (speed/path/or direction change on rural roads) for high speed environments, including urban interstates and freeways. Refer to Table 2 for decision sight distance values.

$$DSD = 1.47Vt \quad \text{(Equation 6D-1\_3)}$$

where:

DSD = decision sight distance, ft

t = break reaction time, t varies from 10.2 to 11.2 seconds

V = design speed, mph

(Reference: Equation 3-5 AASHTO Greenbook, 2011)

Table 2: Decision Sight Distance, Avoidance Maneuver C.

design speed (mph)	decision sight distance (ft)
50	750
55	865
60	990
65	1050
70	1105
75	1180

Intersection Sight Distance

Since vehicle paths cross within intersections, the potential exists for various types of crashes. To reduce potential crashes, an area within the roadside, clear of obstructions, should be provided so drivers at an intersection can see drivers on the intersecting road approaching the intersection. This area is referred to as the clear area. Objects that restrict intersection sight distance should be removed, lowered, or relocated outside of the clear area. Intersections can also be relocated away from the sight obstruction.

To determine whether an object is a sight obstruction, the designer needs to consider both the horizontal and vertical alignments of the intersecting roads, as well as the elevation of the object. To do this, the designer needs to construct departure sight triangles and then determine the elevations of the object(s), the driver at the intersection, and the driver approaching the intersection.

Departure sight triangles for vehicles approaching from the left or right, like those shown in Figure 2, should be provided for stop sign controlled intersections and signalized intersections where right turns on red are permitted. The area within the triangle (the clear area) needs to be free of obstructions that restrict the view of vehicles approaching the intersection.

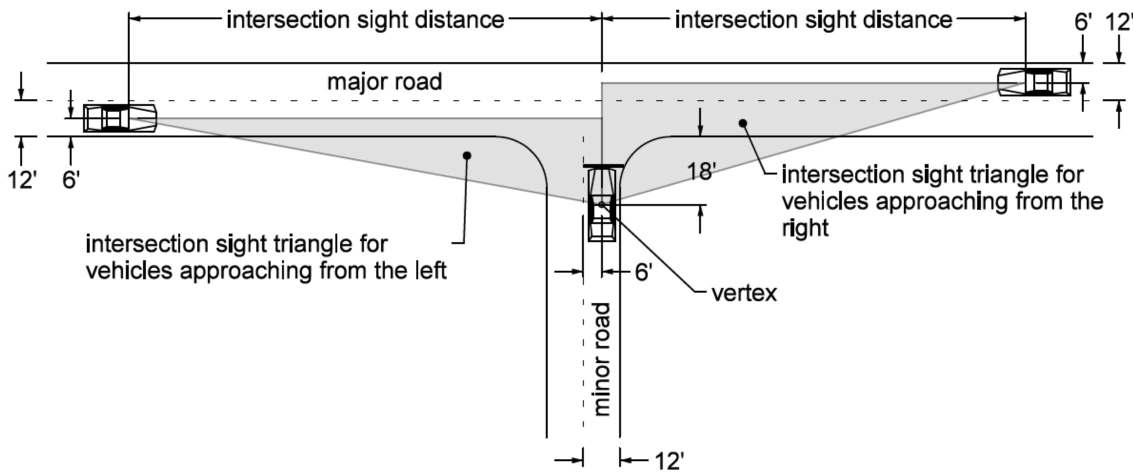

Figure 2: Illustration showing components for departure sight triangles.

Horizontal Intersection Sight Distance

The vertex, or decision point, is where a stopped driver at an intersection is located. The designer should assume the vertex is in the middle of the approach lane. The vertex is measured 18 feet from the edge of the major road traveled way. This distance can be reduced to 14.5 feet, but should only be used in locations where it has been deemed necessary to avoid removing protected obstructions such as historic buildings, or in areas where an existing sideroad intersection is close to bridge.

Intersection sight distance along the major road is determined by the following formula:

$$L = 1.47V_{major}t_g \quad \text{(Equation 6D-1\_4)}$$

where:

L = sight distance along major road, ft

V_{major} = design speed of major roadway, mph

t_g = time gap, s

(Reference: Equation 9-1 AASHTO Greenbook, 2011)

The distance is measured down the middle of the approach lane on the major road.

The time gap variable (t_g) represents the time a stopped driver will accept to accelerate and complete a turning maneuver into traffic. The acceptable time gap is different for a right, left, or crossing maneuver. The acceptable time gap also depends on the design vehicle making the maneuver. Table 3 contains minimum gap acceptance times for maneuvers and design vehicles based upon standard conditions: little to no skew, the major road is a two lane roadway, and the approach grade on the minor roadway less than +3.0%.

Table 3: Time Gap.

design vehicle	minimum gap acceptance time (seconds)		
	left turn	right turn	crossing maneuver
passenger car	*8.0	*7.0	*7.0
single-unit truck	9.5	8.5	8.5
combination truck	11.5	10.5	10.5

*0.5 seconds added to AASHTO Greenbook values for older drivers

Refer to Table 4 for additional time needed for non-standard conditions.

Table 4: Adjusted Time Gap.

condition	adjustment (seconds)
positive approach grades greater than 3%	add 0.2 for each percent grade for left turns
additional 12' lane to cross	add 0.5 for passenger cars, 0.7 for trucks
acute intersection angles less than 60 degrees	add 0.5

Expressways in a rural environment usually have wide depressed medians. Most medians are not wide enough to store a combination truck and allow sufficient clearance to the through lanes. Therefore, the major roadway's horizontal and vertical alignment should provide sufficient intersection sight distance for combination trucks to make a left turn or crossing maneuver without having to stop within the median. Additionally, the provided sight distance should allow a driver in a truck to see approaching drivers in passenger cars.

Providing intersection sight distance for trucks on divided roadways with wide medians can be difficult in areas with rolling terrain. When intersection sight distance cannot be achieved for trucks, the greatest possible length should be provided, but not less than:

- intersection sight distance needed for a single unit design vehicle to depart from the median, or
- decision sight distance to the intersection.

Vertical Intersection Sight Distance

Sight triangles determine the clear area needed. For an object located in the clear area, the designer needs to determine the elevations of the driver's eye at the intersection and the approaching driver's eye to determine if the object affects sight distance. The height of eye of a driver in a passenger car is 3.5 feet above the roadway surface. The height of eye of a driver in a truck is 7.6 feet above the roadway surface. With this information, the designer can determine if an object will obscure sight distance. Vertical profiles that do not allow a stopped driver at an intersection to see an approaching driver's eye should be flattened to provide intersection sight distance.

Example Problem 6D-1_2, Intersection with a Two-lane Highway

Example Problem 6D-1_3, Intersection with Four-lane Expressway

Example Problem 6D-1_4, Signalized Ramp Terminal Intersection

Passing Sight Distance

No Passing Zones locations are determined using Section 7A-1 of the Traffic and Safety Manual.

Measuring Sight Distance

Sight distance along a roadway can be limited by the horizontal or vertical alignment, as well as physical features such as longitudinal barriers, back slopes in cut sections, and bridge berms.

Horizontal Alignment

Physical features along the inside of curve can restrict sight distance. The following equation can be used to determine if the physical feature limits sight distance. The middle ordinate (MO) is the perpendicular distance from the vehicle path along a curve to the face of the physical feature. See Figure 3 for a graphical representation.

$$MO = R\left(1 - \cos\frac{28.65 \times S}{R}\right) \quad \text{(Equation 6D-1\_5)}$$

where:

MO = middle ordinate, ft

R = radius of the vehicle path, ft

S = stopping sight distance, ft

If a feature limits sight distance, the designer can adjust the horizontal alignment or modify the roadway's cross-section to provide adequate sight distance.

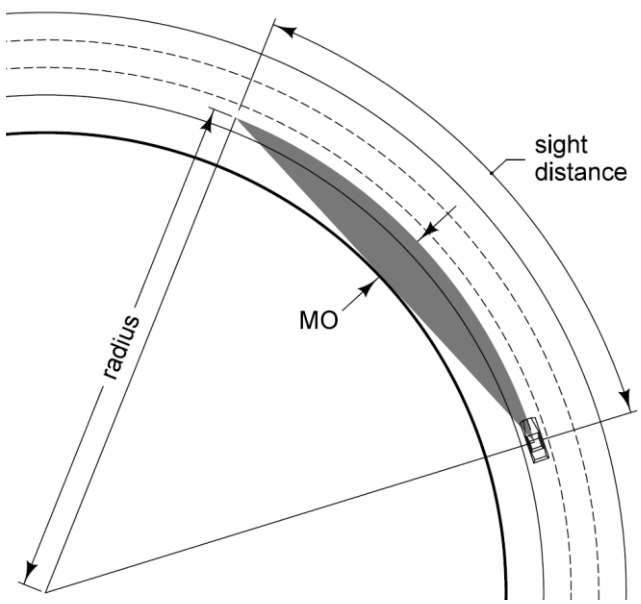

Figure 3: Illustration showing components for determining horizontal sight distance.

Vertical Profile

A change between tangent grades results in a crest or sag vertical curve. The high point (turning point) of a crest vertical curve can limit sight distance to an object in the road or a change in the roadway alignment. Sight distance on sag vertical curves is usually limited by the headlight sight distance of a vehicle.

Crest Vertical Curves

Rate of vertical curvature (denoted by the variable K) is used as a design control on crest vertical curves to ensure the crest vertical provides stopping sight distance for a selected design speed.

$$K = \frac{L}{A} \quad \text{(Equation 6D-1\_6)}$$

where:

K = rate of vertical curvature

L = length of vertical curve, ft

A = algebraic difference in grades, %

The Department uses a minimum vertical curve length of 3 times the design speed and Equation 3-41 from the AASHTO Greenbook to determine minimum rate of curvature. Combining the Equation 6D-1_6 and Equation 3-41 from the AASHTO Greenbook results in the following equation:

$$K = \frac{S^2}{100\left(\sqrt{2h_1} + \sqrt{2h_2}\right)^2} \quad \text{(Equation 6D-1\_7)}$$

where:

K = rate of vertical curvature

L = length of vertical curve, ft

S = stopping sight distance, ft

h_1 = height of driver's eye, ft

h_2 = height of object in road, ft

The height of the driver's eye (h_1) in a passenger car is 3.5 feet and the height of the object in the road (h_2) is 2.0 feet, refer to Figure 4. See Table 5 for minimum K values for crest vertical curve design.

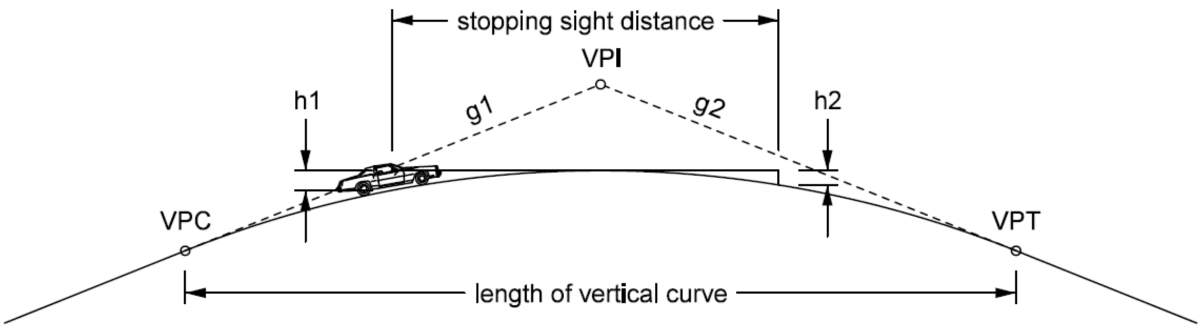

Figure 4: Illustration showing components for sight distance on a crest vertical curves.

Table 5: Design controls for crest vertical curves.

design speed (mph)	stopping sight distance (ft)	minimum rate of vertical curvature, K
25	155	12
30	200	19
35	250	29
40	305	44
45	360	61
50	425	84
55	495	114
60	570	151
65	645	193
70	730	247
75	820	312

Decision Sight Distance

In the measure of decision sight distance, AASHTO specifies the 2.0 feet object height criterion adopted from stopping sight distance. The Department suggests using the height of the pavement surface (0.0 feet) when measuring decision sight, since the decision point may be a point of curvature in the roadway's alignment, a lane drop or a lane add, an exit or entrance ramp taper, a turn lane taper, or an intersection. If decision sight distance to the pavement surface cannot be achieved, the designer needs to adjust the geometry of the roadway or relocate the decision point where the adequate decision sight.

> Special attention to pavement surface drainage should be given to crest vertical curves on roadways where K is greater than 167. K values in excess of 167 can result in flat areas that are slow to shed water.

Sag Vertical Curves

Like crest vertical curves, rate of vertical curvature (K) is used as a design control for sag vertical curves. The Department uses a vertical curve length of 3 times the design speed and Equation 3-48 from the AASHTO Greenbook to determine a minimum rate of vertical curvature. Combining Equation 6D-1_6 and Equation 3-48 from the AASHTO Greenbook results in the following equation:

$$K = \frac{S^2}{400 + 3.5S} \quad \text{(Equation 6D-1\_8)}$$

where:

K = rate vertical curvature

S = sight distance, ft

Table 6: Design controls for sag vertical curves.

design speed (mph)	stopping sight distance (ft)	minimum rate of vertical curvature, K
25	155	26
30	200	37
35	250	49
40	305	64
45	360	79
50	425	96
55	495	115
60	570	136
65	645	157
70	730	181
75	820	206

> Special attention to pavement surface drainage should be given to sag vertical curves on roadways where K is greater than 167. K values in excess of 167 can result in flat areas that are slow to shed water.

If a roadway has continuous lighting, the length of a sag vertical curve (L) may be based upon passenger comfort instead of headlight sight distance.

The following equation may be used to determine the minimum length of a sag vertical based upon passenger comfort:

$$L = \frac{AV^2}{46.5} \quad \text{(Equation 6D-1\_9)}$$

where:

L = length of sag vertical curve, ft

V = design speed, mph

A = algebraic difference in grades, %

(Reference: Equation 3-51 AASHTO Greenbook, 2011)

Table 7: Design controls for sag vertical curves based upon driver comfort.

design speed (mph)	rate of vertical curvature, K
25	14
30	20
35	27
40	35
45	44
50	54
55	66
60	78
65	91
70	106
75	121

For sag vertical curves, a design exception is required for curves that meet passenger comfort criteria, but do not have a fixed lighting source.

Table 8: Sight Distance Application and Boundaries.

Locations to Apply Sight Distance Conditions	Sight Distance Condition			Measured to:	Height of Object (feet)	Length
	SSD	DSD	ISD			
Along the entire route	x			Throughout the route	2	Length based upon the design speed of the route
Approaching points of horizontal curvature		x		The point of horizontal curvature	0.0	Length based upon the design speed of the approach roadway and avoidance maneuver
Approach to a lane drop		x		Beginning of the lane drop taper and through the entire taper	0.0	Length based upon the design speed of the approach roadway and avoidance maneuver
Approach to an exit ramp ramp		x		Beginning of the exit taper and through the taper taper to the back of the gore	0.0	Length based upon the design of the approach roadway and avoidance maneuver C
Approach to an entrance ramp taper		x		Back of the gore through the painted gore nose	0.0	Length based upon the design speed of the approach roadway and avoidance maneuver
Approach to railroad at-grade crossing		x		At the stop bar upstream from the railroad track	0.0	Length based upon the design speed of the approach roadway and avoidance maneuver
Mainline approach to an at-grade intersection on the expressway or a 2-lane highway		x		Point of intersection between the intersecting roadways or to the beginning of the taper for a right or left turn lane	0.0	Length based upon the design speed of the approach roadway and avoidance maneuver
Secondary road approach to an at-grade intersection on the expressway or a 2-lane highway	x			Point of intersection between the intersecting roadways	2	Length based upon the design speed of the approach roadway
Crossroad approach to an interchange at-grade terminal	x			Point of intersection between the crossroad and ramp	2	Length based upon the design speed of the approach roadway
High speed (greater than 45 mph) rural approach to an intersection which is stopped controlled		x		Point of intersection between the intersecting roadways	0	Length based upon the design speed of the approach roadway and avoidance maneuver
Approaches with painted channelized islands		x		First point of island	0.0	Length based upon the design speed of the approach roadway and avoidance maneuver
Approaches with curbed channelized islands		x		First point of island	Curb height	Length based upon the design speed of the approach roadway and avoidance maneuver
Departure from a yield controlled intersection			x	Vehicles approaching from the left or from the right	3.5	Length based upon departure sight triangles for yield controlled intersections
Departure from a stopped controlled intersection			x	Vehicles approaching from the left or from the right	3.5	Length based upon departure sight triangles for stopped controlled intersections

Chronology of Changes to Design Manual Section:

006D-001 Sight Distance

7/2/2015	Revised Add in information regarding passing sight distance
7/18/2013	Revised Retitled and rewrote section. This section replaces Sections 6A-4, 6A-5, 6D-1, 6D-2, 6D-4, and 6D-5.
1/4/2002	New material.