Discussion Paper No. 8.B

INTERSECTION SIGHT DISTANCE

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DISCLAIMER

This background paper represents the viewpoints of the authors. Although prepared for the Oregon Department of Transportation (O.D.O.T.), it does not represent O.D.O.T. policies, standards, practices nor procedures.

GENERAL GOAL

This and other background papers were prepared to provide background, enhance understanding and stimulate discussion among individuals representing a variety of groups, agencies and interests who have concern in Oregon's highways.

SPECIFIC OBJECTIVES

The specific objectives of this discussion paper are to:

1. Summarize the literature and traditional knowledge regarding intersection sight distance.

2. Summarize research and the current state of the art on the factors and elements of driver behavior and traffic operations that affect intersection sight distance.

3. Review current criteria on intersection sight distance within the context of access management.

4. Identify questions and issues regarding the appropriate criteria and use of intersection sight distance.

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ACKNOWLEDGEMENTS AND CREDITS

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OVERVIEW

Background

The safe operation at intersections or driveways requires adequate sight distance so drivers can enter the roadway safely. The primary definition for intersection sight distance is provided by the AASHTO Policy on Geometric Design for Streets and Highways, i.e. the Green Book. The three recent editions of this policy, 1984, 1990 and 1994, have each altered the recommended criteria.

The methods to determine intersection sight distance are based on models that describe the operation of the entering vehicle and the conflicting vehicle on the major roadway.

These methods, or cases as defined in the Green Book, treat:

Case I	Uncontrolled Intersections
Case II	Yield Controlled Intersections
Case III	Stop Controlled Intersections
Case IV	Signal Controlled Intersections
Case V	Left Turns from Major Highway

The primary changes in intersection sight distance arose from the change in vehicle acceleration characteristics.

Content

This background paper summarizes the literature, standards and current practice on intersection sight distance. The primary emphasis of this discussion is on the driver behaviour, traffic operation conditions and vehicle operating characteristics that influence the required intersection sight distance. The discussion will also deal with the height of eye, height of object and location from which intersection sight distance should be measured.

The discussion includes information drawn from policies, standards, current practice and recent research. The primary sources of the policies and standards are the AASHTO Policies on Geometric Design, 1984, 1990 and 1994 Editions, and the Oregon Highway Design Manual. The changes in vehicle sizes, operating characteristics, driver experience and behaviour, and traffic operations necessitate modifications in the criteria.

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OVERVIEW (Continued)

Issues

The intersection sight distance is a major control for the safe operation of roadways. It is of particular concern for access management with the numerous driveways and approach roads that must be safely accommodated. All intersecting driveways and roadways must have adequate intersection sight distance.

The AASHTO Green Book criteria for intersection sight distance are felt to very conservative. They are often viewed as providing desirable sight distances for conditions, rather than the minimum acceptable.

The models describing intersection operations on which the intersection sight distance criteria are based result in very long sight distances for passenger cars, and enormous sight distances for entering trucks.

The height of object at 1300 mm (4.25 ft), the roof of approaching vehicle, is also viewed as inadequate, but because it allows the driver to see the roof of the approaching automobile.

A major issue is how much entering vehicles should be allowed to interfere with the traffic stream. Current AASHTO policies assume that the vehicle on the major roadway is only slowed to 85% of design speed by entering vehicles. An absolute minimum condition is provided by the stopping sight distance for the approaching vehicle to the intersection.

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INTERSECTION SIGHT DISTANCE

OVERVIEW (Continued)

Intersection Sight Distance as an Access Management Measure

Intersection sight distance must be provided for all entering driveways and roadways. The location and spacing of intersections can be impacted by the intersection sight distance.

It can also dictate locations where medians should be placed to assure safe operations.

Questions to be Answered

Intersection sight distance presents a complex and difficult issue. It requires a somewhat involved analysis. The criteria to determine a safe intersection sight distance are not clear. Numerous conditions influence the intersection sight distance. Conditions and operations vary on different highways, by urban vs. rural, speed, expectations, and volume levels. The questions to be answered include:

1. If coefficient of friction is used to determine the minimum distance to stop before an intersection, should it represent a comfortable or an emergency deceleration rate? Should they be the same as for design stopping sight distance?

2. What height of eye should be used? Likely, this will not change from AASHTO's values.

3. The current height of object, according to AASHTO criteria, is 1300 mm (4.25 ft). This is assumed to be the top of a car. The question is how much of the approaching car does a driver need to see to judge the speed and closure rate? Some suggest the height of headlight, 610 mm (2.0 ft), should be specified.

4. If the AASHTO Green Book method is used, a perception reaction time of 2 seconds for the entering driver is assumed for both left turns and right turns. Should the left turn perception reaction time be longer, and if so, how much longer? Should the perception reaction time change for various classes of facilities, speeds, volume levels and urban vs. rural?

OVERVIEW (Continued)

Questions to be Answered (Continued)

5. Should the same intersection sight distance criteria be used for all roadways, regardless of speed, volume, class of facility and urban vs. rural? Do the safety "risks," and effect on traffic, such asplatooned flow, differ for certain conditions?

6. For left turns from the arterial to the cross-road; how much clearance should be provided, what perception-reaction time should be adopted, does sight distance change with the class of facility, volume, speed and urban vs. rural? What are the consequences of inadequate clearances or sight distances?

7. Should sight distance for trucks be considered, if so, how, where, when and why?

8. Should the perception-reaction or intersection sight distance criteria be modified at complex locations?

9. Should the perception-reaction time for elderly drivers be considered in the criteria?

10. Should the "human factors" limit for drivers to see and judge vehicle speed and rate of closure be used to set the intersection sight distance criteria?

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INTERSECTION SIGHT DISTANCE

HEIGHT OF EYE

Current Standard The current standard for height of eye is 1070 mm (3.5 ft). This standard may be changed in the immediate future to 1000 mm (3.28 ft) or 1 meter. This is supported by research that has shown that the height of cars has decreased sufficiently to reduce the height of eye to 1 meter for a significant proportion of the driving population.

Trucks The critical vehicle at some locations is the truck. Truck eye heights have been found to range from 1820 mm (71.5 in) to 2860 mm (112.5 in) with an average height of 2360 mm (93 in). A height of eye of 2400 mm (8.0 ft) is often assumed for design.

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INTERSECTION SIGHT DISTANCE

HEIGHT OF OBJECT

Current Standard The current standard for height of eye is 1300 mm (4.25 ft) for intersection sight distance. This gives a view of the top of the roof, a small splinter. This "splinter" is even more difficult to see if the automobile is an earth tone color. This may not give an adequate view of the approaching car to judge speed and rate of closure.

Suggested Standard The height of headlights, 610 mm (2.0 ft), could give an adequate view of the approaching car in virtually all conditions, day or night. In fact, it is likely that a height somewhat higher than the headlights could be used since the headlights diffuse upward. It is assumed to be at a 1^0 angle for calculation of the stopping sight distance on sag vertical curves. This amounts to 530 mm (1.75 ft) per 30.5 m (100 ft). A height of object of 1000 to 1140 mm (3.25 to 3.75 ft) could be argued, and supported.

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INTERSECTION SIGHT DISTANCE

VEHICLE POSITION FOR SIGHTING

Driver's Eye Position

The vehicle is assumed to be positioned 3 m (10 ft) behind the extension of the pavement edges or curb lines. This places the driver's eye about 6 m (20 ft) from the pavement edge, or curb lines extended. Many jurisdictions assume a location of the driver's eye to be at 4.6 m (15 ft) behind the pavement edge.

Sight Distance with Parked Vehicles

Many driveways are located with relatively close spacing where parked cars block the line of sight. At such locations, the placement of the vehicle 3 m (10 ft) behind the edge of pavement would not be realistic.

The operation of a prudent driver would often be assumed where the driver stops before the sidewalk or crosswalk, then pulls forward far enough to see on-coming traffic without encroaching on the through traffic lanes.

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INTERSECTION SIGHT DISTANCE

AASHTO CRITERIA FOR INTERSECTION SIGHT DISTANCE

AASHTO Intersection Sight Distance Cases

There are five different cases of intersection sight distance that can be used to determine the required sight distance. These are identified and defined in the AASHTO Geometric Design of Highways and Streets, 1990 and 1994. They are discussed following.

Case I: Uncontrolled Intersections

This case would apply for uncontrolled intersections and driveways. According to the O.R.S., a vehicle may enter the roadway from a driveway without stopping if it can do so without conflicting with any vehicles on the roadway.

Case II: Yield Controlled Intersections

This case would apply at any intersection or driveway where a yield sign is used. The sight distance required must meet the requirements for an uncontrolled operation, that is, uncontrolled speed, from the minor street or driveway (Case I) plus the requirements for a stopped control intersection (Case III).

Case III: Stop Controlled Intersections

This case applies to any two way stop controlled intersections. There are three sub-cases for crossing the intersection, making a left turn and making a right turn. This case provides the primary criteria for intersection sight distance conditions for access management.

Case IV: Signal Controlled Intersections

This case applies at signal controlled intersections where the critical condition occurs with free right turns and when the signal is not operating, so essentially a stop controlled condition exits.

Case V: Left Turn Bay Sight Distance

The new 1994 Green Book specifies a new case for sight where a left turn movement must have adequate sight distance to make a turn from a left turn bay. This could apply at intersections, at median openings or at any location where a left turn could be made from a continuous two-way left-turn lane.

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INTERSECTION SIGHT DISTANCE

AASHTO INTERSECTION SIGHT DISTANCE CRITERIA

Case I: Uncontrolled Intersection - Vehicles Adjust Speeds

The uncontrolled intersection sight distance requires that drivers approaching an uncontrolled intersection on a cross street must have sufficient sight distance across the intersection corners to:

1. At least, be able to adjust speeds to avoid a collision.

2. Desirably, be able to stop.

The first sub-case to adjust speeds provides two seconds of perception-reaction time plus one second for braking, accelerating or maneuvering. The distances travelled by the vehicles approaching the intersection in 3 seconds generate the sight triangle shown in Figure 1, where the distance that the vehicle travels on approach is defined by:

$$d_a = \frac{(b)\,(d_b)}{d_b - a}$$

where,

d_a and d_b = distances travelled at speed to perceive and react, and brake, accelerate omaneuver.

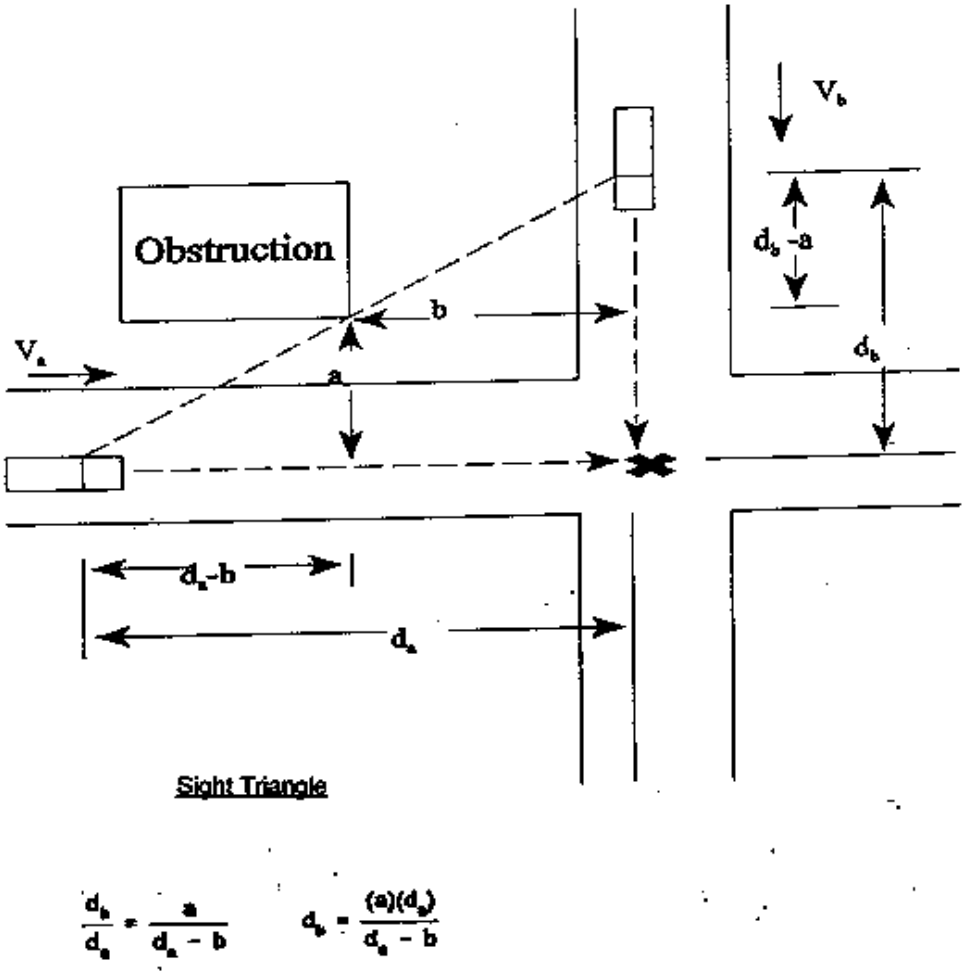
a and b = distances from vehicle path to obstruction.

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AASHTO INTERSECTION SIGHT DISTANCE CRITERIA (Continued)

Case I:
Uncontrolled Intersection - Vehicles Adjust Speeds (Continued)



$$\frac{d_b}{d_a} = \frac{a}{d_a - b} \qquad d_b = \frac{(a)(d_a)}{d_a - b}$$

Figure 1: Sight Distance at Intersections
Case 1: No Stop Control - Enabling Vehicles to Adjust speed

AASHTO INTERSECTION SIGHT DISTANCE CRITERIA (Continued)

Case I': Uncontrolled Intersections - Stopping Sight Distance

The second sub-case allows the vehicles on either or both approaches to stop before reaching the point of impact. Thus, the stopping distances for the critical approach speeds are calculated from the stopping sight distance equation:

$$d = 0.278\,Vt + V^2 / 254f \qquad \text{(Metric)}$$

or

$$d = 1.47\,Vt + V^2 / 30(f \pm g) \qquad \text{(English)}$$

Case II: Yield Control Intersections

The minor street is the only street that needs adequate sight distance to stop at yield controlled intersections. It must meet the uncontrolled intersection sight distance criteria for the allowable approach speeds. Then, if the vehicle on the minor street is stopped, it must have an adequate sight distance to enter the intersection after stopping.

Case III: Stop-Controlled Intersections

The sight distance at stop controlled intersections must be adequate for vehicles to cross, turn left, or turn right. The driver's eye is assumed to be 6 m (20 ft) behind the edge of pavement or curb, with a height of 1070 mm (3.5 ft), and the object height is 1300 mm (4.25 ft) as previously discussed. The three sub-cases of intersection sight distances are illustrated in Figure 2.

where d = stopping distance, m or ft,
V = speed, km/h or mph,
t = perception reaction time, sec,
f = coefficient of friction

AASHTO INTERSECTION SIGHT DISTANCE CRITERIA (Continued)

Case III:
Stop-Controlled
Intersections
(Continued)

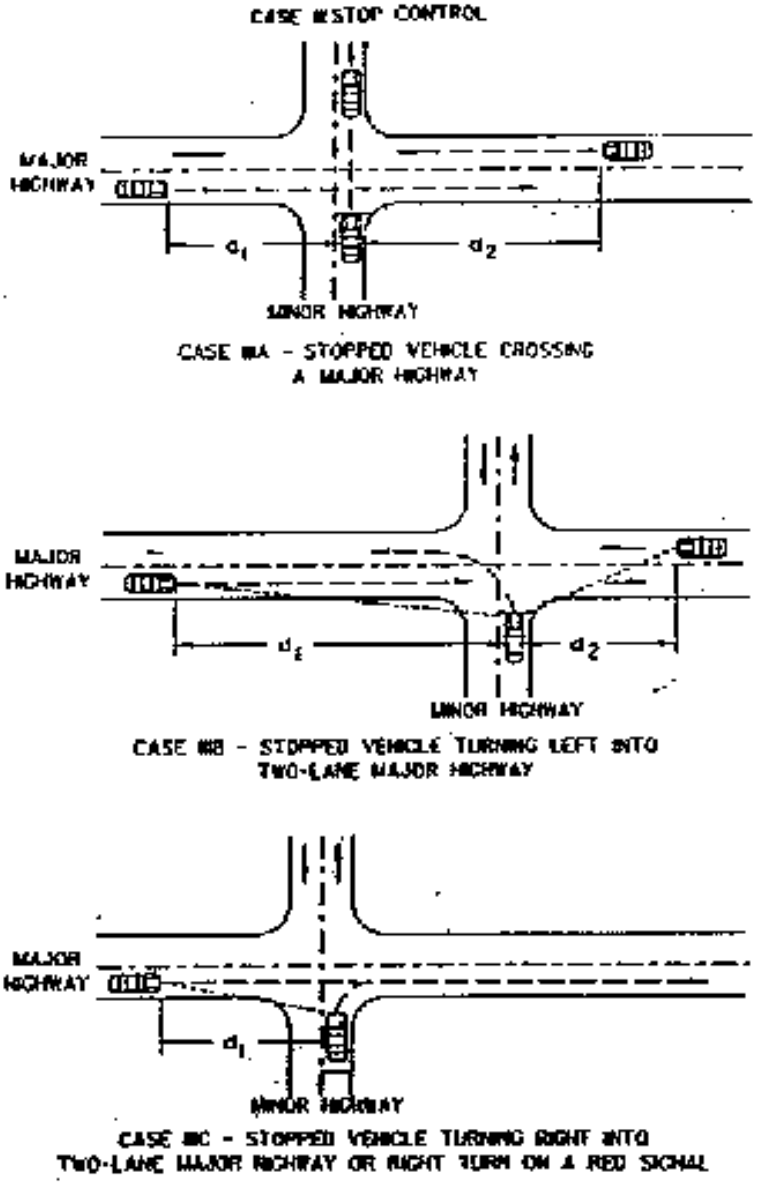


Figure 2. Intersection Sight Distance at At-Grade Intersections (AASHTO, Fig. IX-35)

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AASHTO INTERSECTION SIGHT DISTANCE CRITERIA (Continued)

Case IIIA: Crossing Sight Distance

The stopping sight distance for crossing, referred to as Case IIIA, is determined based on a perception reaction time of two seconds plus the time it takes to accelerate from a stop and cross the roadway, a distance of S;

$$S = 3.05\ m + W + L \qquad \text{(Metric)}$$

$$S = 10\ ft + W + L \qquad \text{(English)}$$

with,

3.05 m (10 ft) = set back from edge of the pavement or curb to the front bumper of the vehicle,

W = width of pavement, or 1/2 of pavement width for sight distance to the left,

L = length of stopped vehicle.

Design Vehicle	Length m (ft)
Passenger car	5.8 (19)
Single unit truck	9.1 (30)
Bus	9.1 (30)
Semi-trailer (WB-50)	16.8 (55)

A graphical representation of the method is given on the next page.

At higher speeds, the sight distance for crossing gives a shorter sight distance than the stopping distance required for a vehicle operating at design speed.

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AASHTO INTERSECTION SIGHT DISTANCE CRITERIA (Continued)

Case IIIA:
Crossing Sight Distance
(Continued)

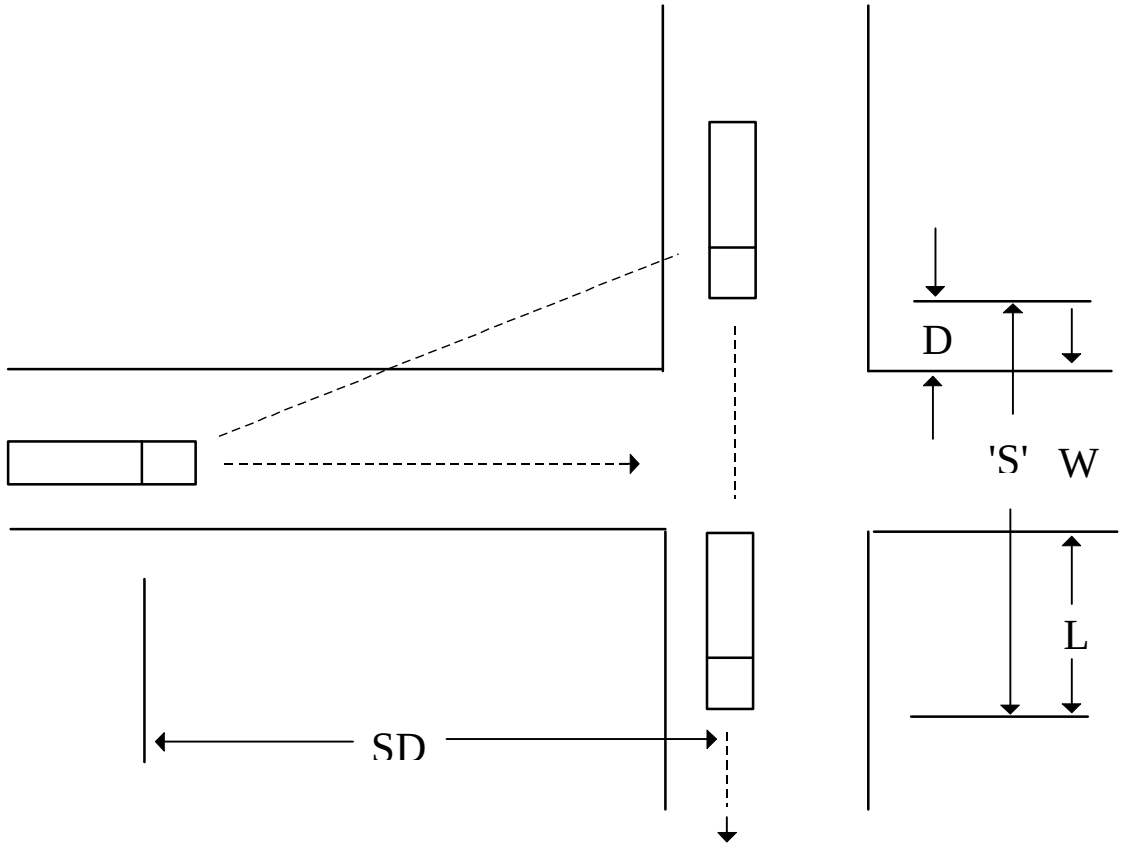


Figure 3: Sight Distance at Intersections

Case IIIA: With Stop Control - Enabling Stopped Vehicles to Cross Major Highway

T_{PR} = "PR" Time + Time to shift
T_A = Time to accelerate and travel 'S'
'S' = D + W + L Distance across highway

AASHTO INTERSECTION SIGHT DISTANCE CRITERIA (Continued)

Case IIIA: Crossing Sight Distance (Continued)

The required intersection sight distance is then the distance a vehicle would travel on the major facility at the design speed during the perception reaction time and the time to accelerate and cross the roadway:

$$T = T_{PR} + T_A$$

where,

T = time to cross,
T_{PR} = initial delay to start, or perception-reaction time, assumed to be two seconds,
T_A = time to accelerate and cross the major facility.

A nomograph for vehicles of varying lengths from the Washington D.O.T. Design Manual follows.

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AASHTO INTERSECTION SIGHT DISTANCE CRITERIA (Continued)

Case IIIA:
Crossing Sight Distance (Continued)

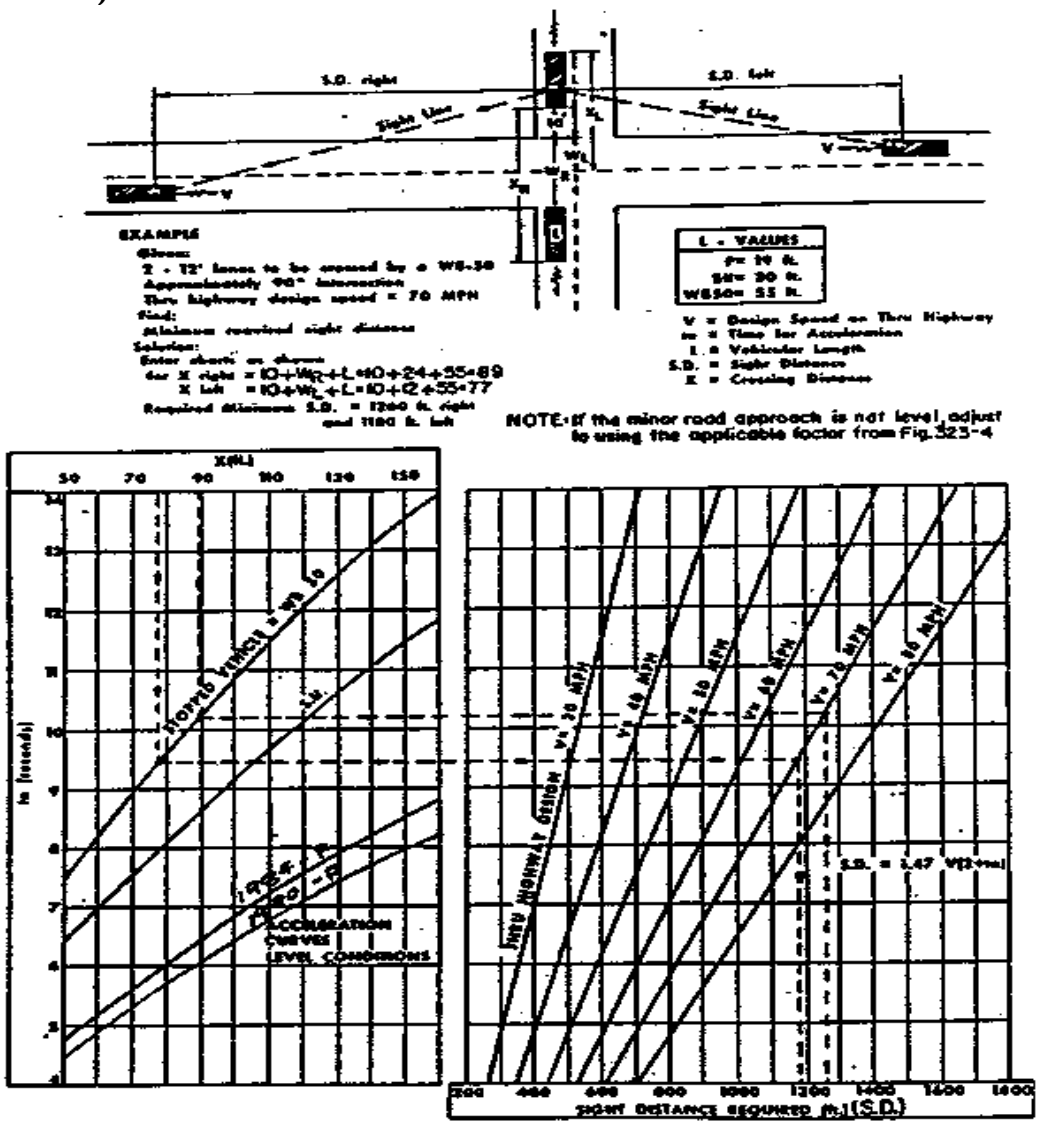


Figure 4: Sight Distance-Grade Intersection with Stop Control

AASHTO INTERSECTION SIGHT DISTANCE CRITERIA (Continued)

Case IIIB: Left Turn Intersection Sight Distance

The second subcase, Case III-B, provides sight distance for vehicles turning left from the stop controlled approach.

This case provides enough sight distance to the left of the intersection to enable the entering vehicle to turn left onto a two-lane, two-way roadway. In this case, the distance travelled by the turning vehicle is greater than when crossing, therefore the required sight distance will increase. Also, the vehicle will be turning toward the arterial vehicle crossing from the left.

The sight distance to the left is calculated based on:

$$d = 0.278V(T_d + T_a)$$

or $$d = 1.47V(T_d + T_a)$$

where,

- d = sight distance to left
- V = design speed of major speed, km/h or mph
- T_d = sum of delay time for perception-reaction and time to shift, assumed to be 2 seconds
- T_a = time required to accelerate and traverse the distance to clear traffic from left

Distance travelled to clear traffic from the left, S:

$$S = 3.05\ m + W_L + L \qquad \text{(Metric)}$$

$$S = 10\ ft + W_L + L \qquad \text{(English)}$$

where,

- 3.05 m (10 ft) = setback from the stop line
- W_L = pavement width for sight distance to left, 1.5 X lane width
- W = vehicle length

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INTERSECTION SIGHT DISTANCE

AASHTO INTERSECTION SIGHT DISTANCE CRITERIA (Continued)

Case IIIB: Left Turn Intersection Sight Distance (Continued)

The sight distance to the right is calculated based on the distance required for the vehicle to accelerate to 85% of design speed with the mainline vehicle having a clearance of a 2 second headway between the entering vehicle on the major facility, which is to decelerate to 85% of design speed.

Case IIIC: Right Turn Intersection Sight Distance

The right turn vehicle must have sufficient sight distance for vehicles approaching from the left, known as Case IIIC. The sight distance requirements for the right turn maneuver is a few feet less than required for the left turn maneuver, Case IIIB with the vehicle coming from the right.

Case IV: Signal Control Intersection Sight Distance

It is recommended that Case III sight distance requirements be applied at signalized intersections due to the potential violation of the signal, right turns on red, signal malfunction or use of flashing red/yellow mode.

It is also suggested that sight restrictions due to parked cars, guard rail location, snow accumulation, signs or other roadside appurtenances should be considered. Where it is not possible or cost effective to change the design conditions sufficiently to provide sight distance, it may be necessary to introduce measures to reduce vehicle speeds.

A summary of all stop controlled intersection sight distances for all case and stopping sight requirements is given in Figure 5 from the 1990 AASHTO Green Book.

Case V: Stopped Vehicle Turning Left from a Major Highway

The sight distance for a vehicle turning left from a major roadway into an intersection or a driveway is given in the 1994 AASHTO Policy on Geometric Design (metric). These criteria control when a left turn, or turn lane is permitted. Under most circumstances, the required critical gap for the left turn will control.

Figure 5: Intersection Sight Distance at At-Grade Intersection (Case IIIB and Case IIIC)

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INTERSECTION SIGHT DISTANCE

GAP ACCEPTANCE

Field Studies

Two states use a gap acceptance measure to determine stop controlled intersection sight distance. Field studies of gap acceptance were undertaken by Fitzpatrick et al. with the following results for both right and left turns (1):

Probability of accepting a gap	Passenger Car	5-Axle Truck
50%	6.5 sec	8.5 sec
85%	8.25 sec	10.0 sec

This study also found gap acceptance data at low volume and/or intersections affected by the geometry, as follows:

Probability of accepting a gap	Passenger Car	5-Axle Truck
85%	10.5 sec	15.0 sec

(1) Kay Fitzpatrick, J. Mason, Jr. and D. Harwood, "Comparison of Sight Distance Procedures for Turning Vehicles from a Stop-Controlled Approach," 1991 Annual T.R.B. Meeting, Washington D.C.

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INTERSECTION SIGHT DISTANCE

GAP ACCEPTANCE (Continued)

CALTRANS Corner Sight Distance

CALTRANS requires that a vehicle must be visible for 7-1/2 seconds to determine the corner sight distance at unsignalized intersections. This is assumed to be adequate for crossing and turning maneuvers. For left-turning vehicles in 2 lane roadways, this will result in some slowing of the vehicle on the major facility For left-turning vehicles on 4 lane facilities, a 7-1/2 second time for sight distance to the outside lane, i.e., the near lane, will provide increased sight distance for left turning vehicles to clear on-coming vehicles in the inside lane.

They further specify that if high costs or disruption due to expensive right-of-way, required building removal, extensive excavation or excessive environmental impacts would result from imposing the 7-1/2 second corner rule, the minimum stopping distance criterion may be used. That is, the approaching vehicle on the major roadway should have minimum stopping distance provided to avoid colliding with the entering vehicle, however, CALTRANS minimum stopping sight distance is equivalent to the average of the AASHTO minimum and desirable stopping sight distances. Further, they specify a set-back from the edge of the roadway to the driver of 4.5 m (15 ft).

They do not apply the corner sight distance requirements to urban driveways. They do require that a decision sight distance be applied at intersections where a state sign route turns or is crossed by another state route.

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GAP ACCEPTANCE (Continued)

7.0 Second Gap

The 7.0 second gap is supported in the 1984 Green Book and 1990 Green Book and the field studies from the Fitzpatrick et al. study. The 1990 Green Book states:

> "A minimum of 7 seconds should be available to the driver of a passenger vehicle crossing the through lanes" of a local road or street. Also, the "sight distance should be sufficient to permit a vehicle in the minor leg of the intersection to cross the travel way without requiring the approaching through traffic to slow down."

Summary of Automobile Gap Acceptance Measures

The minimum gap given is 6.5 sec from field studies. Two states, Michigan and California, respectively, for intersection sight distance at stop controlled intersections. The 85th percentile gap of 8.25 sec was found for both right and left turning vehicles for moderate to high volume intersections. The 10.5 second gap was found for the 85th percentile gap for intersections with low volumes and intersection geometry influences.

Truck Gap Acceptance

The 50th percentile accepted gap for trucks is 8.5 sec, with the 85th percentile gap at 10.0 sec. These are about 2 sec larger than the accepted gaps for passenger cars. At low volume locations and/or locations with intersection geometric influences the 85th percentile gap increases by 5 seconds to 15 sec.

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OTHER INTERSECTION SIGHT DISTANCE MEASURES

Other sight distance measures should be referenced before a comparison or recommendation can be made.

Emergency Stopping Distance

The emergency stopping distance is determined from the same distance relationships shown previously:

$$d = 0.278Vt + V^2 / 254f \quad \text{(Metric)}$$

or $$d = 1.47\,Vt + V^2 / 30(f \pm g) \quad \text{(English)}$$

However, the perception-reaction times would be less; 0.5-1 seconds would be representative values for emergency conditions. A perception-reaction time of 0.5 seconds is about the fastest that a normal driver can react, so a more typical value of 1 second is selected, recognising a slightly longer time to perceive the emergency. The frictional resistance for wet and dry conditions are both evaluated, using the design coefficients of friction for wet pavements, and a typical dry pavement coefficient of about 0.6, in Table 2 discussed later.

Stopping and Decision Sight Distance

The stopping sight distance must also be considered in setting the required sight distance at intersections. Stopping sight distance must be provided at each intersection with a height of eye of 1070 mm (3.5 ft) and a height of object of 150 mm (6"), as discussed in Discussion Paper No.8.A. Due to the complexity of operations and conditions, decision sight distance must be provided at many intersections.

The "decision sight distance to a stop condition" is always equal or greater than the stopping sight distance, so it is a logical minimum criteria for sight distance at intersections. However, at times the decision time for urban areas may be excessive because the driver is only required torecognize that the vehicle is stopping, entering or exiting from the roadway. Background and roadside information do not play a role at these times so times of 4 to 6 seconds may be acceptable.

OTHER INTERSECTION SIGHT DISTANCE MEASURES (Continued)

Critical Gaps, Highway Capacity Manual

Chapter 10 of the Highway Capacity Manual uses a defined critical gap to determine the capacity, or level of service, for various movements into an unsignalized intersection. This is the gap that drivers are as likely to accept as reject. This critical gap by implication is the acceptable time headway, or distance to an on-coming vehicle for a driver to enter the roadway comfortably.

The critical gaps range from 5.5 to 7.5 seconds as shown in Table 1. Research has shown that critical gaps are decreased as volume on the major facility increase, as the time a vehicle waits to enter increases, and at intersections where CTWLTL is present. The critical gap provides an operational definition of required sight distance.

Table 1. Critical Gaps t_g for Two-Way Stop Controlled Intersections (Source: 1994 Highway Capacity Manual)

	Critical Gap t_g	
Vehicle Maneuver	Two -Lane Major Road (sec.)	Four-Lane Major Road (sec.)
Left turn, major street	5.00	5.50
Right turn, minor street	5.50	5.50
Through traffic, minor street	6.00	6.50
Left turn, minor street	6.50	7.00

OTHER INTERSECTION SIGHT DISTANCE MEASURES (Continued)

Human Factors Limits on Intersection Sight Distance

The long intersection sight distance values for high speeds and trucks approach the limits of driver's ability to perceive objects and discern operating conditions. Junward and Pushkarev indicate that a driver cannot perceive movement beyond 245 m (800 ft), or detect detail further than 430 m (1400 ft) because the vehicle appears so small at those distances.(2) A car at 610 m (2000 ft) is the size of a pinhead at 460 mm (18 in).

(2) C. Junward and B. Pushkarev. Man-Made Criteria: Chaos or Comfort? Yale Univ. Press, 1963.

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INTERSECTION SIGHT DISTANCE

DISCUSSION OF INTERSECTION SIGHT DISTANCE CRITERIA

AASHTO Intersection Sight Distance Criteria

The sight distance requirements at intersections as required by AASHTO provides a comfortable operation and safe design.

The relative severity, or safety, of the various cases should be reviewed to determine the reasonability of the various requirements. Most sight distance requirements, other than for intersections, are based on the limiting conditions to provide a minimum acceptable design for safety. Others, in particular, the left-turning intersection sight distance with the vehicle approaching from the right, Case $IIIB_R$, and the sight distance for a right turning vehicle with a vehicle approaching from the left, Case IIIC, are based on a comfortable or desirable condition. For both of these latter cases, the vehicle on the major facility is expected to decelerate to 85% of design speed, which is often nearly equal to the 85th percentile speed for the roadway and typically greater than the mean speed. This is a desirable, or comfortable condition. Where these sight distance cannot be achieved easily or at low cost, these two cases should not be viewed as desirable, not a minimum or limiting condition.

The various sight distance requirements and criteria are shown in Table 2. The AASHTO intersection sight distance requirements cover a broad range of sight distances. For example, at 100 kph (60 mph), the range is doubled from 175 to 350 m (574 - 1,150 ft). Case IIIA crossing and Case IIIB left turning, respectively. The Case IIIA crossing requirements provides adequate clearance for the crossing vehicle, a potential right angle collision, however, no slowing of the major street vehicle is assumed.

Case IIIB, for left turns with the vehicle approaching from the left is slightly longer than the crossing case, by 6 to 11 m (20 - 35 ft), and again no slowing of the major street vehicle is assumed.

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INTERSECTION SIGHT DISTANCE

DISCUSSION OF INTERSECTION SIGHT DISTANCE CRITERIA (Continued)

AASHTO
Intersection Sight
Distance Criteria
(Continued)

TABLE 2: Comparison of Sight Distances at Intersections

Design Speed kph (mph)	AASHTO Intersection Sight Distance, m (ft)			Desirable AASHTO Stopping Sight Distance, m (ft)	Michigan 7[a] Gap m (ft)	Caltrans 7-1/2 Corner Rule m (ft)	Travel Distance based on Highway Capacity Manual Critical Gap	
	Case III-A	Case III-B_1 [1] Left Turns	Case III-B_2 [2] Left Turns				Crossing m (ft)	Left-Turns m (ft)
32 (20)	58 (190)	64 (210)	72 (235)	33 (107)	63 (205)	67 (220)	54 (176)	58 (191)
40 (25)	73 (238)	79 (260)	90 (295)	45 (147)	78 (257)	84 (275)	67 (220)	73 (238)
48 (30)	87 (286)	94 (309)	116 (380)	60 (196)	94 (308)	101 (330)	80 (264)	87 (286)
50 (35)	102 (334)	109 (359)	143 (470)	76 (248)	109 (359)	117 (385)	94 (308)	102 (334)
64 (40)	116 (382)	124 (408)	177 (580)	96 (313)	125 (411)	134 (440)	107 (352)	116 (381)
72 (45)	131 (430)	140 (458)	215 (705)	117 (383)	131 (462)	151 (495)	121 (396)	131 (429)
80 (50)	146 (478)	155 (507)	258 (845)	142 (461)	156 (513)	168 (550)	134 (440)	145 (477)
88 (55)	160 (526)	170 (557)	302 (990)	165 (538)	172 (565)	184 (605)	148 (484)	160 (524)
97 (60)	175 (574)	185 (606)	351 (1150)	195 (634)	188 (616)	201 (660)	161 (528)	174 (572)
105 (65)	190 (622)	200 (656)	410 (1345)	222 (724)	203 (667)	218 (715)	174 (572)	189 (620)
113 (70)	204 (670)	215 (705)	476 (1560)	258 (840)	219 (719)	235 (770)	188 (616)	203 (667)

[1] Vehicle turning left, vehicle approaching from left.

[2] Vehicle turning left, vehicle approaching from right; same as vehicle turning right, Case III-C.

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INTERSECTION SIGHT DISTANCE

DISCUSSION OF INTERSECTION SIGHT DISTANCE CRITERIA (Continued)

AASHTO Intersection Sight Distance Criteria (Continued)

The crossing sight distance, Case IIIA provides for greater sight distance than for minimum stopping sight distance for all speeds. However, it only provides for sight distances greater than desirable stopping sight distance is a more appropriate limit for Oregon, since it recognises the changes in condition complexity and expectations in urban and rural conditions. The decision sight distance for the urban/suburban and rural areas for speed, path or direction change would be appropriate for many conditions omulti-lane roadways. These values are shown in Table 3.

Highway Capacity Manual

The larger critical gap, according to the Highway Capacity Manual, for left turn vehicles at stop controlled intersections yields travel distances that are essentially identical to the crossing sight distance requirements. This condition is typical of the gap that is as likely for a driver to accept as reject in entering the roadway from a stop sign.

CALTRANS 7-1/2 Second Corner Rule

The CALTRANS 7-1/2 second corner rule yields sight distances that are greater than all other sight distance requirements, regardless of design speed, except for the left turn Case IIIB[6] the right turn Case IIIC and desirable stopping sight distance at speeds over 105 kph (65 mph). The effectiveness of the 7-1/2 second corner rule as an intersection sight distance criterion can be seen in Table 4 with a comparison of the travel times, at speed, corresponding to the various sight distance requirements for speeds from 50 to 100 kph (30 to 60 mph). The 7-1/2 second corner accommodates all of the sight distance conditions that are limiting for safety. The left turning case, Case IIIB[3] is based on comfortable level of operation as discussed previously.

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INTERSECTION SIGHT DISTANCE

DISCUSSION OF INTERSECTION SIGHT DISTANCE CRITERIA (Continued)

Table 3: Decision Sight Distance

Design Speed kph (mph)	Decision Sight Distance for Avoidable Maneuver m (ft)				
	A*	B*	C*	D*	E*
50 (30)	70 (220)	155 (500)	140 (450)	155 (500)	190 (625)
65 (40)	105 (345)	220 (725)	185 (600)	220 (725)	250 (825)
85 (50)	155 (500)	300 (975)	230 (750)	275 (900)	315 (1025)
100 (60)	210 (680)	395 (1300)	305 (1000)	350 (1150)	390 (1275)
120 (70)	275 (900)	465 (1525)	335 (1100)	395 (1300)	445 (1450)

*Note: Avoidance Maneuvers

1. Avoidance maneuver A: Stop on rural road
2. Avoidance maneuver B: Stop on urban road
3. Avoidance maneuver C: Speed/path/direction change on rural road
4. Avoidance maneuver D: Speed/path/direction change on suburban road
5. Avoidance maneuver E: Speed/path/direction change on urban road

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INTERSECTION SIGHT DISTANCE

DISCUSSION OF INTERSECTION SIGHT DISTANCE CRITERIA (Continued)

Michigan 8 Second Gap Criteria

The Michigan 8 second gap criterion yields intersection sight distance requirements that are nearly equal to those for AASHTO for a left turning vehicle and a vehicle approaching from the left. Only the AASHTO left turn criteria with the vehicle coming from the right and the Michigan 8 second gap yield sight distances greater than the CALTRANS 7.5 second Corner rule. This criteria would serve well as a minimum criteria for intersection sight distance, since the AASHTO left turn criteria with vehicles coming from the right would provide desirable operating conditions, and significantly exceed minimum distances for safety.

Comparison of Travel Times and Gaps

A perspective on the various possible intersection sight distance criteria is provided by reviewing the travel times or gaps required by each. See Table 4. The Highway Capacity Manual critical gaps give a good measure of what normal operating conditions would require. The left turn maneuver with vehicles coming from the right requires excessively long gaps in the traffic stream, unless trucks are likely to be turning at the intersection. Also, notice that the decision sight distance to a stop in urban areas gives gaps that are longer than the Case $IIIB_R$ Left Turn. The decision time of 13 seconds for 72 kph (45 mph), urban environment, is at the upper limit for driver to be able to perceive speed and operating characteristics of an on-coming vehicle.

Under most conditions, the 7-1/2 or 8 second gap criteria are adequate. With trucks or urban areas, the need to provide decision time will require much longer distances.

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INTERSECTION SIGHT DISTANCE

DISCUSSION OF INTERSECTION SIGHT DISTANCE CRITERIA (Continued)

Comparison of Travel Times and Gaps (Continued)

Table 4: Comparison of Travel Times, or Gaps, for Various Sight Distance Requirements

Design Speed kph (mph)	Case III-A Crossing	Case III-B$_1$ Left Turn[1]	Case III-B$_2$ Left Turn[2]	Decision Sight Distance for Stop Conditions		Michigan 7[s] Gap	Caltrans 7-1/2 Corner Rule	Highway Capacity Manual Critical Gap[3]
				Rural	Urban			
48 (30)	6.5[s]	7.0[s]	8.6[s]	5.0[s]	11.4[s]	7[s]	7.5[s]	6 - 6.5[s]
72 (45)	6.5[s]	6.9[s]	10.7[s]	6.3[s]	13.0[s]	7[s]	7.5[s]	6 - 6.5[s]
97 (60)	6.5[s]	6.9[s]	13.0[s]	7.7[s]	14.8[s]	7[s]	7.5[s]	6 - 6.5[s]

[1] Vehicle turning left, vehicle approaching from left.

[2] Vehicle turning left, vehicle approaching from right; same as vehicle turning right, Case III-C.

[3] 6[s] for through traffic, 6.5[s] for left-turning vehicles.

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INTERSECTION SIGHT DISTANCE

DISCUSSION OF INTERSECTION SIGHT DISTANCE CRITERIA (Continued)

Proposed New Criteria for Intersection Sight Distance

A new criteria for intersection sight distance was proposed at the 1997 Annual Meeting of the Transportation Research Board. A set of time gap values to calculate intersection sight distance were developed based on gap acceptance data collected by the University of Nebraska. The field observed values were analyzed using two separate methods of statistical fitting yielding the values shown in Table 5.

Table 5. Intersection Sight Distance Based on Gap Acceptance Behavior

	Right Turns	Left Turns
Passenger Cars	6.3 - 6.5 s	8.0 - 8.2 s
Single Unit Trucks	8.4 - 9.5 s	9.8 - 10.8 s
Combination Trucks	10.7 - 11.3 s	10.0 - 12.2 s

The recommended criteria match California criteria of 7-1/2 seconds, and Michigan's 8 second criteria quite well. They are:

Passenger Cars - 7.5 s
Single Unit Trucks - 9.5 s
Combination Trucks - 11.5 s

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INTERSECTION SIGHT DISTANCE

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