3.6.9 Selecting Pedestrian Design Speed

Much like other roadway users, the speed at which people walk varies considerably; however, walking speed usually does not have a substantial influence on the geometric design of roadways. A critical exception to this is the pedestrian's influence on the design of intersections and crosswalks, and the timing of traffic signals. The choice of walking speed for intersections and traffic signal design is discussed in the *Manual on Uniform Traffic Control Devices (MUTCD)* and is further discussed in Chapter 6.

3.7 Sight Distance

Sight distance is the length of roadway ahead that is visible to the roadway user. In most cases, specific sight distance measures apply to motor vehicles and bicyclists. The four following aspects are commonly discussed for motor vehicle sight distance:

- Stopping sight distance,
- Passing sight distance,
- Decision sight distance, and
- Intersection sight distance.

All of these sight distances are related to the design speed of the roadway. The designer should refer to AASHTO's *A Policy on Geometric Design of Highways and Streets* for detailed information for the use and calculation of sight distances.

3.7.1 Stopping Sight Distance

The provision of adequate *stopping sight distance* (SSD) is a critical sight distance consideration for design and is described in more detail below.

3.7.1.1 Motor Vehicle Stopping Sight Distance

Stopping sight distance is the distance necessary for a vehicle traveling at the design speed to stop before reaching a stationary object in its path. The sight distance at every point along a roadway should be at least the stopping sight distance. Exhibit 3-8 provides stopping sight distances for a range of design speeds and grades.

Exhibit 3-8
Motor Vehicle Stopping Sight Distances

	Stopping Sight Distance (ft) by Percent Grade (%)						
		Downgrade			Upgrade		
Design Speed	0	3	6	9	3	6	9
20	115	116	120	126	109	107	104
25	155	158	165	173	147	143	140
30	200	205	215	227	200	184	179
35	250	257	271	287	237	229	222
40	305	315	333	354	289	278	269
45	360	378	400	427	344	331	320
50	425	446	474	507	405	388	375
55	495	520	553	593	469	450	433
60	570	598	638	686	538	515	495
65	645	682	728	785	612	584	561
70	730	771	825	891	690	658	631
75	820	866	927	1003	772	736	704

Source: A Policy on Geometric Design of Streets and Highways, AASHTO, Washington DC, 2004. Chapter 3 Elements of Design

3.7.1.2 Bicycle Stopping Sight Distance

For on-road travel, the stopping sight distance for motor vehicles appropriately accommodates bicycles. However, bicycle stopping sight distance is an important consideration in the design of off-road facilities such as shared use paths. Detailed information on the design of these facilities, including stopping sight distance, is provided in Chapter 11.

3.7.1.3 Sight Distance for Pedestrians

There is not a parallel “stopping sight distance” consideration for pedestrians since they usually travel at lower speeds and can stop within a few feet. However, the designer must consider the importance of pedestrians’ ability to view and react to potential conflicts. The designer should provide adequate sight lines at street crossings, around corners, and at other locations where pedestrians interface with other users. For example, at street crossing locations, pedestrians should be able to see a sufficient portion of the traffic stream to judge the suitability of gaps for crossing the street. More detailed information regarding the design of street crossings is presented in Chapter 6.

3.7.2 Passing Sight Distance

For two-lane highways, passing maneuvers in which faster vehicles move ahead of slower vehicles must be accomplished on lanes regularly used by opposing traffic. If passing is to be accomplished safely, **passing sight distance** is necessary to allow the passing driver to see a sufficient distance ahead, clear of traffic, to complete the passing maneuver without cutting off the passed vehicle and before meeting an opposing vehicle that appears during the maneuver. The AASHTO's *A Policy on Geometric Design of Highways and Streets* includes detailed information for the use and calculation of passing sight distances.

3.7.3 Decision Sight Distance

Decision sight distance adds a dimension of time to stopping sight distance to allow a driver to detect and react to an unexpected condition along a roadway. Decision sight distance is suggested when there is evidence that it would be prudent to provide longer sight distance, such as when complex decisions are needed or when information is difficult to perceive. It is 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 maneuver safely and efficiently. Exhibit 3-9 provides decision sight distances for a range of design speeds.

Exhibit 3-9
Decision Sight Distances

	Decision Sight Distance (ft)				
	Avoidance Maneuver				
Design Speed	A	B	C	D	E
30	220	490	450	535	620
35	275	590	525	625	720
40	330	690	600	715	825
45	395	800	675	800	930
50	465	910	750	890	1030
55	535	1030	865	980	1135
60	610	1150	990	1125	1280
65	695	1275	1050	1220	1365
70	780	1410	1105	1275	1445
75	875	1545	1180	1365	1545

Avoidance Maneuver A: Stop on rural road: time (t) = 3.0 sec
Avoidance Maneuver B: Stop on urban road: time (t) = 9.1 sec
Avoidance Maneuver C: Speed/path/direction change on rural road: time (t) varies between 10.2 and 11.2 sec
Avoidance Maneuver D: Speed/path/direction change on suburban road: time (t) varies between 12.1 and 12.9 sec
Avoidance Maneuver E: Speed/path/direction change on urban road: t varies between 14.0 and 14.5 sec
Source: *A Policy on Geometric Design of Streets and Highways*, AASHTO, Washington DC, 2004. Chapter 3 Elements of Design

3.7.4 Intersection Sight Distance

Sight distance is provided at intersections to allow drivers to perceive the presence of potentially conflicting vehicles. This should occur in sufficient time for a motorist to stop or adjust their speed, as appropriate, to avoid colliding in the intersection. Sight distance also allows drivers of stopped vehicles with a sufficient view of the intersecting roadway to decide when to enter or cross the intersecting roadway. If the available sight distance for an entering or crossing vehicles is at least equal to the appropriate stopping sight distance for the major road, then drivers have sufficient sight distance to anticipate or avoid collisions. However, in some cases, this may require a major-road vehicle to slow or stop to accommodate the maneuver by a minor-road vehicle.

To enhance traffic operations, intersection sight distances that exceed stopping sight distances are desirable. The *Highway Capacity Manual* provides guidance on gap acceptance for vehicles departing from minor approaches which can be used to calculate one measure of intersection sight distance. Additionally, AASHTO's *A Policy on the Geometric Design of Highways and Streets* provides procedures to determine desirable sight distances at intersections for various cases are described below and include:

4.2.2 Horizontal Stopping Sight Distance

Horizontal sight distance on the inside of a curve is limited by obstructions such as buildings, hedges, wooded areas, walls, abutments, cut slopes, headlights, vertical curvature, or other topographic features. A comprehensive field survey should identify these obstructions on the critical cross sections and on the base plans.

Safe sight distance must be provided on the inside of horizontal curves to allow the driver sufficient brake reaction time to bring the vehicle to a stop. Obstructions which interfere with the needed sight distance should be moved or removed, if possible. If the obstruction can not be removed, consideration should be given to realigning the road (horizontal and/or vertical) or providing appropriate warning signage.

On horizontal curves, a designer must provide a "middle ordinate" between the center of the inside lane and the sight obstruction. The basic equation is:

$$M = R\left[\left(1 - \cos\frac{28.65S}{R}\right)\right]$$

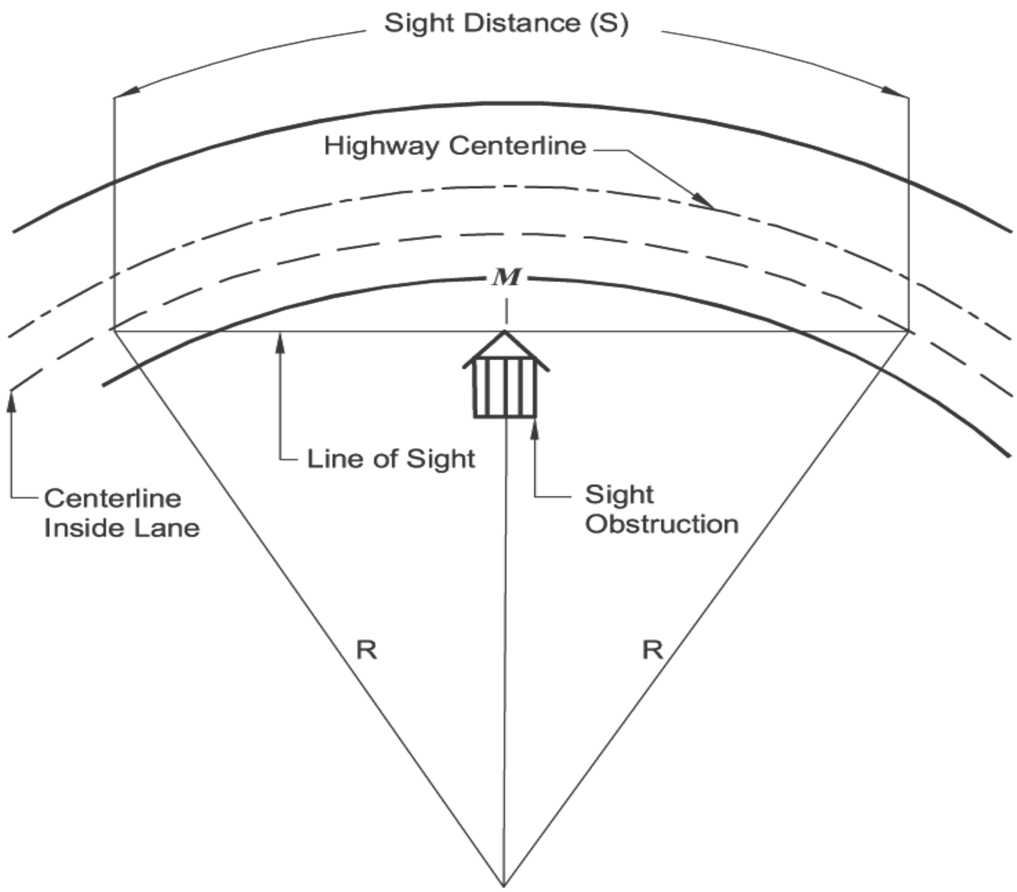
Where: *M* = middle ordinate, or distance from the center of the inside lane to the obstruction, feet.
R = radius of curve, feet.
S = sight distance, feet.

The designer should use the following:

- Exhibit 4-4 illustrates the concept of a middle ordinate and its impact on sight distance around a curve. Exhibit 4-5 is a design chart showing the horizontal sight line offsets (middle ordinate) needed for clear sight areas that satisfy stopping sight distance criteria presented in Exhibit 3-8 for horizontal curves of various radii. The designer should make every practical effort to achieve the stopping sight distance criterion.

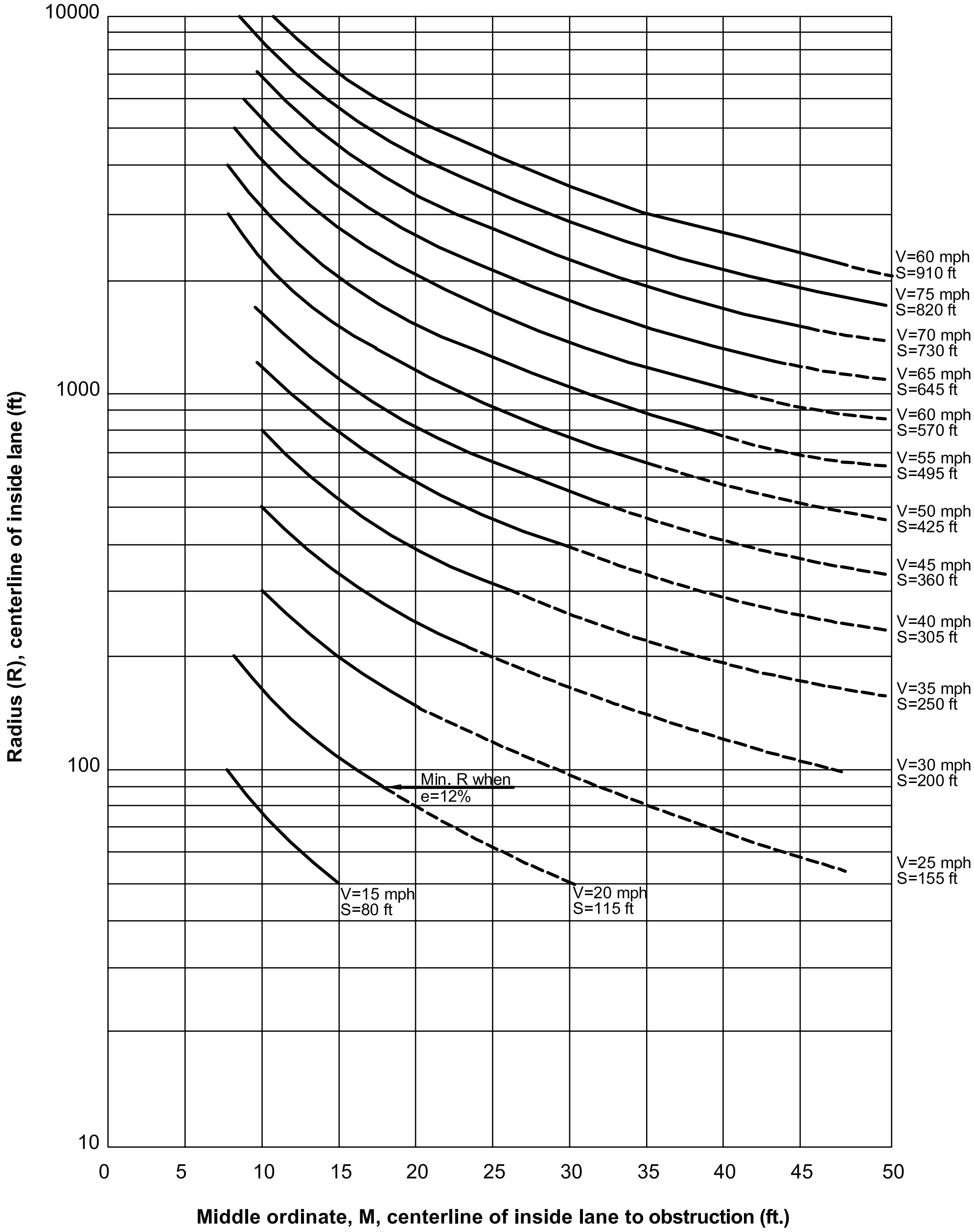
  The stopping sight distance is based on eye height of 3.5 feet and object height of 2 feet. The line-of-sight intercept with the view obstruction is at the midpoint of the sight line and 2.75 feet above the center of the inside lane.

Exhibit 4-4
Sight Distance on a Curve



Source: *A Policy on Geometric Design of Highways and Streets*, AASHTO, 2004. Chapter 3 Elements of Design

Exhibit 4-5
Horizontal Stopping Sight Distance Criteria



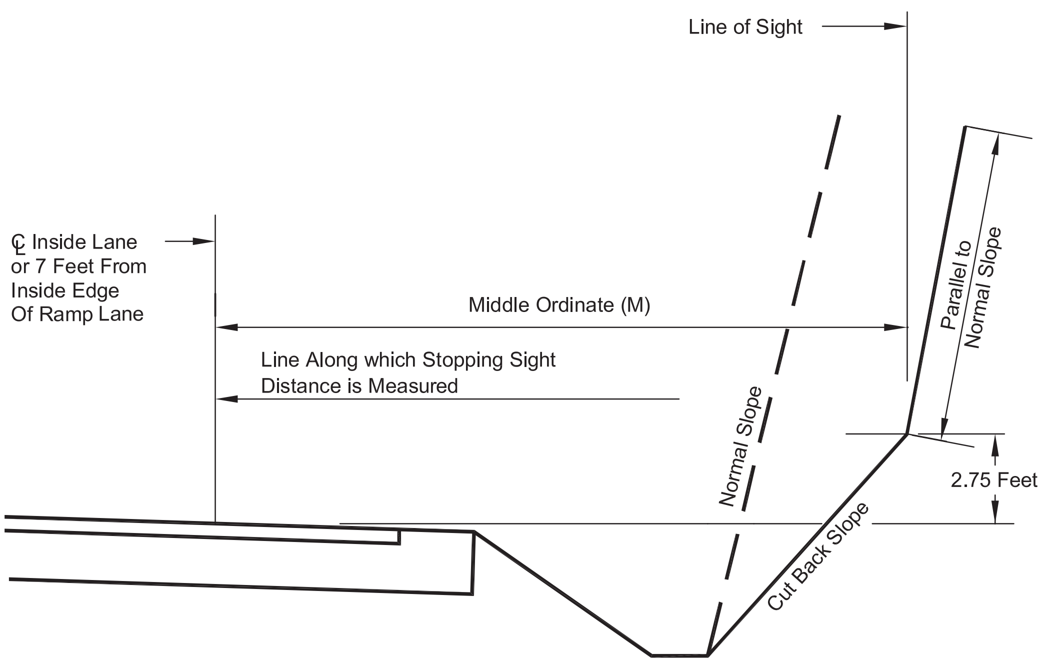
Source: *A Policy on Geometric Design of Highways and Streets*, AASHTO, 2004. Chapter 3 Elements of Design

- If a designer concludes that decision sight distance is needed, greater distance will have to be provided. Chapter 3 discusses those highway conditions where decision sight distance is appropriate and provides procedures for determining the distance. The calculated value would then be used in the basic equation for determining the middle ordinate on the horizontal curve. Also, refer to Chapter 3 in AASHTO's *A Policy on Geometric Design of Highways and Streets*, for further information.

- Normally, it is not practical to provide passing sight distance on horizontal curves. These values yield very large numbers for the middle ordinate. In addition, many drivers will not pass on horizontal curves regardless of the available sight distance. Passing should not be allowed where passing sight distance can not be achieved.

Exhibit 4-6 illustrates the method of ensuring adequate sight distance in cut sections.

Exhibit 4-6
Method of Cutting Slope for Horizontal Sight Distance



Source: MassHighway

4.3.3.1 Crest Vertical Curves

The primary control for crest vertical curves is providing adequate stopping sight distance as described in Chapter 3. Exhibit 4-26 shows computed K values for lengths of vertical curves as required for the value of stopping sight distance for each design speed.

Exhibit 4-26
Design Control for Stopping Sight Distance for Crest Vertical Curves

Design Speed (mph)	Stopping Sight Distance (ft)	Rate of Vertical curvature, K_a	
		Calculated	Design
15	80	3.0	3
20	115	6.1	7
25	155	11.1	12
30	200	18.5	19
35	250	29.0	29
40	305	43.1	44
45	360	60.1	61
50	425	83.7	84
55	495	113.5	114
60	570	150.6	151
65	645	192.8	193
70	730	246.9	247
75	820	311.6	312

Note: Rate of vertical curvature, K, is the length of curve per percent algebraic difference in intersection grades (A). K = L/A
Source: A Policy on Geometric Design of Highways and Streets, AASHTO 2004. Chapter 3 Elements of Design

Crest vertical curves must be balanced with the horizontal alignment. The beginning of the horizontal curve should not be positioned beyond the crest curve in a way that does not allow the advancing driver the ability to see the upcoming change in the horizontal alignment.

For the design of crest vertical curves, the following shall apply:

- **Stopping Sight Distance** —should be available on crest vertical curves. A height of eye of 3.5 feet and a height of object of 2 feet are used. A minimum length curve should be used for driver comfort and vehicular control. The line-of-sight intercept is 2.75 feet or above when the view obstruction is at the midpoint of the sight line.

Where: $L_{min} = 3V$
L_{min} is in feet, V is in mph

Flat vertical curves of less than 0.3% for distances of 50 feet or greater from the crest require careful drainage design. This equates to a K value of 167 or greater.

4.3.3.2 Sag Vertical Curves

Headlight sight distance (see Chapter 7 for additional detail at underpasses) is the primary design control for sag vertical curves on non-illuminated roadways. The height of the headlights is assumed to be 2 feet. The upward divergence of the beam is 1 degree from the longitudinal axis of the vehicle. The curvature of the sag should be such that the headlights will illuminate the pavement sufficiently to provide adequate stopping sight distance.

Exhibit 4-27 shows the range of rounded values of K selected as design controls which provide for minimum headlight sight distance. Minimum lengths of vertical curves for flat gradients are equal to 3 times the design speed in mph.

As for crest curves careful drainage design must be made for K values of greater than or equal to 167.

Designer should check the sight distance under bridges.

4.3.4 Vertical Clearances

Exhibit 4-28 provides the required vertical clearances for all highway types and other clearance criteria. The location of the critical clearance generally occurs where the highest point on the crown line and/or runoff line of the road underpass falls directly under the lowest elevation of the bottom overpass superstructure support member. Refer to the MassHighway Bridge Manual for the method of determining clearances.

Exhibit 4-27
Design Control for Sag Vertical Curves

Design Speed (mph)	Stopping Sight Distance (ft)	Rate of Vertical Curvature, K_a	
		Calculated	Design
15	80	9.4	10
20	115	16.5	17
25	155	25.5	26
30	200	36.4	37
35	250	49.0	49
40	305	63.4	64
45	360	78.1	79
50	425	95.7	96
55	495	114.9	115
60	570	135.7	136
65	645	156.5	157
70	730	180.3	181
75	820	205.6	206

Note: Rate of vertical curvature, K, is the length of curve per percent algebraic difference in intersection grades
Source: A Policy on Geometric Design of Highways and Streets, AASHTO 2004. Chapter 3 Elements of Design

Exhibit 4-28
Vertical Clearances

Minimum[1,4] (ft)	Comments
16.5	Bridges over expressways/freeways
16.5[5]	Bridges over arterial
16.5	Freeway Tunnels
16.5	Tunnels for all other roadway classes
16.5	Bridges over collector
16.5	Bridges over local road
See Note 2	Roadway bridge over railroad
17.0	Sign bridge or pedestrian bridge over roadway
See Note 3	Highway in vicinity of an airport

1. The Chief Engineer shall approve any clearance less than the minimum clearance in writing.
2. The MassHighway Bridge Engineer will coordinate clearance over railroads with the railroads.
3. Clearance in the vicinity of an airport will be coordinated with the FAA through the FHWA.
4. Minimum values allow 4 inches for paving overlays in all cases.
5. New or reconstructed structures should provide 16.5 ft clearance over entire roadway width. In a highly urbanized area a minimum clearance of 14.5 ft may be provided where an alternate route with 16.5 ft clearance is provided. Existing structures that provide 14.5 ft clearance may be retained, if allowed by local statute.
6. Provisions must be made for lighting, overhead signs and pavement overlays.

Source: A Policy on Geometric Design of Highways and Streets, AASHTO 2004. Chapter 3 Elements of Design