2. Profile

Combinations of profile lines that make vehicle control difficult should be avoided. Substantial grade changes should be avoided at intersections, although it is not always feasible to do so. Adequate sight distance should be provided along both highways and across corners, even where one or both intersecting highways are on vertical curves.

The grades of intersecting highways should be as flat as practical on those sections that are to be used for storage space for stopped vehicles. A minimum storage space for 2 vehicles, approximately 50 ft., should be provided for minor streets where stop sign control is employed and the approach grade is up towards the intersection. Such slopes should desirably be less than one percent and no more than 3 percent.

The profile lines and cross sections on the intersection legs should be adjusted for a distance back from the intersection proper to provide a smooth junction and proper drainage. Normally, the profile line of the major highway should be carried through the intersection, and that of the cross road adjusted to it. Intersections with a minor road crossing a multi-lane divided highway with narrow median and superelevated curve should be avoided whenever possible because of the difficulty in adjusting grades to provide a suitable crossing. Profile lines of separate turning roadways should be designed to fit the cross slopes and longitudinal grades of the intersection legs.

As a rule, the horizontal and vertical alignment are subject to greater restrictions at or near intersecting roads than on the open road. Their combination at or near the intersection must produce traffic lanes that are clearly visible to the vehicle operators at all times and definitely understandable for any desired direction of travel, free from sudden appearance of potential hazards, and consistent with the portions of the highway just traveled.

6-02.4 Cross Section

The cross section of the pavement surface within an intersection should be reviewed on a case-by-case basis. The development of the centerline profiles and edge of pavement profiles should flow smoothly through the intersection.

6-03 SIGHT DISTANCE

6-03.1 General

There must be unobstructed sight along both roads at an intersection and across their included corner for distances sufficient to allow the operators of vehicles approaching the intersection or stopped at the intersection to carry out whatever maneuvers may be required to negotiate the intersection.

Superseded

Any object within the sight triangle high enough above the elevation of the adjacent roadways to constitute a sight obstruction should be removed or lowered. Such objects include but are not limited to cut slopes, hedges, bushes, tall crops, signs, buildings, parked vehicles, etc. Also check the vertical curve on the highway to see if it obscures the line of sight from the driver's eye (3.5 ft. above the road) to the approaching vehicle (3.5 ft. above the road) as per the sight distance determined in the next three sections.

6-03.2 Stop Control on Cross Street

Intersection designs should provide sufficient sight distances to avoid potential conflicts between vehicles turning onto or crossing a highway from a stopped position and vehicles on the through highway operating at the design speed.

As a minimum stopping sight distance must be provided. However, to enhance traffic operations, the recommended sight distance along the major roadway from Figure 6-A for various design vehicles to turn left, right or cross should be provided. Where the median width on a divided highway is 6 ft. or greater than the vehicle length, the crossing can be accomplished in 2 steps. The vehicle crosses the first pavement, stops within the median opening, and proceeds when a safe gap in traffic occurs to cross the second pavement. However, when the median width is less than that of a vehicle, the crossing must be made in one step and the median must be included as part of the roadway width (w).

6-03.3 Yield Control

When an intersection is controlled by a yield sign, the sight triangle is governed by the design speed on the main highway and that of the approach highway or ramp.

The approach speed on the yield controlled approach is assumed to be 10 mph for ramps and minor roads. Where two major highways intersect and one leg is controlled by a yield sign, the design speed on both highways should be used in determining the minimum sight triangle.

Figure 6-C illustrates the method for establishing the recommended sight triangle for yield controlled intersections. As a minimum, stopping sight distance should be provided.

6-03.4 Sight Distance at Signalized Intersections

Intersections controlled by traffic signals presumably do not require sight distance between intersecting traffic flows because the flows move at separate times. However, drivers should be provided with some view of the intersecting approaches in case a crossing vehicle violates the signal indication. In addition, sight distance requirements for vehicles permitted to turn right on red signal indications must be considered. Line-of-sight should consider the effect of parked vehicles. As a minimum, stopping sight distance should be provided.

Superseded

6-04 TURNING MOVEMENTS

6-04.1 General

One of the primary concerns of intersection design is to provide adequately for left and right turning movements. The pavement and roadway widths of turning roadways at intersections are governed by the volumes of turning traffic and the types of vehicles to be accommodated.

6-04.2 Design Vehicles

The overall dimensions of the design vehicles considered in geometric design are shown in Table 2-2 of SECTION 2, GENERAL DESIGN CRITERIA. The minimum turning radius of these design vehicles is shown in Figures 6-D through 6-I.

These figures should be used as guides in determining the turning radii at intersections and the widths of turning roadways. The principal dimensions affecting design are the minimum turning radius and those affecting the path of the inner rear tire, tread width and wheel base. The paths shown for the several design vehicles are established by the outer trace of the front overhang and the path of the inner rear wheel.

Due to the greater usage of the 8.5 ft. wide, 48 ft. long trailers, the designer is encouraged to use the WB-62 turning template when designing new intersections or upgrading existing intersections. However, the designer is cautioned not to arbitrarily provide for these larger vehicles in the design of all intersections. For example, if the turning traffic is almost entirely passenger cars, it may not be cost-effective to design for large trucks, provided that an occasional large truck can turn by swinging wide and encroaching on other traffic lanes without disrupting traffic significantly. When selecting the appropriate design vehicle, the designer is encouraged to use vehicle classification counts. Also, the existing land use and/or zoning requirements may be useful in selecting the appropriate design vehicle. However, selection of the design vehicle will depend on the designer's judgement after all the conditions have been analyzed and the effect of the operation of larger vehicles has been evaluated.

It is very possible that the use of more than one design vehicle may be appropriate. As an example, the design of one quadrant of the intersection may warrant the use of a SU truck or passenger vehicle while another quadrant may warrant the use of the WB-62.

It is further recommended that all interstate and freeway ramp terminals be designed to accommodate the WB-62 design vehicle.

The use of the WB-62 design vehicle should also be considered when designing ingress and egress to commercial or industrial buildings along the state highways.

Superseded

6-04.3 Minimum Edge of Pavement Design for Turns

Where it is necessary to provide for turning vehicles within minimum space and slow speeds (less than 10 mph), as at unchannelized intersections, the minimum turning paths of the design vehicles apply.

For most simple intersections with angle of turn of 90 degrees or less, a single circular arc joining the tangent edges of pavement provides an adequate design. Generally, radii of 15 ft. to 25 ft. are adequate for passenger vehicles. Radii of 30 ft. or more should be provided to allow an occasional truck or bus to turn without much encroachment. Radii of 50 ft. or more should be provided where large truck combinations and buses turn frequently.

When provisions must be made for the larger truck units, and the angle of turn exceeds 90 degrees, a 3-centered compound curve may be used in lieu of a single circular arc with a large radius.

Figure 6-J indicates the minimum treatment at unchannelized intersections.

6-05 CHANNELIZATION

6-05.1 General

Where the inner edges of pavement for right turns at intersections are designed to accommodate semitrailer combinations, or where the design permits passenger vehicles to turn at speeds of 15 mph or more, the pavement area at the intersection may become excessively large for proper control of traffic. To avoid this condition, a corner island, curbed or painted, should be provided to form a separate turning roadway.

At-grade intersections having large paved areas, such as those with large corner radii and those at oblique angle crossings, permit and encourage undesirable vehicle movements, require long pedestrian crossings, and have unused pavement areas. Even at a simple intersection, appreciable areas may exist on which some vehicles can wander from natural and expected paths. Conflicts may be reduced in extent and intensity by a layout designed to include islands. For the design of 3-centered curves for right angle turns with corner islands and oblique angle turns with corner islands, see *A Policy on Geometric Design of Highways and Streets,* AASHTO, 2001, Exhibit 9-41 and Exhibit 9-42 respectively.

6-05.2 Islands

An island is a defined area between traffic lanes for control of vehicle movements. Islands also provide an area for pedestrian refuge and traffic control devices. Within an intersection, a median or an outer separation is considered an island. This definition makes evident that an island is no single physical type; it may range from an area delineated by curbs to a pavement area marked by paint.

Superseded

When practical, an acceleration or deceleration lane should be of sufficient width and length to enable a driver to maneuver a vehicle onto it properly and once onto it, to make the necessary change between the speed of operation on the highway or street and the lower speed on the turning roadway. See Figure 6-O for desirable lengths of acceleration and deceleration lanes.

The capacity of a signalized intersection may be increased by adding an auxiliary lane to accommodate through traffic. The introduction of the auxiliary lane can usually be accomplished easily since it is effectively metered into the auxiliary lane. The merging of traffic from the auxiliary lane back into the through lane beyond the signal requires the auxiliary lane to be carried a distance beyond the stop line at the traffic signal to a point where the merging taper is introduced. The minimum length of the auxiliary lane in advance of and beyond the intersection including tapers shall be in accordance with Figure 6-N. The Bureau of Traffic Signal and Safety Engineering must approve the addition of an auxiliary lane to improve capacity at signalized intersections.

6-05.4 Median Openings

Median openings on divided roadways are provided to permit intended movements only. Figures 6-P and 6-Q show application of grass median and concrete barrier curb median openings, respectively, to control the various types of movements along a divided roadway.

The length of the median opening desirably should equal the full roadway width of the cross road, shoulder to shoulder plus 5 ft. on both sides and in no case less than 40 ft. The control radius (R_1) should also be considered in determining the minimum length of median opening. The control radius (R_1) is determined by the design vehicle as follows:

Design Vehicle	Control Radius
P and SU	40 ft.
SU, BUS, WB-40	50 ft.
WB-40, WB-50	75 ft.

Provisions shall be made where pedestrian traffic is present at median openings, see Figures 6-P and 6-Q.

The use of a 40 ft. minimum length of opening without regard to the width of median, the cross road width, pedestrian traffic or the control radius should not be considered The 40 ft. minimum length of opening does not apply to openings for U-turns except at very minor crossroads. Consult *A Policy on Geometric Design of Highways and Streets*, AASHTO, 2001, for the design of U-turn median openings.

On urban divided roadways, median openings for U-turns should not be provided. U-turn movements may be permitted at signalized intersections where there is sufficient pavement width to accommodate the movement. Provisions for U-turns should be made on rural divided roadways where intersections are spaced in excess of one half.

Superseded

6-06.3 Length

The total length of the left-turn lane is the sum of storage length and entering taper.

1. Storage Length

   The median left-turn lane should be sufficiently long to store the number of vehicles likely to accumulate during a critical period. The storage length should be liberal to avoid the possibility of left-turn vehicles stopping in the through lanes (see Figure 6-T)

2. Taper

   The entering taper treatment is illustrated in Figure 6-T.

6-07 CONTINUOUS TWO-WAY LEFT-TURN MEDIAN LANE

6-07.1 General

A continuous two-way left-turn median lane provides a common space for speed changes and storage for left-turn vehicles traveling in either direction and allows turning movements at any location along a two-way roadway.

Continuous two-way left-turn median lanes are an effective means of providing an increased level of service on many urban arterials. They are especially effective in locations of strip commercial development and frequent driveway openings experiencing moderate left-turn demands.

Since it is possible for vehicles traveling in opposite directions to enter the two-way left-turn lane simultaneously, sufficient stopping sight distance must be provided to permit vehicles to stop. Table 6-1 provides the desirable stopping sight distance as related to design speeds that are applicable to two-way left-turn lanes.

Superseded

Table 6-1
Desirable Stopping Sight Distances for Two-Way Left-Turn Lanes

Design Speed (mph)	Stopping Sight Distance (feet)
30	400
35	500
40	610
45	720
50	850
55	990
60	1140

The length of crest vertical curve can be computed by the following formulas. The formulas are based on the height of the driver's eyes of 3.5 ft. and of an object 2 ft. on the road, which is equivalent to the headlight height above the roadway.

When S is greater than L, $L=2S-(2158/A)$

When S is less than L, $L=AS^2/2158$

S= Stopping sight distance from Table 6-1, in feet.
L= Length of vertical curve, in feet.
A= Algebraic difference in grade, in percent.

If there is adequate roadway lighting present, the object height may be increased to 4.25 ft. (top of vehicle), therefore, substitute "3093" for "2158" in the previous formulas. The vertical curve length on the highway should also be checked by Figure 4-I and use the greater of the two "L" values when designing the vertical curve.

Figure 6-U shows a typical two-way left-turn median lane.

6-07.2 Lane Width

Lane widths for continuous two-way left turn median lanes range from 12 ft. to 16 ft. The wider pavement width should be used only when raised islands are provided at major intersections with high left-turn demands. A median lane width of 12 ft. is desirable where raised islands are not provided at major intersections.

6-07.3 Cross Slope

Generally the crown line should be located in the center of the median turn lane. The slope of pavement from the crown line should be the same as the cross slope on the through lane adjacent to the median lane

Superseded

6-08.4 Standard Jughandle Designs

Figures 6-V through 6-X illustrate the three basic jughandle configurations. The dimensions and radii shown are recommended, however, social, environmental or economic impacts may make adherence to the basic geometrics impractical. The recommended design speeds for the basic jughandle configurations are shown in Table 6-2.

Table 6-2
Jughandle Design Speeds

Jughandle Type	Minimum Design Speed (mph)
A	25
B - one lane	15
B - one lane with T Intersection	20
B – two lane	25
C – loop ramp	15 (20 des.)
C - finger ramp	25

When initially providing jughandles at locations where there are no existing cross streets or there is an intersecting street on only one side, the designer should evaluate the future development potential of the property adjacent to the jughandle. Consideration should be given to designing the jughandle for future expansion to accommodate the access needs of the adjacent property.

The design of Type "B" jughandles should generally be limited to locations where the development of the adjacent land is limited due to topography, environmental constraints, zoning restrictions, etc.

6-08.5 Superelevation and Cross Slope

It is desirable to provide as much superelevation as practical on jughandles, particularly where the ramp curve is sharp and on a downgrade. Table 6-3 provides a suggested range of superelevation rates in percent for various ramp radii. Rates in the upper half or third of the indicated range are preferred. The cross slope on tangent sections of ramps is normally sloped one-way at 2 percent, which is considered a practical minimum for effective drainage across the surface (see Figure 5-J).

Superseded

Table 6-3
Jughandle (Ramp) Superelevation (%)

Design Speed mph	Radius (feet)					
	50	90	150	230	310	430
	Superelevation (%)					
15	2-6	2-6	2-5	2-4	2-3	2-3
20	---	2-6	2-6	2-6	2-4	2-3
25	---	---	4-6	3-6	3-6	3-5
30	---	---	---	6	5-6	4-6

Exceptions to the use of full superelevation are at street intersections where a stop or yield condition is in effect.

The length of superelevation transition should be based on Section 4-03.2.2. With respect to the beginning and ending of a curve on the ramp proper (not including terminals), see Table 4-4 for the portion of the runoff located prior to the curve. This may be altered as required to adjust for flat spots or unsightly sags and humps when alignment is tight. The principal criteria is the development of smooth-edge profiles that do not appear distorted to the driver.

See Section 7-06.2, "Ramp Terminals", for a discussion on development of superelevation at free-flow ramp terminals and the maximum algebraic difference in cross slope at crossover line.

6-09 OTHER CONSIDERATIONS

6-09.1 Parking Restrictions At Intersections

Vehicular parking should not be permitted within the immediate limits of at-grade intersections; see Section 6-03, “Sight Distance”, for sight distance requirements at intersections.

6-09.2 Lighting At Intersections

Lighting affects the safety of highway and street intersections and the ease and comfort of traffic operations. In urban and suburban areas where there are concentrations of pedestrians and roadside and intersection interferences, fixed-source lighting tends to reduce accidents. Whether or not rural at-grade intersections should be lighted depends on the planned geometrics and the turning traffic volumes involved. Intersections that generally do not require channelization are seldom lighted. However, for the benefit of non-local highway users, lighting at rural intersections is desirable to aid the driver in ascertaining sign messages during non-daylight period.

Superseded