CHAPTER 12

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INTRODUCTION

When two or more roads intersect, there is potential for conflict between vehicles.

The main objective in design of at-grade intersections is to reduce the potential severity of conflicts between vehicles and, at the same time, assure the convenience and ease of drivers in making the necessary maneuvers.

This chapter describes the types of at-grade intersections and the various criteria that should be considered.

The three basic types of at-grade intersections are the **T** intersection (with variations in the angle of approach), the **four-leg** intersection, and the **multi-leg** intersection. In each particular case the type is determined by the number of legs, the topography, the character of the intersecting highways, the traffic patterns and speeds, and the desired type of operation.

The simplest and most common intersection is the private approach or driveway. At the other extreme, a major highway terminating at an intersection with another major highway usually requires a rather complex design. Typical intersections are shown in Figure 12-1.

Four-leg intersections vary from a simple 90-degree intersection of two lightly traveled local roads to a complex intersection of two main highways. Multileg intersections are seldom used in South Dakota. Most often they are found in urban areas and, where they are required, they usually will involve a complex design.

Detailed discussions of criteria for channelization, speed-change lanes and storage lanes for turns are presented later in this chapter.

Roundabouts

Roundabouts are another tool for the designer to consider in intersection design. A true roundabout is characterized by the following:

- A central island of sufficient diameter to accommodate vehicle tracking and to provide sufficient deflection to promote lower speeds
- Entry is by gap acceptance through a yield condition at all legs
- Speeds through the intersection are 25 mph or less

The use of roundabouts should be determined by a detailed intersection analysis, as is also necessary for other types of intersection design.

For further guidance on roundabouts, refer to the latest documents from FHWA and the TRB, such as publication No. FHWA-RD-00-067 “Roundabouts: An Informational Guide”, or NCHRP Report 572 “Roundabouts in the United States”, or other acceptable sources.

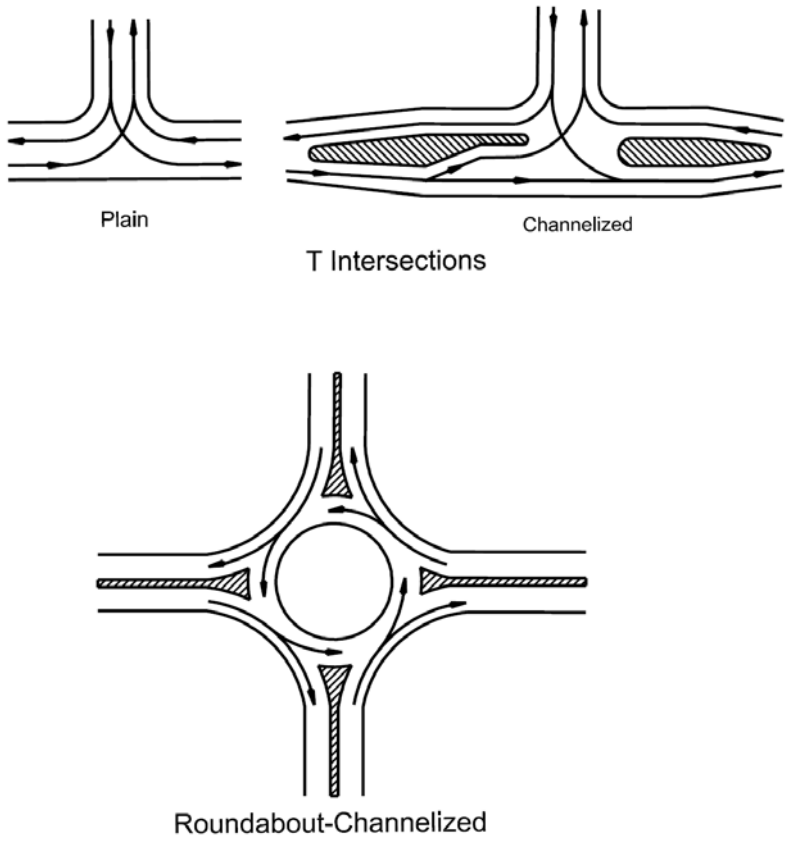


Figure 12-1 Typical Intersections

Level of Service Objectives

Access locations at grade can have a very significant impact on highway capacity and traffic flow characteristics. Sometimes it is neither feasible nor practical to eliminate all congestion. In recognition of this, the Highway Capacity Manual defines six "levels of service." Level A is the highest level, with free-flowing traffic at relatively high operating speeds. Level F is the lowest, with considerable congestion and very low operating speeds.

Once a level of service is selected, it is essential that all elements of the roadway (including intersections) be consistently designed to this level. The need for channelization, left turn lanes, etc., is directly related to acceptable levels of service.

The Highway Capacity Manual presents a more thorough discussion of the level-of-service concept. And it also supplies the analytical base for design calculations and decisions, including capacity analysis. Refer to Road Design Manual Chapter 3 – Scope Process for acceptable levels of service.

Alignment

For safety and economy, access locations should meet at, or nearly at, right angles. An access intersecting at acute angles require extensive turning roadway areas and tend to limit visibility, particularly for drivers of trucks and older drivers. Acute-angle intersections increase the exposure time of vehicles crossing the main traffic flow and may increase the accident potential.

Figure 12-2 shows several practices for realignment of acute-angle intersections. Although a right-angle crossing normally is desired, some deviation is permissible. Angles above approximately 60 degrees produce only a small reduction in visibility, which often does not warrant realignment closer to 90 degrees.

Intersections on sharp curves should be avoided wherever possible because the superelevation of pavements on curves complicates the intersection design. Also, this situation often leads to sight distance problems because of the sharp curve. It may be desirable to flatten the curve, or to introduce two curves with a tangent between them at the point of intersection.

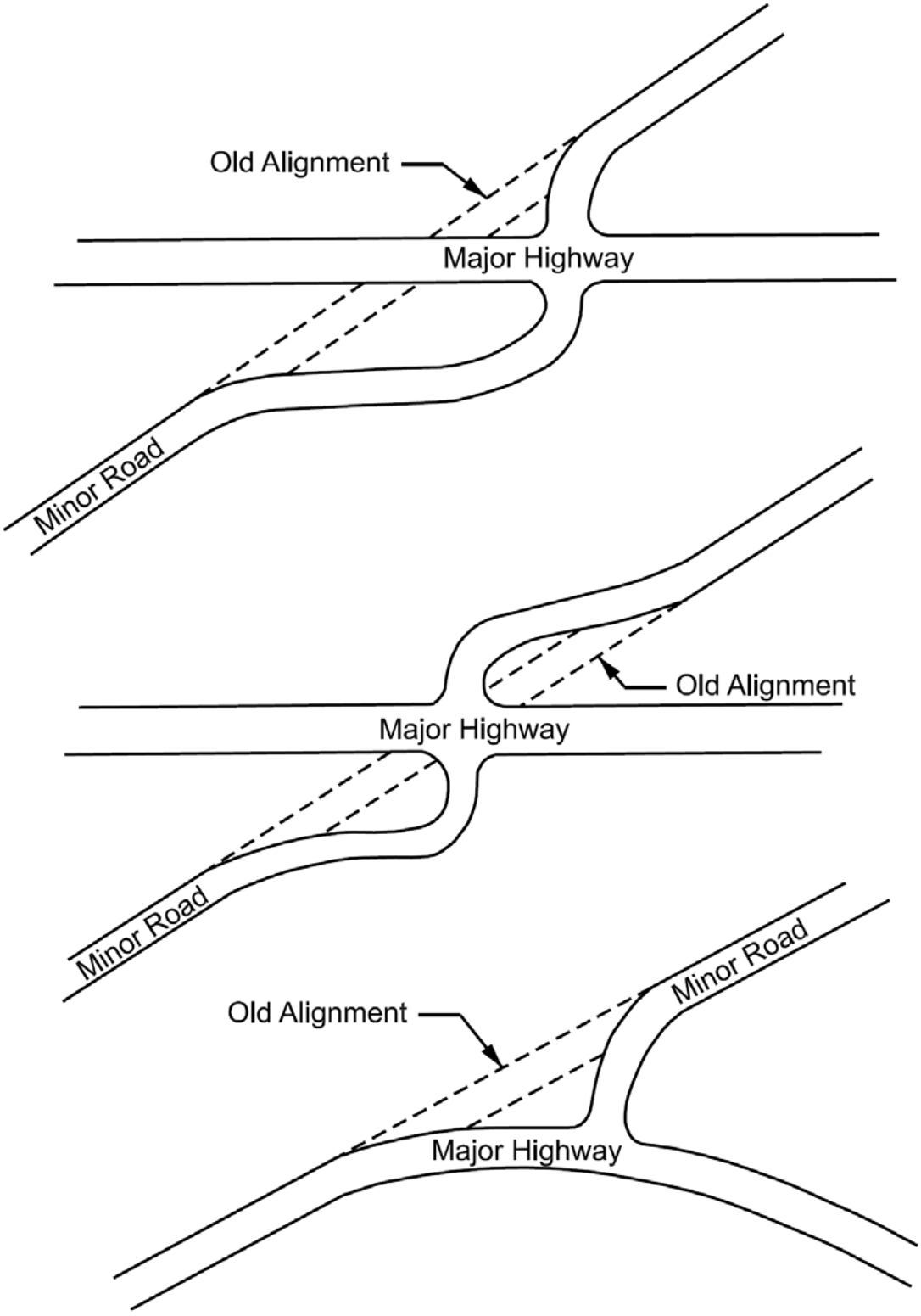


Figure 12-2 Realignment of Acute-Angle Intersections

Intersection Profiles

The grades of intersecting roads should be as flat as practical on those sections that are to be used as storage space for stopped vehicles. Grades in excess of 3 percent generally should be avoided in the vicinity of intersections.

Normally, the gradeline of the major highway should be carried through the intersection, and that of the cross road should be adjusted to it. This design requires transition of the crown of the minor highway to an inclined cross section at its junction with the major highway. For intersections with traffic signals, or where signals may be warranted in the near future, it may be desirable to warp the crowns of both roads. Refer to Exhibit 3-30 and Equation 3-25 of the current AASHTO publication *A Policy on Geometric Design of Highways and Streets* for guidance on proper transition lengths. The edge of pavement gradients should be flat enough to provide a comfortable transition from the normal cross slope to the warped cross slope and yet not so flat as to cause drainage problems.

In urban areas where sidewalks are provided or anticipated, the gradient of the access or adjacent approach pavement shall match the cross slope of the sidewalk to meet ADA requirements as outlined in Chapter 16 – Miscellaneous.

Beyond the vicinity of the intersection the grades for State Highways or Urban Arterials should be as noted in Tables 6-1 and 6-2 in Chapter 6 – Vertical Alignment. Other access locations should be as flat as practical and can use a maximum grade of 10 percent. In extreme situations the 10 percent grade can be exceeded based on economics and/or impacts with the adjoining properties.

Driveway Profiles

Vertical deflections on driveways shall be gradual enough to prevent dragging of central or overhanging portions of passenger vehicles as shown in Figure 12-3. Vertical deflections or humps can present a problem when the elevation behind the tie-in point for an approach is lower than the theoretical top of curb elevation. The designer must evaluate the potential of dragging on the deflection point. The deflection of two adjoining sections should be gradual enough as to not exceed a 3 1/4" hump in a 10' chord. The designer must also evaluate situations so the depression of a sag deflection does not exceed 4 1/4" in a 10' chord.

Some possible solutions to dragging problems may be to construct a flat spot on the approach as shown below, or to alter the slope from a 10:1 to a more gradual slope.

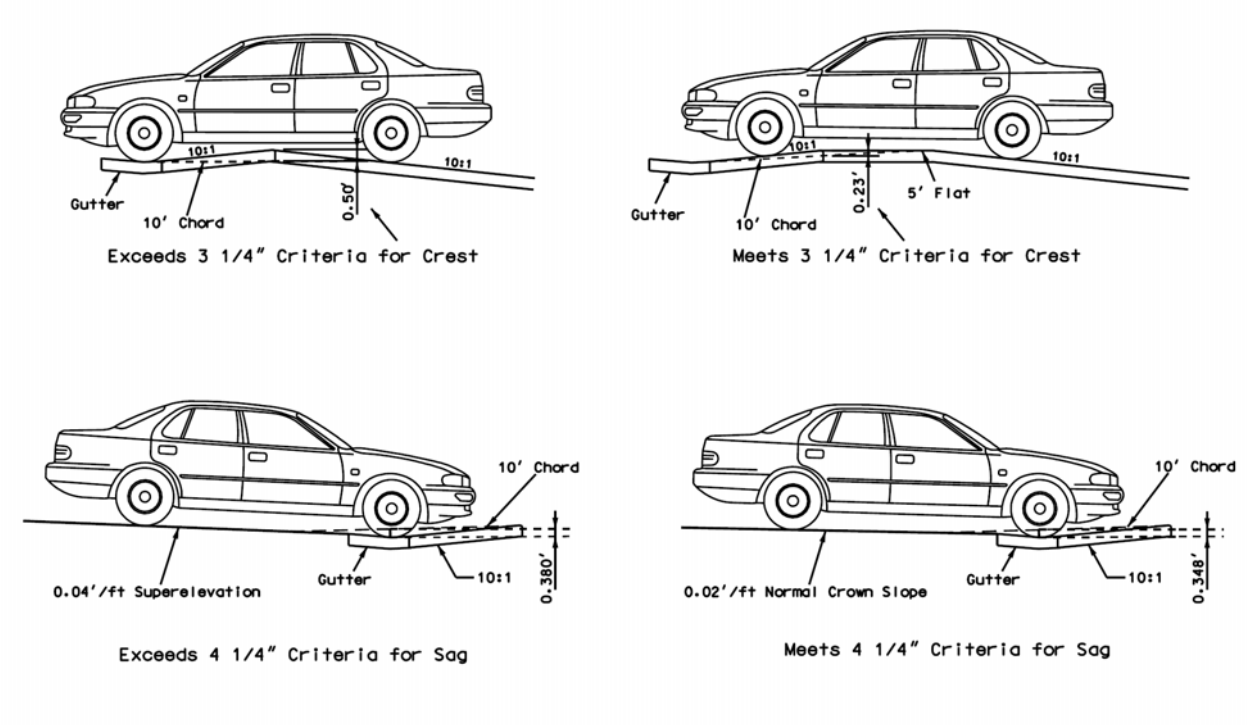


Figure 12-3 Vertical Deflections for Driveways

Width and Radii

Based on research, the speed of traffic leaving the roadway to enter an intersection is approximately the same, no matter what type of access is used. Any type of access has approximately the same potential to cause slowing on the through roadway as drivers turn into the access location.

When multiple lanes are provided per direction on the through roadway, the level of conflicts at access locations will be reduced as a portion of the traffic will be traveling on the inside lane(s) and not have an effect on turning vehicles to and from access from the outside lane. When traffic volumes are high, the section for Turn Lanes at the end of this chapter should be reviewed to determine if turn lanes are warranted. When warranted, the use of deceleration/turn lanes can further reduce the level of conflicts at access locations.

The access width shall be adequate to properly handle the anticipated volume and type of traffic.

Under normal conditions, radii are not provided for urban driveways when used in curb and gutter sections. The use of radii is dependent on the turning characteristics of the vehicles using the driveway, rather than speed or volume. When radii are not used, drivers will use more of the driveway width for their maneuver. When the driveway is narrow, incoming drivers may have to stop in the roadway to allow outbound traffic to clear. So, the most important design factors are:

- A significant proportion of trucks using the driveway, and

- The possibility that an outbound vehicle will be using the driveway at the same time as an inbound vehicle.

The use of shoulders, either on the through roadway or the intersecting access, can also aid in the maneuverability of a vehicle in and out of a driveway. Shoulders on the through roadway can reduce the width of the access as well as reduce or eliminate the need for a radius.

Tables 12-1 and 12-2 are provided as guidelines regarding widths and radii to be used for intersecting access. It may be required that a separate analysis of each access be performed depending on the traffic volumes and the turning characteristics of the vehicles using the access. Reference can be made to the section for Turning Movements described later in this chapter.

Table 12-1 Guidelines for Width and Radii for Access Locations

Rural or Urban	Type of Entrance	Minimum Width	Maximum Width	Minimum Radius	Maximum Radius
Rural	Farm or Field Entrance	24’	40’ (Double)	[1]	[1]
Rural	Intersecting Road	28’	[2]	35’ [3]	[4]
Urban	Drive	24’ [5]	40’	NA or 15’ [6]	[6]
Urban	Intersecting Street	24’ [7]	[7]	25’ [8]	[4]

[1] A radius is not typically noted in the plans for rural entrances. “A minimum practical radius should be constructed between the approach inslope and mainline inslope for farm and field entrances” per Standard Plate 120.01.

[2] Variable widths can be used based on existing geometrics and the highway functional classification of the intersecting road.

[3] “The turning radius shall be 35’ for intersecting roads unless stated otherwise in the plans” per Standard Plate 120.01.

[4] The radius is dependent on the turning characteristics of the vehicles using the intersection. For certain conditions a more detailed geometric analysis should be performed as described later in this chapter in the section for Turning Movements.

[5] The minimum width for an urban driveway can be reduced to 16’ based on impacts with the adjoining properties and matching existing conditions. Alleys are typically 16’ wide.

[6] Under normal conditions, radii are not provided for urban driveways when used in curb and gutter sections. A standard driveway includes tapered curbs (Standard Plate 650.35) at the edges and PCC approach pavement (Standard Plate 380.20). The use of driveway radii is dependent on the turning characteristics of the vehicles using the driveway. For certain conditions (See Table 12-2) a more detailed geometric analysis should be performed as described later in this chapter in the section for Turning Movements. If a radius is warranted, the minimum radius should be 15 feet.

[7] The width shall match the width of the existing intersecting street or in new locations meet City design guidelines.

[8] The minimum radius used is typically 25 feet (Standard Plate 380.16 or 380.17), but can be reduced in extreme conditions based on economics and/or impacts with the adjoining properties.

Table 12-2 Recommended Driveway Features by Land Use Type

Land Use Type	Range or Maximum Driveway Width (ft) [1]	Radius? N or [2]
Alley	16-24	N
Single family residence	16-24	N
Apartment/condominium	24-28	N
Bank	32	N
Congregate Care Facility/Nursing Home	32	N
Hotel/Motel, little truck use	32	N
Convenience store/gas station	32-40	N
Grocery store	32-40	N
Hospital	32-40	N
Office, less than or equal to 10,000 square feet	32-40	N
Park/recreation/entertainment	32-40	N
Restaurant/bar/fast food	32-40	N
School	32-40	N
Small retailer, specialty strip retail	32-40	N
“Big Box” retail	32-40	[2]
Hotel/Motel, significant truck use	40	[2]
Industrial plant	40	[2]
Office, greater than 10,000 square feet	40	[2]
Truck terminal, warehouse	40	[2]

[1] The width of a driveway can be reduced for one-way traffic. Other variances to reduce the recommended widths can be made with supporting justification and documentation.

[2] The use of driveway radii is dependent on the turning characteristics of the vehicles using the driveway. A more detailed geometric analysis should be performed as described later in this chapter in the section for Turning Movements. If a radius is warranted, the minimum radius should be 15 feet.

Distance Between Access Locations

Criteria for location and frequency of access spacing (i.e. field entrances, intersecting roadways, driveways, etc.) can be found in Figure 17-1 of Chapter 17 – Access Management. Chapter 17 also includes techniques to be used to evaluate access issues presented in access applications or during project design. The techniques are listed with an indication whether the technique should be used for evaluating new access or in retrofit situations.

Frontage Road Intersections

When a divided arterial highway is flanked by a frontage road, the problems of design and traffic control are more complex. These intersections exist at each cross street.

The problem becomes more severe when the distance between the arterial and the frontage road is relatively small. Generally, the separation between the mainline roadway and the frontage road should be 250 feet (76m) or greater, as indicated in Figure 12-4, with a minimum of 150 feet (46m),.

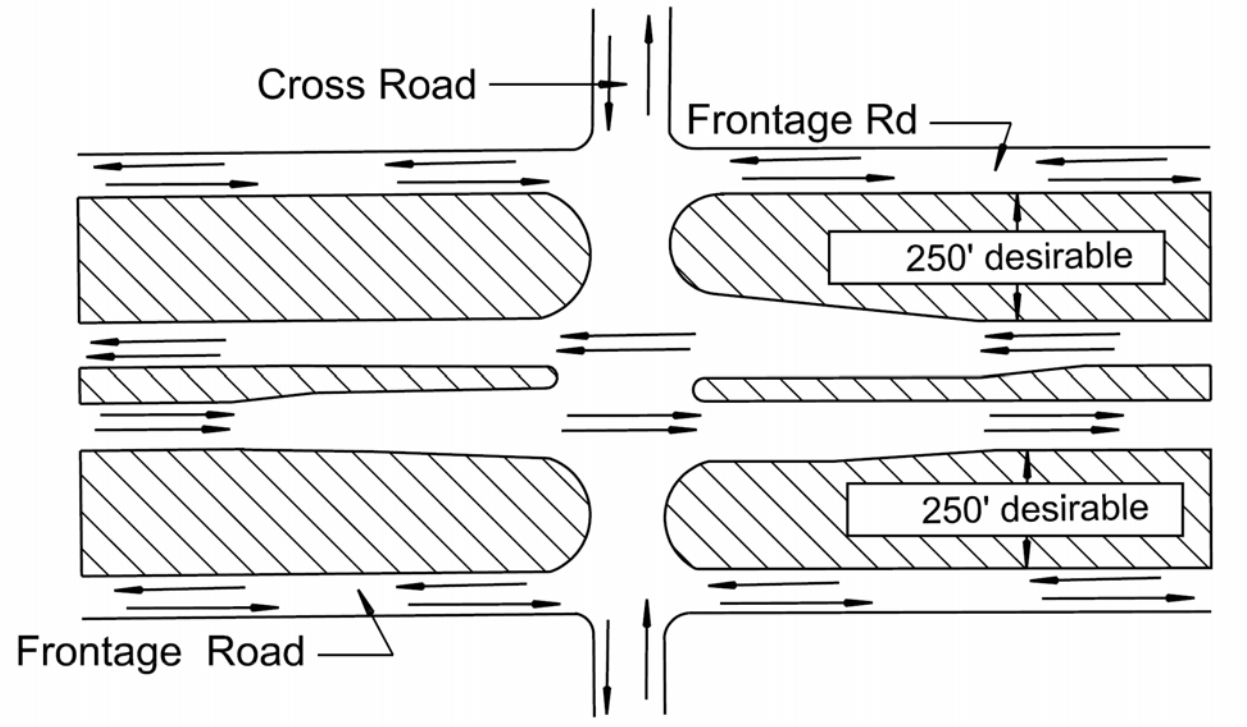


Figure 12-4 Two-Way Frontage Roads with Wide Outer Separation

Quite often, right-of-way considerations make it impractical to provide the full desired outer separation width. The alternative is to accept a narrow outer separation between cross roads and design a bulb-shaped separation in the immediate vicinity of each cross road. This design is illustrated in Figure 12-5. Refer to NCHRP Report 402 for more information on frontage roads.

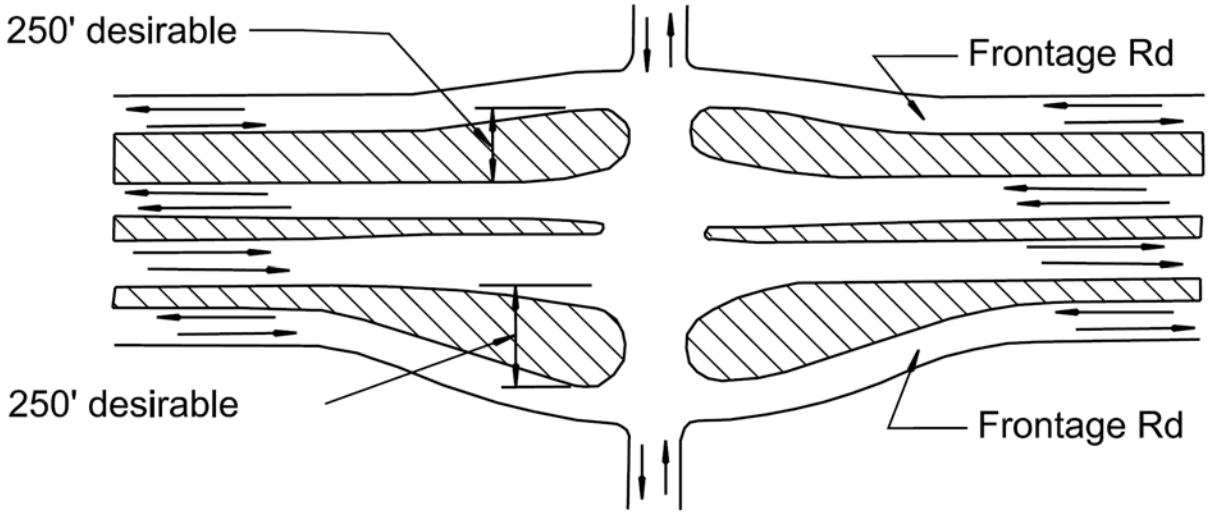


Figure 12-5 Two-Way Frontage Roads with Bulbed Separation

TURNING MOVEMENTS

This section discusses the various factors that influence the geometric design of the turning lanes and pavement edges. All intersections involve some degree of vehicle turning movements. The designer should evaluate turning movements at each intersection, which can be aided by the computer software package AutoTURN or similar software, to determine the most practical edge of pavement design that will accommodate the design vehicle. The amount of allowable encroachment by the design vehicle into the adjacent lanes of traffic as described below should also be evaluated from a cost-benefit aspect.

Design Vehicles

In the design of any highway facility, the largest design vehicle likely to use that facility with considerable frequency, or a design vehicle with special characteristics that must be taken into account in dimensioning the facility, is used to determine the design of such critical features as radii at intersections and radii of turning vehicles. The following criteria should be used to determine which design vehicle to use:

- WB67 at the intersection of two State and or Federal highways, at the intersections of State or Federal highways with major County roads and major City streets, and other intersections where large truck traffic is frequent (i.e. elevators, truck stops, rail terminals, warehouses, etc.)

- SU30 at the intersections of State or Federal Highways and residential streets and County or Township gravel roads where only an occasional truck is likely to enter or exit the highway.

For site specific locations (i.e. urban areas, recreational, commercial or industrial sites, etc.) there should be additional consideration given for turning vehicles to determine the appropriate design vehicle to be used.

Where dual left turn lanes are used and truck traffic is expected, the designer should assume the outside turn lane is occupied by a WB67 vehicle and the inside turn lane is occupied by an SU30 vehicle. The median island should be appropriately designed to allow both of these vehicles to turn at the same time.

The boundaries of the turning paths of the design vehicles when making the sharpest possible turns are established by (1) the outer trace of the front wheel overhang, and (2) the path of the inner rear wheel.

Refer to Chapter 2 of the current AASHTO publication *A Policy on Geometric Design of Highways and Streets* for design vehicle dimensions and minimum turning radii.

Encroachment

To determine the acceptable encroachment into adjacent lanes, the designer should evaluate several factors including traffic volumes, one-way or two-way operations, pedestrian requirements, urban/rural location, and the functional classes of the intersecting roads or streets. The following criteria should be followed:

- Urban: Desirably, the selected design vehicle will not encroach into the opposing travel lanes. However, this is not always practical or cost effective at all urban intersections. Table 12-3 presents recommended guidelines for acceptable encroachments for turning vehicles at urban intersections. The designer must evaluate these encroachment guidelines against the construction, right-of-way, and pedestrian needs. For example, if these impacts are significant and if through and/or turning volumes are relatively low, the designer may decide to accept an encroachment of the design vehicle which exceeds the criteria in Table 12-3.

- Rural: For rural intersections, the selected design vehicle should not encroach onto the adjacent lane of the road from which the turn is made or onto the opposing lanes of traffic of the road onto which the turn is made. If there are two or more lanes of traffic in the same direction on the road onto which the turn is made, the selected design vehicle can occupy both travel lanes. Desirably, the turning vehicle will be able to make the turn while remaining entirely in the closest through lane.

- Entrances and Driveways: Under normal conditions vehicles will be allowed to encroach into adjacent lanes when turning into a driveway. But if the traffic volumes at the entrance are significant, the driveway may be treated as a normal intersection in which case the allowable encroachments would be as described in Table 12-3,

Table 12-3 Guidelines for Acceptable Lane Encroachments

Turn Made From	Turn Made Onto	Acceptable Encroachment for Design Vehicle into Opposing Lanes of Travel
Freeway Ramp	Other Facility	No Encroachment
Arterial	Arterial Collector Local	No Encroachment 1 ft. Encroachment 2 ft. Encroachment
Collector	Arterial Collector Local	No Encroachment 1 ft. Encroachment 2 ft. Encroachment
Local	Arterial Collector Local	No Encroachment 2 ft. Encroachment 2 ft. Encroachment

See guidelines on the following page for use of Table 12-3.

The following guidelines should be followed using Table 12-3:

[1] State and Federal Highways are considered “Arterials” for the purposes of this table.

[2] The above encroachment criteria refer to the appropriate design vehicle.

[3] Before the turn is made, the design vehicle is assumed to be in the outermost through travel lane for right turns, innermost through lane for left turns, or in an exclusive turn lane, whichever applies. It is assumed that the vehicle does not encroach onto adjacent lanes on the road/street from which the turn is made.

[4] When determining the acceptable encroachment, the designer should also consider turning volumes, through volumes and the type of traffic control at the intersection.

[5] The table indicates the amount by which the turning vehicle can encroach into the opposing lanes of travel. If there are two or more lanes of traffic in the same direction on the road onto which the turn is made, the selected design vehicle can occupy both travel lanes. Desirably, the turning vehicle will be able to make the turn while remaining entirely in the closest through lane.

[6] All proposed designs should be checked with the applicable vehicular turning template and all assumptions and decisions made should be documented.

Edge-of-Pavement Designs

In the design of the edge of pavement for the minimum path of a given design vehicle, it is assumed that the vehicle is properly positioned within the traffic lane at the beginning and end of the turn, 2 feet (0.6m) from the edge of pavement on the tangents approaching and leaving the intersection curve.

Four types of curves commonly are used for the design of pavement edges at intersections:

- Simple Curve (Figure 12-6)
- 2-Centered Curve (Figure 12-7)
- 3-Centered Symmetric Compound Curve (Figure 12-8)
- 3-Centered Asymmetric Compound Curve (Figure 12-9)

Use of the simple curve usually is limited to private driveways and low traffic volume intersections where there is little heavy truck traffic. The 2-centered or 3-centered curve should be used for edge-of-pavement design at all major intersections.

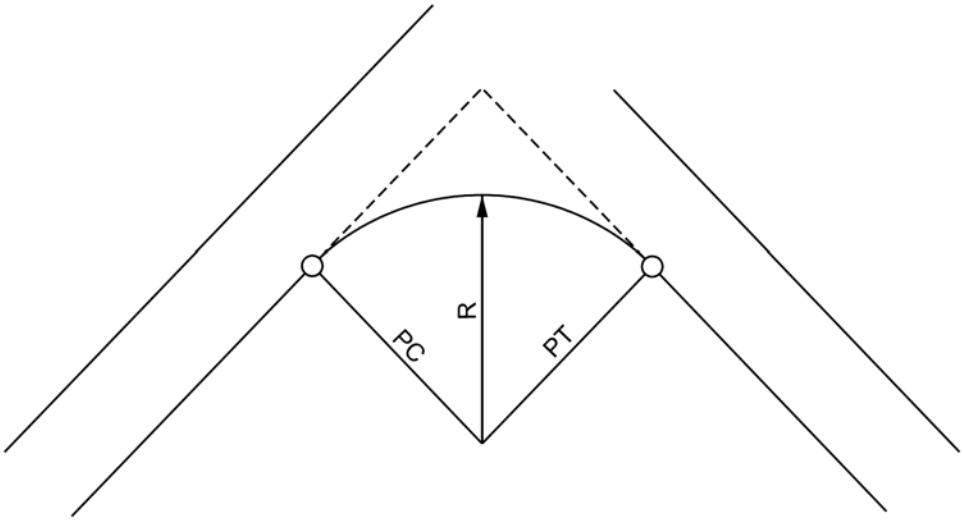


Figure 12-6 Intersection Edge-of-Pavement Designs Using Simple Curves

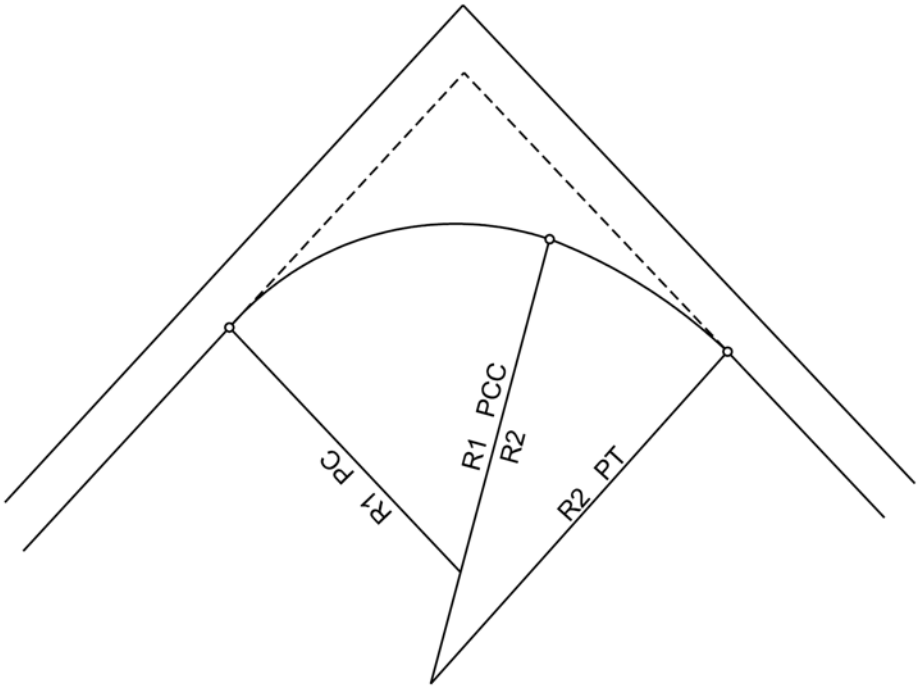


Figure 12-7 Intersection Edge-of-Pavement Design Using 2-Centered Curve

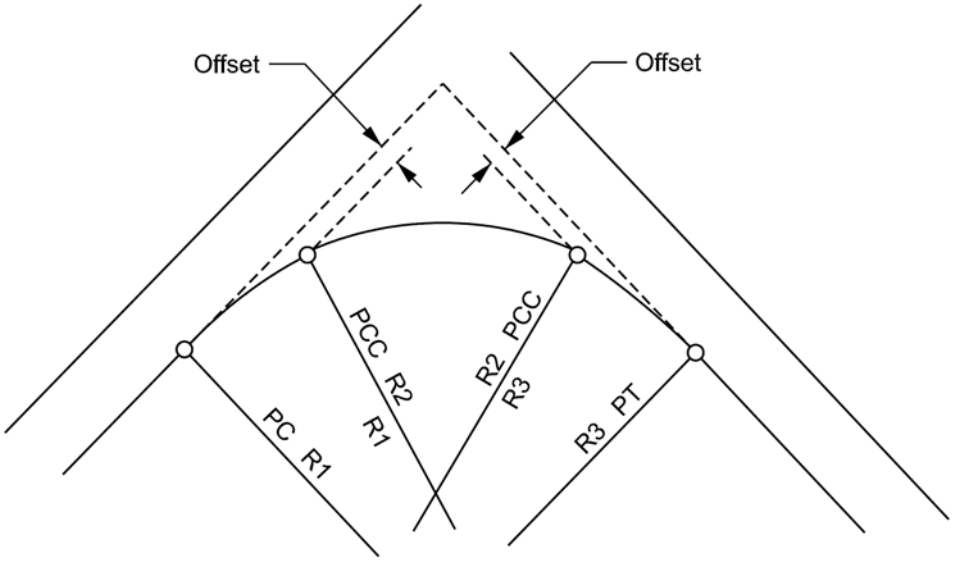


Figure 12-8 Intersection Edge-of-Pavement Design Using 3-Centered Compound Curve – SYMMETRIC

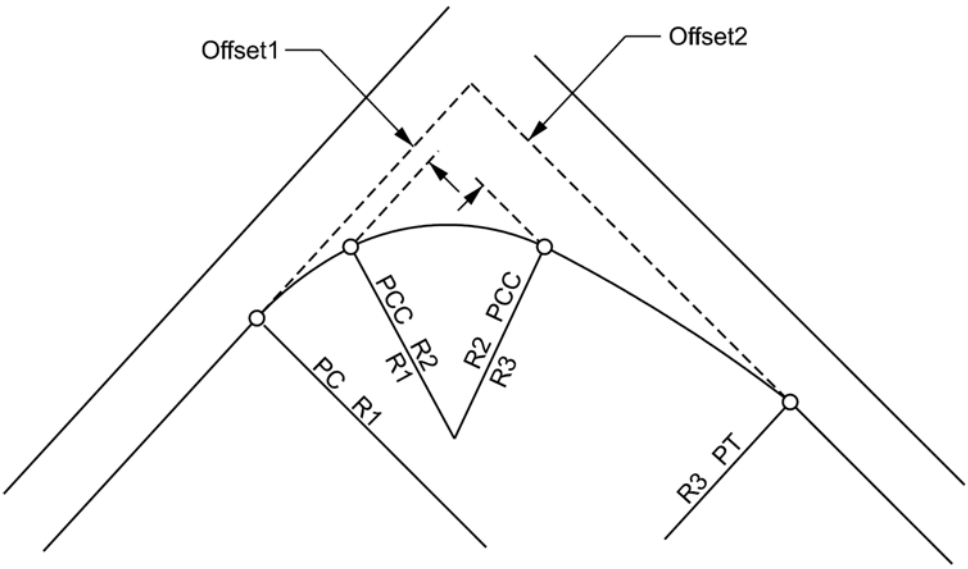


Figure 12-9 Intersection Edge-of-Pavement Design Using 3 Centered Compound Curve – ASYMMETRIC

Pavement Widths for Turning Roadways

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 and may be designed for one-way or two-way operations, depending on the geometric pattern of the intersection. Widths determined for turning roadways may also apply on through roadways within an intersection, such as between channelizing islands.

Pavement widths for turning roadways are classified for the following types of operations:

- Case I - one-lane, one-way operation with no provision for passing a stalled vehicle
- Case II - one-lane, one-way operation with provision for passing a stalled vehicle
- Case III - two-lane operation, either one-way or two-way

Widths under Case I usually are used for minor turning movements and for moderate turning volumes where the connecting roadway is relatively short. The chance of a vehicle breakdown is remote under these conditions, but one of the edges of pavement preferably should have either a mountable curb or be flush with the shoulder.

Under Case II, widths are determined to allow operation at low speed and with restricted clearance past a stalled vehicle. These widths are applicable to all turning movements of moderate to heavy traffic volumes that do not exceed the capacity of a single-lane connection. In the event of a breakdown, traffic flow can be maintained at somewhat reduced speed. Many ramps and connections at channelized intersections are in this category.

Widths under Case III are applicable where operation is two-way or where operation is one-way but two lanes are needed to handle the traffic volume.

Exhibit 2-2 of the current AASHTO publication *A Policy on Geometric Design of Highways and Streets* may be used to determine the minimum turning radii for the appropriate design vehicle. Table 12-3 & 12-4 can be used to determine needed design widths for turning roadways. Exhibits 9-19 and 9-20 of the current AASHTO publication *A Policy on Geometric Design of Highways and Streets* may be used for typical edge of pavement designs given the design vehicle and angle of turn. The designer may elect however, to lay out the intersection graphically to determine the best design for that particular intersection.

Table 12-4 Design Widths of Pavements for Turning Roadways

R Radius on Inner Edge of Pavement (feet)	PAVEMENT WIDTH (feet)								
	Case I One-lane, one-way operation – no provision for passing a stalled vehicle			Case II One-lane, one-way operation -- with provision for passing a stalled vehicle			Case III Two-lane operation -- either one-way or two-way		
	Design Traffic Condition *								
	A	B	C	A	B	C	A	B	C
50	18	18	23	20	26	30	31	36	45
75	16	17	20	19	23	27	29	33	38
100	15	16	18	18	22	25	28	31	35
150	14	15	17	18	21	23	26	29	32
200	13	15	16	17	20	22	26	28	30
300	13	15	15	17	20	22	25	28	29
400	13	15	15	17	19	21	25	27	28
500	12	15	15	17	19	21	25	27	28
Tangent	12	14	14	17	18	20	24	26	26
Width modification regarding edge-of-pavement treatment:									
No Stabilized Shoulder	None			None			None		
Mountable Curb	None			None			None		
Barrier curb**									
One Side	Add 1 ft.			None			Add 1 ft.		
Two Sides	Add 2 ft.			Add 1 ft.			Add 2 ft.		
Stabilized Shoulder One or Both Sides	Lane width for conditions B & C on tangent may be reduced to 12 ft. where shoulder is 4ft. or wider.			Deduct shoulder width; minimum pavement width as under Case I			Deduct 2 ft. where shoulder width is 4 ft. or wider		

* Traffic Condition A -- Predominately P vehicles but some consideration for SU trucks.
Traffic Condition B -- Sufficient SU vehicles to govern design, but some consideration for semi trailer vehicles.
Traffic Condition C -- Sufficient semi trailer, WB-40 or WB-50 vehicles to govern design.

** Dimension to face of curb, gutter pan included with surface width.

Table 12-5 Design Widths of Pavements for Turning Roadways

R Radius on Inner Edge of Pavement (feet)	PAVEMENT WIDTH (M)								
	Case I One-lane, one-way operation – no provision for passing a stalled vehicle			Case II One-lane, one-way operation -- with provision for passing a stalled vehicle			Case III Two-lane operation -- either one-way or two-way		
	Design Traffic Condition *								
	A	B	C	A	B	C	A	B	C
15	5.4	5.5	7.0	6.0	7.8	9.2	9.4	11.0	13.6
25	4.8	5.0	5.8	5.6	6.9	7.9	8.6	9.7	11.1
30	4.5	4.9	5.5	5.5	6.7	7.6	8.4	9.4	10.6
50	4.2	4.6	5.0	5.3	6.3	7.0	7.9	8.8	9.5
75	3.9	4.5	4.8	5.2	6.3	6.7	7.7	8.5	8.9
100	3.9	4.5	4.8	5.2	5.9	6.5	7.6	8.3	8.7
125	3.9	4.5	4.8	5.1	5.9	6.4	7.6	8.2	8.5
150	3.6	4.5	4.5	5.1	5.8	6.4	7.5	8.2	8.4
Tangent	3.6	4.2	4.2	5.0	5.5	6.1	7.3	7.9	7.9
Width modification regarding edge-of-pavement treatment:									
No Stabilized Shoulder	None			None			None		
Mountable Curb	None			None			None		
Barrier curb**									
One Side	Add 0.3m			None			Add 0.3m		
Two Sides	Add 0.6m			Add 0.3m			Add 0.6m		
Stabilized Shoulder One or Both Sides	Lane width for conditions B & C on tangent may be reduced to 3.6m where shoulder is 1.2m or wider.			Deduct shoulder width; minimum pavement width as under Case I.			Deduct 0.6m where shoulder width is 1.2m or wider.		

* Traffic Condition A -- Predominately P vehicles but some consideration for SU trucks.
Traffic Condition B -- Sufficient SU vehicles to govern design, but some consideration for semi trailer vehicles.
Traffic Condition C -- Sufficient semi trailer, WB-40 or WB-50 vehicles to govern design.

** Dimension to face of curb, gutter pan included with surface width.

AUXILIARY LANES

Under conditions of relatively high traffic volumes, traffic congestion problems can be significantly alleviated with auxiliary lanes to handle turning movements.

One common practice in commercial and industrial areas is to provide a continuous left turn lane (two-way) in a paved, flush, traversable median which can be used for left turn storage by traffic in either direction. The median lane should be 12 feet (3.6m), but not less than 10 feet (3.0m) wide and should be clearly marked for the purpose.

Auxiliary lanes also can be introduced to provide for both left turns and right turns at intersections. The need for such lanes is determined by capacity analysis and the acceptable level of service designated for the facility. The lanes should be at least 9 feet (2.7m) wide for reconstruction and resurfacing projects and at least 10 feet (3.0m), preferably 12 feet (3.6m) for new construction projects. Auxiliary lane shoulders can be reduced to 2' (0.6 m) wide on rural sections and 0' wide on sections with curb and gutter.

Typical turn lane designs can be found in Figures 12-13 and 12-14.

The length of auxiliary lanes consists of five components:

1) Approach Taper
2) Deceleration Length
3) Bay Taper
4) Storage Length, and
5) Departure Taper.

1) The length of the Approach Taper varies depending on the operating speeds. Guidelines for determining lengths are:

   For speeds of 45 mph (70 kph) and over: $L = WS$, $(L = 0.6\ WS)$

   For speeds under 45 mph (70 kph): $L = WS^2/60$, $(L = WS^2/100)$

   where: L = Length of entering taper, ft., (m)
   W = Width to be tapered, ft., (m)
   S = Operating Speed, mph (kph)

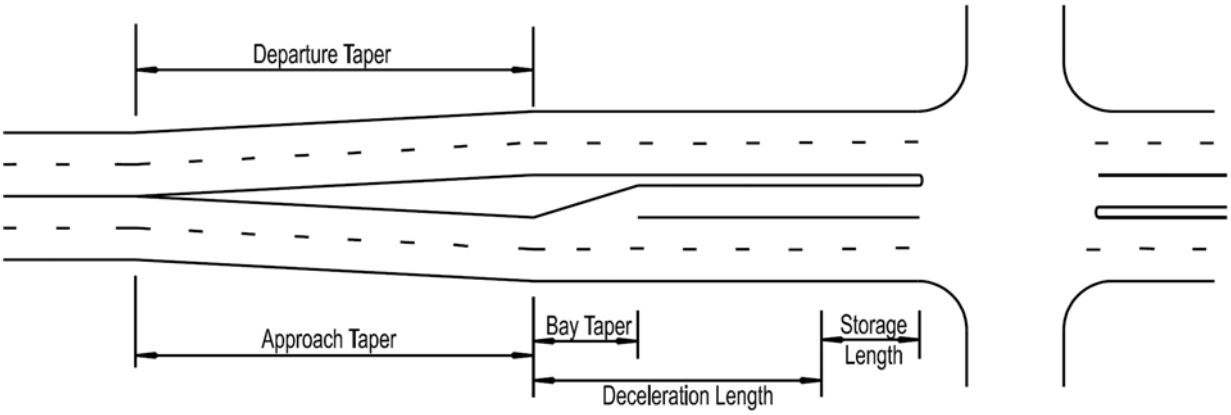


Figure 12-10 Auxiliary Lane Components

2) The Deceleration Length is that required for a comfortable stop from a speed that is typical of the average running speed on the facility. The Bay Taper can be considered part of the deceleration length.

   On many facilities, it is not practical to provide full length of auxiliary lane for deceleration and, in many cases; the storage length overrides the deceleration length. In such cases, at least part of the decelerations must be accomplished before entering the auxiliary lane. Inclusion of the taper length as part of the deceleration distance for an auxiliary lane assumes that an approaching turning vehicle can decelerate comfortably up to 10 mph (15 km/h) in a through lane before entering the auxiliary lane. Shorter auxiliary lane lengths will increase the speed differential between turning vehicles and through traffic. A 10 mph (15 km/h) differential is commonly considered acceptable on arterial roadways. Higher speed differentials may be acceptable on collector highways and streets due to higher levels of driver tolerance for vehicles leaving or entering the roadway due to slow speeds or high volumes.

   See Figure 12-13 for recommended deceleration lengths as function of design speed. Note that the deceleration lengths shown in the table are based on the assumption that the turning vehicle slows at the start of the Bay Taper.

3) The Bay Taper should be a straight line taper with ratios of 5:1 to 10:1. Higher speed facilities should generally have longer tapers.

4) The Storage Length should be sufficiently long to store the number of vehicles likely to accumulate during the average daily peak period.

At unsignalized intersections the length (exclusive of taper) should be based on the number of vehicles likely to arrive in an average 2-minute period within the peak hour.

At signalized intersections, the required length depends on the signal cycle length, the signal phasing arrangement and the rate of arrivals and departures of left turning vehicles.

In rural areas, a typical Storage Length of 100 feet (30m) should be used.

5) The Departure Taper should normally be equal in length to that of the approach taper and should begin opposite the beginning of the Bay Taper. .

TURN LANE WARRANTS

- Warranted - Where turn lanes are warranted, the typical taper and lane lengths should be as shown in Figure 12-13 which is for use on rural or urban and divided or undivided roadways.

- Non-warranted - Where turn lanes do not meet warrants, but are deemed necessary for other reasons, Figure 12-14 may be used as a minimum design.

Distances shown in Figures 12-13 and 12-14 should be adjusted for steep grades as shown in Tables 13-4 and 13-4m of Chapter 13 - Interchanges.

Left Turn Lane Warrants

Left turn lanes should be provided where through and turning volumes create an operational or a potential accident problem. The following nomograph provides a means of determining whether a left turn lane is warranted. A separate left turn lane is not required on roadways that have a design hour volume that is less than 150.

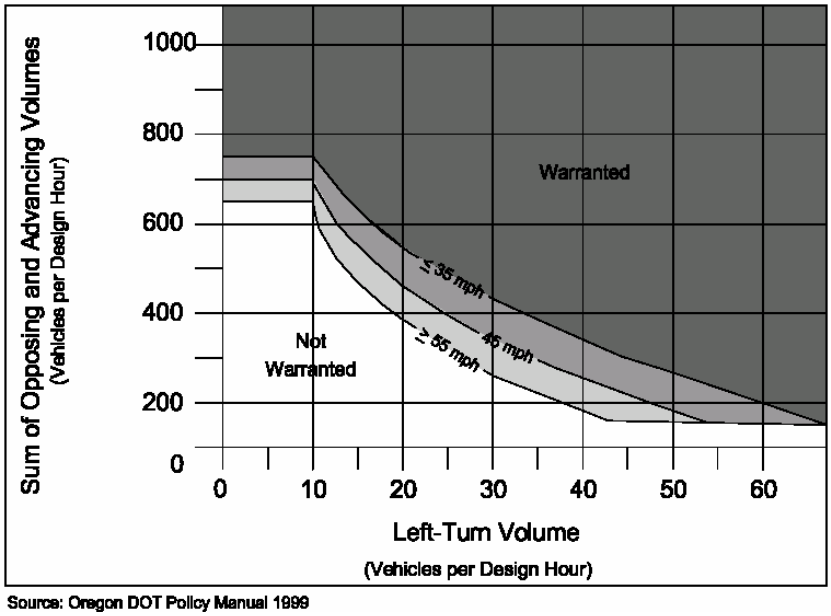


Figure 12-11 Left Turn Lane Warrants

A separate left turn lane may be warranted if five or more reported intersection related accidents have occurred within a 12-month period.

Right Turn Lane Warrants

Right turn lanes should be provided where indicated in the following graph. A separate right turn lane may also be warranted if five or more reported accidents, of the type susceptible to correction by a right turn lane, have occurred within a 12-month period.

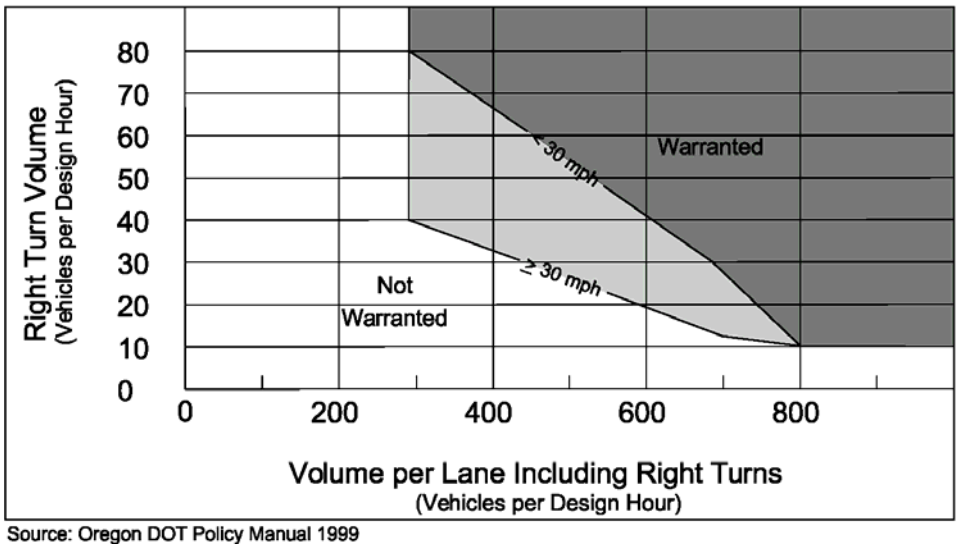
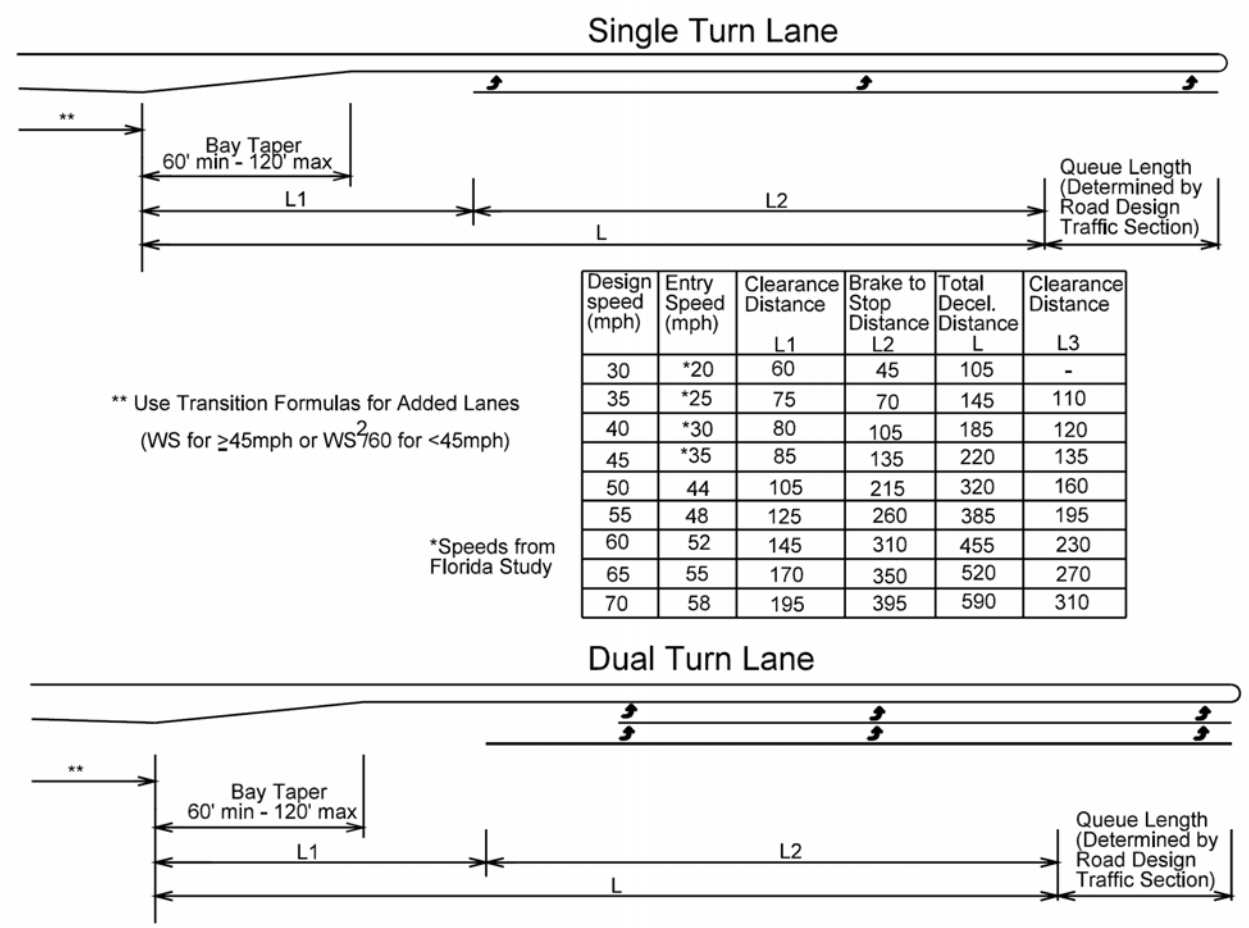
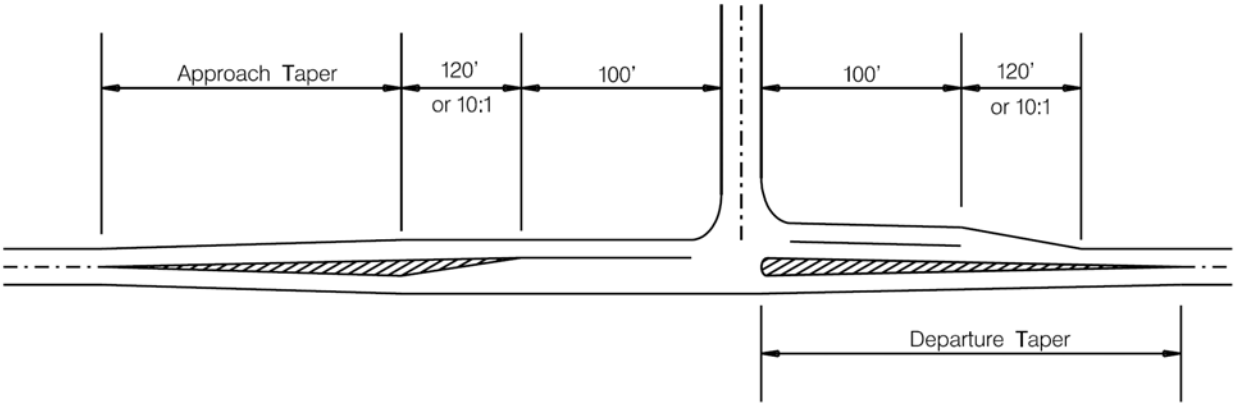


Figure 12-12 Right Turn Lane Warrants



Design speed (mph)	Entry Speed (mph)	Clearance Distance L1	Brake to Stop Distance L2	Total Decel. Distance L	Clearance Distance L3
30	*20	60	45	105	-
35	*25	75	70	145	110
40	*30	80	105	185	120
45	*35	85	135	220	135
50	44	105	215	320	160
55	48	125	260	385	195
60	52	145	310	455	230
65	55	170	350	520	270
70	58	195	395	590	310

Figure 12-13 Right or Left Turn Lane Design (Warranted)



Approach/Departure Taper = WS for ≥ 45mph or $WS^2/60$ for <45 mph
where: W = Width of Transition
S = Design Speed

Figure 12-14 Minimum Turn Lane Design (Non-Warranted)

CHANNELIZATION

Channelization is the separation or regulation of conflicting traffic movements into definite paths of travel by traffic islands or pavement marking to facilitate the safe and orderly movements of both vehicles and pedestrians. Proper channelization increases capacity, improves safety, provides maximum convenience, and instills driver confidence. Improper channelization has the opposite effect and may be worse than none at all. Over channelization should be avoided because it could create confusion and worsen operations.

Purpose

Channelization of at-grade intersections is generally warranted for one or more of the following factors.

- The paths of vehicles are confined by channelization so that not more than two paths cross at any one point.
- The angle and location at which vehicles merge, diverge or cross are controlled.
- The amount of paved area is reduced and thereby decreases vehicle wander and narrows the area of conflict between vehicles.
- Clearer indications are provided for the proper path in which movements are to be made.
- The predominant movements are given priority.
- Areas are provided for pedestrian refuge.
- Space is provided for traffic control devices so that they can be more readily perceived.
- Prohibited turns are controlled.

Design Principles

Design of a channelized intersection usually involves the following significant controls: the type of design vehicle, the cross sections on the crossroads, the projected traffic volumes in relation to capacity, the number of pedestrians, the speed of vehicles, and the type and location of traffic control devices. Furthermore, the physical controls such as right-of-way and terrain have an effect on the extent of channelization that is economically feasible.

Certain principles should be followed in the design of a channelized intersection, but the extent to which they are applied will depend on the characteristics of the total design plan. These principles are as follows:

- Motorists should not be confronted with more than one decision at a time.
- Unnatural paths that require turns greater than 90 degrees or sudden and sharp reverse curves should be avoided.
- Areas of vehicle conflict should be reduced as much as possible. Channelization should be used to keep vehicles within well-defined paths that minimize the area of conflict.
- The points of crossing or conflict should be studied carefully to determine if such conditions would be better separated or consolidated to simplify design with appropriate control devices added to ensure safe operation.
- Refuge areas for turning vehicles should be provided clear of through traffic.
- Prohibited turns should be blocked wherever possible.
- Location of essential control devices should be established as a part of the design of a channelized intersection.
- Channelization may be desirable to separate the various traffic movements where multiple-phase signals are used.
- Conflict points should be separated.

Islands

A principle concern in channelization is the design of the islands. An island is a defined area between traffic lanes for control of vehicle movements. It may range from an area delineated by barrier curbs to a pavement area marked by paint.

Islands are grouped in three major functional areas:

- Channelizing Islands - designed to control and direct traffic movement, usually turning;
- Divisional Islands - designed to divide opposing or same direction traffic streams, usually through movements; and
- Refuge Islands - to provide refuge for pedestrians.

Most islands combine two or all of these functions. Several types and shapes of islands are shown in Figure 12-15.

Islands may be delineated or outlined by a variety of treatments, depending on their size, location and function. Types of delineation include: (1) raised islands outlined by curbs, (2) islands delineated by pavement markings, buttons, or raised (jiggle) bars placed upon all paved areas, and (3) non-paved areas formed by the pavement edges, possible supplemented by delineators on posts or other guide posts. Typically, in an urban setting the islands will be concrete and in a rural area the islands will be delineated with pavement parking tape or paint.

Islands should be sufficiently large to command attention. Curbed islands normally should be no smaller than about 50 square feet ($4.6m^2$) for urban streets and about 75 square feet ($6.9m^2$) for rural intersections. However, 100 square feet ($9.3m^2$) minimum is preferable for both. Triangular islands should not be less than about 12 feet (3.6m), preferable 15 feet (4.6m), on a side after rounding the corners. Elongated or divisional islands should not be less than 4 feet (1.2m) wide and 20 to 25 feet (6m to 7.6m) long.

Approach ends of islands should be offset from the edges of the traveled way in order to funnel drivers smoothly into the desired path. Failure to offset approach ends can make an island appear more restrictive than it actually is and can have a psychological effect on drivers causing them to make erratic movements as they approach the intersection. For larger islands the offset should be increased in direct relation to the design speed and the width of the open area preceding the end of the island. Tapers should be smooth and extended to provide a natural transition from the offset back to the controlling edge of the island.

In the case of curbed islands, the typical offset from the face of curb to the edge of traveled lane should be 4 to 5 feet (1.2m to 1.5m). For the approach end of larger curbed islands, the offset from the face of curb to the edge of the traveled lane should normally be at least 2 feet (.6m) greater than the offset to the side of the controlling edge of island. Where the through road has shoulders, the entire curbed island should be offset from the through traveled lane by an amount equal to the shoulder width.

Figure 12-16 can be used to estimate the offset needed for island approach noses. Refer to Exhibits 9-37 and 9-38 of the current AASHTO publication *A Policy on Geometric Design of Highways and Streets* for other details (i.e. radius) of corner island designs.

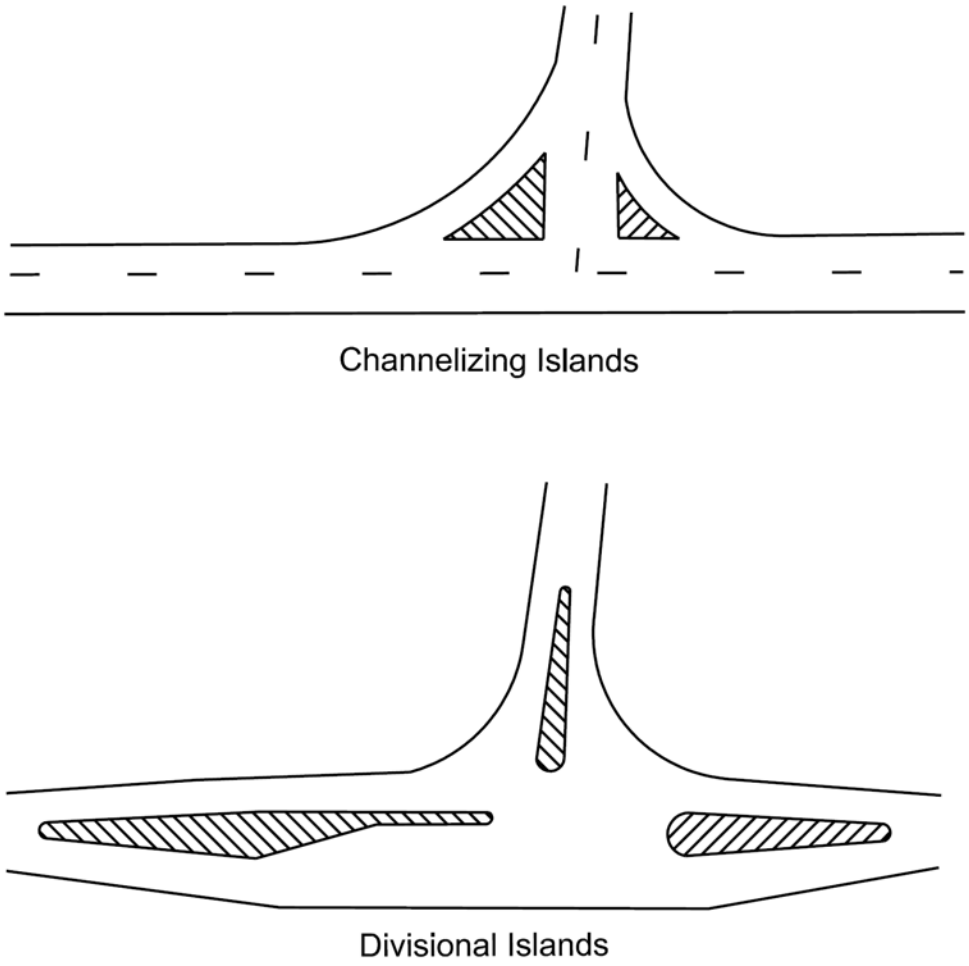
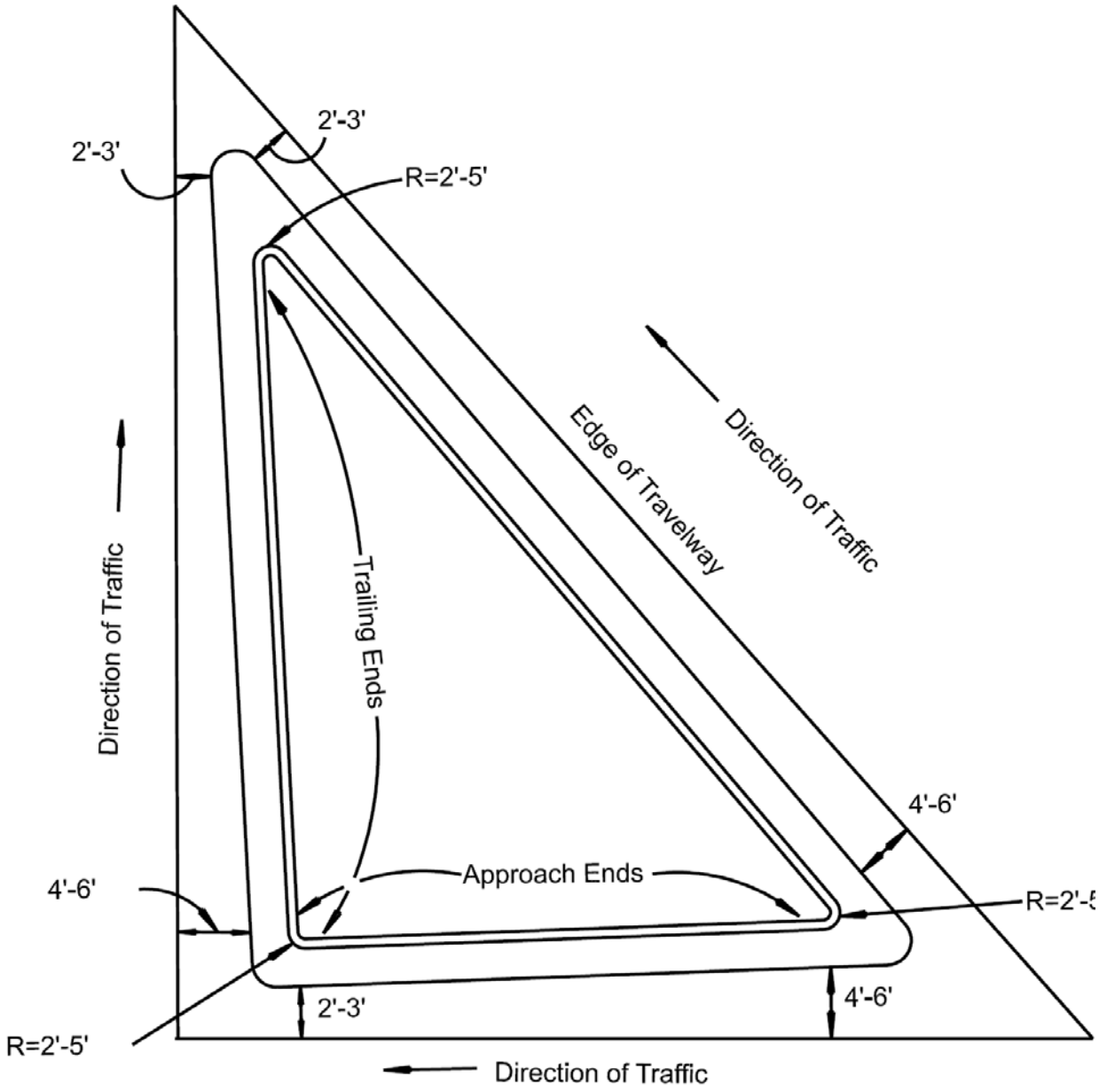


Figure 12-15 Types and Shapes of Islands.



Note: Offset values at the high end of the range are appropriate for high speed roadways and large islands.

For roadways with shoulders the island should be offset from the outside edge of shoulder

Figure 12-16 Offset of Island Approach Noses

INTERSECTION SIGHT DISTANCE

The operator of a vehicle approaching an intersection at grade should have an unobstructed view of the whole intersection and of a sufficient length of the intersecting highway to permit control of the vehicle to avoid collisions. The minimum sight distance considered safe under various assumptions of physical conditions and driver behavior is directly related to vehicle speeds and to the resultant distances traversed during perception, reaction time, and braking.

Minimum Sight Triangles

Specified areas along intersection approach legs and across their included corners should be clear of obstructions that might block a driver's view of potentially conflicting vehicles. These specified areas are known as clear sight triangles. The dimensions of the legs of the sight triangles depend on the design speeds of the intersecting roadways and the type of traffic control used at the intersection. These dimensions are based on observed driver behavior and are documented by space-time profiles and speed choices of drivers on intersection approaches. Two types of clear sight triangles are considered in intersection design, approach sigh triangles and departure sight triangles.

Approach Sight Triangles

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.

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 feet above the road) to the approaching vehicle (3.5 feet above the road).

Each quadrant of an intersection should contain a triangular area free of obstructions that might block an approaching driver's view of potentially conflicting vehicles. The length of the legs of this triangular area, along both intersection roadways, should be such that the drivers can see and potentially conflicting vehicles in sufficient time to slow or stop before colliding within the intersection. Figure 12-17(A) shows typical clear sight triangles to the left and to the right for a vehicle approaching an uncontrolled or yield-controlled intersection.

The vertex of the sight triangle on a minor-road approach (or an uncontrolled approach represents the decision point for the minor-road driver. This decision point is the location at which the minor-road driver should begin to brake to a stop if another vehicle is present on an intersecting approach. The distance from the major road, along the minor road, is illustrated by the dimension “a” in Figure 12-17(A).

The geometry of a clear sight triangle is such that when the driver of a vehicle without the right of way sees a vehicle that has the right of way on an intersection approach, the diver of that potentially conflicting vehicle can also see the first vehicle. Dimension “b” illustrates the length of this leg of the sight triangle. Thus, the provision of a clear sight triangle for vehicles without the right of way also permits the drivers of vehicles with the right of way to slow, stop, or avoid other vehicles, should it become necessary.

Although desirable at higher volume intersections, approach sight triangles like those shown in Figure 12-17(A) are not needed for intersection approaches controlled by stop signs or traffic signs. In that case, the need for approaching vehicles to stop at the intersection is determined by the traffic control devices and not by the presence or absence of vehicles on the intersecting approaches.

Departure Sight Triangles

A second type of clear sight triangle provides sight distance sufficient for a stopped driver on a minor road approach to depart from the intersection and enter or cross the major road. Figure 12-17(B) shows typical departure sight triangles to the left and to the right of the location of a stopped vehicle on the minor road. Departure sight triangles should be provided in each quadrant of each intersection approach controlled by stop or yield signs. Departure sight triangles should also be provided for some signalized intersection approaches.

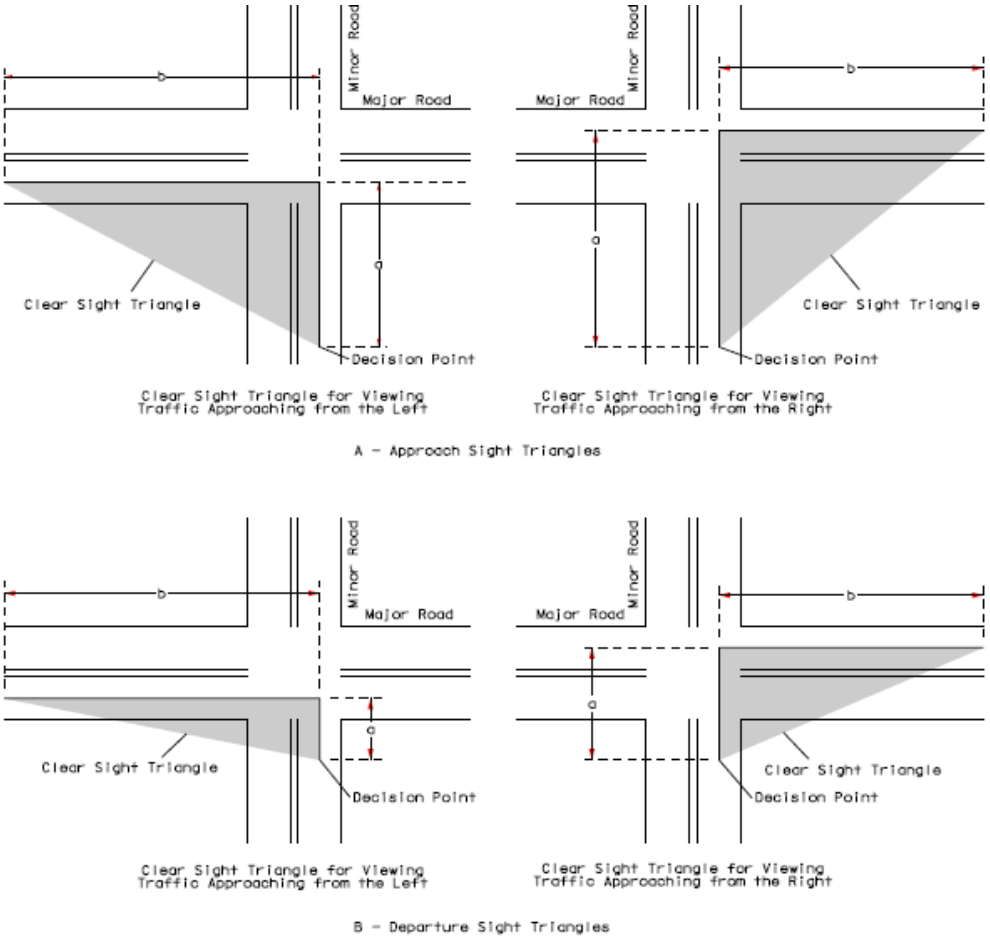


Figure 12-17 Intersection Sight Triangles

Identification of Sight Obstructions within Sight Triangles

The profiles of the intersecting roadways should be designed to provide the recommended sight distances for drivers on the intersection approaches. Within a sight triangle, any object at a height above the elevation of the adjacent roadway that would obstruct the driver's view should be removed or lowered, if practical.

The determination of whether an object constitutes a sight obstruction should consider both the horizontal and vertical alignment of both intersecting roadways, as well as the height and position of the object. In making this determination, it should be assumed that the driver's eye is 3.5 ft above the roadway surface and that the object to be seen is 3.5 ft above the surface of the intersecting road.

This object height is based on a vehicle height of 4.35 ft, which represents the 15th percentile of vehicle heights in the current passenger car population less an allowance of 10 in. This allowance represents a near-maximum value for the portion of passenger car height that needs to be visible for another driver to recognize it as the object. Th use of an object height equal to the driver eye height makes intersection sight distances reciprocal (i.e., if one driver can see another vehicle, then the driver of that vehicle can also se the first vehicle).

Intersection Control

The recommended dimensions of the sight triangles vary with the type of traffic control used at an intersection because different types of control impose different legal constraints on drivers and, therefore, result in different driver behavior. Procedures to determine sight distances at intersections are presented in Chapter 9 of the current AASHTO publication *A Policy on Geometric Design of Highways and Streets* according to different types of traffic control, as follows.

- Case A – Intersection with no control
- Case B – Intersection with stop control on the minor road
  - Case B1 – Left turn from the minor road
  - Case B2 – Right turn from the minor road
  - Case B3 – Crossing maneuver from the minor road
- Case C – Intersection with yield control on the minor road
  - Case C1 – Crossing maneuver from the minor road
  - Case C2 – Left or right turn from the minor road
- Case D – Intersection with traffic signal control
- Case E – Intersection with all-way stop control
- Case F – Left turns from the major road

Effect of Skew

When two highways intersect at an angle considerably less than a right angle, e.g., less than 60°, and when realignment to increase the angle of intersection is not justified, some of the factors for determination of corner sight distance may need adjustment.

As shown in Figure 12-18, for skewed intersections, the legs of the sight triangle will lie along the intersection approaches and each sight triangle will be larger or smaller than the corresponding sight triangle would be at a right-angle intersection. The area within each sight triangle should be clear of potential sight obstructions.

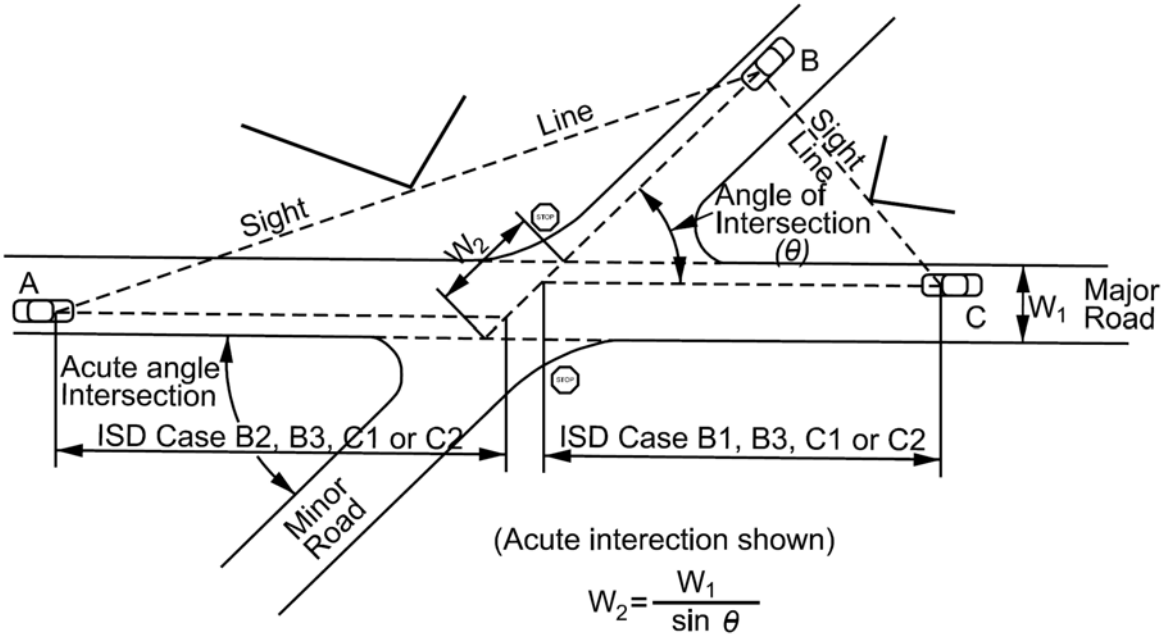


Figure 12-18 Sight Distance at Intersections, Effect of Skew

For an obtuse-angle quadrant, the angle between the sight lane A-B and the path of either vehicle is small, therefore vehicle operators can look across the full sight triangle area with only a little side glance from the vehicle path. For an acute-angle quadrant, sight line B-C, operators are required to turn their heads considerably to see across the whole sight triangle area. The difficulty of looking for approaching traffic makes it undesirable to treat the intersection under the assumptions of Case A, even where traffic volumes on both roads is low. Treatment by Case B or Case C, whichever is larger, should be used at oblique-angle intersections.

Effect of Vertical Profiles

The evaluation of sight distance at intersections in Case C is based on the safe stopping distance of a vehicle traveling at a stated speed on level highways. One or more of the roads approaching the intersection may not be level. A vehicle descending a grade requires a somewhat greater distance to stop than does one on a level grade; also, a vehicle ascending a grade requires less distance in which to stop.

The differences in stopping distances on various grades at intersections are the same as those given in Chapter 3, of the current AASHTO publication *A Policy on Geometric Design of Highways and Streets*. The differences indicate that grades up to 3 percent have little effect on stopping sight distances. Grades on an intersection leg should be limited to 3 percent unless the sight distances are greater than the lower limits or stopping on a level grade, in which case the grades should not be greater than 6 percent.

In the Case B derivations, the time required to cross the major highway is materially affected by the grade of crossing on the minor road. Normally, the grade across an intersection is so small that it need not be considered, but when curvature on the major road requires the use of superelevation, the grade across it may be significant, in which case the sight distance along the major road should be increased.

Horizontal Control

The sight distance control as applied to horizontal alignment has an equal, if not greater, effect on design of turning roadways than the vertical control. The sight line across the inner part of the curve, clear of obstructions, should be such that the sight distance measured on an arc along the vehicle path equals or exceeds the stopping sight distance needed for the design speed. A likely obstruction may be a bridge abutment or line of columns, wall, cut sideslope, or a side or corner of a building.

Refer to Chapter 9 of the current AASHTO publication *A Policy on Geometric Design of Highways and Streets* for intersection sight distance calculation procedures.

MEDIAN OPENINGS

Median openings on divided highways (except freeways) normally will be provided at all intersections with existing roads and streets, and occasionally at other intermediate locations.

The design of a median opening and median ends should be based on traffic volumes and types of turning vehicles. Cross and turning traffic must operate in conjunction with the through traffic on the divided highway. This requirement makes it necessary to know the volume and composition of all movements occurring simultaneously during the design hours. The design of a median opening becomes a matter of considering what traffic is to be accommodated, choosing the design vehicle to use for layout controls for each cross and turning movement, investigating whether larger vehicles can turn without undue encroachment on adjacent lanes and, finally, checking the intersection for capacity. If the capacity is exceeded by the traffic load, the design must be expanded, possibly by widening or otherwise adjusting widths for certain movements. Traffic control devices such as yield signs, stop signs or traffic signals may be required to regulate the various movements effectively and to improve the efficiency of operations.

Control Radii

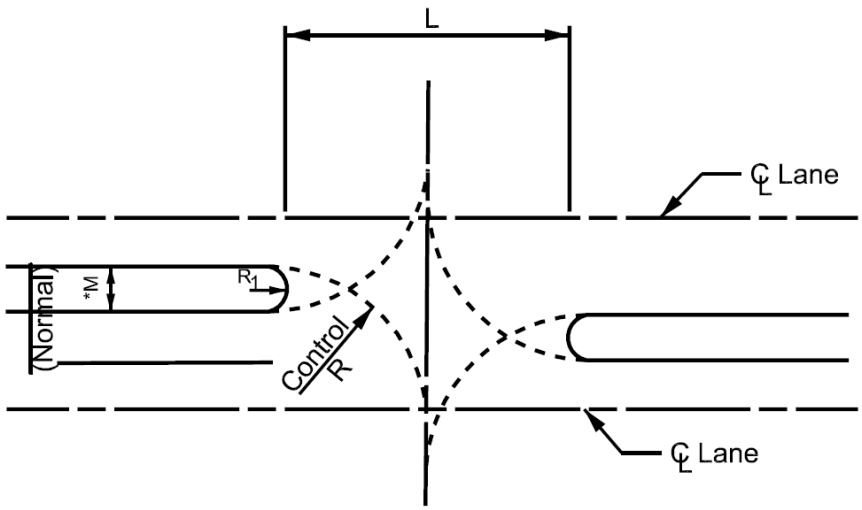
An important factor in designing median openings is the path of each design vehicle making a minimum left turn at low speed. Where the volume and type of vehicles making the left turn movement call for higher than minimum speed, the design may be made by using a radius of turn corresponding to the speed deemed appropriate. However, the minimum turning path at low speed is needed for minimum design and for testing layouts developed for one design vehicle for use by an occasional larger vehicle.

Shape of Median Ends

The ends of medians at openings may be semicircular shapes or bullet nose shapes. The shape normally depends on the effective median width at the end of the median. Criteria for selection of shape are given below:

Effective Median Width	Median End Shape
Less than 10 feet (3m)	Semicircular
10 feet (3m) - 64 feet (20m)	Bullet Nose
Over 64 feet (20m)	Treated as separate intersection

The two shapes are illustrated in Figure 12-19. The designer should evaluate each intersection to determine the best median opening shape that will accommodate the design vehicle.



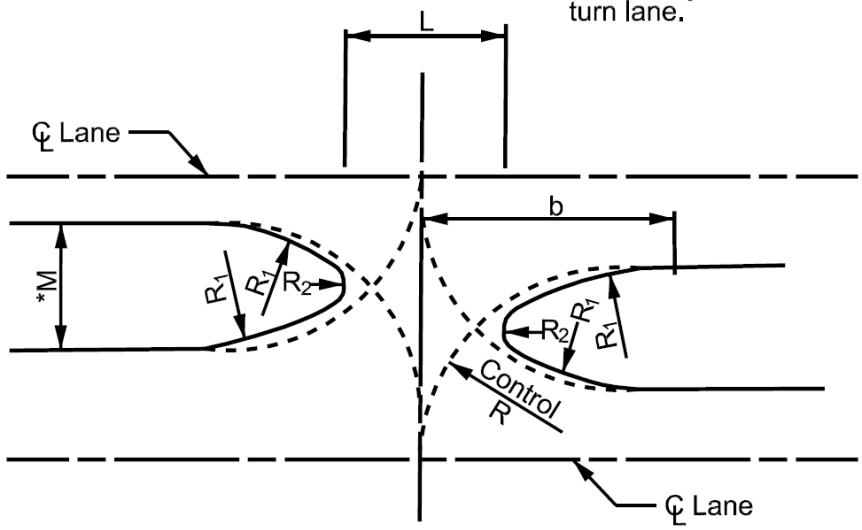
SEMICIRCULAR ENDS

*M = Less than 10 feet

L = 2 x Control R

$R_1 = \frac{M}{2}$

*The controlling median width (M), for the purpose of determining the length of opening, is the remaining width of divider adjacent to the median left-turn lane.



BULLET-NOSE ENDS

*M = 10 feet - 64 feet

$R_2 = \frac{M}{5}$

Figure 12-19 Shape of Median Ends

Median Left Turn Lanes

Median left turn lanes should be provided at intersections and at other median openings where there is a high volume of left turns or where the vehicular speeds are high.

Median widths of 20 feet or more are desirable at intersections with single turn lanes, but widths of 16 to 18 feet permit reasonable arrangements when a separator is not installed. Where two left turn lanes are used, a median width of at least 32 feet is desirable to permit the installation of two 12-foot lanes and an 8-foot separator.

Although not equal in width to a normal traveled lane, a 10-foot lane with a 2-foot curbed separator or with traffic buttons or paint lines, or both, separating the median lane from the opposing through lane may be acceptable where speeds are low, the intersection is controlled by traffic signals and right of way is limited.

Left Turn Lane Offsets

Vehicles turning left from opposing left turn lanes can restrict each other's sight distance unless the lanes are sufficiently offset. Offset is defined as the lateral distance between the left edge of a left turn lane and the right edge of the opposing left turn. When the right edge of the opposing left turn is to the left of the left edge of the left turn lane, the offset is negative as shown in Figure 12-20. If it is to the right, it is a positive offset as indicated in Figures 12-20 and 12-21.

Where the width of the center median allows, positive offsets should be considered. Typically a 2-foot positive offset will provide improved sight distance to motorists; however intersections should be evaluated on a case by case basis.

Where wider median widths allow, a tapered offset should be considered as shown in Fig. 12-22.

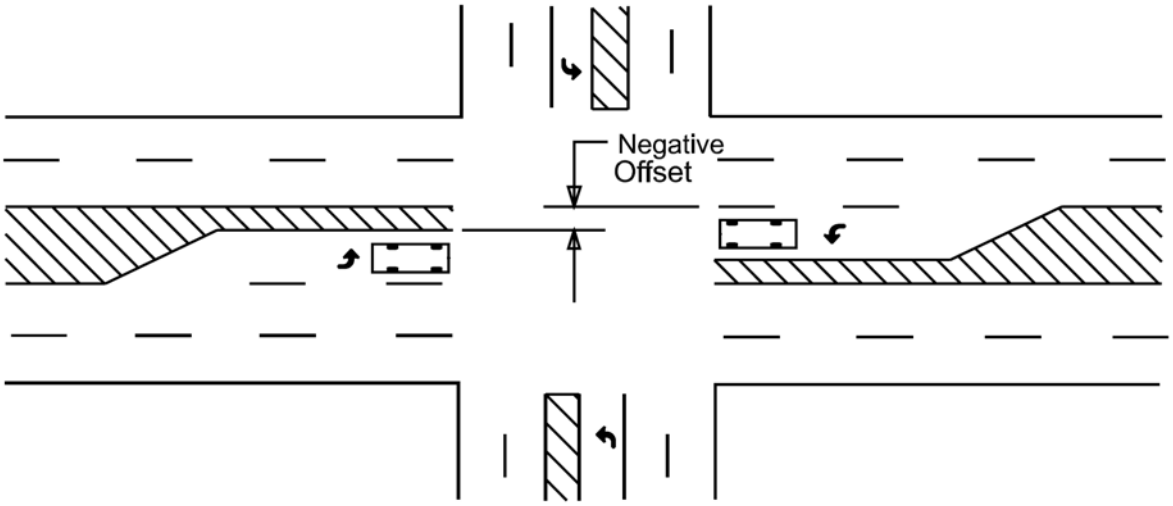


Figure 12-20 Typical Left Turn Lane Design with Negative Offset

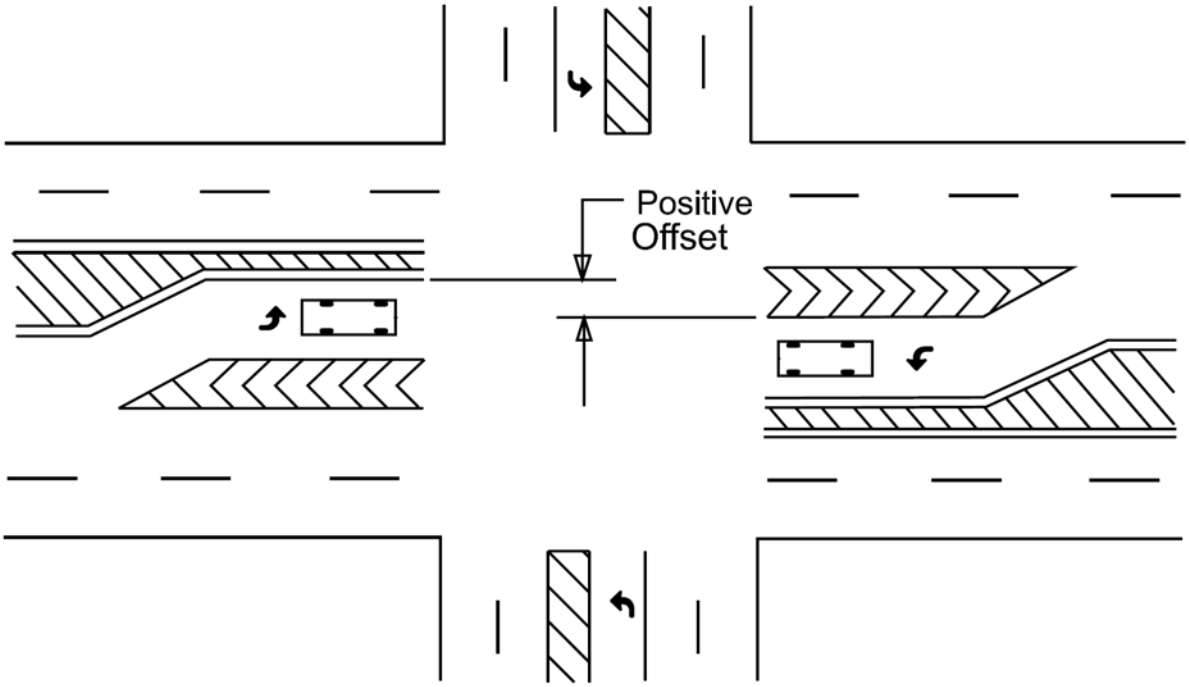


Figure 12-21 Positive Offset between Opposing Left-Turn Lanes-Parallel Design

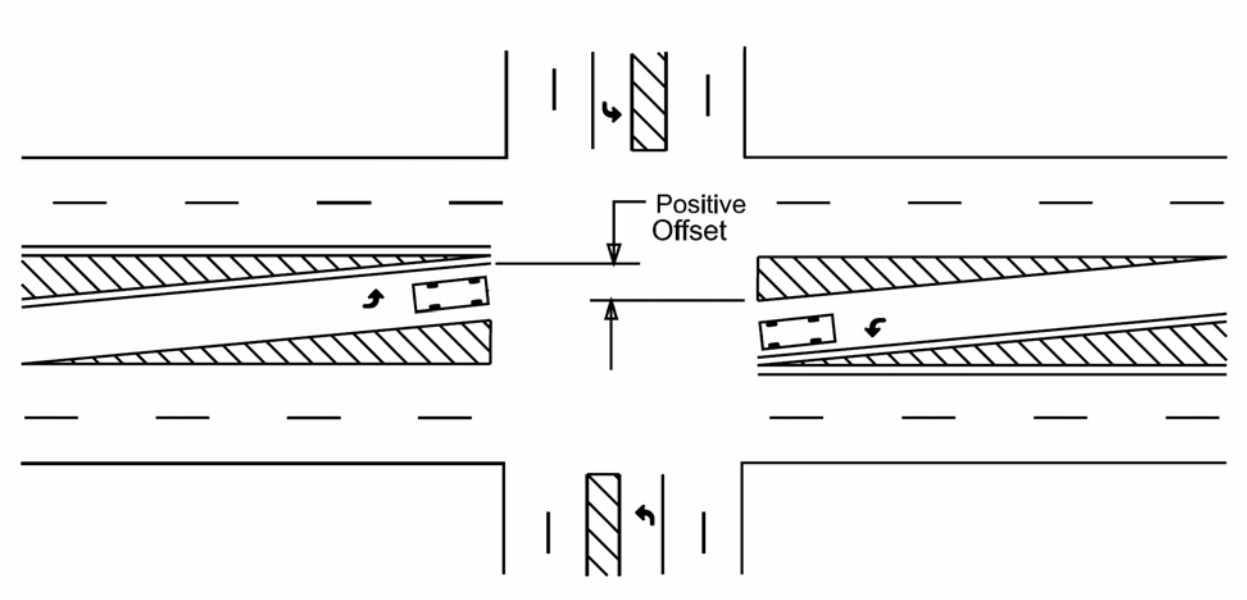


Figure 12-22 Positive Offset between Opposing Left-Turn Lanes – Tapered Design

Length of Median Opening

For any intersection on a divided highway the length of median opening should be as great as the width of crossroad roadway pavement plus shoulders and in no case less than 40 feet (12m), or less than the width of the crossroad pavement plus 8 feet (2.4m). Where the crossroad is a divided highway, the length of opening should be at least equal to the width of the crossroad roadways plus that of the median, plus 8 feet (2.4m).

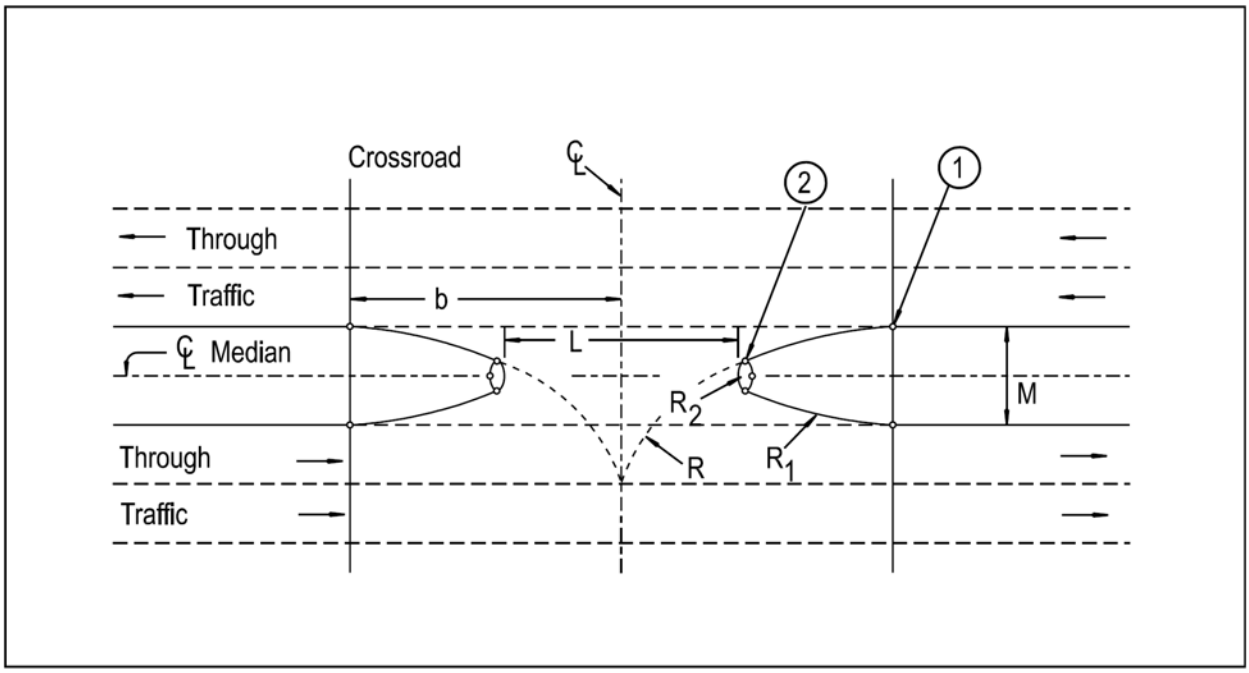
The use of a 40 foot (12m) minimum length of opening without regard to the width of median or the control radius should not be considered except at very minor crossroads. The 40 foot (12m) minimum length of opening does not apply to openings for U-turns, as discussed elsewhere.

Above-Minimum Designs for Left Turns

Median openings that enable vehicles to turn on minimum paths, and at very low speeds, are adequate for intersections where traffic for the most part proceeds straight through the intersection. Where through-traffic volumes and speeds are high and left turning movements are important, undue interference with through traffic should be avoided by providing median openings that permit turns without encroachment on adjacent lanes. This arrangement would enable turns to be made at speeds above those for the minimum vehicle paths and provide space for vehicle protection while turning or stopping. The general pattern for minimum design can be used with larger dimensions.

Median openings having above-minimum control radii and bullet-nose median ends are shown in Figure 12-13. The design controls are the three radii R, R1 and R2. Radius R is the control radius for the sharpest portion of the turn, R1 defines the turnoff curve at the median edge, and R2 is the radius of the tip. When a sufficiently large R1 is used, an acceptable turning speed for vehicles leaving the major road is ensured and a sizeable area inside the inner edge of through-traffic lane between points (1) and (2) may be available for speed change and protection from turning vehicles. Radius R1 may vary from about 80 to 400 feet (25m to 120m) or more.

The tabulated values shown (90, 150 and 230 feet) (30m, 50m and 70m) are established minimum radii for turning speeds of 20, 25 and 30 mph, (30, 40 and 50 kph) respectively. In this case the ease of turning probably is more significant than the turning speeds, because the vehicle will need to slow down to about 10 to 15 mph (15 to 25 kph) at the sharp part of the turn or may need to stop at the crossroad. Radius R2 can vary considerably, but is pleasing in proportion and appearance when it is about one-fifth of the median width. Radius R is tangent to the crossroad centerline (or edge of crossroad median). Radii R and R1 comprise the two-centered curve between the terminals of the left turn. For simplicity, the PC is established at Point (2). Radius R cannot be smaller than the minimum control radius for the design vehicle, or these vehicles will be unable to turn to or from the intended lane even at low speed. To avoid a large opening, R should be held to a reasonable minimum, e.g. 50 feet (15m), as used in Figure 12-22.



Assumed: R = 50' (15m)

$R_2 = \underline{M/5}$

M Width Of Median (Feet)	Dimensions in Feet, when						M Width Of Median (Meters)	Dimension in Meters, when					
	R_1 = 90'		R_1 = 170'		R_1 = 230'			R_1 = 30m		R_1 = 50m		R_1 = 70m	
	L	b	L	b	L	b		L	b	L	b	L	b
20	58	65	66	78	71	90	6.0	18.0	20.2	20.2	24.4	21.3	27.6
30	48	68	57	85	63	101	9.0	15.1	21.4	17.7	26.5	19.0	30.4
40	40	71	50	90	57	109	12.0	12.8	22.4	15.6	28.3	17.1	32.7
50	--	--	44	95	51	115	15.0	--	--	13.8	29.9	15.4	34.7
60	--	--	--	--	46	122	18.0	--	--	--	--	13.8	36.7
70	--	--	--	--	41	128	21.0	--	--	--	--	12.4	38.4

Figure 12-23 Above-Minimum Design of Median Openings (Bullet Nose Ends)

Median Openings for U-turns

Median openings designed to accommodate vehicles making U-turns only are needed on some divided highways. Preferably, a vehicle should be able to begin and end the U-turn on the inner lanes next to the median, but the required median widths are larger than practicable on some highways. Figure 12-23 shows the median widths required for U-turn maneuvers by various design vehicles.

The designer should, however, use AutoTurn or other available tool to graphically check the tracking of the design vehicle as it attempts to make a U-turn. In many cases, it may not be practical to design for large trucks to U-turn within the available roadway width. In such cases, other provisions need to be made for trucks.

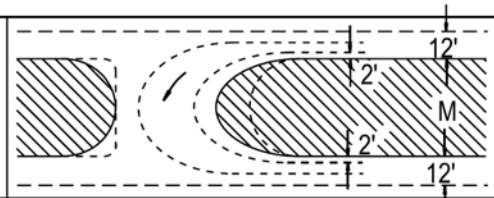
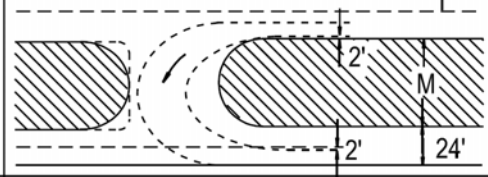
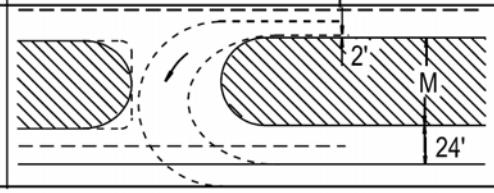
TYPE OF MANEUVER		M-Min. width of median-feet for design		
		P	SU	WB-60
		Length of design vehicle		
		19'	30'	65'
Inner Lane to Inner Lane		30	63	71
Inner Lane to Outer Lane		18	51	59
Inner Lane to Shoulder		8	41	49

Figure 12-24 Minimum Design of Median Openings For U-Turns