9.0 INTERSECTION AND INTERCHANGE DESIGN

- **General**

  This chapter covers the design standards, guidelines, and processes for designing road approaches, signalized and unsignalized at-grade intersections, and interchanges for State Highways. For information on general design considerations not fully covered in this chapter, or other parts of this manual, refer to AASHTO's "*A Policy on Geometric Design of Highways and Streets – 2001,*" Chapters 9 and 10; the FHWA "*Design of Urban Streets*," Jan. 1980; "*Technology Sharing Report 80-204,*" Chapter 8; and/or the ODOT "*Modern Roundabouts For Oregon, Report 98-SRS-522,*" and those documents referenced in Section 9.5.

  The Preliminary Design Unit can provide design assistance in the areas of interchange design, intersection design, channelizations, road approaches, roundabouts, large vehicle accommodation, and alternative mode accommodation. The Preliminary Design Unit is responsible for the preparation of all interchange layout sheets for all new and modified interchanges. In addition, the Preliminary Design Unit should be consulted about complex intersection designs that cannot meet the standards contained in this design manual.

  Information on traffic volumes and requirements can be found in Section 10.6 of this manual or further information can be obtained from the Transportation Planning Analysis Unit of the Transportation Development Division of ODOT.

9.1 ROAD APPROACHES

- **General**

The location and spacing of road approaches should be in conformance with the Access Management standards as described in the Oregon Highway Plan, Appendix C. The decision for placement and design of a road approach must be consistent with the function of the highway and optimize the safety and operational efficiency for vehicles as well as bicyclists and pedestrians. The road approach design must accommodate the turning movements of the appropriate design vehicle. All road approaches, public and private, require a construction permit from the appropriate District Maintenance Office. The District Manager and Regional

Access Management Engineer and/or Access Management sub-team should be involved early in any road approach discussion and decisions.

Road approaches can be classified as either private or public. Private approaches connect private property with a state highway across the highway right of way. Public approaches are at-grade intersections of public roadway right of way with a state highway. The remaining part of this section will discuss the design requirements for private approaches. For public approach design, see Section 9.2, Intersection Design.

9.1.1 DESIGN REQUIREMENTS FOR PRIVATE ROAD APPROACHES

Private approaches are connections to adjacent businesses, residences, or other private roadways. Generally, private approaches provide access to/from the highway and an adjacent property across the highway right of way. These approaches service all land use types including residential, commercial, and industrial. Typically, private approaches in urban areas will use a 'dust pan' style approach. This style drops the curb and possibly the sidewalk to highway grade to allow vehicular access. Standard Drawings RD725 through RD750 should be used when designing "dust pan" style private approach roads. For high volume driveways, a radius design style similar to that used by a public approach should be used. Refer to Table 9-1 to determine the style of approach to be used.

There are three general types of private road approaches. These are:

- Type A Non-curbed, ditch section highway with radius style approach.
- Type B Curbed highway section with "dust pan" style approach.
- Type C Curbed highway section with radius style approach.

Type C private approaches should be designed in accordance with Section 9.2, Intersection Design. The design of Types A and B are described below.

The design of private road approaches is affected by many factors. The type of access, volume of vehicles, type of vehicles, grades, alignment, and adjacent land use all influence the design. The spacing of approach roads should be consistent with the spacing guidelines specified in the Oregon Highway Plan, Appendix C. The designer is encouraged to read the Access Management Policy contained in the OHP for clarification of spacing guidelines.

- Road approaches should be placed so that intersection sight distance is provided. The vehicle entering the traffic stream should have a view along the highway equal to the intersection sight distance for the design speed of the highway. At a minimum, stopping sight distance for the design speed of the highway must be provided at all approaches. For more information on intersection and stopping sight distances refer to AASHTO's *"A Policy on Geometric Design of Highways and Streets-2001"* and Section 5.2 herein. Any proposed approach that cannot provide stopping sight distance must obtain an approval from the Region Access Management Engineer (RAME). For more information related to access management deviations, see Section 5.11. Cut slopes may need to be widened and roadside vegetation removed in order to provide required sight distance.

- Road approach grades should be designed so that drainage from the approach does not run on or across the traffic lane, shoulder areas, or sidewalk. In no case should the normal slope of the shoulder be altered. In urban areas where the drainage is along a curb and gutter, only the paved approach area to the right of way line may drain into the gutter. In the case of an approach below the street grade, a short vertical curve should be used to confine the drainage in the gutter line. In some instances inlets may be required on each side of the approach to collect runoff without ponding or to ensure that roadway drainage does not leave the right of way. The approach road should provide a flat landing area for vehicles entering the highway for at least 20 feet from the edge of the shoulder. A grade of two percent is desirable for these landings and four percent is the maximum. Approach grades steeper than four percent should be carefully evaluated by the Designer.

- The maximum grade break between highway shoulder and approach is eight percent for Type A and B approaches. In addition, a 20 foot landing area should be provided. In some situations, the maximum break cannot be met. The designer should attempt to achieve a roadway-to-approach transition as smooth as possible. This may require using a short vertical curve.

- The approach must accommodate the appropriate design vehicle. Generally, commercial accesses should be designed for at least a Single Unit (SU) truck design vehicle. Vehicles larger than an SU are not to be treated as the design vehicle unless 3 or more WB-40 or larger trucks are anticipated between 7:00AM and 7:00PM. Anytime the design vehicle is larger than a SU, the approach is to be designed as a radius style. When vehicles larger than an SU are anticipated, but are not the design vehicle as described above, the approach must accommodate the larger vehicle. (‘Accommodation’ only refers to the physical ability to make the maneuver including encroaching on other lanes, whereas ‘designed for’ means that design elements do not require encroachment. (See Figure 9-1 for more detail.)

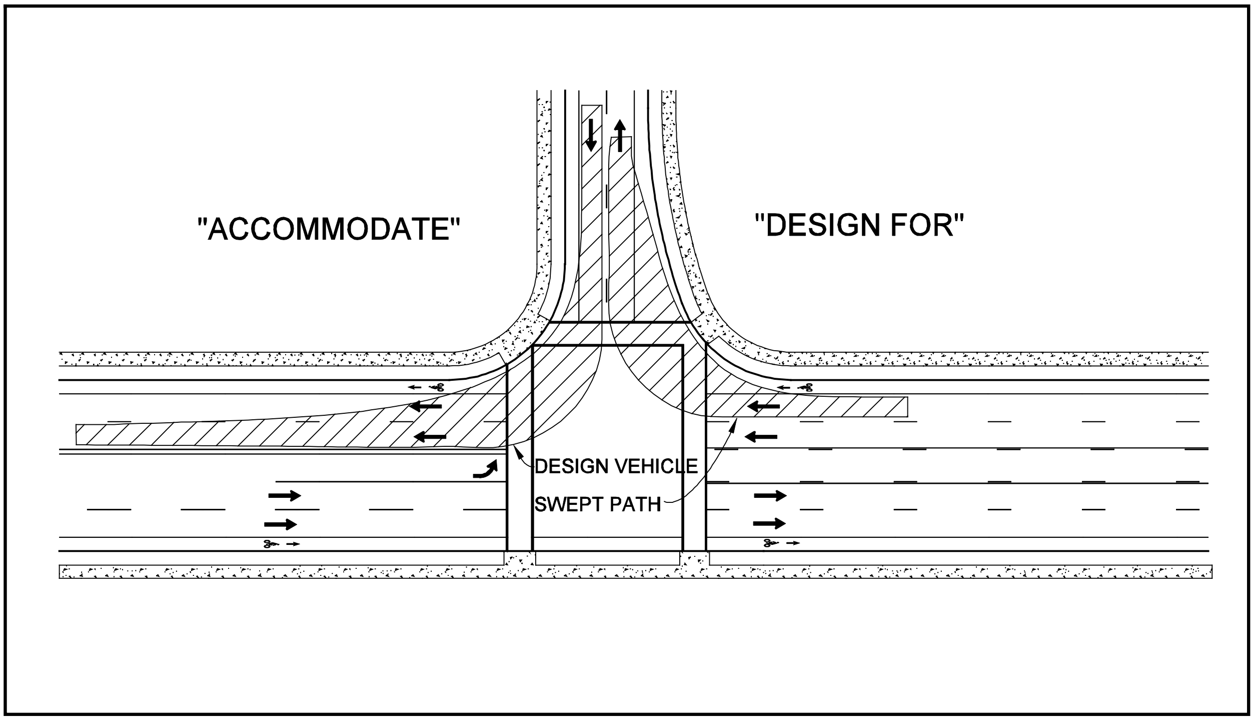


Figure 9-1
Accommodating And Designing For Vehicles

- All approaches must be designed to aid in the longitudinal crossing of pedestrians. It is preferable to maintain sidewalks at a continuous grade. However, without a buffer strip or set back, this is nearly impossible. Route continuity is also important to pedestrians. If a curbside sidewalk cannot be set back for a significant longitudinal distance, it is best to leave it curbside rather than break up the pedestrian continuity.

- All curbs and delineators used at approaches on highways without continuous curbs should be placed at the normal shoulder width from the edge of the traveled way to provide adequate shoulder adjacent to the approach.

- Approaches on opposite sides of the highway should be located across from each other whenever possible. However, under high speed and high traffic volume conditions, approaches may need to be separated to reduce the complexity and number of conflicts (see Figure 9-2). The approaches need to be separated far enough that they operate independently outside their functional areas (see Figure 9-3). Although this situation is possible at some high volume private approaches, this treatment is generally only appropriate for public road approaches. Preliminary Design and the Region Access Management Engineer should be contacted when considering separation of private approach roads. Major public roads with large volumes of through traffic should generally not be separated.

- No approach road should be constructed within the functional area of an adjacent intersection. Refer to the Access Management Policies from the Oregon Highway Plan for more information on functional area (see Figure 9-3).

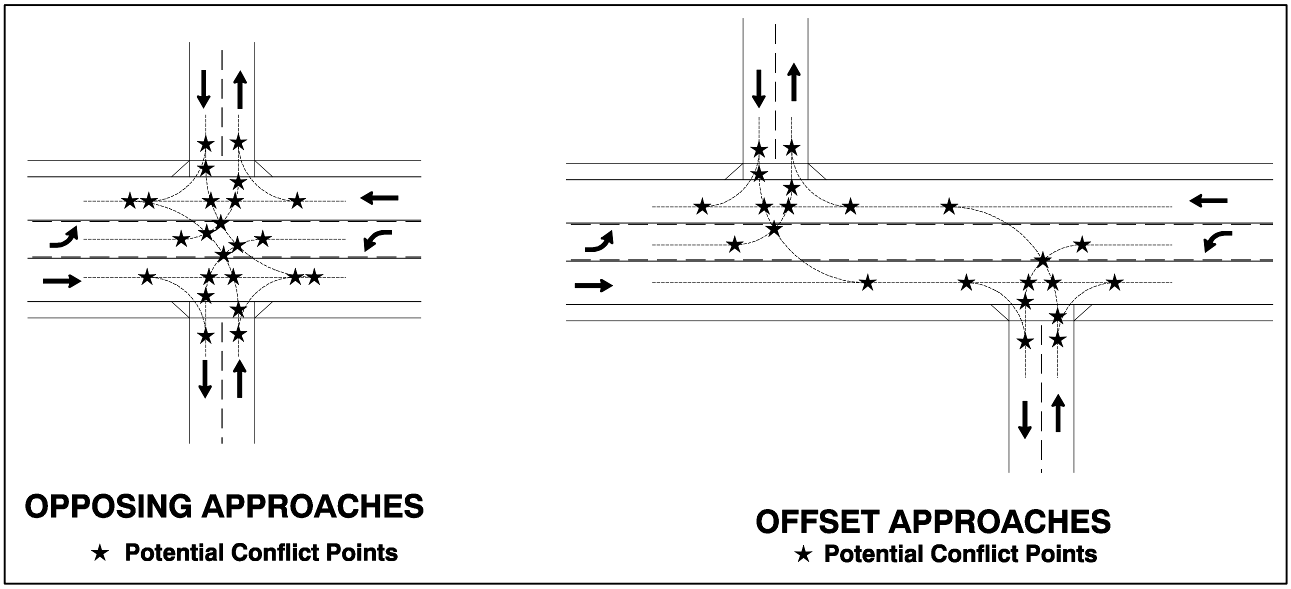


Figure 9-2
Offset Approaches

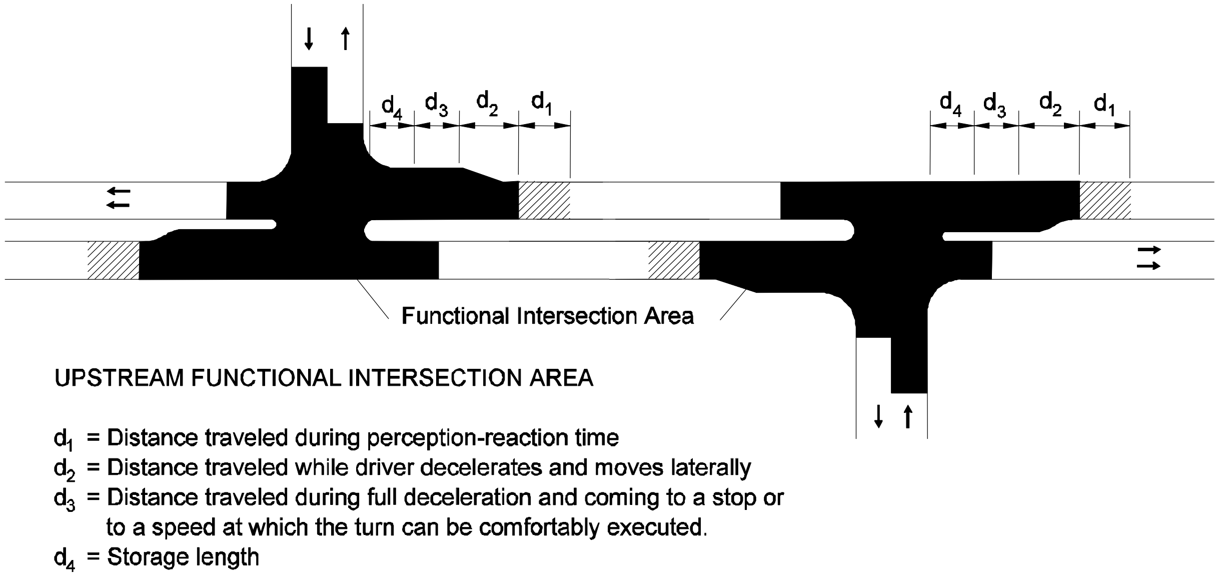


Figure 9-3
Functional Intersection Area

- Where a private approach serves a high volume of traffic, additional design and/or traffic controls may need to be incorporated into the design. High volume approaches often will require channelization along the highway. Refer to Section 9.2 for details on left and right turn lanes. In some instances, the approach may require a traffic signal in order to operate safely and efficiently. The designer should work with the Region Access Management Engineer to determine solutions for high volume private approaches and potential private approaches opposite signalized intersections. Private approaches are not allowed directly opposite interchange ramp terminals. NOTE***: All traffic signals must be approved by the State Traffic Engineer prior to installation. Generally only public road approaches should be considered for signalization. Signalizing private approaches should be avoided.***

- Type A approaches need to be designed to minimize the pedestrian longitudinal distance. This may require the design to incorporate a two-centered curve rather than a single radius when accommodating design vehicles larger than a Single Unit (SU) truck.

- The approach design and corresponding site circulation plan should specify the entry/exit throat distance. This throat distance is critical in order to provide an efficient and functional connection between the highway and adjacent property. Throat lengths are critical for commercial and industrial type land use approaches. The Transportation Planning Analysis Unit or the Region Access Management Engineer can assist with determining the appropriate throat distance. See Figure 9-4.

- **Legal Considerations for Road Approaches**

The legal issues involved with approaches are specialized and complicated. Refer to the "*Access Management Manual*" for access rights and road approach issues. This manual includes information from "*Oregon Administrative Rules, Chapter 734, Division 51 – Access Management,*" that defines legal criteria relating to road approach permitting and design. Additional information on access management can be found in Section 5.11.

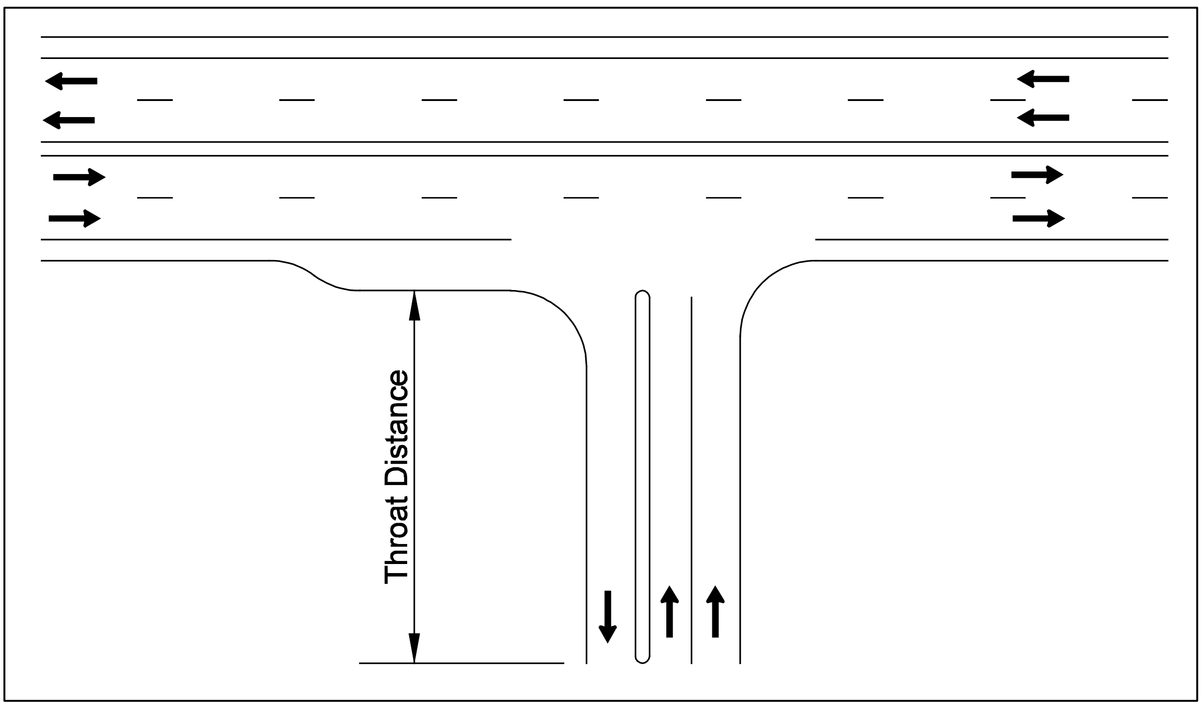


Figure 9-4
Throat Distance at Approaches

Table 9-1
Typical Private Approach Style and Width

Land Use Type	Approach Peak Hour Volume	Approach Style	Typical Throat Width[1]
SF Residential[2]	0 – 10	Dust Pan	16’
SF Residential[2]	11+	Dust Pan	24’
MF Residential	0 – 10	Dust Pan	16’
MF Residential	11 – 150	Dust Pan	24’ – 28’
MF Residential	151 – 300	Dust Pan[3]	36’ – 40'
MF Residential	301 – 399	Radius[4]	Variable[5]
MF Residential	400+	Radius	Variable[5]
Commercial	0 – 20	Dust Pan	24’
Commercial	21 – 150	Dust Pan	28’ – 32’
Commercial	151 – 300	Dust Pan[3]	36’ – 46’
Commercial	301 – 399	Radius[4]	Variable[5]
Commercial	400+	Radius	Variable[5]
Industrial		Dust Pan/Radius[6]	Variable[5]
Special Uses[7]		Radius	Variable[5]

Notes: SF= Single Family
MP= Multiple Family

[1] The typical throat widths are only to be used as guides to the designer or permit specialist. The throat width needs to be checked to ensure traffic movements are accommodated acceptably.

[2] Generally, multiple single-family residences don’t share a single approach unless they are on a public road.

[3] The dust pan style designs are primarily to be used. However a radius style may be used if the traffic composition at the driveway contains a substantial number of recreational vehicles, buses, and single unit trucks, and the highway posted speed is greater than 35 mph, or access spacing each side is 660 feet or more.

[4] The radius style design should generally be used. However, a dust pan style may be considered where the highway posted speed is 30 mph or less and access spacing is 165 feet or less.

[5] The typical width is variable dependant upon approach style, design vehicle, and number of lanes.

[6] Special care should be used when determining the appropriate style. Some industrial uses operate similar to commercial uses and should use commercial style approaches and dimensions. Heavy industrial/warehouse uses that serve significant truck volumes should use a radius style.

[7] Special Uses include developments such as truck stops, amusement parks, stadiums, distribution centers, etc.

9.2 GENERAL INTERSECTION DESIGN

- **General**

  This section describes the standards and guidelines for the geometric design of traditional at-grade intersections including lane widths, shoulders, superelevation, skew angles, turning radii, left turn lanes, right turn lanes, channelization islands, curb extensions, and bicycle and pedestrian needs. Other factors in the design of intersections include the adjacent land use, urban or rural condition, and speeds.

  Specific design issues and concerns related to signalized and unsignalized intersections are discussed in Sections 9.3 and 9.4, respectively. The design standards and considerations for modern roundabouts are contained in Section 9.5

9.2.1 DESIGN CONSIDERATIONS

- **Approach Grades**

  The approach grades of intersecting roadways with a state highway should be kept to a minimum. It is preferable to have a relatively flat or slightly elevated roadway connecting with a state highway. This helps improve the visibility of the intersecting roadway.

  Generally the intersecting roadway's vertical alignment should match with the cross slope of the highway as long as the cross slope is less than 3%. Where the cross slope is equal to or greater than 3% a small break in the grade or vertical curve may necessary. The goal is to provide a connection that does not require vehicles to stop and enter the highway from a steep grade. The flatter the approach, the better, particularly for large vehicles.

  The maximum grade break between the highway shoulder and intersecting road should be held to 6% or less. Where the algebraic grade difference is greater than 6%, a short vertical curve should be used. In addition, a 20 foot landing should be provided (see Figure 9-5, Standard Drawing RD725). In a marked or unmarked crosswalk, the cross slope should be held to 2% or less to meet ADA requirements.

  NOTE: Crosswalks, whether marked or unmarked, exist across each approach to an intersection unless specifically closed by the road authority.

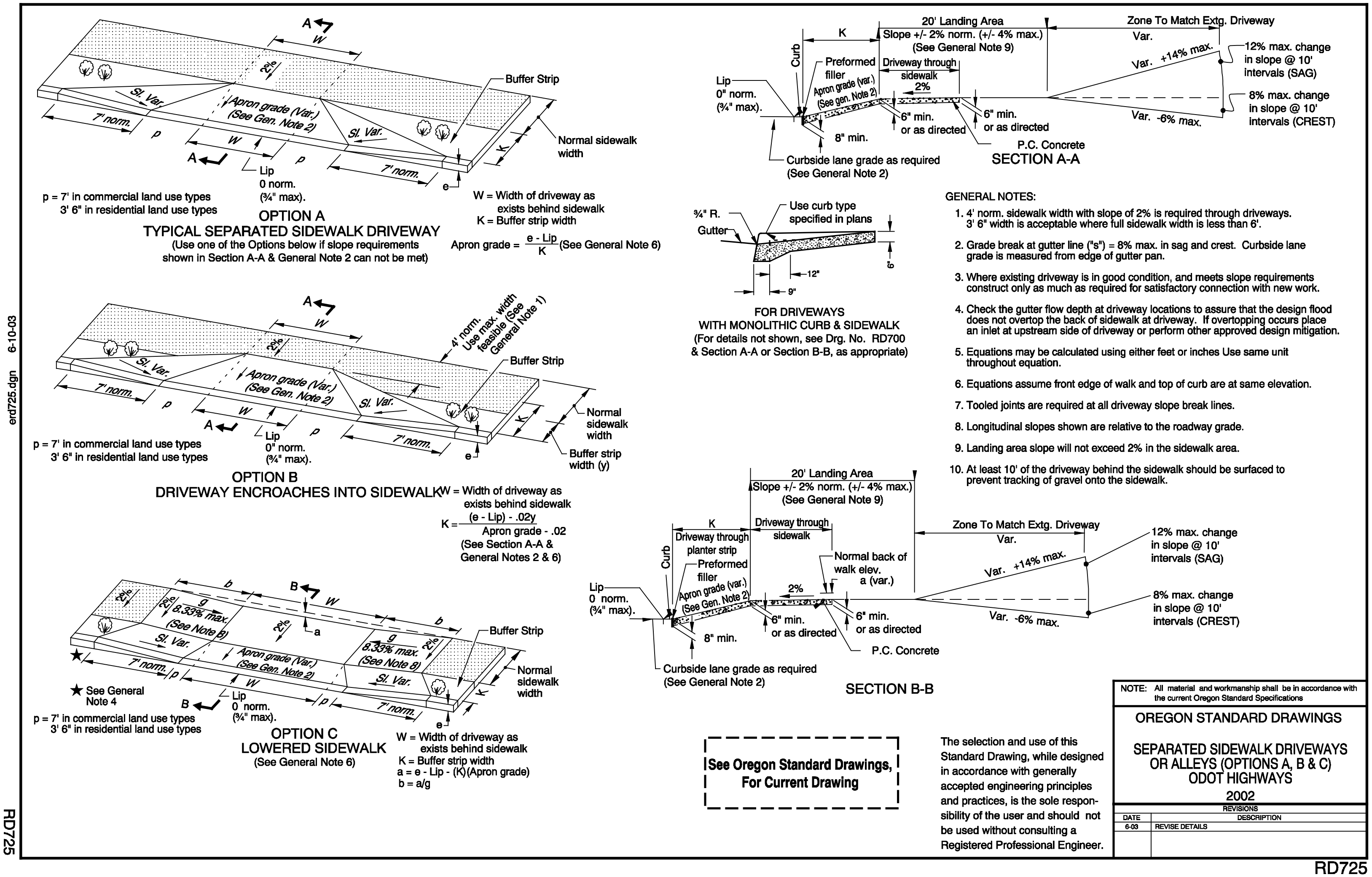


Figure 9-5
Approach Roads/Sidewalks

- **Travel Lane Widths**

  Through travel lane widths should remain constant through an intersection. The lane lines should line up throughout the entire intersection and not be offset. This helps to discourage lane changes through the intersection area. The appropriate travel lane width is determined by the location (rural or urban), design speed, volume of trucks, and alignment. The rural or urban highway design chapters of this manual should be used to determine the appropriate through lane width.

  Through travel lanes in a left turn channelization are typically widened to 14 feet. The overall width of the combination travel lanes and shoulders does not vary through the intersection, but is accomplished through striping. The striped 14 foot lanes are taken from the 8 foot typical shoulder width. For example an existing 8 foot shoulder will be narrowed to 6 feet while the 12 foot travel lane is widened to 14 feet through the channelization. See Standard Drawing RD 220. In low speed urban/suburban environments where the design speed is 45 mph or less, the through travel lanes can be maintained at 12 feet.

  When an intersection is a part of or connecting to a turning roadway, the lane widths may need to be increased to allow for large vehicle off tracking. Refer to chapters 3 and 9 of the AASHTO's *"A Policy on Geometric Design of Highways and Streets-2001"* for more details of turning roadways.

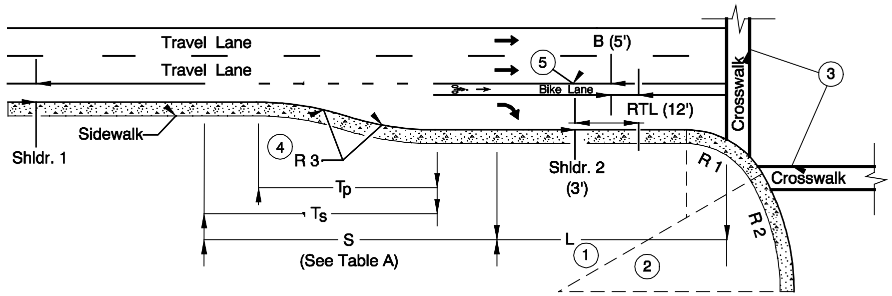
- **Shoulder Widths**

  As with travel lanes, the width of shoulders should generally remain constant through an intersection. However, two-lane highways that are flared to provide left turn channelization may require shoulder width modifications. When the through travel lanes are widened, the shoulder should be reduced 2 feet from standards but shall be no less than 4 feet. Where the travel lanes are not widened, the shoulder width should remain at standard width.

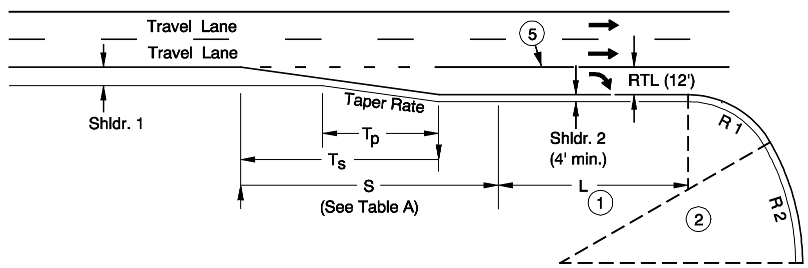
  Shoulder widths will also require modifications where the intersection includes a right turn lane. In these situations, the shoulder should be reduced to match the dimensions of Figure 9-6 (Standard Drawing RD225).

To be used in locations where a traffic investigation has determined a right turn lane to be warranted.

CURBED SECTION



NON-CURBED SECTION



DESIGN PROCEDURE

1. Decide on values for 'B', 'TL', 'Shldr.1' and 'Shldr.2'
2. Determine 'S' from Table A
3. Calculate 'T_S'
4. Determine 'L' (see note 1). For unsignalized intersections, check to see that $S - T_S \geq 50'$. If so, L = 0. If not, $L = 50 - (S - T_S)$.
5. Calculate 'T_P' for layout of curb or edge of pavement

NOTES:

1. Minimum Storage Length 'L'
   Unsignalized:
   Provide 50' minimum beyond end of 'Ts' distance.
   Signalized:
   Determined by traffic study.
2. Compound radii shall accomodate design vehicles, yet minimize pedestrian crossing distance. Compound radii are recommended for larger design vehicles. Radii are measured to the edge of travel lane or face of curb.
3. See Traffic Section for placement of crosswalk and Standard Drawing RD725.
4. R 3 for reversing curves used only in curbed sections.
5. **Through bike lane is generally constructed and striped in sections with a posted speed of 45 mph or less, even where there is no approaching shoulder or bike lane. Consult the Bicycle and Pedestrian Program for clarification.**

TABLE A

Design Speed (mph)	Taper Rate	S (ft.)
25	8:1	150
30	8:1	150
35	9:1	160
40	10:1	180
45	11:1	235
50	12:1	295
55	13:1	355
60	14:1	420
65	15:1	485
70	15:1	555

DESIGN EQUATIONS AND VARIABLES

S = Deceleration distance for initial speed (10 mph less than design speed)

T_P = Pavement or Curb Taper Length = Taper Rate x [(B + TL) + (Shldr. 2 - Shldr. 1)]

T_S = Striping Taper Length = Taper Rate x (B + TL)

R 3 = Reversing Curve Radius

$$= T_P \times \frac{\text{Taper Rate} + \frac{1}{\text{Taper Rate}}}{4}$$

B = Bicycle Lane Width (5' typ.)

RTL = Right Turn Lane Width (12' typ.)

See Oregon Standard Drawings, For Current Drawing

The selection and use of this Standard Drawing, while designed in accordance with generally accepted engineering principles and practices, is the sole responsibility of the user and should not be used without consulting a Registered Professional Engineer.

NOTE: All material and workmanship shall be in accordance with the current Oregon Standard Specifications

OREGON STANDARD DRAWINGS

RIGHT TURN CHANNELIZATION

2002

DATE	REVISIONS DESCRIPTION

RD225

erd225.dgn 12-3-99

RD225

Figure 9-6
Right Turn Channelization

- **Superelevation**

  It is undesirable to have an intersection located within a horizontal curve. However, in many existing situations, intersections are present within a highway curve. In many situations, these connections cannot be relocated. When an intersection occurs within a highway curve, the highway superelevation should be kept to a minimum. The highway still needs to provide for safe movement of traffic through the intersection at highway speeds. However, stopping traffic on steep cross slopes is undesirable due to the potential for slippage under ice conditions. In most situations, the superelevation should be held to 4% or less.

  In some cases, trying to hold the superelevation to 4% or less will result in design speeds less than desirable for a specific highway. At a minimum, the superelevation at an intersection should provide safe speeds equal to the desirable design speed. This means that if the design speed for the highway segment is 45 mph, then the safe speed for the curve at the desired superelevation must be at least 45 mph.

  It is critical to ensure that connections on the high side of a superelevated highway curve provide an approach with adequate sight distance. Ideally, intersection sight distance should be provided. Where this is not feasible or practical, stopping sight distance must be provided.

- **Skew Angles**

  Roadway connections with a state highway should intersect at a 90 degree angle. 90 degree intersections maximize sight distance, improve safety, increase efficiency, and improve operations and safety of bike and pedestrian movements. In some situations however, obtaining a 90-degree intersection is impractical or excessive in cost. Where this is the case, skewed intersections may be unavoidable. Skew angles of up to 30 degrees from perpendicular may be justified. The amount of skew should be held to a minimum.

  Several factors can help determine the amount of skew that is acceptable for any particular intersection. Intersections with all or most of the following characteristics might justify allowing a skew angle of up to 30 degrees.

  (a) highway speeds are low;
  (b) volumes on both the highway and intersecting roadway are low (not much above left or right turn channelization warrant limits);
  (c) large vehicle turning movements are minimal;
  (d) intersecting roadway has a functional classification of minor collector or below, and
  (e) intersection sight distance is available.

For all other intersections, the maximum skew should be held to 15 degrees from perpendicular. Refer to AASHTO's *"A Policy on Geometric Design of Highways and Streets-2001"*, pages 584-585, for possible alignment solutions to skewed intersections.

- **Turning Radii**

Turning radii are one of the most important design elements of intersections. The operations, safety, and efficiency of an intersection are controlled by the turning movements. If the turning vehicles are geometrically limited from completing the maneuver properly, the intersection will break down, capacity is limited, and accident potential will increase.

The appropriate design vehicle must be identified prior to designing the intersection turning movements. Selection of the appropriate design vehicle can sometimes be difficult. Issues to take into consideration in choosing a design vehicle include number and type of trucks, functional classification of the intersecting roadways, surrounding land use, consideration of future changes in land use and traffic, freight route designation, etc. After determining the appropriate design vehicle, a decision needs to be made as to the level of design accommodation to be made. In other words, is the intersection radii to be designed for the design vehicle or merely to accommodate the design vehicle? The concept of designing for the design vehicle is to provide a path for the vehicle that is free of encroachments upon other lanes. Providing a design that only accommodates the design vehicle means that some level of encroachment upon other lanes is necessary for the vehicle to make a particular movement (see Figure 9-1). An example of an intersection that would need to be designed for trucks with no encroachment into adjacent lanes would be a stopped controlled intersection with a state highway, the highway being two lane or multi-lane with higher speeds and/or high traffic volumes. Finding a gap in multiple traffic flows may not be possible, therefore requiring the truck driver to turn from their lane into a single lane. Other factors to consider in turning radii are the affects on pedestrians and bicycles: long crossing distances and exposure times negatively impact their safety.

Another item that must be decided is the turning radius of the design vehicle. The turning radius of the design vehicle determines the ease and comfort of making the turning maneuver. The smaller the turning radius, the larger the off-tracking of the vehicle and the slower the speed. Forcing large vehicles to use very small turning radii forces the driver to perform a very slow maneuver that may not be in the best interests of the operation of the intersection. Generally the radius chosen is in line with the surrounding culture. Tighter radii are chosen for low and/or urban speeds, while larger radii are selected for higher speeds and rural intersections.

Once the design vehicle is selected and the level of design accommodation determined, then the intersection radii can be designed. Intersection radii should be kept as small as possible to minimize the size of the intersection and the pedestrian crossing distance. Any time the design vehicle is larger than a Single Unit (SU) truck or a bus, the radii may need to consider using a two-centered curve. Off-tracking templates or automated off-tracking programs should be used to determine the vehicle path. Once this path is identified, a two-centered curve can be developed which closely emulates this path. The designer may need to look at a range of vehicle turning radii and the subsequent intersection designs. This allows the designer to select the best design for the design vehicle while minimizing the size of the intersection.

Designers are encouraged to keep the size of intersections to a minimum. Often when accommodating large trucks, the intersection radii become very large. This can substantially increase the size of the intersection. Larger intersections generally have greater accident potential, are difficult to delineate, can be confusing, require more right of way, and significantly increase pedestrian and bicycle crossing times and distances.

- **Left Turn Lanes**

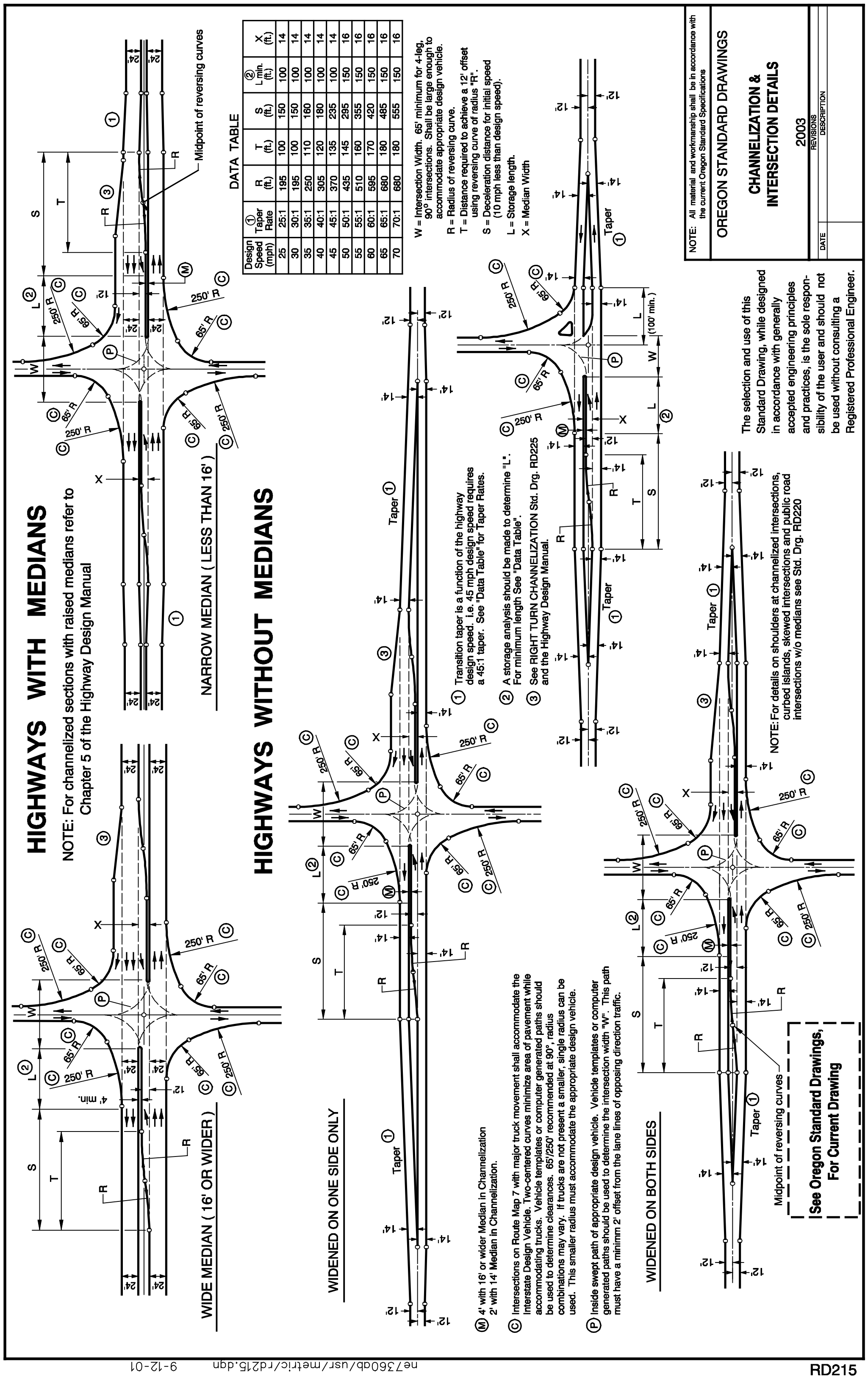
Providing a left turn lane at an intersection will significantly improve the safety of the intersection. Eliminating conflicts between left turning vehicles decelerating or stopping and through traffic is an important safety consideration. A left turn lane must be provided at all non-traversable median openings. Left turn lanes may be installed at intersections meeting the installation criteria. The left turn lane installation criteria are different for signalized and unsignalized intersections. Refer to Section 9.3, Signalized Intersections, and Section 9.4,Unsignalized Intersections, for the appropriate siting criteria.

Left turn lanes shall be 12 feet wide plus the appropriate traffic separator width. The width of the traffic separator is determined by several factors. If the median includes a raised curb design, the traffic separator width shall be a minimum of 4 feet. When pedestrians are to be accommodated on the raised portion of the median with separate phases for the crossing maneuver, the raised traffic separator width shall be 6 feet minimum. Medians that use raised curb also need to provide the appropriate shy distance from the curb and adjacent through travel lanes. The width of striped traffic separators is determined by the design speed of the highway and the type of land use area. For design speeds of 45 mph or less, the striped separator shall be 2 feet and 4 feet for design speeds of 50 mph or greater. For more information on median design, refer to Section 5.5.

Development of left turn lanes should be in conformance with Standard Drawing RD215. However, where the median width is developed non-symmetrically, a reversing curve may be used in lieu of the straight speed tapers. The reversing curve option can reduce the overall widening thereby saving construction costs and possibly saving right of way or significant features. Figure 9-7 depicts the standard left turn channelization design. Figure 9-8 depicts the reversing curve channelization option.

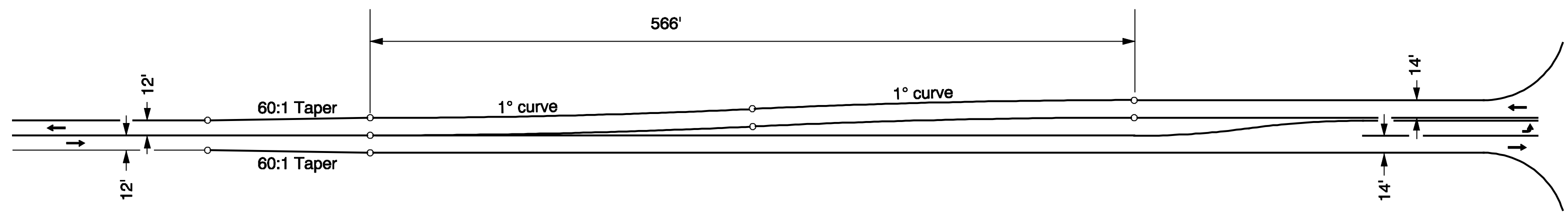
Left turn lanes should be striped in accordance with the ODOT Striping Design Guidelines. Essentially this means that the reversing curve entry taper shall be used for:

- All dual left turn lanes;
- All left turn lanes developed from sections without medians or with narrow medians, and
- All left turn lanes located within wide median sections or CTWLTLs that have design speeds greater than 45 mph.



Design Speed (mph)	(1) Taper Rate	R (ft.)	T (ft.)	S (ft.)	(2) L min. (ft.)	X (ft.)
25	25:1	195	100	150	100	14
30	30:1	195	100	150	100	14
35	35:1	250	110	160	100	14
40	40:1	305	120	180	100	14
45	45:1	370	135	235	100	14
50	50:1	435	145	295	150	16
55	55:1	510	160	355	150	16
60	60:1	595	170	420	150	16
65	65:1	680	180	485	150	16
70	70:1	680	180	555	150	16

Figure 9-7
Left-Turn Channelization



NOTES:

1. Site parameters
   - Rural highway.
   - Design speed of 60 mph
   - Tangent section
2. Used only when widening for channelization is done on one side of the highway.
3. Survey crew must lay out stripe locations.

Figure 9-8
Reversing Curve Option For Left-Turn Channelization

It is critical to the operation of intersections to provide adequate storage length for left turning vehicles out of the through traffic lanes. At a minimum, the turn lane should provide 100 feet of storage for design speeds of 40 mph or less and 150 feet of storage for design speeds of 45 mph or greater. The Transportation Planning Analysis Unit should be contacted to determine the appropriate storage length.

- **Right Turn Lanes**

Speed differential between right turning traffic with through traffic can create significant safety problems at intersections. To reduce this conflict, installation of right turn lanes may be appropriate at some intersections. Right turn lanes also help improve traffic operations and mobility standards at some intersections. Installation of right turn lanes should be considered at intersections that meet the siting criteria. The appropriate siting criteria for signalized and unsignalized intersections can be found in Appendix F. Not all intersections that meet the siting criteria should have right turn lanes installed. In urban situations, only significant public roads and large private approaches should be considered for installation of a right turn lane. A proliferation of right turn lanes along an urban arterial is undesirable for bicycles and pedestrians, creates an aesthetically unpleasing typical section, and may not improve safety throughout the section. Multiple right turn lanes could, in effect, create a continuous right turn lane, which is not desirable on state highways.

Right turn lanes should be designed in conformance with Standard Drawing RD225, Figure 9-6. The right turn lane should be 12 feet wide with a shoulder of 3 feet or 4 feet for curbed or non-curbed sections respectively.

- **Acceleration Lanes**

At-grade intersections should not have short tapers or acceleration lanes constructed for vehicles entering the state highway from a crossroad or another state highway. Acceleration lanes are generally only provided at grade separated facilities. However, in some situations acceleration lanes may be justified. All acceleration lanes from at-grade intersections must be approved by the Roadway Engineering Manager through a design exception.

- **Channelization Islands**

Channelization islands help to direct turning traffic through an intersection. Channelization islands are a tool to help decrease the exposed crossing area of very large intersections. These islands can provide a refuge area for crossing pedestrians and offer a location for signal poles and sign posts. Where channelization islands are to accommodate poles or sign posts, the island should ideally have an area of 100 square feet.

Channelization islands are also useful for decreasing the crossing distance of pedestrians. When intersections are very wide, pedestrians must cross very long distances which increases their exposure time to traffic, reduces safety, and reduces efficiency of the signal due to the time necessary to cover the crossing maneuver. The designer should consider using channelization islands where crossing distances are greater than 90 feet and where right turn lanes are used (Section 9.2.2 of this section gives additional guidance on channelization islands). Channelization islands should be designed in conformance with Standard Drawing RD220. Figure 9-9 provides additional information regarding pedestrian crossings and channelization islands.

In rural areas it may be advantageous to provide a moderate to high speed right turn movement at major intersections. Channelization islands could also be used in these instances.

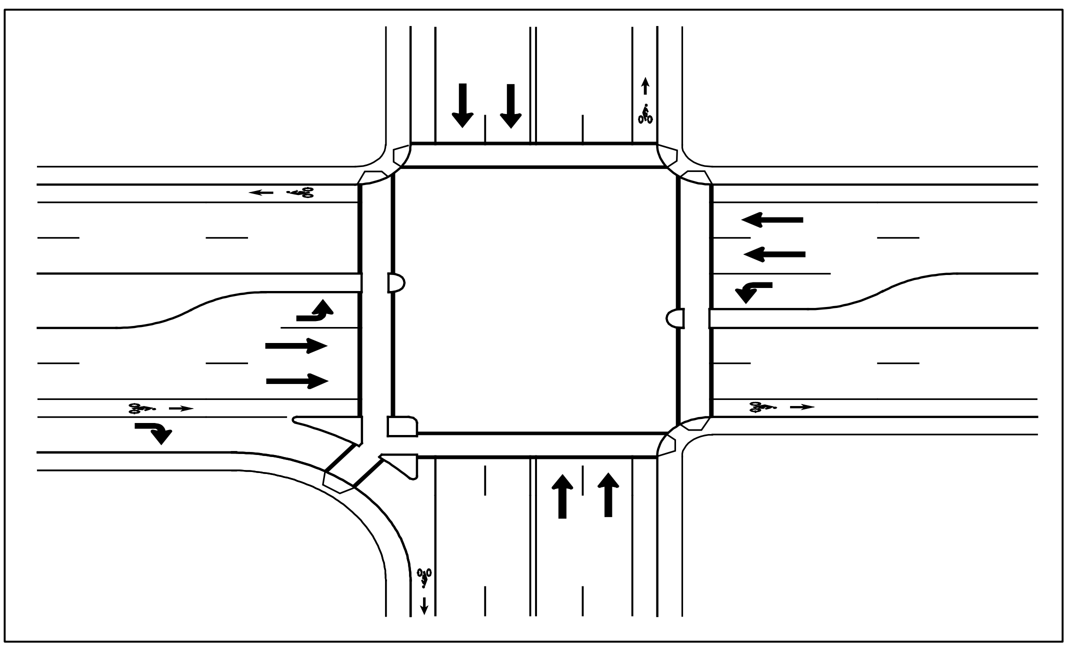


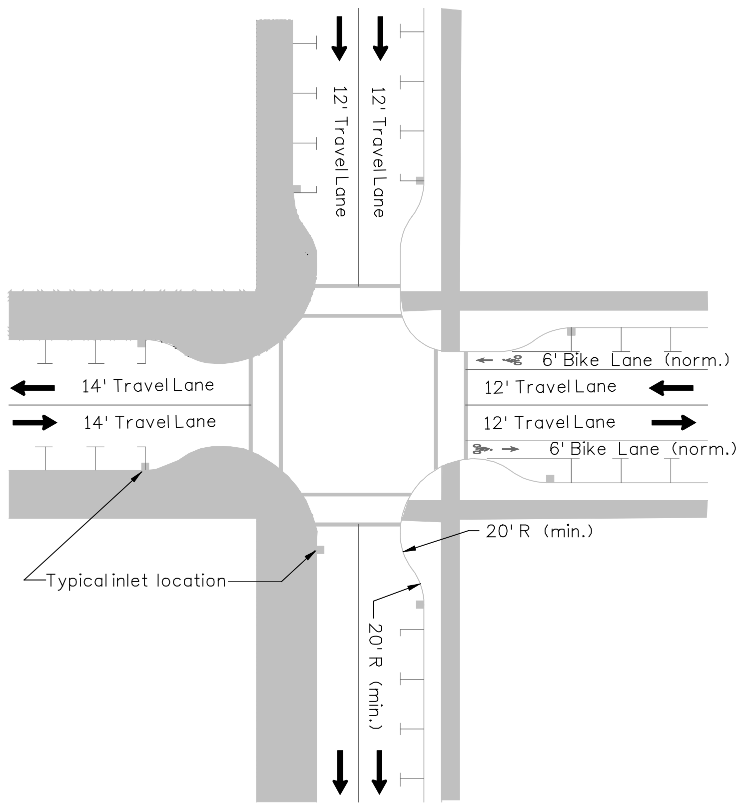
Figure 9-9
Channelized Intersection

- **Curb Extensions**

Curb extensions, also known as “bulb-outs,” are good tools to help reduce the pedestrian crossing distances in areas with on-street parking. Curb extensions also increase pedestrian visibility, help control vehicular speeds, and give a “downtown look” to an urban area. Curb extensions are generally appropriate within slower speed compact areas, such as Special Transportation Areas (STAs).

The curb extensions still must be designed to accommodate the appropriate design vehicle. However, due to the speed, traffic characteristics, and importance of alternative modes in these areas, the level of accommodation (see Section 9.2.1) of large vehicles should be minimal.

Curb extensions should generally be constructed to the full width of the on-street parking. However, the curbside lane should be at least 14 feet wide from the lane line to the curb. Each curb extension design is different. The curb extension should not block bicycle lanes. Figure 9-10 contains several design concepts for consideration. Additional curb extension ideas can be found in the ODOT “*Oregon Roadway Design Concepts*” (Pattern Book). Special consideration is required in many situations for addressing drainage in conjunction with curb extensions, especially in retrofit situations.



General Notes

1. Intersections on state facilities should be designed to accommodate the appropriate design vehicle with the SU as the minimum. Corner curb radii are normally no less than 33' in cases where vehicles are turning right onto a roadway without a bike lane. The introductions of bike lanes, one-way streets and different combinations of turning movements may reduce the curb radius requirements to as low as 16'. These radii should be confirmed by the appropriate vehicle turning template or computer-generated turning paths.
2. Other curb radii should be no less than 20' to accommodate street maintenance equipment. This radius may be reduced if approved by local authorities.
3. Sidewalk ramps should be designed in accordance with Standard Drawing RD 735 and RD 740. Ramps should be located at the normal crosswalk location.
4. Storm water inlets should be placed at the point where the curb extension matches into the normal street section. Normally, 2 inlets are required, one at each end of the curb extension. Drainage may be required in the sidewalk area, depending on slopes and sidewalk design. Drainage may also be provided through the use of a slotted drain or a pipe through the curb extension.
5. Curb extension should be kept clear of obstructions that could obscure sight distance

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HIGHWAY DESIGN MANUAL CURB EXTENSIONS	
Figure: 9-10	2003

Figure 9-10
Curb Extensions

9.2.2 Bicycle and Pedestrian Needs

The design of intersections takes into account the needs of bicyclists and pedestrians. The level and amount of design effort required to ensure adequate design for these modes will vary among different areas.

Intersection designs should try to keep the crossing distances and pedestrian exposure to a minimum. Pedestrians and motorists must be able to see each other clearly and understand how the other will proceed through the intersection. This can sometimes be difficult at major intersections that accommodate multiple turn lanes. When intersections become excessively large and complex, pedestrian safety is often at a higher risk. The designer should try to find mitigation measures to reduce the crossing distance.

When pedestrians must cross more than 6 lanes of traffic or 6 lanes with an intersection skew angle of 20 degrees or greater, a pedestrian median refuge should be provided to enable the pedestrian to cross the street in two phases. A right turn channelization island should also be considered to reduce the pedestrians' exposure to both through and right turning vehicles. Curb extensions are another tool available to reduce the crossing distance for roadways with on-street parking. Median refuges and right turns channelization islands may be more appropriate in suburban locations, and curb extensions may be a more appropriate tool in more compact areas such as STAs or Commercial Business Districts. However, any of these tools could apply in a multitude of situations. A general rule of thumb is to consider pedestrian crossing remediation when the crossing distance exceeds 90 feet in typical urban environments such as Urban Business Areas (UBAs) and 72 feet in compact densely developed areas such as STAs.

ADA requirements shall be met in every intersection design. Issues such as proper ramps, location of pedestrian and signal poles, obstructions, fixed objects, drainage, etc., need to be reviewed and designed to accommodate all roadway and intersection users. Chapter 11, Pedestrian and Bicycle, has additional information on intersection accommodation.

- **Intersection Design Affecting Pedestrians**

There are several aspects of intersection design that impact the safety, comfort or access needs of pedestrians. For each identified issue, measures that can be used to mitigate these effects will be proposed.

- **Excessive Skews**

Skewed approaches have several negative effects for pedestrians:

1. They make the crossing longer;
2. They enable motorists to make a turn at high speeds;

3. They force entering motorists to look backwards for conflicts, so that a pedestrian approaching from the other direction is out of sight, and
4. They place crossing pedestrians with their backs to approaching traffic.

The best way to mitigate for a skew is to reconfigure the intersection at or close to a right angle. If sufficient right of way is not available for total reconfiguration, the negative effects can be mitigated with a curb extension in the flat-angle corner(s). Figure 9-11 shows an example of an intersection with excessive skew and the intersection reconfigured with improve skew angle. If a curb extension isn't feasible, then use the tightest possible radius in the flat-angle corner(s).

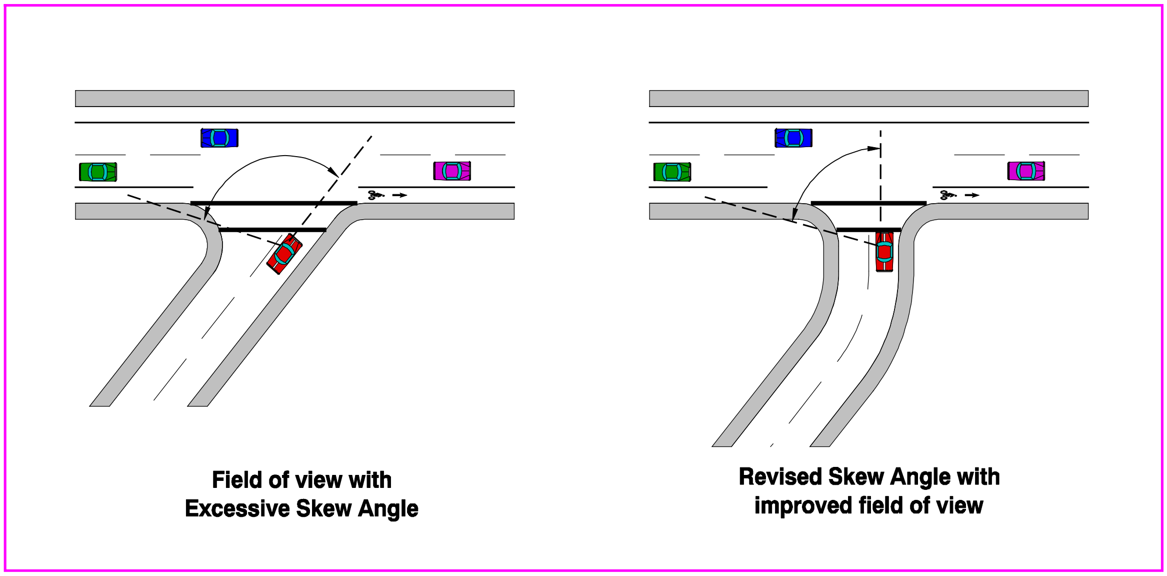


Figure 9-11
Skew Angle and Field of View

- **Long Crosswalks**

Long crosswalks are a problem for all road users for several reasons:

1. The pedestrian is exposed to conflicts longer;
2. It is difficult for some people to see pedestrian signals if they are too far away, and
3. The capacity of the intersection is reduced if the signal cycle is governed by the pedestrian crossing time.

Several methods may be considered, individually or jointly, to reduce crosswalk lengths:

1. Narrow the cross-section;
2. Provide curb-extensions on streets with parking;
3. Reduce the skew of the intersecting street, and
4. Minimize curb radius.

If the overall crosswalk length cannot be reduced, or the above techniques still do not provide sufficient reductions, then consider placing a refuge island(s) to enable the pedestrian to cross in two or more phases. Pedestrians should not be forced into a two-phase crossing; rather, the option should be available should they be stranded on a refuge island. Always provide a pedestrian push-button in islands. Pedestrian median refuges are strongly recommended when crossing more than 6 lanes.

- **Island Geometry**

An island placed between a slip lane and through traffic can offer pedestrians a refuge, but if it is poorly designed, the geometry can encourage drivers to make turns at high speeds without looking for pedestrians. This can be mitigated by a design that brings the motorist to the intersecting street at close to a right angle, rather than a skew. This forces the driver to slow down, and enables the driver to see the crossing pedestrian. Figure 9-12 shows an example of a reconfigured right angle design skewed flat angle design. The type of design chosen varies depending upon the right turn vehicle accommodation. In many cases the presence of large trucks prohibits the use of this treatment.

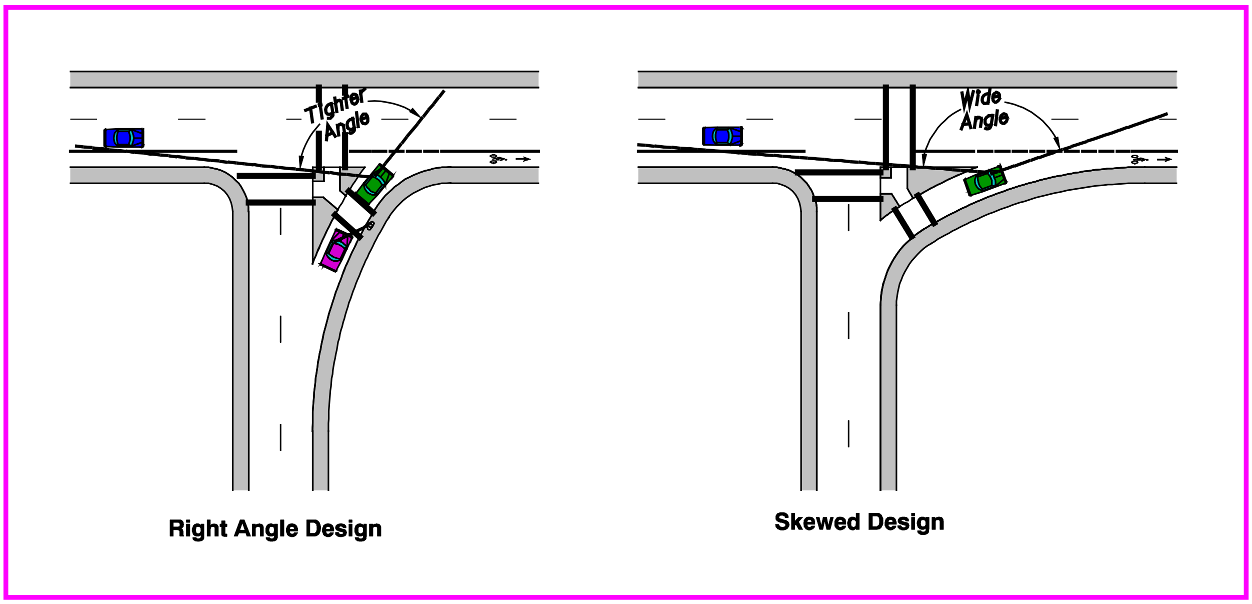


Figure 9-12
Island Geometry

- **Corner Radii**

Large corner radii present several problems for pedestrians:

1. They make the crossing longer;
2. They enable motorists to make a turn at high speeds, and
3. They make it very difficult to line up the sidewalks, crosswalks and curb cuts.

Designers should try every possible technique to minimize the corner radii at intersections in urban areas. Refer to the techniques described in Section 9.2.1, Design Considerations, Turning Radii.

Choosing the appropriate radius is often dependent on factors other than strict interpretation of design parameters. For example, it may be acceptable to design to a tight radius on approach streets with very little truck traffic, even if that means that the occasional truck may have to encroach into traffic to make a turn.

- **Crosswalk and ramp placement**

Crosswalk and ramp placement becomes a concern when an intersection is skewed, or if the corner radii are too large, especially with curb-tight sidewalks. The pedestrian expects the sidewalk, the curb cuts and the crosswalks to be in a reasonably straight line. The natural crossing point will be a continuation of the sidewalk.

Again, large corner radii create very long crosswalks. The designer may then be tempted to move the crosswalk away from the intersection, where the crossing is shorter, and crosswalks and curb cuts are perpendicular to the curb. This creates a new problem, as the crosswalk is offset from the intersection. The crossing pedestrians may not be visible to turning motorists, or they may ignore the crosswalk markings and walk where they are less inconvenienced. In other circumstances, squaring up the crossing may be the appropriate treatment. The best solution is to tighten up the intersection as much as possible.

In most instances, the best design will be arrived at through an iterative process, by trial and error, and imagining the natural path the pedestrian will take and the various turning movements, to reach optimal visibility, driver and pedestrian expectation, and reasonable crossing distances.

Another consideration is trying to ensure that sidewalks are separated with a buffer strip. This has two advantages: the extra separation will place the sidewalks between the offset crosswalk and the curb-tight crosswalk described above, and a curb cut traced through the buffer strip will more effectively channel pedestrians to the right crossing point.

- **Curb cuts - placement and number**

ADA requires two curb cuts at each corner of an intersection on new construction, and reasonable efforts should be made to install two on retrofit projects. Two curb cuts enable people in wheelchairs and other mobility aids to enter a crosswalk directly, without having to turn 45º in the roadway. Two curb cuts also make it easier to construct them perpendicular to the curb, as required.

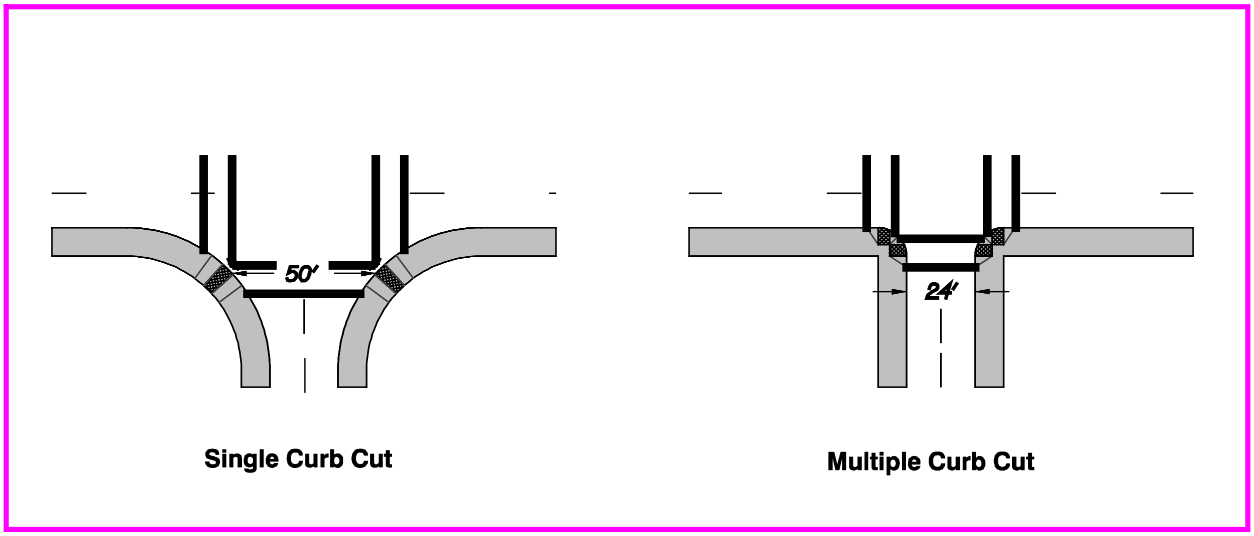


Figure 9-13
Crosswalk Ramp Placement

However, on corners with a large radius, placing two curb cuts may make it difficult to line everything correctly, as noted above. In these situations, after other mitigation has been tried, placing one diagonal ramp may work better. Figure 9-13 is an example of number of curb cuts based upon radius.

- **Signal pole placement**

Signal poles must be placed in a location where they do not interfere with pedestrians' path of travel. But they should not be placed so far away that it is difficult or inconvenient to reach the pedestrian push-buttons. The designer should work with Traffic Management Section concerning placement of signal poles.

Placing the poles correctly is made easier with tight corner radii, sidewalks separated with a buffer strip, and two curb cuts per corner. As the radius increases, it becomes more difficult to place the pole out of the ramps and out of the walking area, but still within reach. The best location for a signal pole is between the two curb cuts. If that is not feasible, the pole can be placed in the back of walk. This may make it difficult for pedestrians to reach the push-buttons. In this situation, consider placing a pedestrian pole at a more convenient location, preferably between the two curb cuts.

On corners with one curb cut, it may be best to place the pole at the back of curb, while ensuring that there is a minimum 3 foot level area between the pole and the top of the curb cut. Under no circumstances should poles be placed in a curb cut, or in the level landing at the top of a curb cut. Figure 9-14 provides an example of signal pole placement.

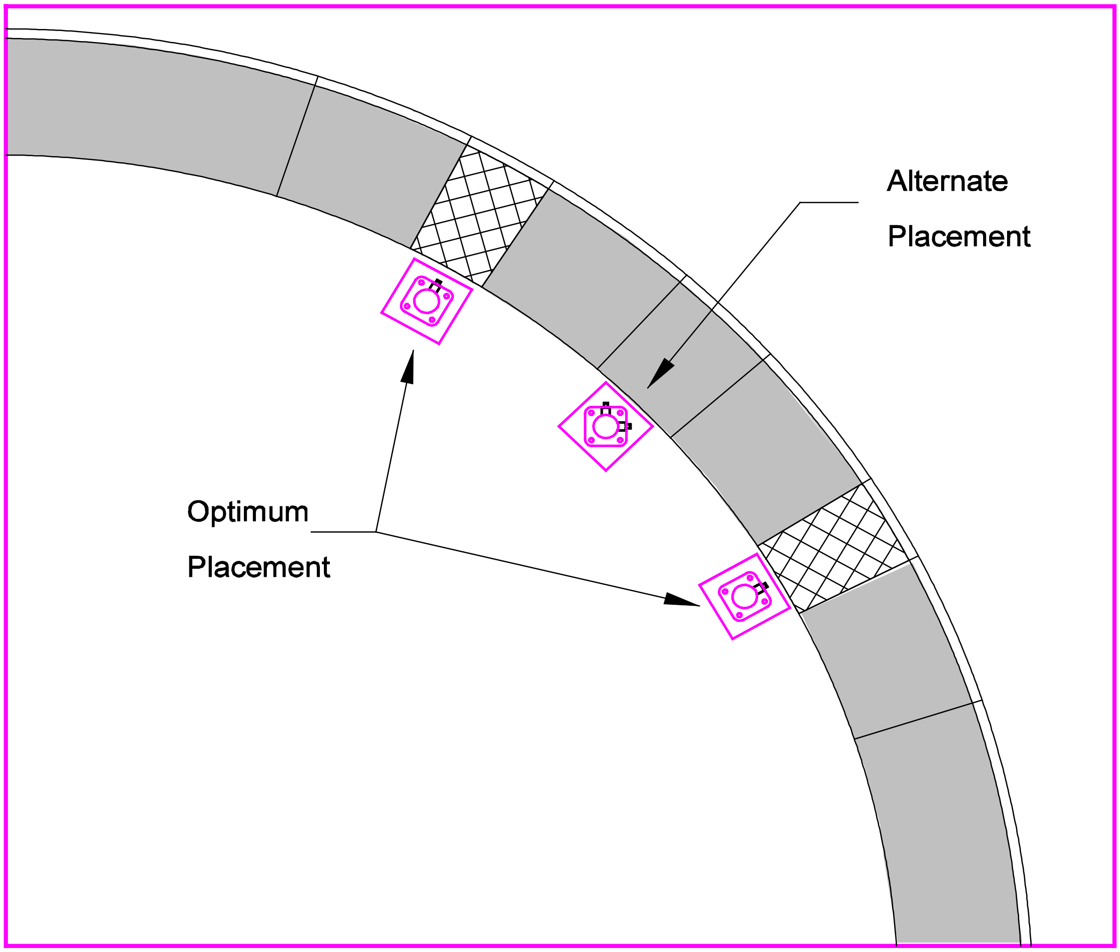


Figure 9-14
Signal Pole Placement

- **Free-flow acceleration (add) lanes**

This type of intersection treatment should be avoided in urban areas. Acceleration lanes are generally not allowed for at-grade intersections in accordance with Section 9.2.1. They create an unexpected condition for both pedestrians and cyclists.

If an acceleration or add lane is provided for capacity reasons, then every reasonable effort should be made to create conditions that make the crossing safer and easier for pedestrians and cyclists.

Most of the design principles offered so far would apply to free-flow lanes also: tighten the turning radius, narrow the lane, and keep the angle of approach as close to a right angle as possible. These three elements combined will force drivers turning right to slow down and look ahead, where pedestrians and bicyclists may be present, before turning and accelerating onto the roadway.

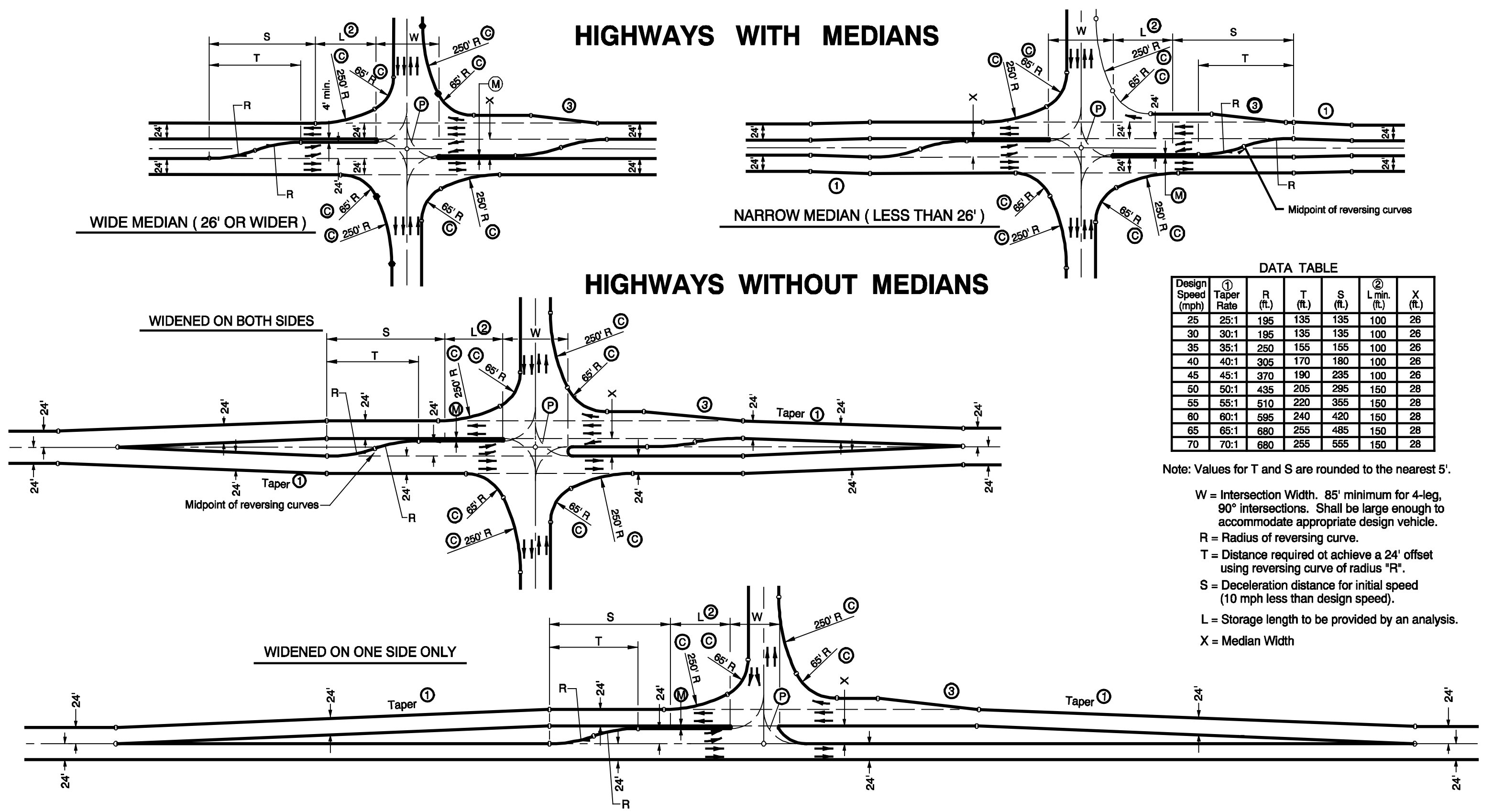
9.3 SIGNALIZED INTERSECTIONS

Signalized intersection design will need to consider the following issues in addition to the design standards for general intersection design that were discussed in Section 9.2.

- **Left Turn Lanes**

  Most signalized intersections will have left turn lanes. When left turning traffic is allowed from a two way highway at a signalized intersection, a left turn lane must be provided. Providing a traffic signal phase for left turning traffic is determined by Traffic Management Section (see Traffic Signal Guidelines and Policy).

  When the left turning volume is very large, a single left turn lane may not be able to handle the volume and still provide an acceptable mobility standard or safety. In these instances, a dual left turn lane may be needed. Requests for dual left turn lanes must be approved by the State Traffic Engineer (see OARs 734-020-0135 and 0140 for criteria). When it is determined that a dual left turn is the appropriate solution, the receiving lanes and appropriate throat width shall accommodate the design vehicle. Dual left turn lanes should be designed in conformance with Figure 9-15.



DATA TABLE

Design Speed (mph)	① Taper Rate	R (ft.)	T (ft.)	S (ft.)	② L min. (ft.)	X (ft.)
25	25:1	195	135	135	100	26
30	30:1	195	135	135	100	26
35	35:1	250	155	155	100	26
40	40:1	305	170	180	100	26
45	45:1	370	190	235	100	26
50	50:1	435	205	295	150	28
55	55:1	510	220	355	150	28
60	60:1	595	240	420	150	28
65	65:1	680	255	485	150	28
70	70:1	680	255	555	150	28

Note: Values for T and S are rounded to the nearest 5'.

W = Intersection Width. 85' minimum for 4-leg, 90° intersections. Shall be large enough to accommodate appropriate design vehicle.

R = Radius of reversing curve.

T = Distance required ot achieve a 24' offset using reversing curve of radius "R".

S = Deceleration distance for initial speed (10 mph less than design speed).

L = Storage length to be provided by an analysis.

X = Median Width

① Transition taper is a function of the highway design speed. i.e. 45 mph design speed requires a 45:1 taper. See "Data Table" for Taper Rates.

② A storage analysis should be made to determine "L". For minimum length See "Data Table".

③ See RIGHT TURN CHANNELIZATION Std. Drg. RD225 and the Highway Design Manual.

NOTE: For details on shoulders at channelized intersections, curbed islands, and skewed intersections see Std. Drg. No. RD220

Ⓜ 4' with 28' or wider Median in Channelization
2' with 26' Median in Channelization.

Ⓒ Intersections on Route Map 7 with major truck movement shall accommodate the Interstate Design Vehicle. Two-centered curves minimize area of pavement while accommodating trucks. Vehicle templates or computer generated paths should be used to determine clearances. 65'/250' recommended at 90°, radius combinations may vary. If trucks are not present a smaller, single radius can be used. This smaller radius must accommodate the appropriate design vehicle.

Ⓟ Inside swept path of appropriate design vehicle in inside lane. Vehicle templates or computer generated paths should be used to determine the intersection width "W". This path must have a minimm 2' offset from the lane lines of opposing direction traffic.

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HIGHWAY DESIGN MANUAL
DUAL LEFT TURN CHANNELIZATION & INTERSECTION DETAILS

Figure: 9-15 2003

Figure 9-15
Dual Left Turn Channelization

- **Right Turn Lanes**

  There are no specific warrants for installation of a right turn lane at a signalized intersection. A rule of thumb is to install a right turn lane when peak hour right turn volume is 200 or more. Installation of a right turn lane at signalized intersections should be justified by engineering analysis. The Transportation Planning Analysis Unit (TPAU) should be consulted where right turn lanes might be necessary.

  It is critical to the operation of signalized intersections that adequate storage length for right turning vehicles (out of the through traffic lanes) be provided. The storage length needs to accommodate the 95% queue distance through the design life of the project. The 95% queue length means that there is only a 5% probability that the actual volume of vehicles will exceed the storage available. In areas where obtaining the 95% queue distance is impractical, the designer should provide as much storage as possible. Consideration should be given to shortening the entrance taper to lengthen the available storage. Any exceptions, however, will require an approval from the Roadway Engineering Manager. The Transportation Planning Analysis Unit should be contacted to determine the appropriate storage length.

  At some intersections, right turn demands might be so large that dual right turn lanes may be necessary. TPAU and Traffic Management Section must be consulted and the approval of the State Traffic Engineer obtained prior to installation of dual right turn lanes (see OARs 734-020-0135 and 0140). Where dual right turn lanes are required, follow the guidelines shown in Figure 9-16.

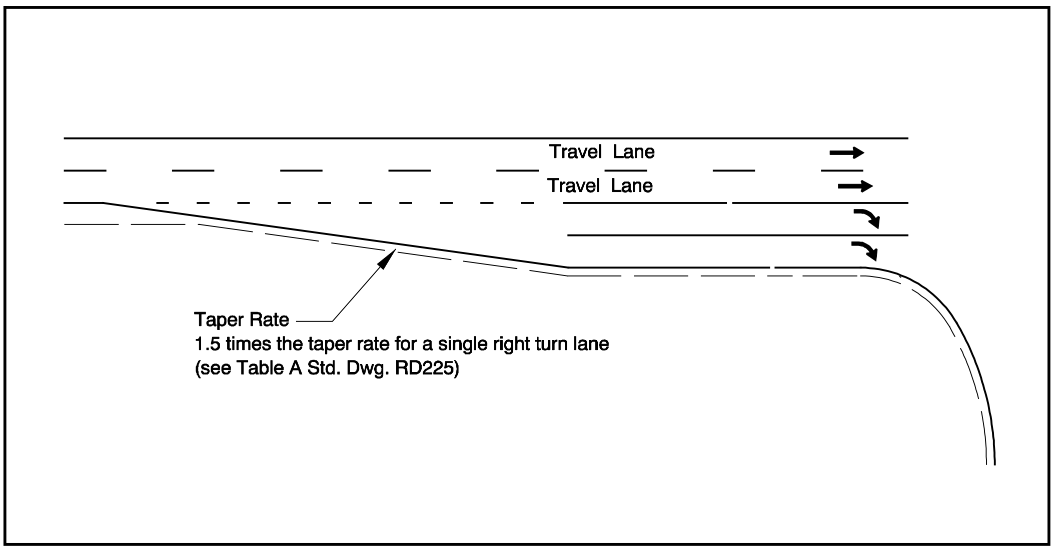


Figure 9-16
Dual Right Turn Channelization

- **Bicycle and Pedestrian Needs**

  Signalized intersections should provide marked pedestrian crossings at all approaches. The only exceptions are:

  (a) Intersections include multiple left or right turn lanes,
  (b) Intersections with one or more legs being one way roadways, and
  (c) Intersections that are a ‘T’ configuration.

  The idea is to only close a crossing where a turn movement has a direct protected green arrow conflict with a crossing pedestrian. Only the State Traffic Engineer can close a legal pedestrian crossing. The Traffic Management Section should be contacted early in the project to determine the appropriate pedestrian crossing locations.

9.4 UNSIGNALIZED INTERSECTIONS

Unsignalized intersection design will need to consider the following issues beyond the design standards for general intersection design that were discussed in Section 9.2.

The design of unsignalized intersections must account for the needs of bicyclists and pedestrians. The level and amount of design effort required to ensure adequate design for these modes will vary among different areas. Because of the complexity of urban areas, a higher level of effort is needed in those areas.

By law, every intersection is a legal crossing location for pedestrians. This is true whether the crossing is marked or unmarked. Therefore, it is important to ensure that pedestrian needs are included in the intersection design, particularly in urban areas. The marking of crosswalks shall meet the guidelines and recommendations of the Traffic Management Manual and ODOT Striping Guide.

- **Left Turn Lanes**

Left turn lanes at unsignalized intersections must meet the siting criteria to justify installation. Regardless of the funding source, the Region Traffic Engineer must approve all unsignalized channelized left turn lanes. The designer should work with the Traffic Management Section in locations where left turn lanes are being considered. Left turn siting criteria has been established and is located in Appendix F along with a left and right turn lane siting example.

- **Right Turn Lanes**

Unsignalized intersections and private approach roads must meet the installation criteria prior to constructing a right turn lane. Regardless of the funding source, the Region Traffic Engineer must approve all unsignalized right turn lanes.

Since the right turning vehicles only have to yield to pedestrians at unsignalized intersections, there is no need to provide vehicle storage at an unsignalized right turn lane. The one exception is where vehicular storage may be required where the right turn lane is next to an at grade railroad crossing as per Siting Criterion 3-1. The right turn lane siting criteria are located in Appendix F.

9.5 MODERN ROUNDABOUTS

- **General**

(This section provides some basic information on single lane roundabouts and site criteria. Please contact the Preliminary Design Unit for additional design criteria and recommendations.)

A modern roundabout is a form of intersection control. The distinctive characteristics of a modern roundabout include a central island with a circulatory roadway, raised splitter islands at the entry to introduce deflection to the vehicle path, and a yield control for approaching vehicles. Figure 9-17 details several major roundabout elements.

9.5.1 ROUNDABOUT ELEMENTS

Modern roundabouts show promise of reducing crashes and delay. They can be particularly efficient where traffic volumes are roughly equal on all approaches. But they can also have limitations:

- Generally, higher capacities can be achieved with traffic signals,
- Roundabouts are more expensive than stop control at low volume locations,
- They provide a less positive form of intersection control, and
- They cannot provide a smooth progression for arterial flows.

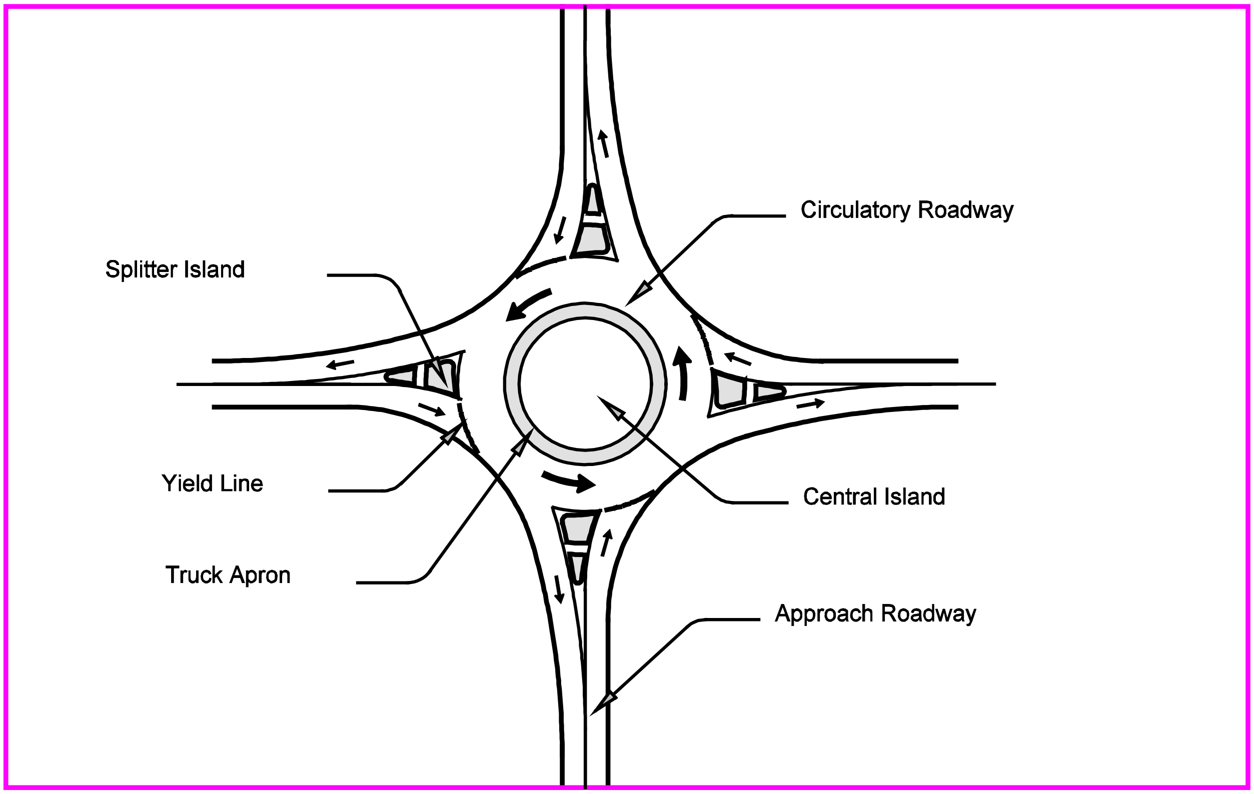


Figure 9-17
Elements of a Roundabout

9.5.2 ROUNDABOUT SELECTION CRITERIA AND APPROVAL PROCESS

The State Traffic Engineer has been delegated the authority to approve the installation of roundabouts on State Highways. Formal requests for evaluation of proposed roundabouts shall be sent to the State Traffic Engineer. Planning level evaluation requests including TSP and Comprehensive plan proposals shall be sent to the State Traffic Engineer to insure consistency. Requests for roundabout evaluation shall be made through the Region Traffic Engineer in collaboration with the Technical Services Roadway Manager.

- **Engineering Investigation**

A comprehensive investigation of traffic conditions and physical characteristics of the location shall be made by the Region Traffic Engineer or applicant. Details of crash history, traffic volumes, analysis of roundabout operation, and other safety concerns should be included. The investigation should include comparisons of alternative intersection control, i.e., stop control, signal control, both operational aspects and other considerations. A discussion of nearby land use issues, access management issues, operational issues and local support for the roundabout are desirable. For normal STIP projects a 20-year design life from the date of construction shall be used. The State Traffic Engineer must approve exceptions to the minimum design life. A scale drawing of the proposed roundabout should be included to assure appropriate geometry and layout elements can be obtained (see Section 9.5.3-Design Considerations and contact the Preliminary Design Unit for design details). Horizontal and vertical geometry must be clearly identified. Surrounding topography and approximate Right of Way should also be included.

- **Evaluation of Proposals**

The following recommendations will be used in evaluating proposed roundabout locations:

- Should not have more than 4 approach legs.
- Should meet acceptable v/c ratios for the proposed design life.
- Should have posted speeds 35 mph or less.
- Should have normal circular geometry.
- Should have similar or balanced volumes on all approach legs.
- Should be at an intersection of two highways with roughly the same functional classification or no more than one level of difference (i.e., arterial to arterial, arterial to collector).
- Should be mostly commuter and local traffic.
- Should not have high pedestrian volumes.
- Should not have high volumes of large trucks.
- Should not be located within an interconnected signal system.
- Should not be in locations where exiting vehicles would be interrupted by queues from signals, railroads, drawbridges, ramp meters, or by operational problems created by left turns, accesses, etc.
- Should not be located where grades or topography limit visibility or greatly complicate construction.

(Contact the Preliminary Design Unit for further information regarding geometric design requirements and considerations.)

- **Process and Approval**

Once the State Traffic Engineer receives a request, Traffic Management staff will coordinate review with other Technical Services staff and will make a recommendation to the State Traffic Engineer. If the information provided is insufficient or not of appropriate methodology (as determined by Oregon State Highway Division) the State Traffic Engineer may request further analysis. The State Traffic Engineer will make the final decision whether the roundabout will be approved.

9.5.3 DESIGN CONSIDERATIONS

It is the intent of the Oregon State Highway Division to ensure that the geometric design of roundabouts adheres to principals that encourage lower speeds and increased safety for all users. These principals will also have traffic-calming benefits on the road system. It must be recognized that the design of a roundabout is an iterative process. Geometric layout may need to be refined several times before capacity and safety requirements can be achieved. Engineering judgement will be required to refine the layout.

The following discussion points present some basic design considerations for modern roundabouts. Additional design details and layout considerations can be obtained through consultation with the Preliminary Design Unit.

- **Design Vehicle**

In the design of roundabouts, as with other highway facilities, layouts should provide for the largest design vehicles likely to use the facility. Intersections on state highways shall accommodate the Interstate Design Vehicle.

- **Design Speed**

Design speed plays an important part for safety at roundabouts. Roundabouts are purposely designed so that traveling speeds are restricted to a low and consistent speed through the roundabout. The design speed of the roundabout intersection should not be confused with the design speed of the highway. A safely designed roundabout should have geometry that accommodates all traffic movements at the chosen intersection design speed, thereby maximizing safety benefits and minimizing the area needed. The recommended design speed of all vehicles entering and traveling through a roundabout is 25 mph.

- **Inscribed Circle and Central Island**

The inscribed circle is the outside edge of travel of the circulatory roadway. The central island is the raised area surrounded by the circulatory roadway. There are two areas of a central island, the mountable truck apron and the non-traversable raised area. Figure 9-18 shows a typical cross-section of the truck apron and central island.

On low-truck-volume roads, encroachment on the truck apron is permitted; however, all vehicles smaller than the Interstate Design Vehicle should be accommodated without encroachment.

Where high proportion of heavy vehicles is expected, the design of adequate circulatory roadway width with minimal use of the truck apron is preferred.

The minimum inscribed circle diameter for a single lane roundabout (accommodating the Interstate Design Vehicle) shall be 165 feet. The recommended circulatory roadway width for a single lane roundabout is 21 feet, excluding the truck apron width. A truck apron should be designed in such a way that mounting over by a passenger car would feel uncomfortable but not unsafe.

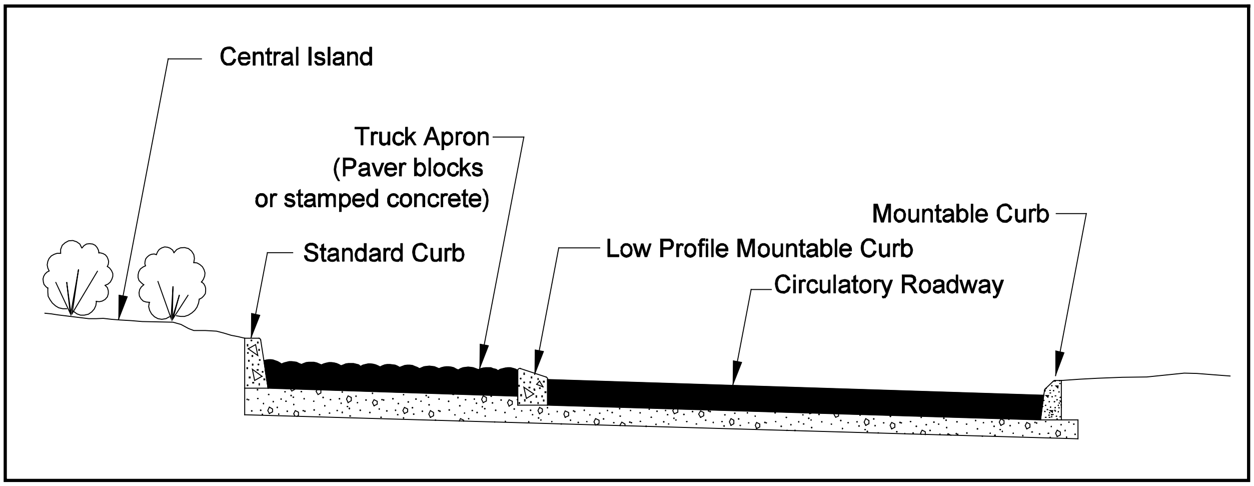


Figure 9-18
Central Island Cross-Section

- **Entry/Exit**

All approaches should be designed as perpendicular to each other as possible. This approach design will help ensure sufficient separation between two adjacent legs. If approaches are built too close together, it can lead to potential traffic conflicts due to the entering driver being unaware of entering vehicle on the upstream approach leg.

- **Splitter Island**

The purposes of splitter islands are to:

1. Help alert drivers of the upcoming roundabout, regulate entry and exit speed;
2. Physically separate entering and exiting traffic, minimize potential for wrong-way movement;
3. Introduce deflection into vehicle paths; and
4. Provide a refuge for pedestrians, and a place to mount traffic signs.

The length of the island measured along the approach should be at least 50 feet long to provide sufficient protection for pedestrians. Longer islands or extended raised medians should be used in areas with high approach speeds. A separation between the yield line on the circulatory roadway and the pedestrian crossing is crucial to safety and operation. This separation distance helps split up the decision points of yielding to a pedestrian and picking a gap in the vehicular flow of the roundabout. It is recommended that the pedestrian crossing be located at least 33 – 40 feet from the yield line to the center of the crosswalk. The recommended crosswalk width is 10 feet. The opening through the splitter island should be 6 feet at the center of the crosswalk. Typically, the splitter island will have a cut through design to accommodate pedestrians. Figure 9-19 shows an example of a splitter island.

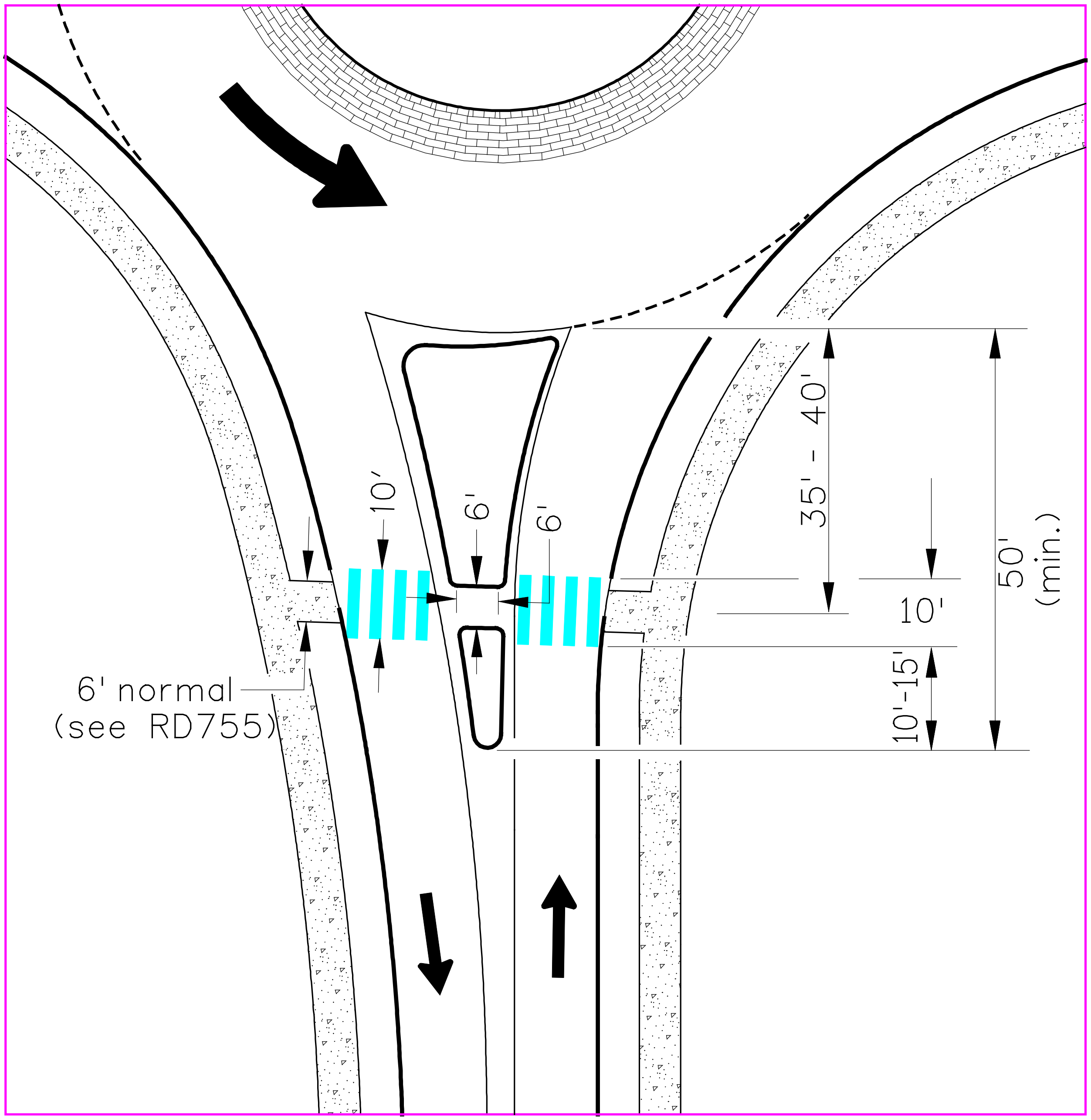


Figure 9-19
Minimum Splitter Island Dimensions

9.5.4 MULTI-MODAL ROAD USERS

- **Pedestrians**

The accommodation and safety of pedestrians at roundabouts is dependent on the following design features:

- Slow speeds, achieved through sufficient deflection.
- Separation of conflicts, achieved by placing the crosswalk 26 – 40 feet (approx. one car length) away from the yield line of the circulatory roadway; and
- Breaking up the pedestrian crossing movements, achieved by placing a splitter island at each leg.

- **Bicyclists**

On single lane roundabouts, bicyclists will generally be given a choice to enter the roundabout as a vehicle and occupy a lane until exiting the roundabout, or to use the sidewalks and crosswalks as pedestrians.

Approach legs that have a shoulder or bike lane should have the shoulder/bike lane terminate at a distance sufficient to allow cyclists to merge into traffic before drivers' attention is on roundabout traffic coming from the left. Curb ramps should be placed where the shoulder/bike lane terminates, allowing cyclists to access the sidewalk. The bike lane should end 165 feet in advance of the yield line and curb ramp width should be a minimum of 8 feet with no texturing. See Figure 9-20 for bike curb cut information.

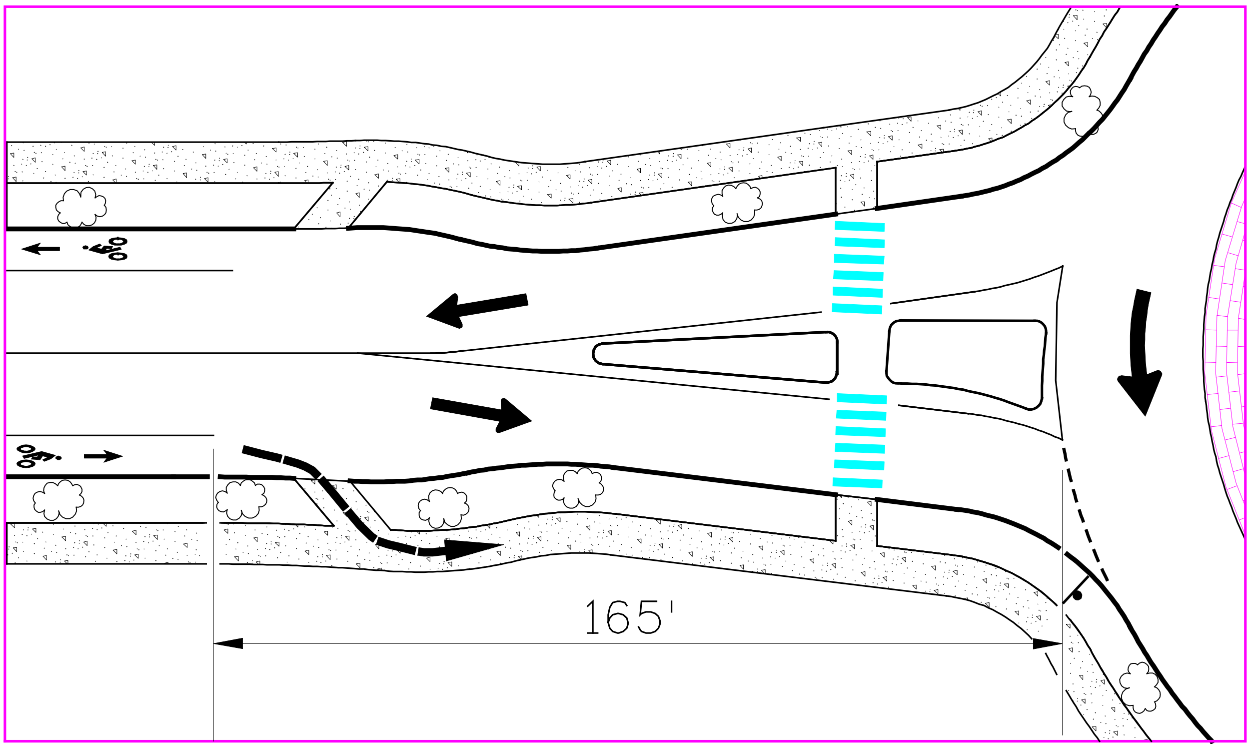


Figure 9-20
Bike Curb Cut

- **Transit Considerations**

The placement of bus stops near roundabouts should be consistent with the needs of the users and the desired operations of the roundabout. Bus stops should be close to passenger generators or destinations, and pedestrian crossings of the roundabout legs should be minimized. A bus stop is best situated:

- On an exit lane, in a pullout just past the crosswalk; or
- On an approach leg 60 feet upstream from the crosswalk, in a pullout; or
- On a single lane entrance leg, just upstream from the crosswalk, if the traffic volume is low and the stopping time is short. This location should not be used on two-lane entrances (a vehicle should not be allowed to pass a stopped bus in the interest of pedestrian crossing safety).

Bus pullouts shall not be located in the circulatory roadway on the state highway system.

9.6 INTERCHANGE DESIGN

- **General**

Prior to the location and design stage, ODOT staff approval and FHWA approval must be obtained for the reconstruction or addition of an interchange on the Interstate system. The approval procedures are processed through the Preliminary Design Unit. Justification is based on a number of issues, including roadway system analysis, traffic studies, interchange spacing, cost/benefit ratio, etc. The following documents provide the basis of interchange planning and design process:

1. OSHD Policy for New Interchanges on Full Access Controlled Highways-1988
2. AASHTO *"A Policy on Geometric Design of Highways and Streets, 1994"*
3. AASHTO *"A Policy on Design Standards- Interstate System, 1991"*
4. FHWA Policy Statement on Additional Interchanges to the Interstate System
5. The *"Oregon Highway Plan,"1999*

- **Traffic Studies**

Traffic studies should be requested from the Transportation Planning and Analysis Unit as early in the development of the design as possible. Typical requests for analysis should include volumes, turning movements, capacity and levels of service. Analysis for weaving sections, storage lengths and spacing should also be done as needed. Analysis shall be considered on the basis of a 20-year design life after construction of the project. Further information on traffic studies can be found in Section 10.6.

- **Standard Interchange Layout Sheet**

The proposed interchange design shall be prepared on the Standard Interchange Layout Sheet by the Preliminary Design Unit or authorized representative. Study copies of the "Standard Sheet" are typically submitted to the Roadway Section, Transportation Planning Analysis Unit, and the Bridge Section for approval. Depending on the level of interchange detail, FHWA approval is obtained locally for minor interchange revisions and at the national level for major freeway to freeway type interchange revisions.

The approved design must be used for contract plans. If revisions are desired, they must be made by the Preliminary Design Unit, which will consult with the appropriate Technical Services Sections and circulate the revised copies.

Interchanges can be designed for freeways or non-freeways. The first half of this section will discuss the design elements and issues for freeway interchanges. The second half will discuss non-freeway design.

9.6.1 FREEWAY INTERCHANGE DESIGN

- **Interchange Spacing**

Table 9-2 shows the access spacing standards for interchanges for freeway and non-freeway locations. The spacing shown is measured crossroad to crossroad centerline distance.

Table 9-2
Freeway Interchange Spacing

Access Management Classification	Area	Interchange Spacing
Interstate and Non-Interstate Freeways	Urban Rural	3 miles 6 miles
All Expressways, Statewide, Regional, and District Highways	Urban Rural	1.9 miles 3 miles

- **Design Speed**

The design speed of an interchange ramp varies from 50% (minimum) to 85% (desirable) of the freeway speed, with the exception of loop ramps. Design speed applies to the ramp proper and not to the terminals, which are relative to the speed of the highway involved. The design speed influences the horizontal and vertical curvature of the ramp. Table 9-3 below can be used to determine the appropriate ramp design speed. Ramp capacity is also influenced by the design speed. (See Table 9-4.)

Table 9-3
Ramp Design Speed

	Highway Design Speed (mph)				
	50	**55**	**60**	**65**	**70**
Ramp Design Speed (mph) - Desirable - Minimum	 45 25	 45 30	 50 30	 55 35	 60 35

Note: Loop Ramp Design Speed should not be less than 25 mph

Table 9-4
Single Lane Ramp Capacity

Approximate Service Flow Rates for Single Lane Ramps (Passenger Cars Per Hour)					
LOS	**Ramp Design Speed (mph)**				
	< 20	**21 - 30**	**31 - 40**	**41 – 50**	**Over50**
A	*	*	*	*	600
B	*	*	*	900	900
C	*	*	1100	1250	1300
D	*	1200	1350	1550	1600
E	1250	1450	1600	1650	1700
F	Variable	Variable	Variable	Variable	Variable

* Level of service not obtainable due to restricted design speed.

<u>NOTE:</u> For two lane ramp, multiply the values in the table by:
1.7 for 20 mph or less
1.8 for 21 - 30 mph
1.9 for 31 - 40 mph
2.0 for 41 mph or over

- **Typical Section**

The urban and rural arterial design chapters, Chapters 7 and 8, discuss typical section elements for roadways. These chapters should be referenced for the crossroad design. See Figures 9-21 and 9-22 for details of the ramp design.

- **Horizontal Alignment**

The main curve (the curve immediately following the exit taper or preceding the entrance taper) should conform to the desirable ramp design speed, with maximum degrees of curvature shown in Table 9-5. Variations of this will require adjustments to the exit taper or acceleration lane length. See Figures 9-21 and 9-22 (Standard Drawings RD205 and RD210).

Table 9-5
Maximum Degree of Curvature and Sight Distance on Ramps

Design Element	**Design Speed of Ramp (mph)**							
	25	**30**	**35**	**40**	**45**	**50**	**55**	**60**
Maximum Design Degree of Curvature	36°	26°	19°	14°	10°30’	8°15’	6°30’	5°
Stopping Sight Distance (feet)	155	200	250	305	360	425	495	570

Also See Figures 9-21 & 9-22

The layout of the interchange is influenced by the skew and horizontal alignment of the crossroad. The skew of the crossroad to the highway should be as close to 90 degrees as possible. The use of horizontal curves on either highway through the interchange should be avoided. A discussion on horizontal alignments for roadways can be found in Section 5.3.

When one way, one-lane ramps exceed 1500 feet in length, a second lane should be added to relieve congestion caused by slow moving or stalled vehicles. Steep grades and/or a high percentage of trucks may require an added lane on shorter ramps.

Typical horizontal exit and entrance details to the main highway can be found in Figures 9-21 and 9-22. Ramp terminals are generally perpendicular to the crossroad.

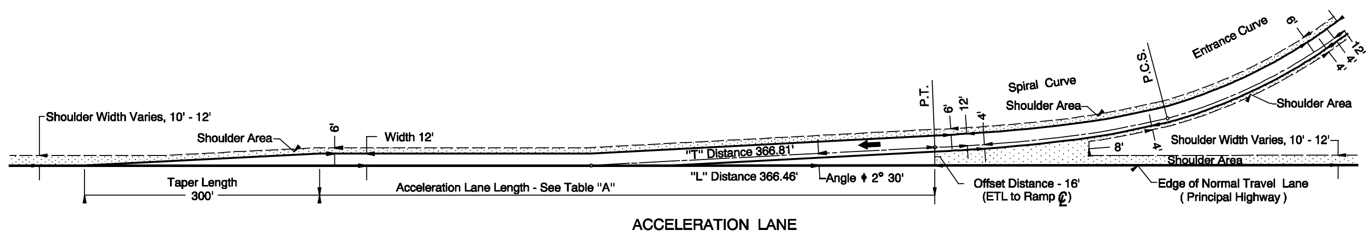


TABLE "A"
MINIMUM ACCELERATION LANE LENGTHS

Design Speed of Turning Curve (mph)	25	30	35	40	45	50+
Minimum Curve Radius (ft.)	160	230	320	430	555	695
Design Speed of Highway (mph)	TOTAL LENGTH OF ACCELERATION LANE (WITHOUT TAPER) Length (ft.)					
40	540	540	540	540	540	540
45	540	540	540	540	540	540
50	550	540	540	540	540	540
55	780	670	550	540	540	540
60	1020	910	800	550	540	540
65	1220	1120	1000	770	*600	*540
70	1420	1350	1230	1000	820	*580

* Desirable length is **750'**, this allows additional decision time for picking gaps.

TABLE "B"
RATIO OF LENGTH OF ACCELERATION LANES ON MAINLINE GRADES TO LENGTH ON LEVEL

Design Speed of Highway (mph)	Design Speed of Turning Roadway (mph) 25	30	35	40	45	50	ALL Speeds
	3% to 5% Upgrade						3% to 5% Down
40	1.30	1.30	1.20	1.00	1.00	1.00	0.70*
45	1.30	1.35	1.30	1.00	1.00	1.00	0.65*
50	1.35	1.40	1.40	1.40	1.35	1.00	0.65*
55	1.40	1.45	1.45	1.45	1.45	1.00	0.65*
60	1.45	1.50	1.50	1.50	1.55	1.60	0.60*
65	1.50	1.55	1.55	1.60	1.65	1.70	0.60*
70	1.55	1.60	1.65	1.70	1.75	1.80	0.60*
	5% and over Upgrade						5% and over Down
40	1.50	1.50	1.50	1.00	1.00	1.00	0.60*
45	1.55	1.60	1.65	1.00	1.00	1.00	0.60*
50	1.60	1.70	1.80	1.90	1.45	1.00	0.55*
55	1.70	1.80	1.90	2.05	2.15	1.00	0.55*
60	1.80	1.90	2.05	2.20	2.35	2.50	0.50*
65	1.95	2.05	2.20	2.40	2.60	2.75	0.50*
70	2.10	2.20	2.40	2.60	2.80	3.00	0.50*

* If the ratio from Table "B" yields a length less than 540', use 540' as the minimum acceleration lane length. The desirable length is 750', this allows additional decision time for picking gaps.

ENTRANCE CURVES & SPIRALS

Ramp Design Speed (mph)	Degree of Curve	Radius (ft)	e (%)	Spiral Length (ft.)	Spiral Parts "a" Value	"S" Value
70	1° 00'	5729.58	3.5	200	0.5	1.0
	2° 00'	2864.79	6.5	200	1.0	2.0
	3° 00'	1909.86	8	240	1.25	3.6
65	4° 00'	1432.39	9	240	1.667	4.8
60	5° 00'	1145.92	9.5	250	2.0	6.25
55	6° 00'	954.93	10	240	2.5	7.2
50	7° 00'	818.51	10.5	240	2.917	8.4
	8° 00'	716.20	10.5	250	3.2	10.0
45	10° 00'	572.96	11	250	4.0	12.5
40	12° 00'	477.46	11.5	240	5.0	14.4
	14° 00'	409.26	11.5	200	7.0	14.0
35	16° 00'	358.10	12	200	8.0	16.0
	18° 00'	318.31	12	200	9.0	18.0
30	20° 00'	286.48	12	200	10.0	20.0
	24° 00'	238.73	12	200	12.0	24.0
25	30° 00'	190.99	12	200	15.0	30.0
	36° 00'	159.15	12	200	18.0	36.0

EXAMPLE:

Find: Adjusted Acceleration Lane Length
Given: Principal Highway design speed 70 mph
Turning Highway design speed 30 mph
Meeting on a 5% upgrade

Solution: From Table "A" acceleration lane length = 1350'
From Table "B" ratio on upgrade = 2.20
Adjusted acceleration lane length = 1350' x 2.20 = 2970'

Note: If adjusted acceleration lane length appears impractical, a merge analysis should be performed. Lengthening of acceleration lane length may be necessary due to high truck volumes.

See Oregon Standard Drawings, For Current Drawing

Contact the Preliminary Design Unit for assistance on any portion of this drawing.

The selection and use of this Standard Drawing, while designed in accordance with generally accepted engineering principles and practices, is the sole responsibility of the user and should not be used without consulting a Registered Professional Engineer.

NOTE: All material and workmanship shall be in accordance with the current Oregon Standard Specifications

OREGON STANDARD DRAWINGS

ENTRANCE RAMP DETAILS

2003

REVISIONS

DATE	DESCRIPTION

RD205

nt7360ab/usr/metric/rd205.dgn 1-8-96

RD205

Figure 9-21
Entrance Ramp Details

Ratio of Length of Deceleration Lanes on Mainline Grade to Length on Level		
Grade	Down	Up
3% to 5%	1 .20	0.9
5% and over	1 .35	0.8

NOTE: Adjust "T" Distance to the length required to give adjusted deceleration lane length.

MINIMUM DECELERATION LANE LENGTHS (1 LANE)

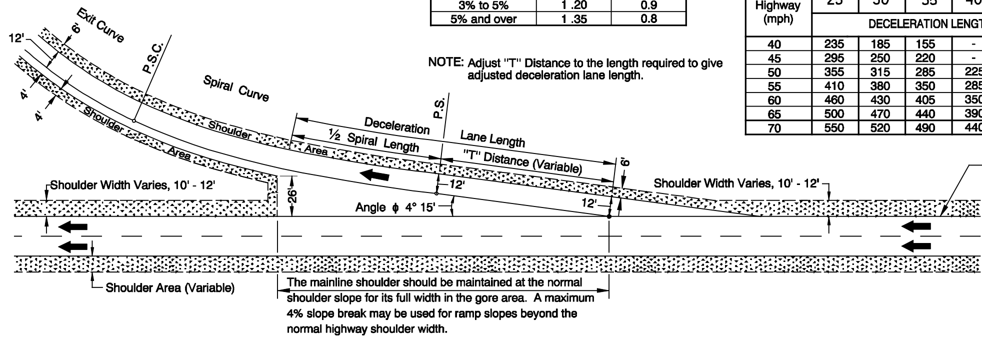
Design Speed of Highway (mph)	Design Speed of Turning Curve (mph)					
	25	30	35	40	45	50
	DECELERATION LENGTHS (ft.)					
40	235	185	155	-	-	-
45	295	250	220	-	-	-
50	355	315	285	225	175	-
55	410	380	350	285	235	-
60	460	430	405	350	300	240
65	500	470	440	390	340	280
70	550	520	490	440	390	340

EXAMPLE 1:

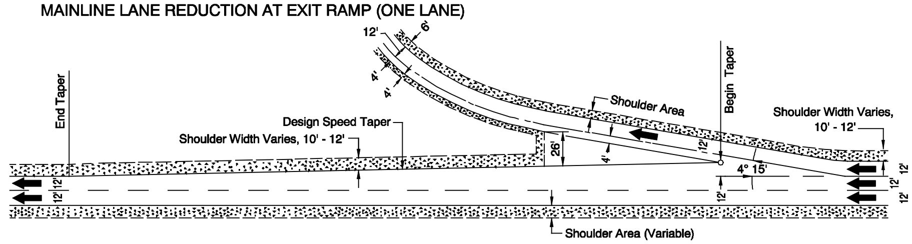
Find: Deceleration lane length.
Given: One lane ramp, 24° curve
Design speed = 30 mph (From Table)
Less than 3% downgrade
Solution: T = 420', ½ Spiral Length = 100' (from table)
T = 420'
+ ½ Spiral Length = 100'
Deceleration Lane Length = 520'

EXAMPLE 2:

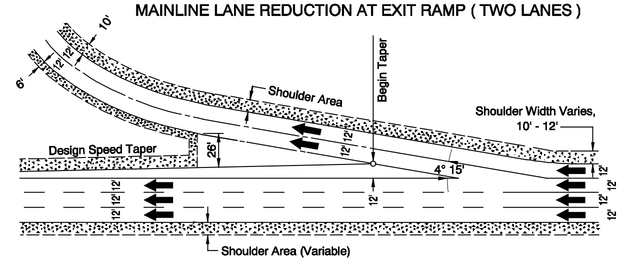
Find: Adjusted 'T' distance
Given: Data from Example 1
Deceleration lane length (calculated in Example 1) = 520'
6% mainline downgrade.
Solution: Adjusted Deceleration Lane length =
520' x 1.35 (from table) = 702' (round to 705')
Adjusted Length = 705'
- ½ Spiral Length = 100'
Adjusted "T" Distance = 605'



MAINLINE LANE REDUCTION AT EXIT RAMP (ONE LANE)



MAINLINE LANE REDUCTION AT EXIT RAMP (TWO LANES)



EXIT CURVES & SPIRALS

Ramp Design Speed (mph)	Degree of Curve	Radius (ft)	e (%)	1 LANE (Highway Design Speed 70 mph) Spiral Length (ft.)	1 LANE Spiral Parts "a" Value	1 LANE Spiral Parts "S" Value	1 LANE "T"* Distance (ft.)	1 LANE "T" TRUCK Distance (ft.)	2 LANE (Highway Design Speed 70 mph) Spiral Length (ft.)	2 LANE Spiral Parts "a" Value	2 LANE Spiral Parts "S" Value	2 LANE "T"* Distance (ft.)	2 LANE "T" TRUCK Distance (ft.)
70	1° 00'	5729.58	3.5	200	0.5	1.0	240	340	300	0.333	1.5	300	400
	2° 00'	2864.79	6.5	200	1.0	2.0	240	340	300	0.667	3.0	300	400
	3° 00'	1909.86	8	240	1.25	3.6	220	320	360	0.833	5.4	300	370
65	4° 00'	1432.39	9	240	1.667	4.8	220	320	360	1.111	7.2	300	370
60	5° 00'	1145.92	9.5	250	2.0	6.25	215	315	375	1.333	9.375	300	365
55	6° 00'	954.93	10	240	2.5	7.2	220	320	360	1.667	10.8	300	370
50	7° 00'	818.51	10.5	240	2.917	8.4	220	400	360	1.944	12.6	300	450
	8° 00'	716.20	10.5	250	3.2	10.0	215	395	375	2.133	15.0	300	445
45	10° 00'	572.96	11	250	4.0	12.5	265	470	375	2.667	18.75	315	520
40	12° 00'	477.46	11.5	240	5.0	14.4	320	545	360	3.333	21.6	370	595
	14° 00'	409.26	11.5	200	7.0	14.0	340	565	300	4.667	21.0	400	625
35	16° 00'	358.10	12	200	8.0	16.0	390	650	300	5.333	24.0	450	710
	18° 00'	318.31	12	200	9.0	18.0	390	650	300	6.0	27.0	450	710
30	20° 00'	286.48	12	200	10.0	20.0	420	700	250	8.0	25.0	505	785
	24° 00'	238.73	12	200	12.0	24.0	420	700	240	10.0	28.8	510	790
25	30° 00'	190.99	12	200	15.0	30.0	450	745	240	12.5	36.0	540	835
	36° 00'	159.15	12	200	18.0	36.0	450	745	240	15.0	43.2	540	835

* "T" distance is based upon spiral length shown. Variations in spiral lengths will cause change in "T" distance. If spiral length is shortened, then lengthen "T" distance for minimum deceleration length. "T" should be increased if high truck volumes are present on the ramp. "T" truck distance to be used with high truck volumes.

See Oregon Standard Drawings, For Current Drawing

Contact the Preliminary Design Unit for assistance on any portion of this drawing.

The selection and use of this Standard Drawing, while designed in accordance with generally accepted engineering principles and practices, is the sole responsibility of the user and should not be used without consulting a Registered Professional Engineer.

NOTE: All material and workmanship shall be in accordance with the current Oregon Standard Specifications

OREGON STANDARD DRAWINGS

EXIT RAMP DETAILS

2003

DATE	REVISIONS DESCRIPTION

RD210

RD210 ne7360ab/usr/metric/rd210.dgn 6-3-97

Figure 9-22
Exit Ramp Details

Adjacent loop ramps on the same side of the freeway are not usually permitted unless the weaving section is carried on a Collector-Distributor, C-D, road. Loop ramps on the same side of the crossroad are discouraged due to the short weaving section normally available between the loop ramps.

Loop ramps should be as large as practical and never be sharper than a 36° curve. When designing an exit loop ramp where the crossroad is below the freeway, the maximum degree of curve should be 30°, the use of spirals longer than the standard is recommended in this situation. Loop ramp connections usually come parallel to the crossroad using a spiral rather than an angled connection.

Terminal curves (where a ramp terminates at a crossroad) are generally sharper than the main curve, varying with the conditions.

Due to the crossroad grade often being adverse to a normal superelevation for terminal curves and the fact that traffic is slowing to stop at the crossroad, ramp terminal curves seldom are fully superelevated and may not be superelevated at all. Therefore, the need for spirals, particularly standard length spirals, is diminished and sometimes eliminated on terminal curves. While spirals may not be required, their use is always beneficial for leading traffic smoothly into the terminal curve. The ramp terminal curve superelevation rate is typically one-half the full superelevation rate for that curve.

- **Vertical Alignments**

Ramp grades should be as flat as possible. (See Table 9-6 following.) Where ramp traffic consists chiefly of heavy trucks or buses, 3 or 4% gradients are preferred. A gradient of 2% for "landings" at ramp terminals shall be provided when possible. In Figure 5-14, the effect of grades on truck speeds is shown. Speed of trucks on grades is directly related to the weight/horsepower ratio. (See AASHTO *"A Policy on Geometric Design of Highways and Streets – 2001"* page 252.) Vertical alignments and clearances for the crossroad and ramps should be designed in accordance with Figures 5-11 and 5-12.

The deceleration and acceleration characteristics of trucks are quite different from the normal passenger vehicle. When there is significant truck traffic (over 20 trucks with 4 or more axles per hour), the minimum deceleration design lengths for trucks should be consistent with Figure 9-22. Due to the long acceleration requirements for trucks, it is not practical for acceleration lanes to be designed for significant numbers of large trucks, but, instead, all types of vehicles should be considered in the design of interchange ramps.

Table 9-6
Maximum Grades For Ramps

Design Speed	Ascending Grades %		Descending Grades %	
	Desirable	Maximum	Desirable	Maximum
25-30 mph	5	7	7	8
35-40 mph	4	6	6	7
45-50 mph	3	5	5	6

Except in special cases, descending grades on exit ramps should be the same as the ascending grades.

- **Superelevation**

The superelevation on ramps shall follow the same standards as those on the main roadway with consideration given for speed and local conditions. *(*See rural and urban design sections, Section 5.3*)*. The terminal curve will use minimal superelevation as appropriate for the intersection (typically one-half the full super rate).

- **Ramp Terminals**

The separation or "spread" between ramp terminals on the crossroad should be adequate to allow for standard median channelization if left turns are required. Figure 9-23 gives minimum spread distances for a basic diamond interchange at various design speeds. Particular attention should be paid to adequate vertical and horizontal sight distance at the ramp terminals. Design elements such as barrier, protective screening, superelevation rates, and landscaping can have an impact on the sight distance of ramp terminals.

Exit ramp and entrance ramp terminals on the crossroad should be offset to encourage drivers to use the entrance ramp and to discourage wrong way moves. See Figure 9-24 for methodology in designing exit and entrance ramp terminals.

Freeway ramp terminals, and intersections pre-approved for interstate trucks as shown on Route Map 7 (Route Map 7 can be found at http://www.odot.state.or.us/trucking/od/maps.htm) at major truck use locations, shall accommodate the current Interstate Design Vehicle. Other intersections that have known large truck usage should be designed to accommodate the current Interstate Design Vehicle where feasible. Overlay templates or computer and CADD generated wheel paths of the design vehicle should be used to determine adequate clearances. This is particularly important when determining stop lines for left turn bays and when designing double left turns and two lane loop ramps.

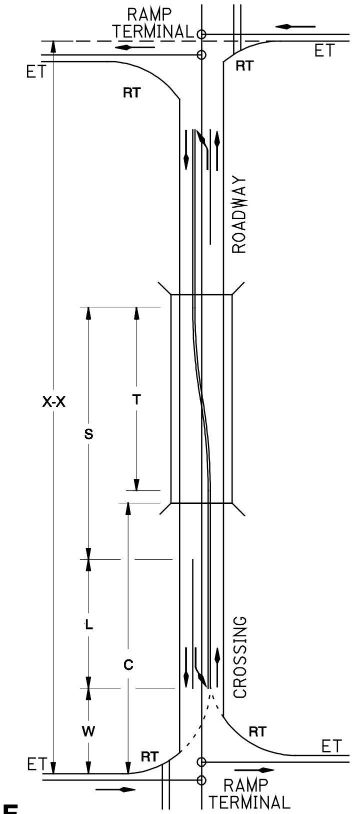
DIAMOND INTERCHANGE - TERMINAL RAMP SPREAD

CHANNELIZATION DIMENSIONS

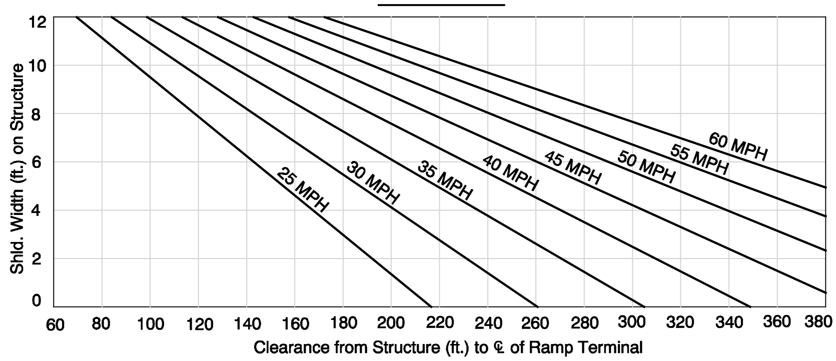
MPH	R (ft.)	T (ft.)	S (ft.)	L min. (ft.)	X-X MIN	
					3-Lane	5-Lane
25	195	100	150	100	600	510
30	195	100	150	100	600	510
35	250	110	160	100	610	520
40	305	120	180	100	640	550
45	370	135	235	100	735	645
50	435	145	295	150	945	855
55	510	160	355	150	1050	960
60	595	170	420	150	1170	1080
65	680	180	485	150	1290	1200
70	680	180	555	150	1430	1340

GLOSSARY OF TERMS

MPH = Design speed of crossing roadway.
R = Radius of reversing curve.
T = Length of reversing curve.
*S = Stopping sight distance for a speed 10 mph less than the Design Speed.
L = Length of storage determined by storage analysis - Minimums shown.
W = 100' for 3-lane @ 90° in tangent section. 55' for 5-lane @ 90° in tangent section. W determined by where turning vehicle's off-track crosses edge of left-turn lane (See figure right). This is where stop bar should be placed.
X-X = Minimum distance between the left edges of travel of the ramp terminals (see diagram left). X-X = 2(W+L+S)-T ; where S ≥ T. Else X-X = 2(W+L)+T.
C = Combined horizontal and vertical sight distance clearance from the structure. Typically 200 feet or more. See Sec. 9.6.1, Hwy. Design Manual, Frontage Roads and Outer Separations.
RT = Ramp terminal radii should accommodate a WB-67 Interstate Design Vehicle (IDV). Two Centered radii should be used to satisfy this requirement.
ET = Edge of Travel



'C' TABLE



'C' TABLE NOTES

1) 'C' Table values are based on the appropriate vertical curve and horizontal safe sight distance values for the design speed in a tangent section.
2) Clearance calculations do not include sidewalks; as there may or may not be barrier separation from the roadway. Barriers must be used when the cross-road design speed is 45 mph or greater.

SOURCE: PRELIMINARY DESIGN

State of Oregon
Department of Transportation

HIGHWAY DESIGN MANUAL
INTERCHANGE RAMP SPREAD

Figure: 9-23 2003

Figure 9-23
Interchange Ramp Spread

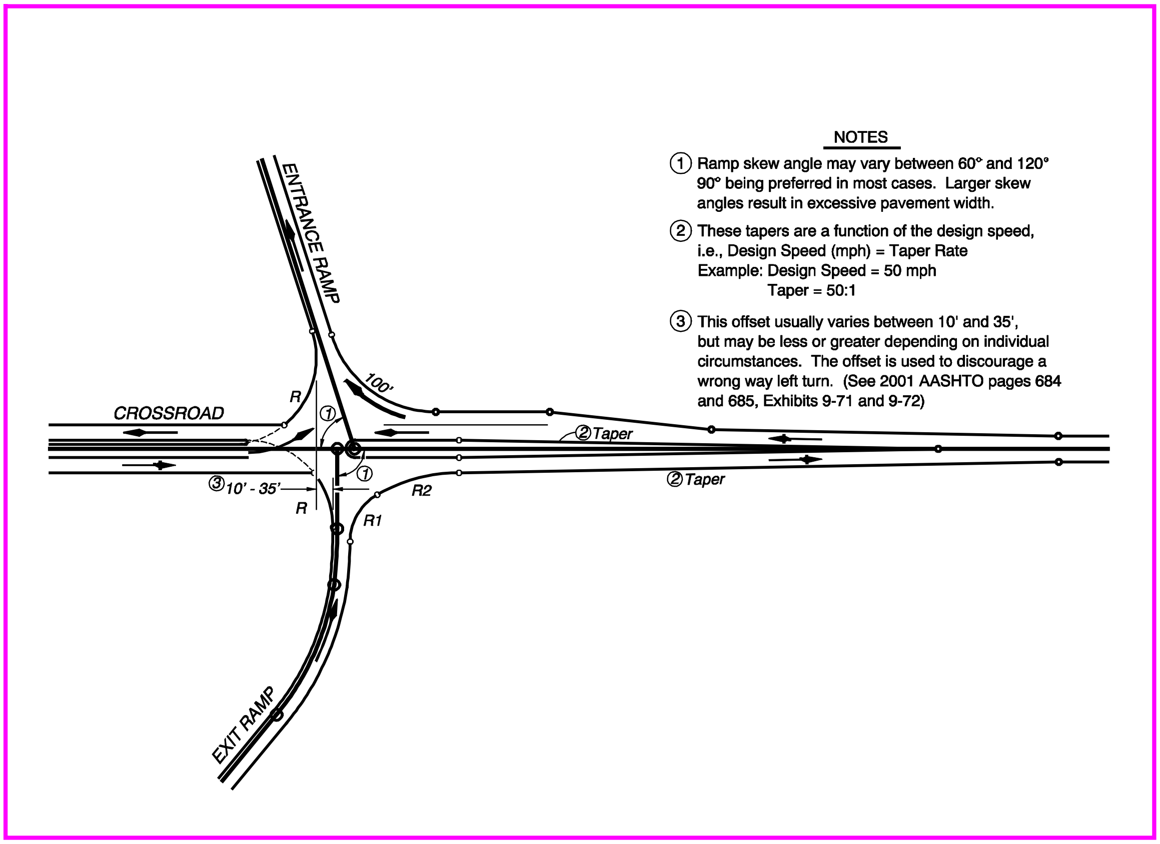


Figure 9-24
Exit and Entrance Ramp Terminals

Recommendations for radii can be found in Section 9.2 and in "Turning Paths of Design Vehicles," a design guide prepared by Preliminary Design. Interstate Design Vehicle path requirements can also be found on Figure 9-25. Typically, two centered curves are used at ramp terminals due to the benefits of matching the turning characteristics of large vehicles. Two centered curves assist in reducing the crossing distance at ramp terminals while accommodating the turning requirements of the design vehicle.

- **Access Control**

Complete restriction of access must be obtained in the interchange area consistent with the following:

A) At all rural and suburban/urban fringe area interchanges, access shall be controlled a minimum distance of 1320 feet from the centerline of the ramp. The access control shall be applied equally to both sides of the crossroad. No reservations of access should be allowed within these access controlled areas. No private access should be allowed across from the interchange ramp terminal.

B) All other urban interchange areas should also be access controlled for 1320 feet from the centerline of the ramp. In many existing urban interchange environments however, this distance will be very difficult to achieve due to the built up environment surrounding the interchange. In these situations, the crossroad shall be controlled for a minimum distance of 750 feet. This controlled section applies equally to both sides of the crossroad and shall not include any reservations of access. No private access should be allowed across from the interchange ramp terminal.

Exceptions from the above have been developed through a deviation process associated with interchange access management area planning. OAR 734 Division 51 provides information and rules involving access management for road connections to state highways. Potential justifications for not obtaining the minimum access control may include but are not limited to:

(A) The cost of obtaining the access rights far exceeds the benefits.

(B) Existing development patterns make it difficult and costly to provide alternative access routes such as frontage roads, combined access, or completing local roadway networks.

(C) Topographical constraints make it impractical to achieve the desired spacings.

Exceptions from the access control standards for new interchanges will generally not be approved. In these situations, the standards should be achievable at a reasonable cost and impact. Only extreme cost or environmental impacts may justify an exception.

Additional guidance on controlling access at interchanges can be found in the 1999 Oregon Highway Plan.

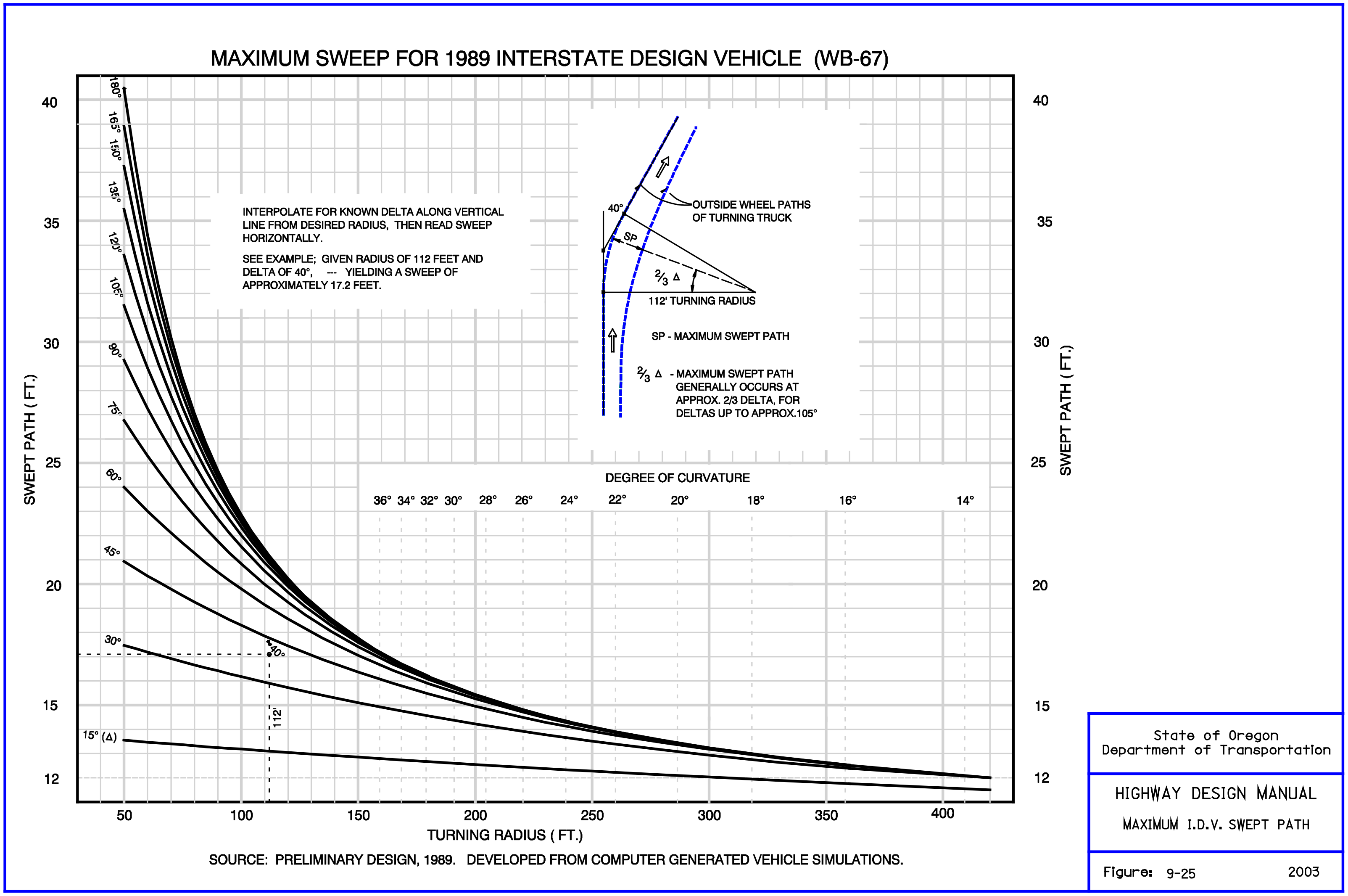


Figure 9-25
Swept Path

Ramp Meters

In highly congested areas, typically urban, the use of ramp meters may be beneficial to freeway traffic operations. Ramp meters reduce merge area turbulence and regulate total freeway flow through downstream bottlenecks. The Traffic Management Section should be contacted when ramp meters are being considered in the project development process. In addition, there are geometric and safety issues with the design of the ramps and placement of the ramp meter signals that should be considered in the design.

Ramp meters can be installed on single lane or two lane entrance ramps. Ramp meters should not be installed on ramps connecting freeways to freeways, as freeway ramps should be designed to operate as free flow ramps. Where ramp meters are to be installed on a single lane entrance ramp, the ramp design shall be consistent with the appropriate design for 4R/New Construction for Freeway or Non-Freeway Ramps found in Figure 9-21 and 9-26. In a 3R project, installation of a two lane ramp meter on a single lane ramp should be built to 4R/New Construction standards (ramp should be widened to full two lane ramp standards). In constrained areas, an evaluation should be made to determine if the existing one lane ramp should be widened to two full standard lanes or if the existing one lane ramp width can be retrofitted for installation of two ramp meters. Single lane ramps retrofitted for two lane ramp meters require a design exception. The location of the ramp meter signals should be located just prior to the paved edge of the ramp gore area. Figure 9-27 details the proper location and typical section for a two lane tapered to one lane parallel entrance ramp. It is important to locate the ramp meter signals outside of the freeway clear zone.

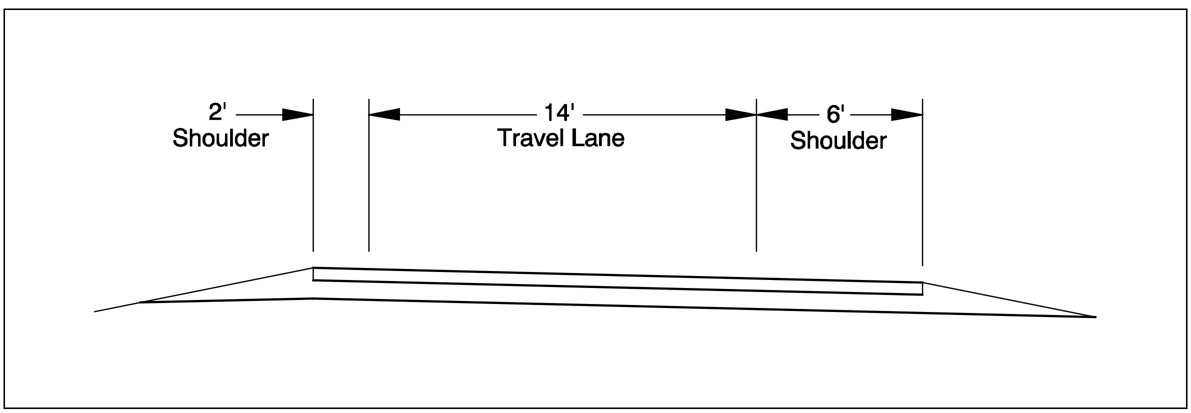


Figure 9-26
Non-Freeway Interchange Ramp Typical Section

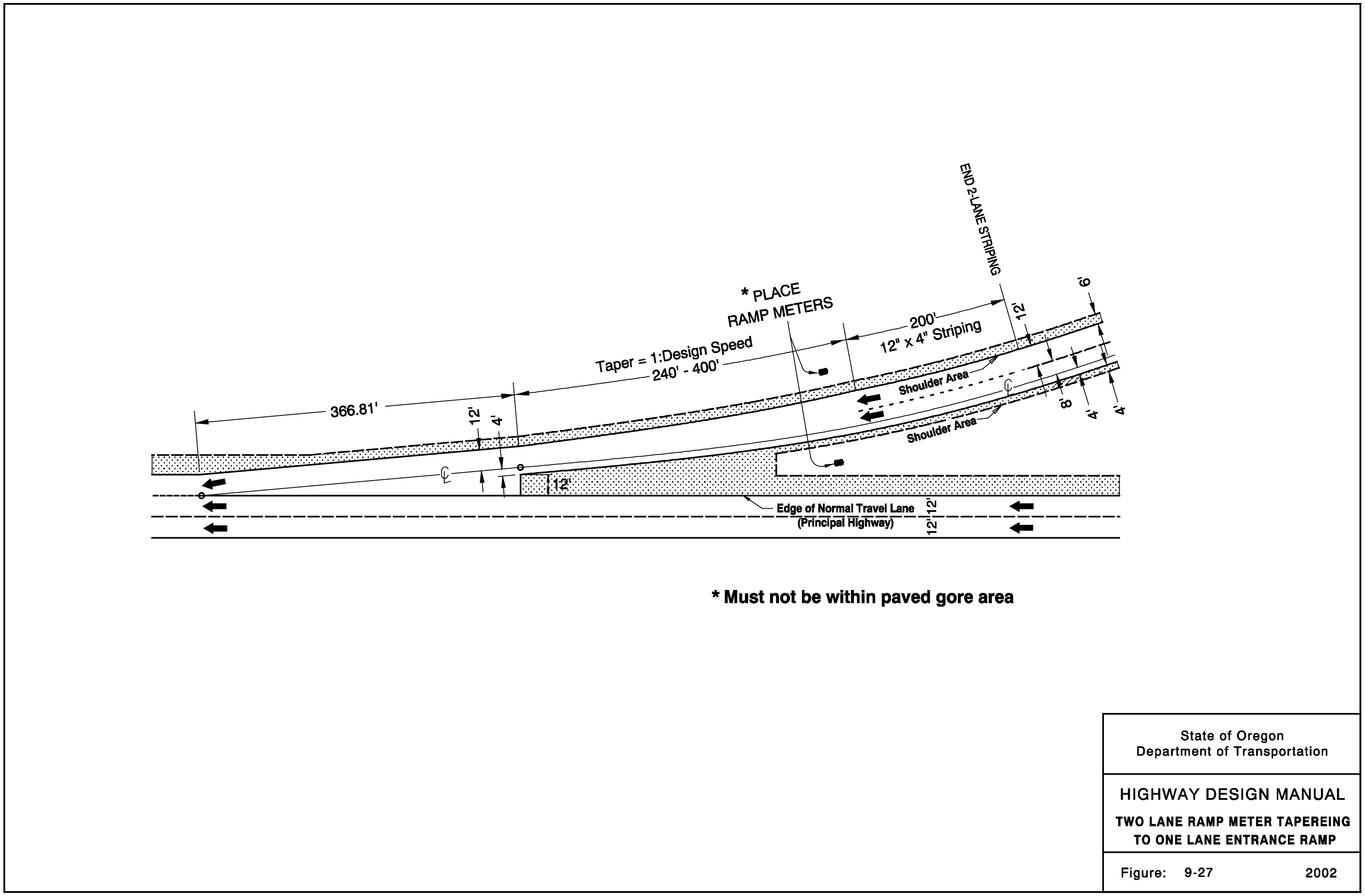


Figure 9-27
Two-Lane Ramp Meter With Taper To One-Lane Entrance Ramp

- **Lane Balance**

To realize efficient traffic operation through an interchange, there should be a balance in the number of traffic lanes on the highway and ramps. Design traffic volumes and capacity analysis determine the number of lanes to be used on the highway and on the ramps, but the number of lanes for some sections should be increased to ease operation from one roadway to another. Lane balance should be checked after the minimum number is determined for each roadway on the basis of the following principles:

A) The number of lanes beyond the merging of two traffic streams should not be less than the sum of all traffic lanes on the merging roadways minus one.

B) For entrance ramps bringing two lanes of traffic onto a highway, the road beyond the ramp entrance should be at least one lane wider than the road approaching the entrance. The parallel design for two lane entrance ramps shall be used. Any exception from this standard shall be approved by the Roadway Engineering Manager. (See AASHTO's "*A Policy on Geometric Design of Highways and Streets - 2001* ", pages: 860-863).

As a preliminary guide, the minimum distance between a freeway entrance and exit ramp at separate interchanges is one mile for urban freeways and two miles for rural freeway (see Oregon Highway Plan, Appendix C). The minimum distance between successive freeway entrance and exit ramp terminals is 1000 feet. The minimum distance for a single exit followed by a secondary exit or split is 800 feet. Exceptions from the standard spacing must be obtained from the Roadway Engineering Manager. All exception requests should be reviewed by the Transportation Planning Analysis Unit to ensure the freeway and ramps will function acceptably.

Where the distance between an entrance terminal and an exit terminal is 2500 feet or less, the interim space generally becomes a weaving section and must be analyzed for required length and design by the Transportation Planning Analysis Unit. Where the distance is 1500 feet or less, an auxiliary lane may be introduced.

Collector-Distributor roads may be used to reduce traffic friction from multiple entrance and exit connections on the same side of the freeway, thereby permitting higher speeds on the through traffic lanes.

- **Weaving Sections**

Weaving sections occur when entrance ramps are closely followed by exit ramps, and/or an auxiliary lane is utilized. Such areas present special design problems due to the concentrated lane changing maneuvers of merging and diverging traffic. The development of the design involves the following factors: desired mobility standard; length; number of lanes; traffic volumes; weaving and non-weaving vehicles; and average speed. Auxiliary lanes generally will be below access management spacing standards and may require a deviation. Design guidance may be obtained from "Design Controls and Criteria, Chapter 2 of AASHTO's "*A Policy on Geometric Design of Highways and Streets – 2001"* and from "Freeway Weaving" TRB #209, *Highway Capacity Manual, Chapter 24*.

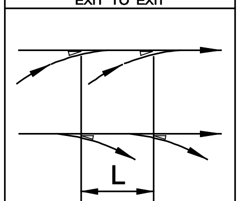
The Transportation Planning Analysis Unit shall be consulted for data and direction on the design of each weaving section and the location of consecutive entrance and exit ramps.

Figure 9-28 shows the terminal points for measuring the length of a weaving section.

RECOMMENDED MINIMUM RAMP TERMINAL SPACING (ft.)

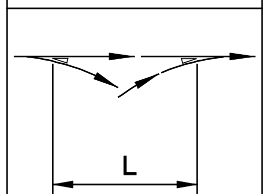
(BASED UPON OPERATIONAL EXPERIENCE AND NEED FOR FLEXIBILITY)

ENTRANCE TO ENTRANCE / EXIT TO EXIT



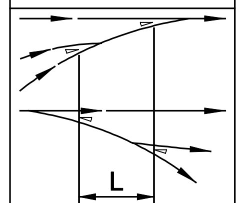
GUIDELINES	FULL FREEWAY	C-D ROAD OR FWY. DIST.
DESIRABLE	1500	1200
ADEQUATE	1200	1000
MINIMUM	1000	800

EXIT TO ENTRANCE



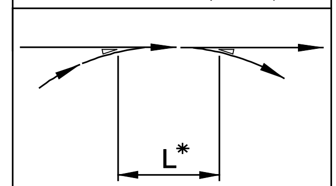
GUIDELINES	FULL FREEWAY	C-D ROAD OR FWY. DIST.
DESIRABLE	750	600
ADEQUATE	600	500
MINIMUM	500	400

TURNING ROADWAYS



GUIDELINES	SYSTEM INTCHG.	SERVICE INTCHG.
DESIRABLE	1200	1000
ADEQUATE	1000	800
MINIMUM	800	600

ENTRANCE TO EXIT (WEAVING)



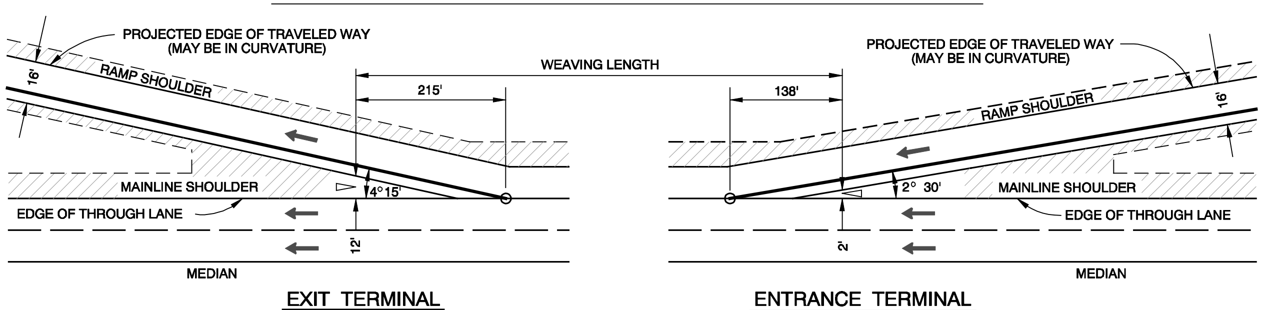
GUIDELINES	SYSTEM TO SERVICE INTERCHANGE		SERVICE TO SERVICE INTERCHANGE		GUIDELINES
	FULL FREEWAY	C-D RD. OR FWY. DIST.	FULL FREEWAY.	C-D RD. OR FWY. DIST.	
DESIRABLE	3000	2000	2000	1500	DESIRABLE
ADEQUATE	2500	1800	1800	1200	ADEQUATE
MINIMUM	2000	1600	1600	1000	MINIMUM

*RECOMMENDED: SHOULD BE CHECKED IN ACCORDANCE WITH PROCEDURE OUTLINED IN THE HIGHWAY CAPACITY MANUAL, 2001. (LARGER OF THE VALUES TO BE USED)

SOURCE: FOR DESIRABLE AND ADEQUATE RAMP TERMINAL SPACING, TRANSPORTATION RESEARCH RECORD 1100. DESIGN AND OPERATIONAL EFFECTS OF GEOMETRICS, PAGE 42. TRANSPORTATION RESEARCH BOARD, 1986.

FOR MINIMUM RAMP TERMINAL SPACING, SEE AASHTO, 2001. EXHIBIT 10-68, PAGE 848.

TERMINAL POINTS FOR MEASURING LENGTH OF WEAVING SECTION



State of Oregon
Department of Transportation

HIGHWAY DESIGN MANUAL

RAMP TERMINAL SPACING

Figure: 9-28 2002

Figure 9-28
Minimum Ramp Terminal Spacing

- **Frontage Roads and Outer Separations**

The area between the traveled ways of a through traffic roadway and a frontage road or street is called the outer separation. Outer separations shall be a minimum of 33 feet (desirably 40 feet) between edge of travel lanes for one-way frontage roads with traffic proceeding in the same direction as the adjacent freeway or expressway traffic. A minimum of 40 feet (desirably 50 feet) is the required outer separations for frontage roads having two-way traffic. Screening of headlight glare should be considered on frontage roads with two-way traffic or traffic opposing the main roadway traffic. These outer separation requirements should not be confused with the ramp terminal and roadway spacing standards (Appendix C of the 1999 Oregon Highway Plan).

A thorough study should be made to determine appropriate widths of outer separations on ground level freeways. The outer separation should be as wide as can be economically attained to provide a safe buffer zone (see AASHTO's *"A Policy on Geometric Design of Highways and Streets – 2001"*, pages: 512).

At intersections on major streets and on expressways, outer separations shall be minimum of 40 feet (desirably 65 feet) to provide room for turning movements.

Intersections of roads or streets with a crossroad having a structure shall be located 200 feet or more from the end of the structure to improve sight distance for vehicles on the intersecting facilities, unless the intersections are signalized.

- **Safety Rest Areas**

Safety rest areas provide the driver an opportunity to pull off the highway and rest, thus making the highway safer. Rest areas also provide picnic areas, water and sanitary areas, and motorist service information. Rest areas are located on freeways and other highways where there is a need.

The design of rest areas will vary depending upon location and need. Some rest areas are quite large while other rest areas only serve a few vehicles and are more of a wayside than rest area. The Preliminary Design Unit should be contacted concerning the design of rest areas.

Rest areas located on the freeway system should be designed with exit and entrance ramps. The exit and entrance ramps should be designed in the same manner as interchanges. Because rest areas accommodate large numbers of trucks, the design should consider the use of exit and entrance ramps that better accommodate trucks.

As mentioned above, rest areas have different functions. One of those functions is providing travel information at the rest areas. Many times the rest area will be closed for long periods of time and this has an impact on the travel information provider. In cases where the rest area requires remodeling or repair, the designer should see that tourist information facilities are kept in service if possible or look at ways of minimizing the closure time.

9.6.2 NON-FREEWAY INTERCHANGE DESIGN

- **General**

The types and styles of interchange designs on highways other than freeways are quite varied. They can range from freeway designs to intersection right in/out jug handles. Many of the design standards for freeway interchange design are also applicable to non-freeway interchange design. Unless otherwise noted below, the freeway design standards generally apply to non-freeway designs as well. However, other design elements and issues related to non-freeway design are also discussed below.

- **Design Speed**

As with freeway style interchanges, the design speed of the ramps should be between 50% and 85% of the design speed of the mainline. However, the ramp design speed should never be below 25 mph.

- **Typical Section**

The design of the crossroad should be the same as for freeways. The ramp sections are different, however. Non-freeway ramp design should be in conformance with Figure 9-26.

- **Access Control**

In addition to controlling access at the ramp terminals at the crossroad, access control along the mainline needs to be acquired upstream and downstream of the deceleration and acceleration lanes. Access needs to be controlled one mile (urban)/two miles (rural) in advance of a deceleration lane and one mile (urban)/two miles (rural) downstream of an acceleration lane. Achieving the access spacing may be very difficult on already developed existing roadways and may require a design deviation. Appendix C of the Oregon Highway Plan contains information on access management requirements.

- **Deceleration Lanes**

  All exit ramps for non-freeway interchanges require a deceleration lane. The deceleration lane can be a freeway style exit taper with gore area or an intersection right turn deceleration lane. Either option is adequate for loop ramp or jug handle style ramps. Interchanges that look like a standard diamond should use freeway style deceleration design.

- **Acceleration Lanes**

  The decision to use acceleration lanes will vary depending upon the speed of the highway, ramp volume, highway volume, number of lanes, level of service, and the highway roadside culture downstream from the ramp.

  Acceleration lanes should generally only be used when merging with a multilane highway. Only where safety is not compromised, could acceleration lanes be considered on two lane two-way roadways. Where acceleration lanes are used, they should conform to the lengths shown on Standard Drawing RD205. Non-freeway acceleration lanes may or may not use the entrance angle design associated with freeway interchanges. Consistency among ramps and throughout sections should be maintained as much as possible. If the exit ramps utilize an exit angle, the following acceleration lane should use the entrance angle. However, each interchange and ramp needs to be evaluated separately to determine the appropriate design. Typically, if the facility uses a "freeway style" interchange, exit and entrance angles should be used. "Jughandle style" interchanges should use parallel deceleration and acceleration ramps. Refer to Figures 9-29 and 9-30 for non-freeway interchange design concepts.

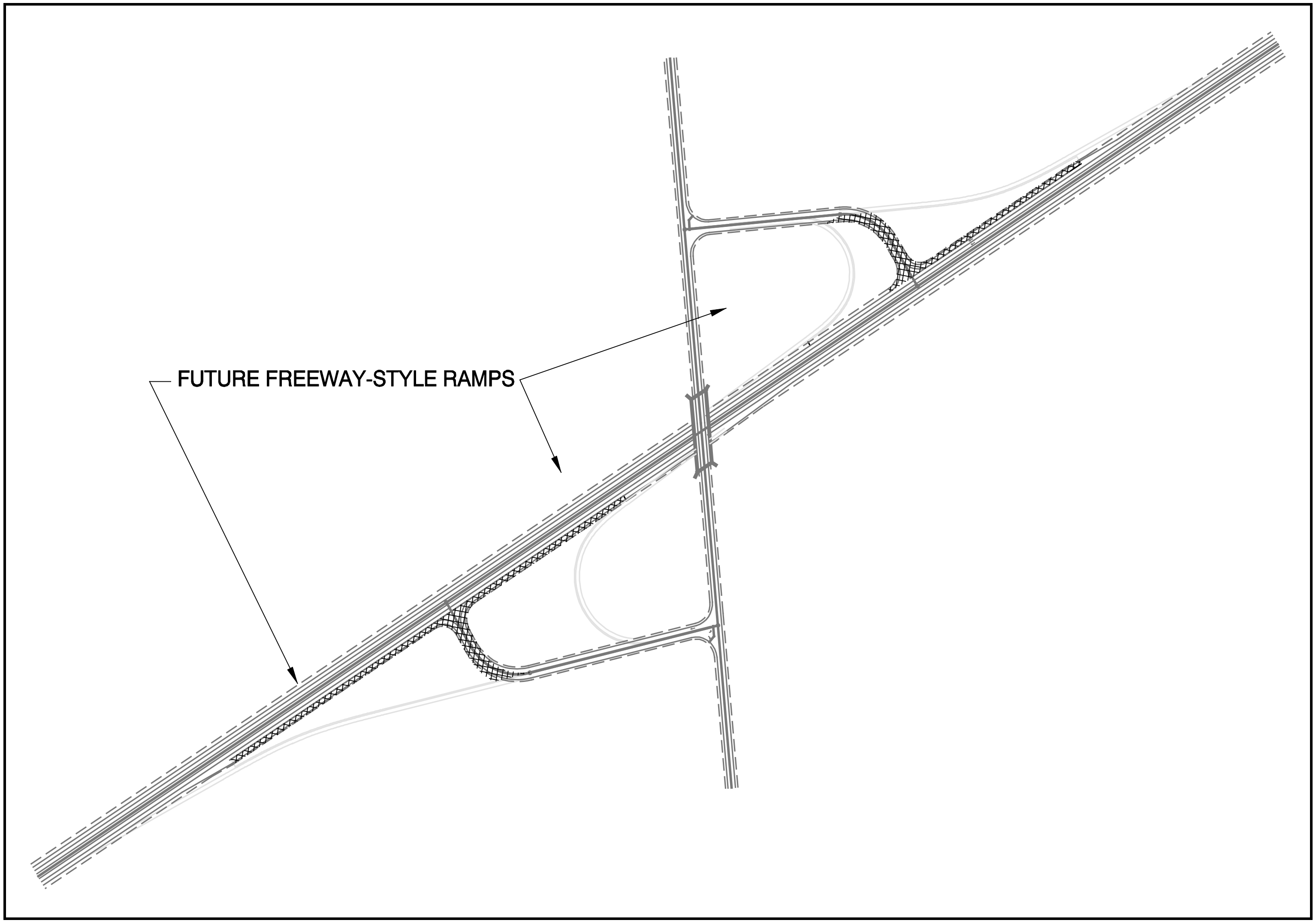


Figure 9-29
Non-Freeway Interchange Example

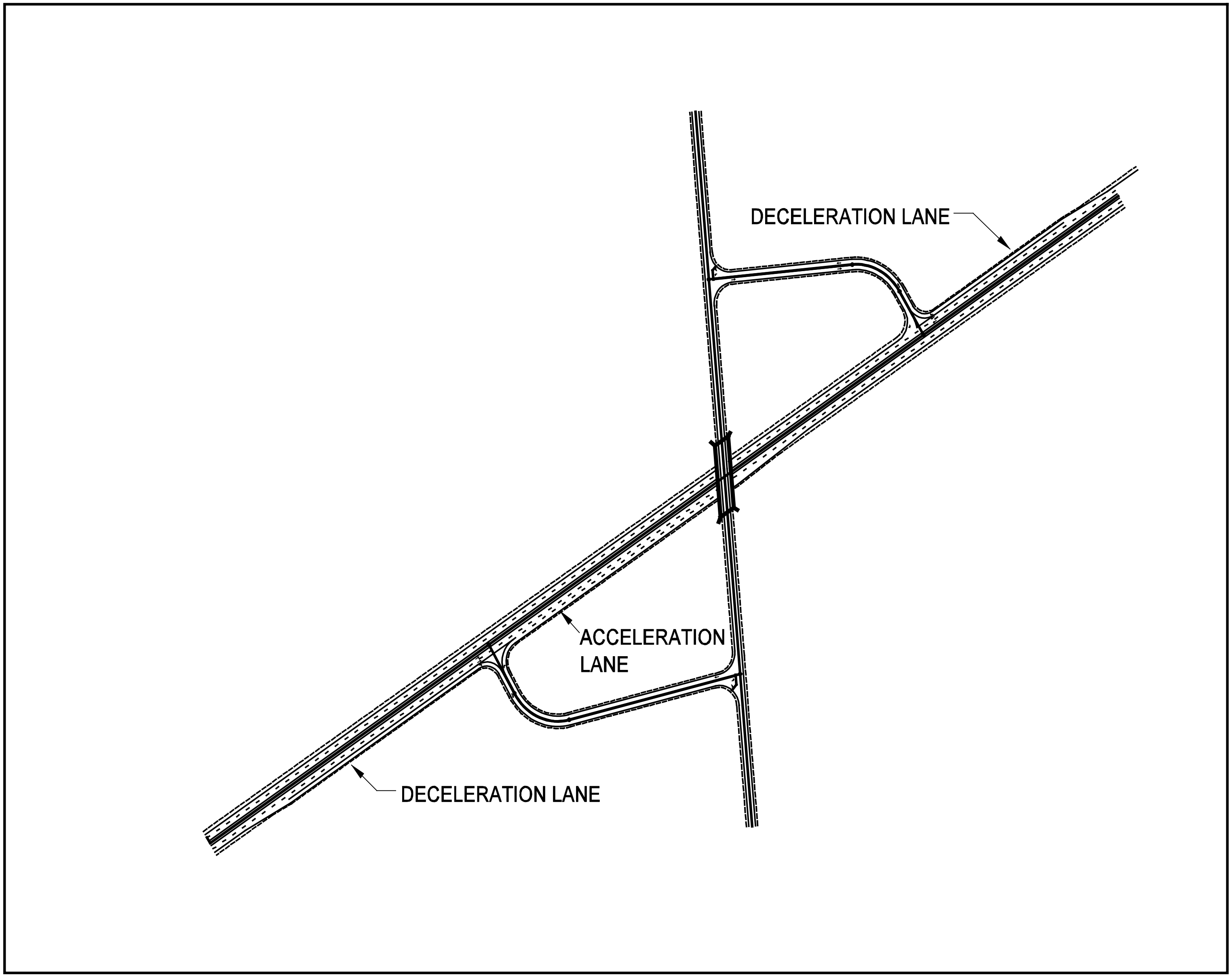


Figure 9-30
Non-Feeway Interchange Example And Future Improvements