Chapter 7

Driveway Design

This chapter presents data on the forward speed and the paths of passenger cars when making a 90° right turn. It is recommended that driveway design standards be based on the functional characteristics of the roadway—specifically, when an exiting vehicle is present in the driveway throat, under what circumstances might it be permissible for a vehicle making an entry maneuver to block the traffic lane while waiting for the exiting vehicle to clear the driveway? When should the driveway geometrics provide for a simultaneous exit and entry? Is the driveway to be designed for cars only, or for cars and trucks? Suggested design criteria and guidelines for combinations of throat width and curb return radius guidelines for throat length and number of driveway lanes are also presented. Finally, guidelines for maximum change in grade between the roadway cross-slope and the driveway apron and driveway profiles are provided.

Driveway Operations

The Driveway Entry Maneuver

The path of the right front wheel of passenger cars making a 90° driveway right-turn maneuver were observed and plotted to evaluate the dispersion in the vehicle trajectories as a function of curb return radius and throat widths. (Note: Dimensions are given in traditional U.S. units because the observations were recorded in these units.)

For example, consider Figure 7–1, which shows the pattern of trajectories of the right front wheel of passenger cars making a right turn into a driveway having a 10 ft. (3.1 m) curb return radius and a 30 ft. (9.2 m) width. The solid line labeled "mean" is the average position of the right front wheel during the maneuver. The dashed line labeled "+1" is one standard deviation above the mean. Approximately 50 percent of the vehicle paths were to the left of the mean. In interpreting the figure, remember that the vehicle (which is approximately 6 ft. wide, 2 m) will be to the left of any given trajectory of the right front wheel. Therefore, the drivers of vehicles at "+2" standard deviations are using the entire throat width on the ingress maneuver.

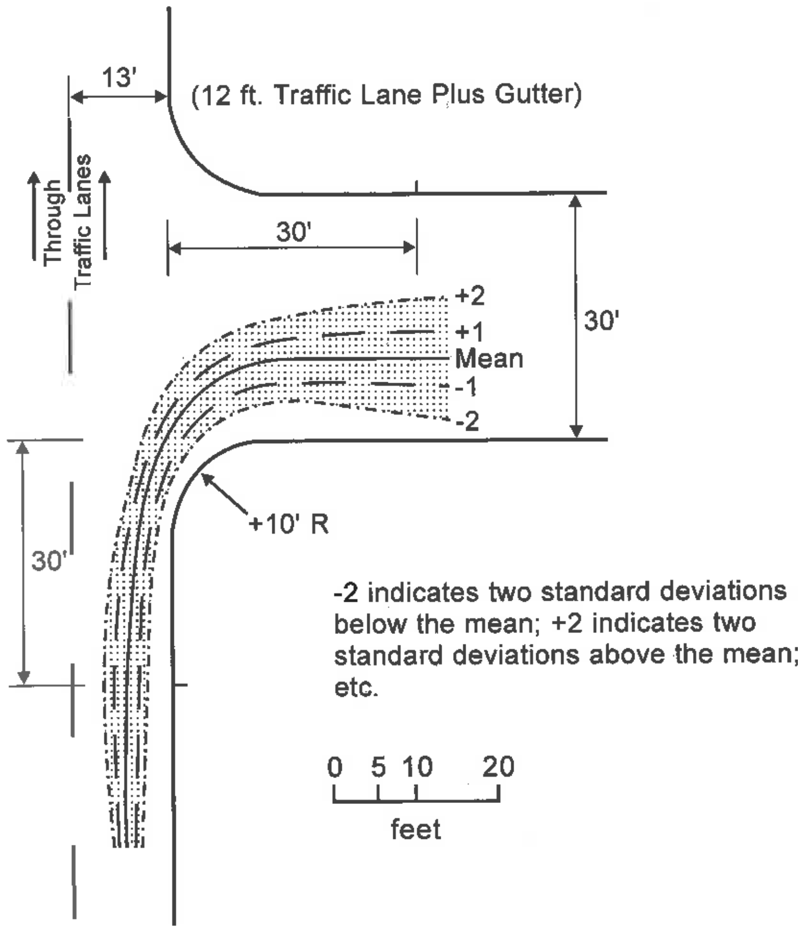


Figure 7–1. ***Observed Paths of Right-Front Wheel of Passenger Cars on Right-Turn Entry Maneuver***

Source: Stover [4].

Figure 7–2 shows the pattern of trajectories when an exiting vehicle is not present in the driveway throat. Inspection of the trajectories observed for the various combinations of curb return and throat width yields the following:

- Drivers must use most or all of the driveway width when the curb return radius is short or the driveway throat is narrow;
- The driveway geometrics have little effect on driveway entry speeds. The research also showed that tapered approaches to driveways had little or no effect on the speed of the turning vehicle;

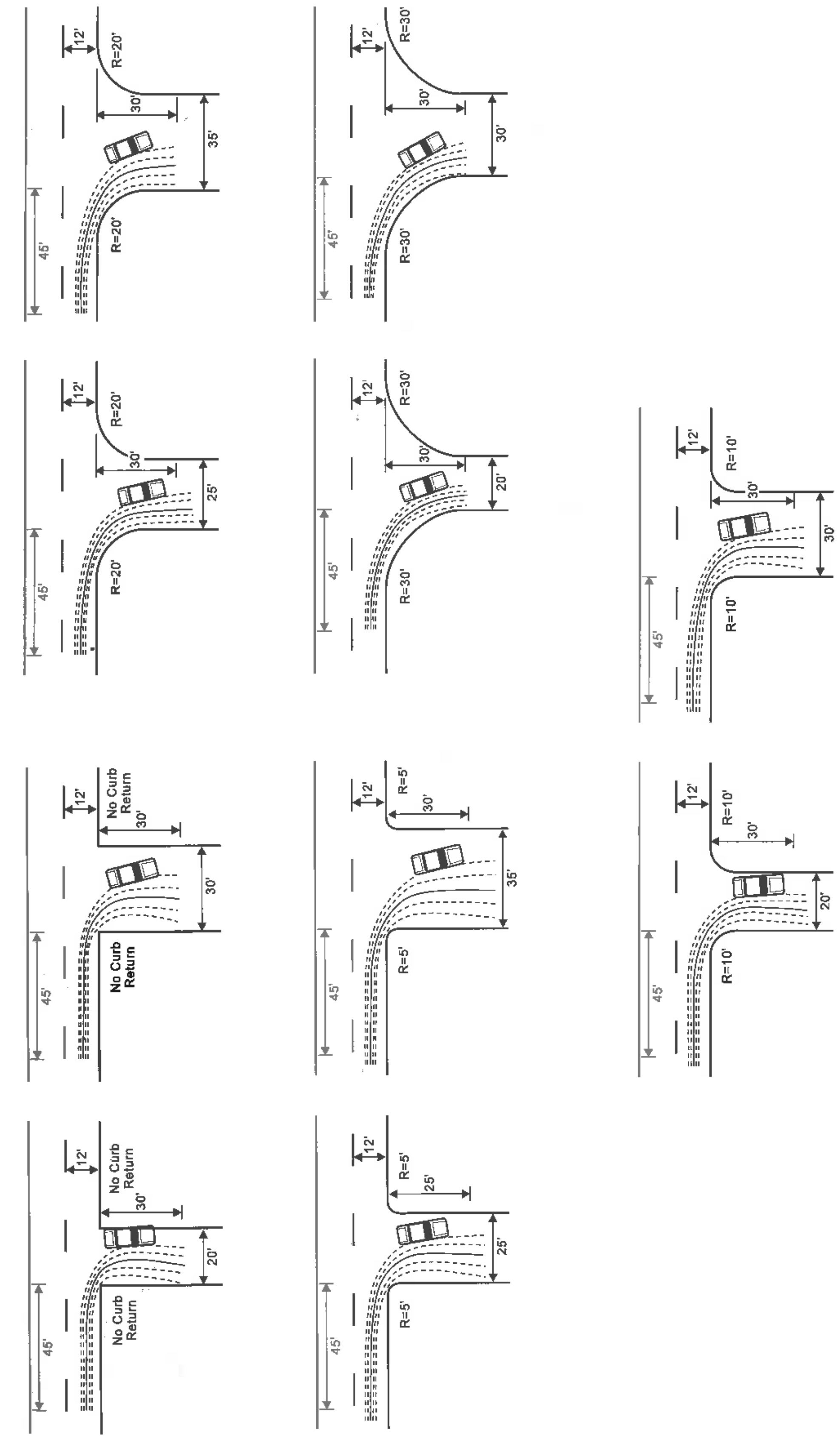


Figure 7–2. ***Observed Paths of Right-Front Wheel of Passenger Cars During Right-Turn Entry Maneuvers When No Exiting Vehicle Is Present***

Source: TTI Project 5182-2 [3].

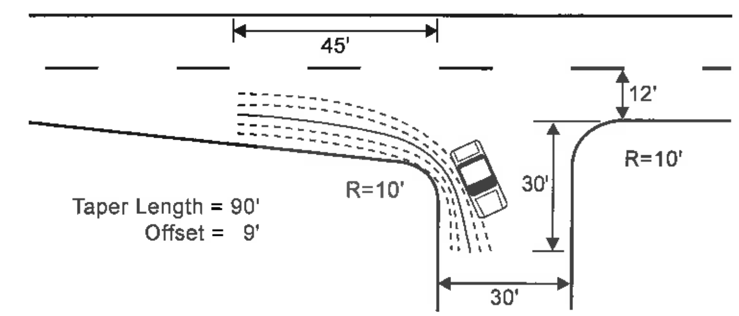
- At driveways with a curb return radius of 10 ft. (3 m) or less, drivers tend to make a wide turn using all of the available throat width to compensate for the relatively small curb return radius. Once in these driveways, drivers immediately steered back toward the entry curb line to reposition the vehicle on the proper (entry) side of the driveway. This adds complexity to the driving task;
- At driveways with a curb return radius of 20 ft. (6.1 m) or more, the paths of vehicles turning right into the driveways tended to parallel the entry curb line, and drivers tend to remain on the entry side, regardless of driveway width, when no exiting vehicle was present. This minimizes the driving task;
- The trajectories of right-turning vehicles entering an access connection are less dispersed when a long entry curb return radius is used. Thus, narrower throat widths can be used on access connections which have larger radii;
- The dispersion of the vehicle wheel paths increases as the radius decreases. The greatest dispersion is with no curb return (a "dustpan" design). This exposure makes the driving task more difficult and simultaneously increases the exposure area for pedestrians crossing the driveway. Hence, increasing the vehicular-pedestrian crash potential;
- Curb return radii less than the physically possible minimum inside turning radius of the passenger car, slightly less than 15 ft. (4.6 m), result in a dispersed entry pattern, except for narrow throat widths where the width of the paved driveway physically restricts the drivers' paths; and
- The curb return radius, including the "dustpan" design, has little influence on the forward speed of vehicles making a driveway entry maneuver. The "dustpan" design is discussed later in this chapter.

Taper and offset approach treatments, shown in Figure 7–3, were found to have the following effects:

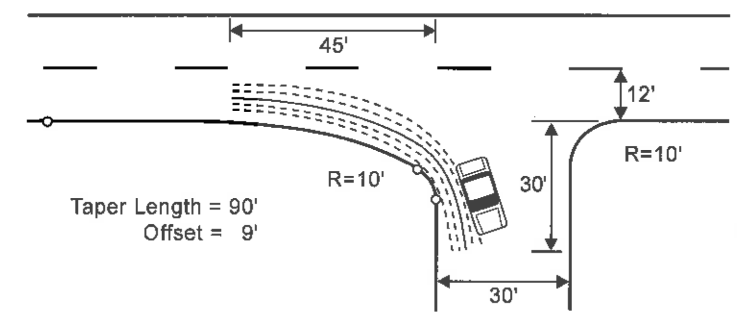
- The forward speed of the turning vehicle is essentially unaffected;
- The time for which following vehicles are exposed to extremely slow speed because of a turning vehicle is reduced;
- More dispersion occurs in the approach to the right turn and less dispersion occurs in the driveway throat; and
- A spiral taper results in a more compact pattern of wheel trajectory than a straight taper.

Driveway Entry Speed

The speed at which a vehicle is able to leave the through lane on an arterial, or other classification of roadway, and safely enter a driveway has a significant effect on the safety



a. Direct taper approach treatment.



b. Spiral taper approach treatment.

Figure 7–3. *Observed Paths of the Vehicle, Right-Front Wheel During Right-Turn Entry Maneuvers on Taper Approaches*

Source: Adapted from TTI Project 5182-2 [3].

and operational efficiency of the specific roadway. Contrary to common opinion, however, research [2, 3, 4, 6] has shown that all commonly used driveway geometrics (combinations of driveway curb return radii and driveway throat width) result in drivers executing a right turn at about the same speed. Anecdotal evidence of this was reported in *NCHRP Report 93,* [5] in 1970.

The speed of the vehicle while maneuvering through a range of commonly used driveway design openings decreases only slightly as the available throat width or curb return radius decreases as illustrated in Figure 7–4. The presence of an exiting vehicle stopped in the throat has a greater effect on the speed and path of the right front wheel than can be explained only by the reduction in the available throat width. This undoubtedly results from the driver's desire (requirement) to maintain a greater clearance between his or her vehicle and a stopped vehicle, than an edge of a driveway. Nevertheless, Figure 7–4 clearly shows that the speed of a vehicle entering a driveway is very slow for all reasonable combinations of throat width and curb return radii. Even the combination of a long radii (30 ft.) and a wide throat (35 ft.) produces a forward entry speed of only 12 to 13 mph.

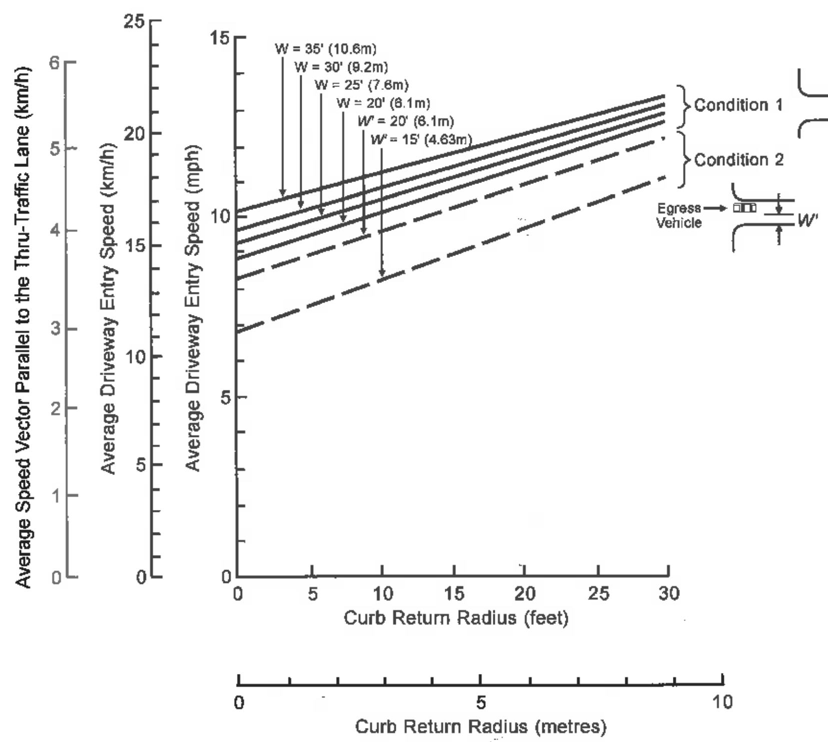


Figure 7–4. ***The Influence of Driveway Width and Curb Return Radius on Driveway Entry Speed***

Source: Adapted from TTI Project 5182-2 [3].

These findings are confirmed by recent studies conducted for the Oregon DOT [2], which found forward speed of right-turning vehicles to be essentially unrelated to the driveway radius/taper and throat widths. The Oregon data are summarized in Table 7–1. Such data debunk the commonly held view that designs using a dropped curb (or small

Table 7–1. ***Summary of the Oregon Observation of Driveway Entry Speed***

Driveway Geometrics				Entry Speed (mph)		
Throat Width (ft.)	Curb Return Radius (ft.)	Bike Lane (ft.)	Change in Grade[1] %	Minimum	Maximum	Average
30.25	0[2]	5	15	5.8	13.3	9.4
45	0[2]	5	17	4.6	9.3	7.4
42	25	5	6.6	9.9	14.8	12.8
42	20	5	6.8	7.1	14.7	11.9
42	0[2]	5	12.3	5.0	10.7	7.0

[1]Change in grade between the pavement cross-slope and the driveway apron at the gutter.

[2]Dropped curb design.

flare of very short radii) and narrow throat widths improve pedestrian safety because of slower entry speeds. An interesting and unexpected finding of the Oregon observations was that drivers turning left into a driveway made the turn at a higher speed when a pedestrian was approaching the driveway than when no pedestrian was present.

The right-turning vehicle was considered to have cleared the through traffic lane when a following vehicle could go on by without physically encroaching upon the adjacent through lane as illustrated in Figure 7–5. The entry speeds result in a speed vector parallel to the through traffic lanes of less than 5 mph (8 km/h). The speed vector parallel to the through traffic lane is relatively unaffected by the forward speed of the vehicle because the entering vehicle has substantially completed the 90° turn when the rear bumper sufficiently clears the through traffic lane so that a following vehicle can go by without physically encroaching on the inside traffic lane. Hence, all reasonable combinations of curb return radii and entry throat width produce a speed differential that is essentially equal to the speed of the through traffic. Figure 7–6 shows that the speed profile (as well as entry speed) of right-turning vehicles is similar for all reasonable combinations of radius and throat width. Moreover, Figure 7–6 also shows that a driver making a driveway maneuver is decelerating a considerable distance upstream from the driveway. This produces high-speed differentials a considerable distance upstream from where the driveway entry maneuver is to be made—especially during off-peak periods. This can result in an under-reporting of accidents resulting from driveway traffic.

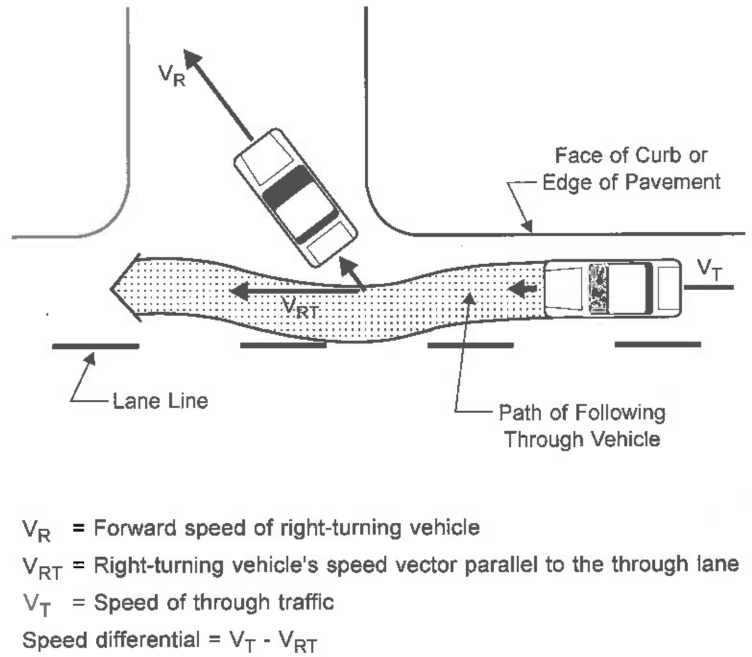


Figure 7–5. *Schematic Illustration of the Speed Differential*

The Exit Maneuver

The combination of curb return radius and throat width should allow drivers to enter and exit an access connection quickly and with minimal interference with through traffic.

The departure radius should allow a right-turning vehicle to exit the driveway without encroaching on the adjacent lane of a multilane highway or on the opposing lane of a two-lane highway. As illustrated in Figure 7–7, a simple curb return radius of at least 25 ft. (7.6 m) will permit the driver of a passenger car to exit a driveway without encroaching on the adjacent lane. In lieu of a simple radius of, say, 30 ft. (9.1 m), a compound curve of 20 ft. (6.1 m) radius followed by a 35 to 40 ft. (10.7 m or 12.2 m) radius will accommodate off-tracking of the right rear wheel while permitting the driver to make the turn without encroaching on the adjacent traffic lane.

Use of a two-centered compound curve for the departure radius will facilitate the exit maneuver by both passenger cars and single-unit trucks. This helps encourage exiting drivers to stay on the exit side of the access drive and to complete the exit maneuver parallel to the outside edge of the pavement. Exit speed is not affected.

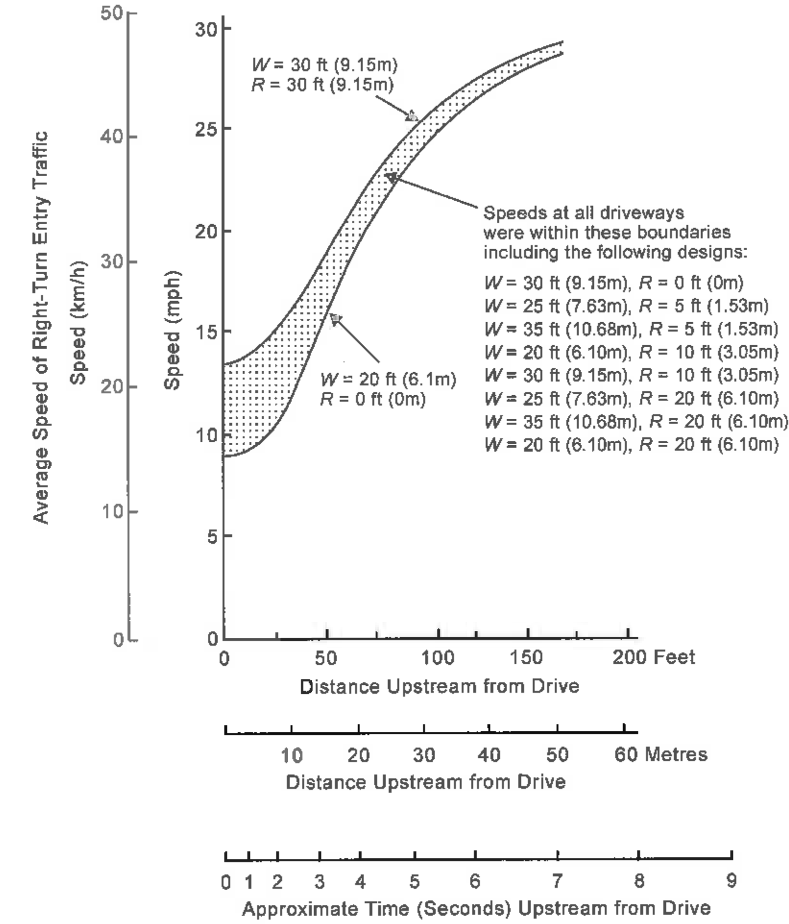
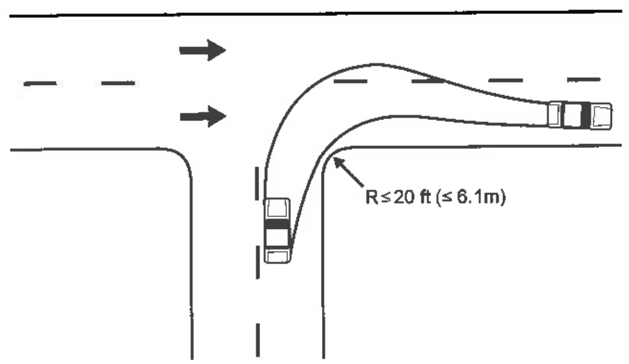


Figure 7–6. *Speed Profiles of Passenger Car Drivers Approaching an Access Drive*

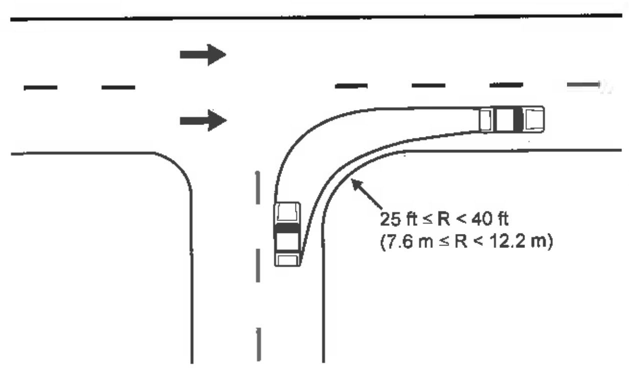
Source: Stover [4].

Drivers exiting a driveway tend to position themselves left of the driveway center. Double-yellow paint lines are effective in guiding exiting drivers to the proper exit position so as not to encroach on the entry side of the access drive.

Figure 7–8 shows a driveway serving a shopping center where the original departure radius was too short. This caused the egressing vehicles to encroach on the inside traffic lane of a four-lane divided arterial as schematically illustrated in Figure 7–7a. As can be seen in the photograph, the departure radius was increased so that egressing vehicles entered the curb lane without encroaching on the adjacent lane, as schematically illustrated in Figure 7–7b.



a. Short departure radius results in encroachment on inside traffic lane.



b. Radius so departure vehicle does not encroach on adjacent traffic.

Figure 7–7. *Schematic Illustration of Vehicle Trajectory of Driveway Departure*

Driveway Geometrics

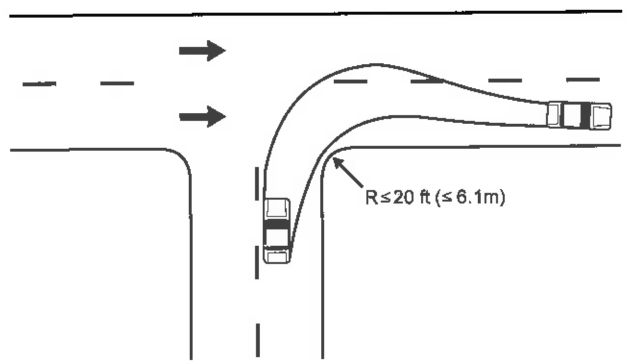
Access design needs to consider the functional classification and volume of the roadway as well as the volume and type of vehicles that will use the driveway. Questions that need to be addressed in selecting design standards for driveways include the following:

- What design vehicle should be used?
- Is the driveway to operate one-way or two-way?
- Is the driveway operation to be simultaneous exit and entry?

Figure 7–8. *Retrofit of a Driveway to Increase Curb Return Radius, College Station, TX*

- If an exiting vehicle is occupying the driveway, is it permissible for the entering vehicle to wait until the exiting vehicle clears the driveway?
- If simultaneous operation, is the design to permit a single-unit truck or a larger vehicle to enter when a passenger car is waiting to complete an exit maneuver? Or, is the design for simultaneous entry and exit of passenger cars? In the latter case, a truck would not be able to make the entry maneuver if a passenger car was waiting to complete an exit maneuver. Or, does simultaneous exit and entry of trucks need to be accommodated?
- Will passenger cars and trucks be using the access drive during the same hours? Or will trucks be entering or exiting the site at times of the day when very few autos will be using the driveway? Suggested design vehicle criteria are given in Table 7–2.
- Will pedestrians frequently cross the driveway?

The combination of curb return radius and throat width should allow ingress and egress vehicles to complete right turns with minimal impact on through traffic or other driveway traffic. In many jurisdictions, however, the driveway practices need to be amended to permit appropriate designs. Figure 7–9 and 7–10 illustrate a driveway design that does not accommodate simultaneous exit and entry maneuvers by passenger cars. Single-unit trucks must use the entire throat width and then, only with some difficulty. If an exiting vehicle is present in the driveway throat, a truck driver must wait in the traffic lane until the exiting vehicle clears the driveway throat.



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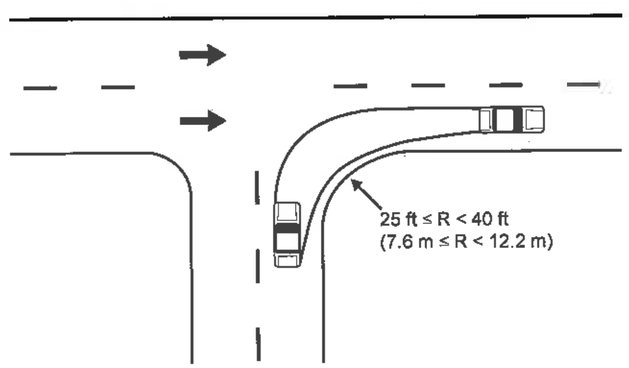

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Table 7-2. *Suggested Driveway Design Criteria*

1. Single-family residential		
Number of Residences Served	Operation	Design Vehicle
≥ 2 du	Alternating[1]	P
≥ 3 du	Simultaneous 2-way[2]	P
2. Commercial office uses		
Number of Trucks per Hour	Operation	Design Vehicle[3]
≤ 2	Simultaneous 2-way	P[4]
≥ 3	Simultaneous 2-way	P[5]
3. Industrial uses		
	Operation	Design Vehicle
	Simultaneous 2-way	WB-50[6,7]
4. Other uses		
	Operation	Design Vehicle
Truck stop	Simultaneous 2-way	Largest vehicle[7]
Recreational	Simultaneous 2-way	Motor home with trailer

[1]When a vehicle is exiting, an entering vehicle must wait until the exiting vehicle clears the driveway throat.

[2]A vehicle can enter when another vehicle is waiting to exit the driveway.

[3]Design driveway so that WB-50 can off-track through the driveway.

[4]A vehicle can enter while another vehicle is waiting to exit.

[5]An SU can enter when a vehicle is waiting to exit.

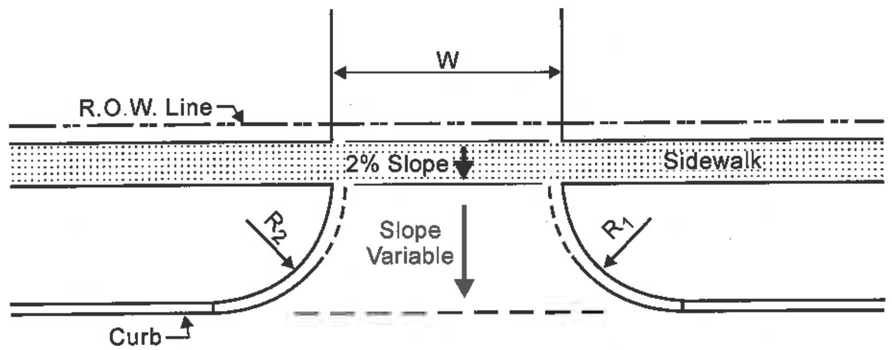
[6]Designed so that larger vehicles can off-track through the driveway.

[7]Interstate semitrailer, triple trailer and turnpike double trailer will be the design vehicles in many states, especially in the vicinity of freeway interchanges.

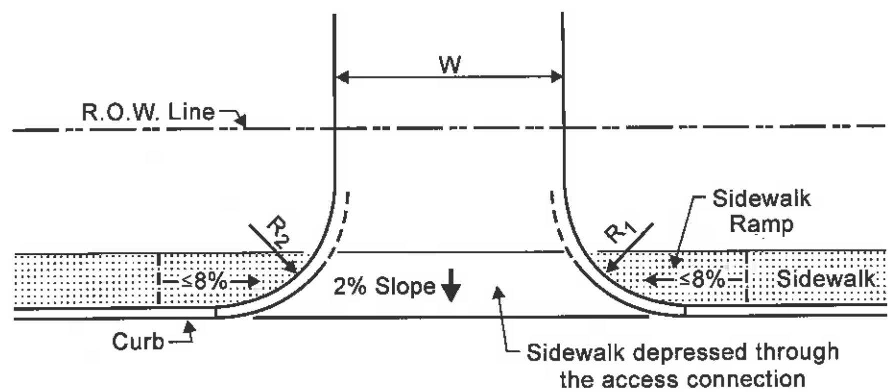
a. Numerous observations on several different days indicated that drivers consistently used 17 to 18 ft. (about 5.2 m) of the 25 ft. throat width when making a right-turn entry from the curb lane.

b. The fact that the driver of a single-unit truck must use the entire 25 ft. (7.6 m) throat width when making a 90° turn is not surprising as the outside turning radius is 42 ft. (12.8 m) and the minimum inside radius is nearly 28 ft.

Figure 7-9. *This Dustpan Driveway With a 2.5 ft. (0.8 m) Flare and a 25 ft. Throat Width Serves a Motel and a Restaurant in Salem, OR*



a. Sidewalk separated from curb.



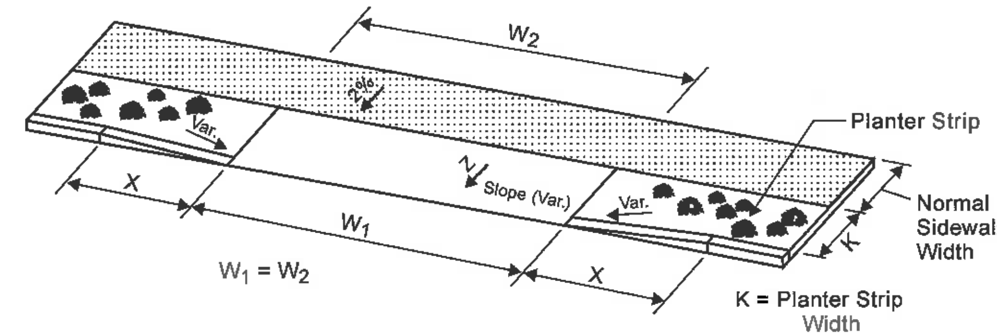
b. Sidewalk abuts curb.

Figure 7–10. *Curb Return Designs*

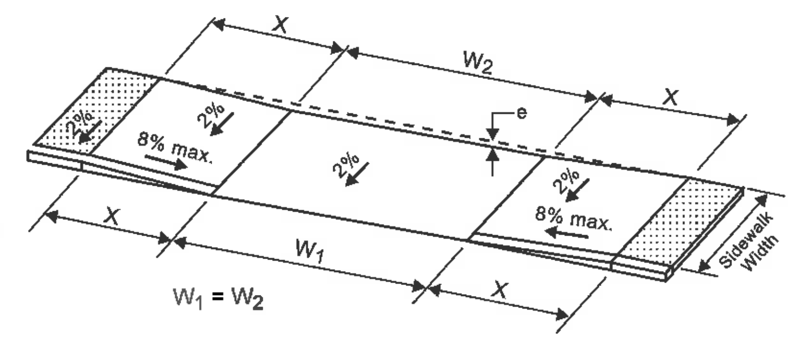
Type of Curb Opening

The curb return design (Figure 7–10) is commonly used for major access connections. It is increasingly used for private driveways—especially those on major streets.

The dropped curb design (Figure 7–11) is still used by some state DOTs and local agencies. This design and the dustpan (Figure 7–12) design were originally adopted when cut stone was used for curbs and gutters, because cutting a stone radius was difficult.



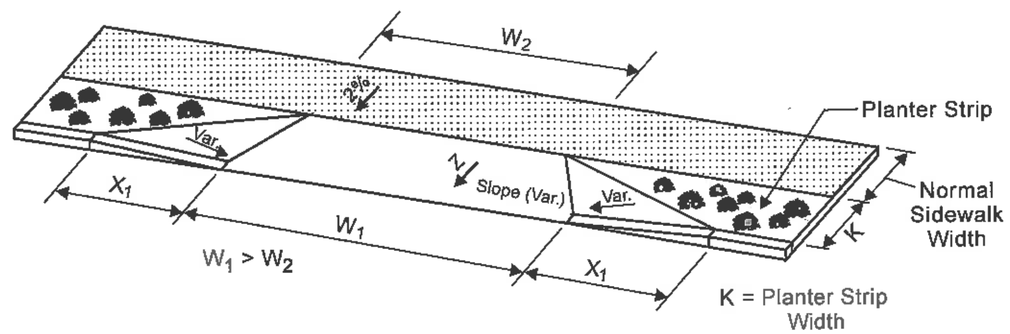
a. Sidewalk separated from curb.



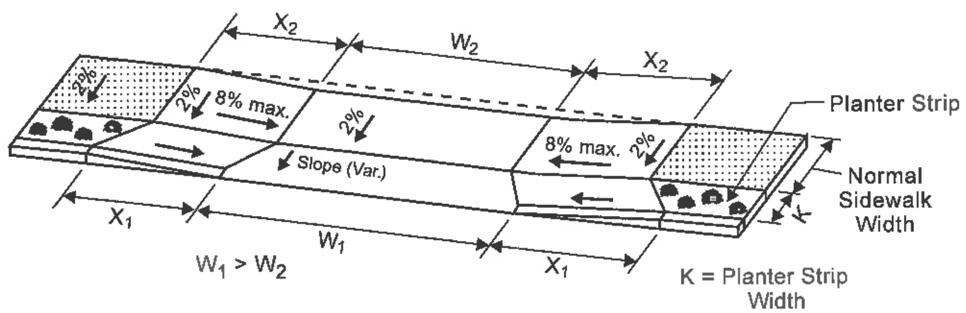
b. Sidewalk abuts curb.

Figure 7–11. *Dropped Curb Design*

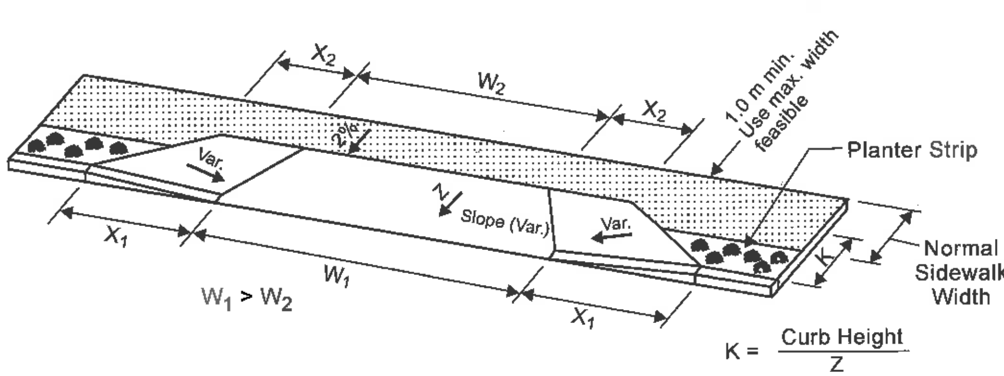
Some individuals argue that the use of the dropped curb or the dustpan design for private access connections is needed to distinguish them from public road connections. This practice is of questionable value as the development served by the access connection usually provides the driver with significant visual cues as to whether the access is a private or public connection. More importantly, a dropped curb or dustpan design necessitates use of an undesirably wide throat if simultaneous exit and entry is to be provided—even if by autos only.



a. Separated sidewalk driveway.



b. Lowered sidewalk.



c. Driveway encroaches into sidewalk.

Figure 7–12. *Dustpan Designs*

Driveways with dropped curb and dustpan designs commonly result in the following operational problems: 1) when an exiting vehicle is not present, drivers of entering vehicles use much of the exit side of the driveway when making the entry maneuver and 2) when an exiting vehicle is present in the driveway throat, an entering vehicle is prevented from completing the entry maneuver until the exiting vehicle has cleared the driveway throat or entering vehicles are required to off-track over the curb (Figure 7–13).

Throat Width and Radius

Driveway throat width and return radius or flare, are interrelated. As one is decreased, the dimension of the other can be increased to result in a comparable operation. In addition, within narrow limits, flare and radii can provide equivalent service.

In theory, there is an extremely large number of combinations of throat width and return radius, or flare. In practice, however, an agency should identify specific design criteria and then adopt a single design, or a very limited number of designs, for each criteria. Table 7–3 gives a partial list of equivalent geometrics.

Common current practice is to have a table of range of values for throat width and a separate table with a range of values for return radii. Little or no guidance is provided as to the use of a given width with a given radius. The implication is that any width can be used with any radius so long as the values are within the range of values indicated. Many jurisdictions currently have limitations as to maximum throat width that do not permit good design.

As the throat width is increased, return radii can be decreased for a given design criteria. Throat width and radii should be adequate to accommodate convenient maneuvering for the design condition but restrictive enough to discourage erratic maneuvers. The entry width is a function of the off-set, return radius and clearance to the edge of the exit side of the driveway throat, as illustrated in Figure 7–14. The presence of a bike or parking lane adjacent to the curb increases the effective radius. Therefore, the throat width or the return radius can be reduced somewhat when a bike or parking lane exists.

A raised narrow and short divider such as shown in Figure 7–15 should not be used to separate the entry and exit sides of an access connection. Such designs are a result of poorly conceived regulations that have a maximum throat width which is too narrow and consider the connection to be a one-way exit, and a one-way entry when separated by a 6 in. (1.50 mm) high raised divider that is no more than 4 ft. wide by 25 ft. long (1.2 m x 7.6 m). These short, narrow dividers are not adequately visible to the driver and are not

a. Tire marks indicate that the combination of a dropped curb and a 30 ft. (9.1 m) throat width is inadequate for simultaneous entry and exit by passenger cars. Off-tracking over the curb face for a distance of 10 ft. (9.1 m).

b. This 2.5 dustpan design within 30 ft. (9.1 m) throat width results in off-tracking for a distance of about 6 ft. (2 m).

Figure 7–13. *Evidence of Vehicles Having Off-Tracked Over the Curb*

Table 7–3. *Equivalent Radii and Throat Width*

Driveway Entry Width (ft.) as a Function of Offset and Curb Return Radius, Passenger Car, 90° Right-Turn Creep Forward Speed

Vehicle Offset from Face of Curb, or Edge of Pavement, Prior to Turn (ft.)	Curb Return Radius (ft.)					
	0	5	10	15	20	25
0	—[a]	—[a]	23[b]	20	17	14
2	—[a]	24[b]	20	17	14	14
4	24[b]	21[b]	17	14	14	14
6	21[b]	18	15	14	14	14
8	19	16	14	14	14	14

Driveway Entry Width (ft.) as a Function of Offset and Curb Return Radius, Passenger Car, 90° Right-Turn, Forward Speed ≈ 10 mph

Vehicle Offset from Face of Curb, or Edge of Pavement Prior to Turn (ft.)	Curb Return Radius (ft.)					
	0	5	10	15	20	25
0	—[a]	—[a]	—[a]	23[b]	20	16
2	—[a]	—[a]	24[b]	21[b]	18	14
4	—[a]	25[b]	23[b]	20	17	14
6	25[b]	22[b]	21[b]	18	15	14
8	23[b]	20	19	16	14	14

[a] An inappropriately wide throat width is required.

[b] A combination of narrower width and longer radius is a better design. In-bound throat width wider than 20 ft. should be avoided.

Source: Adapted from Flora and Keitt [1].

suitable for landscaping. Drivers frequently strike them when making the entry maneuver and also occasionally when exiting. The recommended minimum divider size for landscaped visibility is 10 ft. wide by 50 ft. long (3 m x 15 m).

The maximum driveway width permitted by some jurisdictions is not sufficient for a one-lane entry and a two-lane exit. Such jurisdictions often consider the access to be two one-way driveways when the entry and exit sides are separated by a 6 in. (150 mm) high divider that is 25 ft. (7.6 m) long. A much better practice for driveways having one entry lane and two exit lanes is to permit a 40 ft. (12.2 m) throat width as illustrated in Figure 7–16.

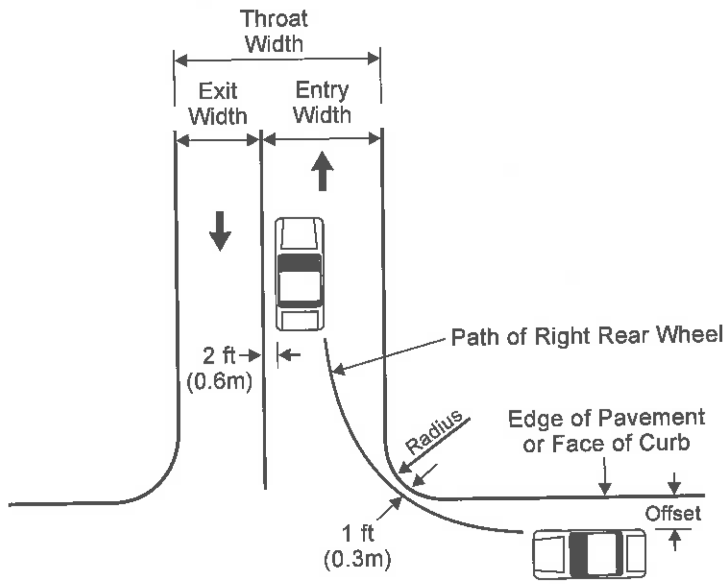
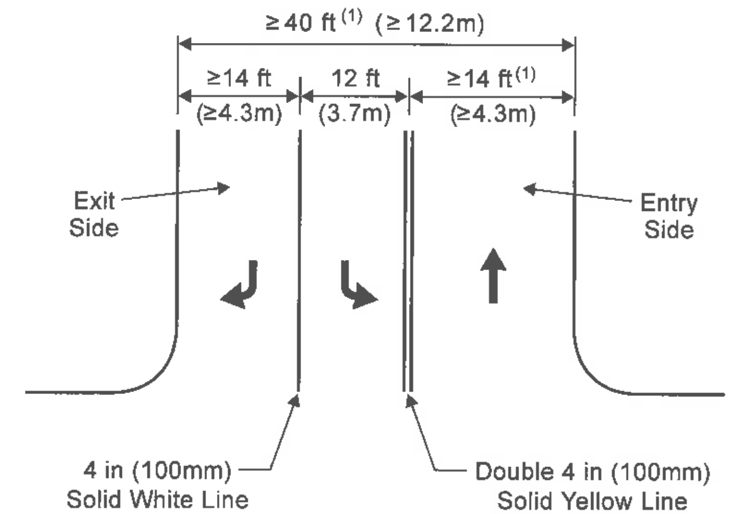


Figure 7–14. *Illustration of Driveway Elements*

Such a design should be avoided. A double-yellow 4 in. (100 mm) paint line separating the entry and exit sides of the access connection is preferred. This could require a change in a jurisdiction's regulations as to the maximum throat width.

Figure 7–15. *Example of an Access Connection Having a 6 In.-High, 4 Ft.-Wide and 25 Ft.-Long (150 mm X 1.2 m X 7.6 m) Divider*



(1) Entry lane and outside exit lane may need to be more than 14 ft (4.3m) wide and the total throat width greater than 40 ft (12.2m) when a "dustpan" design is used or the return radius is less than 15 ft (4.6m).

Figure 7–16. *Illustration of the Appropriate Pavement Markings for a Driveway Having One Entry Lane and Two Exit Lanes*

Table 7–4 presents minimum geometrics for two-way driveways. The simultaneous two-way operation allows a right-turn entry when an exiting vehicle is stopped in the driveway while the driver is waiting to complete the egress maneuver. The simultaneous operation by single-unit vehicles assumes that both the exiting and entering drivers are making a right turn. Tables 7–5 and 7–6 include recommended driveway geometrics for unsignalized and signalized access drives, respectively. (The topic of driveway throat length is discussed in the following section.)

A two-centered, compound curve, or a short radius followed by a spiral on the departure side of an access drive, more closely approximates the right-rear wheel path than a simple curve of having a constant radius. This allows the driver making a right turn to make a more natural entry traffic lane. When a two-centered compound curve is used, a flexible form must be used in the vicinity of the junction of the two radii to avoid a noticeable "kink" in the curvature. A 1 in. thick board with closely spaced saw cuts on the back (the side that will be the inside of the form) perpendicular to its long dimension is commonly used and fitted "by eye" to eliminate the "kink."

Table 7–4. *Suggested Minimum Designs[1] for Throat Width and Radius or Flare in Feet*

	With Bike Lane		Without Bike Lane	
Operation	Width	Radius or Flare[2]	Width	Radius or Flare[3]
Two-way, entering passenger car is delayed if a vehicle is exiting[4, 5]	20	0	24	0
	18	5	20	5
	16	10	17	10
	15	15	15	
Two-way, simultaneous entry and exit by passenger cars	34	0	38	0
	30	5	35	5
	28	10	32	10
	27	15	31	15
	26	20	28	20
	26	25	26	25
Two-way, simultaneous entry by SU[4, 6] vehicle and exit by passenger car	50	0	56	0
	45	5	51	5
	36	10	40	10
	33	15	35	15
	29	20	30	20
	27	25	28	25
Two-way, simultaneous entry and exit by SU vehicle[5]	60	10	65	10
	50	15	55	15
	40	20	45	20
	35	25	40	25
	30	30	35	30

[1]Forward speed of the vehicle ≤ 10 mph.

[2]6 ft. bike lane.

[3]Flares over 10 ft. are uncommon and impractical ≥ 15 ft.

[4]Driver of entry vehicle will have considerable difficulty in making the entry maneuver. Entering drivers will need to wait until the exiting vehicle clears the throat.

[5]Right rear of passenger car will often off-track over the curb.

[6]Right rear of trucks will commonly off-track over the curb.

Table 7–5. *Suggested Guidelines for Driveway Throat Width Return Radius and Throat Length for Undivided Driveways[1], Passenger Car Design*

Roadway Class	Number of Lanes: Enter	Number of Lanes: Exit	Entry Side: Radius (ft.)	Entry Side: Width (ft.)	Exit Side: Radius (ft.)	Exit Side: Width (ft.)	Total Throat Width (ft.)	Minimum Total Throat Length (ft.)
Principal Arterial	1	1[2]	30	14	30	12	26	50
	1	2[3]	30	14	30	24	38	50
Other Major Arterial	1	1[1]	25	14	25	12	26	50
	1	2[3]	25	14	25	24	38	50
Minor Arterial	1	1[1]	20	14	20	12	26	30
	1	2[3]	20	14	20	24	38	30
Minor Collector	n/a[4]	n/a[4]	15	—	15	—	26	25
Local Street	n/a	n/a	5	—	5	—	15—25	20

[1]Combinations of throat width and return radii are for passender cars; wider throat widths and/or longer return radii must be used where trucks are expected.

[2]Entry and exit sides of the driveway shall be separated by 4-in. solid yellow line.

[3]Entry and exit sides of the driveway shall be separated by 4-in. double solid yellow lines; exit lanes shall be separated by a 4-in. solid white line. Paint lines shall extend the full length of the driveway throat.

[4]Entry and exit lanes are not normally defined.

Table 7–6. *Suggested Guidelines for Driveway Throat Width, Return Radius and Throat Length for Signalized and Divided Driveways[1], Passenger Car Design*

Number of Lanes			Minimum Throat Length	Entry		Exit	
Enter	Exit	Divider	(ft.)	Radius (ft.)	Width[2] (ft.)	Radius (ft.)	Width[2] (ft.)
1	2	not landscaped[3]	75	25	14	25	24
1	2	landscaped[4]	75	30	16	30	24
2	3[5]	landscaped[4]	200	30	26	30	36
2	4[5]	landscaped[4]	300	30	26	30	48

[1]Driveways with more than two lanes should incorporate channelization features. Double-yellow lines may be considered instead of medians where truck off-tracking is a problem.

[2]Width face-to-face of curbs, or face of divider to edge of driveway pavement.

[3]Driveway medians (dividers) that are not landscaped shall have a surface color that contrasts with the driveway pavement surface; the surface of such a median (divider) shall not be more than 3 in. above the driveway pavement surface. The median (divider) shall be outlined with a 4-in. wide solid yellow line.

[4]Landscaped medians shall be at least 10-ft. wide, face-to-face of curb. The length shall be equal to the throat length. A mountable type curb shall be used, preferably 4 in. in height but not to exceed 6 in. A more liberal design is needed with a landscaped divider because an entering vehicle cannot encroach on the exit side of the drive.

[5]Includes a separate right-turn lane.

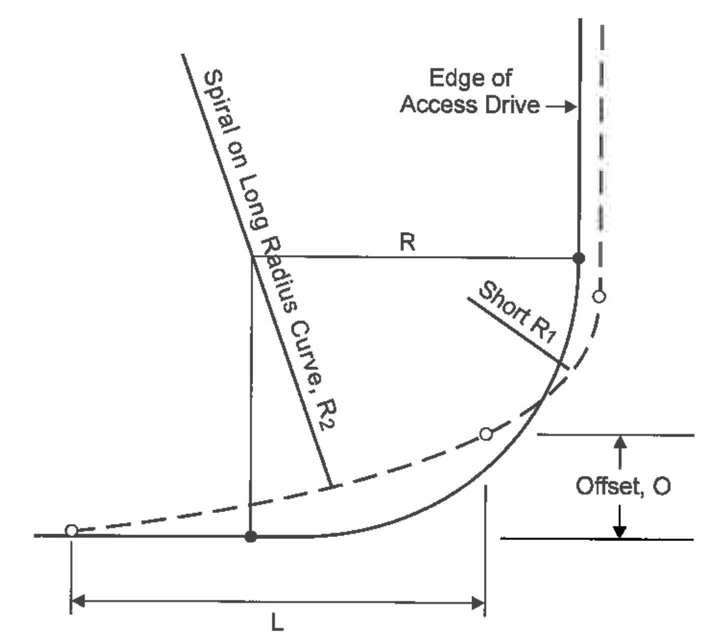
Advantages of using a compound curve in lieu of a single radius curb return include the following:

- The total throat width is less;
- Better guidance is provided for redirecting drivers who have tended to "drift" to the right when passing through wide driveway openings (tending to "drift" to the left with left-hand traffic);
- Where the access connection is designed primarily for autos, the occasional truck can be better accommodated; and
- When the access connection is designed for trucks, the narrower exit lane width and geometrics of the connection provide better positive guidance to automobile drivers.

There are a large number of combinations of short radius, offset and spiral length (or long radius) that can be used in place of a curve of simple radius. A very limited number of combinations should be selected for design. One set of dimensions that produces similar operations is presented in Table 7–7.

Table 7–7. *Equivalent Geometrics for Departure Radii*

Simple Curve,	Spiral			Compound Curve		
R (ft.)	R_1 (ft.)	O (ft.)	L (ft.)	R_1 (ft.)	O (ft.)	R_2 (ft.)
15	10	8	20	10	8	20
20	15	5	15	15	5	15
25	15	5	15	15	5	20
30	15	8	20	15	8	25
35	15	10	25	15	10	30



Examples of multilane and single-lane access connections are illustrated in Figures 7–17 and 7–18.

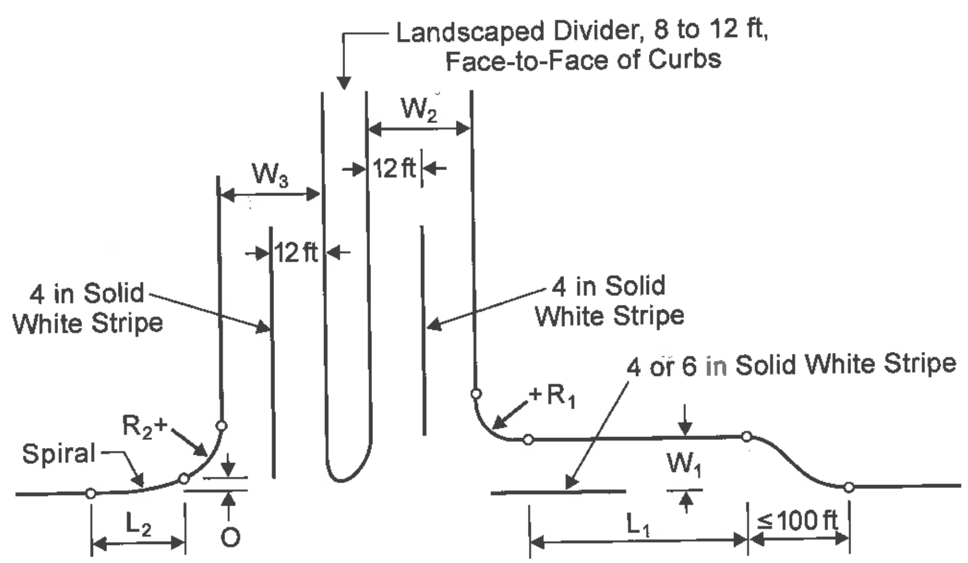


Figure 7–17. ***Composite Illustration of the Design of an Access Connection Having Two Entry Lanes and Two Exit Lanes***

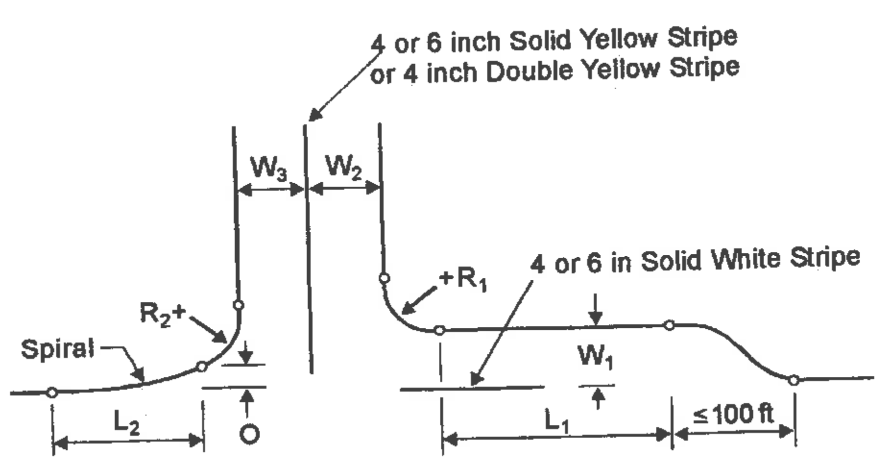


Figure 7–18. ***Composite Illustration of the Design of an Access Connection Having a Single Entry Lane and a Single Exit Lane***

Throat Length

The driveway throat must be of sufficient length to enable the intersection at the access connection and abutting highway, and the on-site circulation to function without interfering with each other. Drivers entering the site should first clear the intersection of the highway and access connection before encountering the intersection of the access connection and on-site circulation. When the throat length and width of an access drive are inadequate, the capacity of the signalized intersection of an access drive and an arterial will be limited by the conflicts of the intersection of the access drive and the ring road (Figure 7–19).

The exit side of an access connection should be designed to enable traffic leaving the site to do so efficiently. STOP-controlled commercial connections should be of sufficient length to store at least two passenger cars. This will greatly reduce move-up time and allow two cars to exit using a gap that would otherwise accommodate a single car.

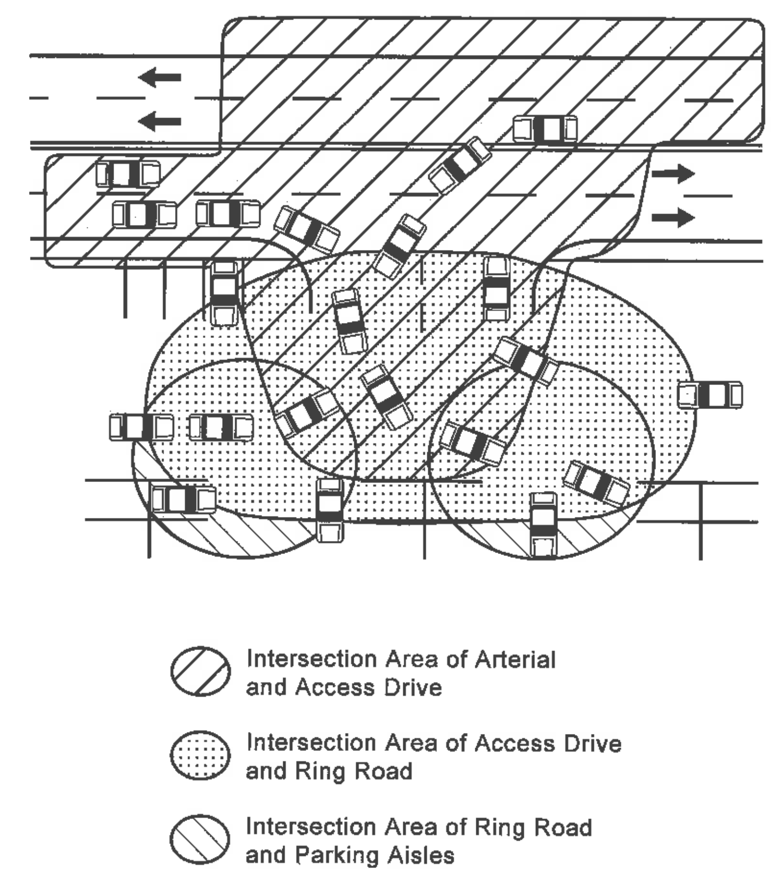


Figure 7–19. ***Overlapping Conflict Areas Results from Inadequate Throat Lengths and Poor Circulation Design***

The throat length and cross-section are interrelated; the wider the cross-section the longer the exit throat length needs to be. This relationship results from the one fact that the weaving maneuver becomes more complex and requires a longer length as the number of exit lanes increases. Also, the need to achieve very high exit flow rates becomes more important as the exit volume increases. Thus, the exit condition controls the length of large traffic generators; while the entry condition controls the throat length of small generators. Minimum throat lengths for unsignalized and signalized access drives are summarized in Tables 7–8 and 7–9 respectively.

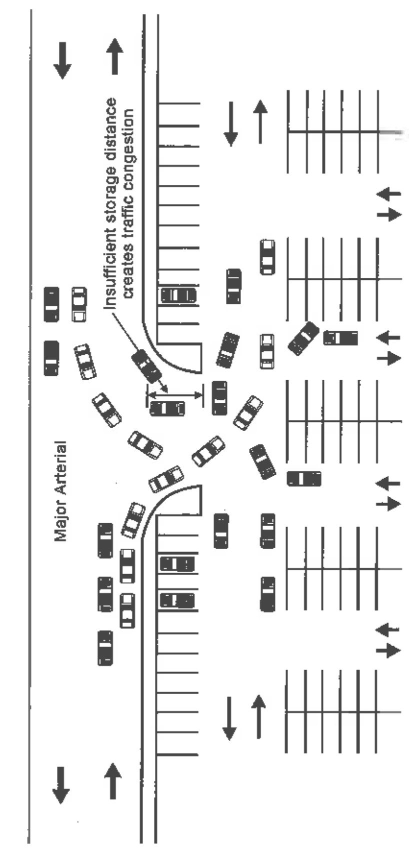
Table 7–8. ***Summary of Minimum Throat Lengths for Unsignalized Access Drives***

Number of Lanes	On-Site Development	Minimum Throat Length ft.	(m)
1 enter and 1 exit	parking	75	(25)
	intersection	30	(10)
1 enter and 2 exit	parking	75	(25)
	intersection	50	(20)

Table 7–9. ***Summary of Throat Lengths for Signalized Access Drives***

Number of Egress Lanes (left, thru and right)	Minimum Throat Length ft.	(m)
2	75	(25)
3	200	(60)
4	300	(95)

Figure 7–20 illustrates a shopping center access where entering drivers are in the intersection of the access drive and the ring road before clearing the intersection of arterial with the access drive. This produces congestion and high crash rates on the abutting street as well as on site. Pedestrian-vehicular conflicts are especially critical because of the confusion caused by the complex pattern of overlapping conflict areas. This complex pattern of overlapping conflicts results in low capacity and high crash rates.



Schematic Illustration of Inadequate Entry Throat Length

Example of Inadequate Throat Length

Figure 7–20. ***Inadequate Entry Throat Length Results in Poor Traffic Operation in the Vicinity of the Access Drive. This Produces Congestion and High Crash Rates on the Abutting Street as Well as On-Site. Pedestrian-Vehicular Conflicts are Especially Critical Because of the Confusion Caused by the Complex Pattern of Overlapping Conflict Areas.***

An unparking vehicle will block an entering vehicle when parking is permitted directly off the access drive, as illustrated in Figure 7–21. Drivers attempting to make a left turn onto the site must observe vehicles in the opposing traffic lane(s) and select a gap; they must also look for pedestrians and bicyclists. Expecting them to simultaneously observe on-site activities often creates an excessive workload—especially under high-volume or high-speed conditions. Where the left turn is made from a through traffic lane, turning drivers are also "pressured" by their exposure to following through traffic. Drivers making right turns onto the site are presented with a need to observe on-site activity that is 90° to their direction of travel and are unlikely to see unparking until they have begun their entry maneuver. Additionally, the unparking maneuver might not begin until after the driver attempting to enter the site is "committed" and has begun the entry maneuver.

A potentially hazardous situation occurs when a vehicle entering a driveway is blocked by a vehicle already on the site (Figure 7–21). A throat length of at least 50 ft. (15 m) beyond the sidewalk as illustrated in Figure 7–22, will permit the driver of an entering passenger car to be clear of the through lane as well as the sidewalk while stopped waiting for an unparking vehicle to clear the driveway throat. Where an occasional large vehicle (single-unit truck or motor home) might enter the site, the distance should be at least 75 ft. (23 m).

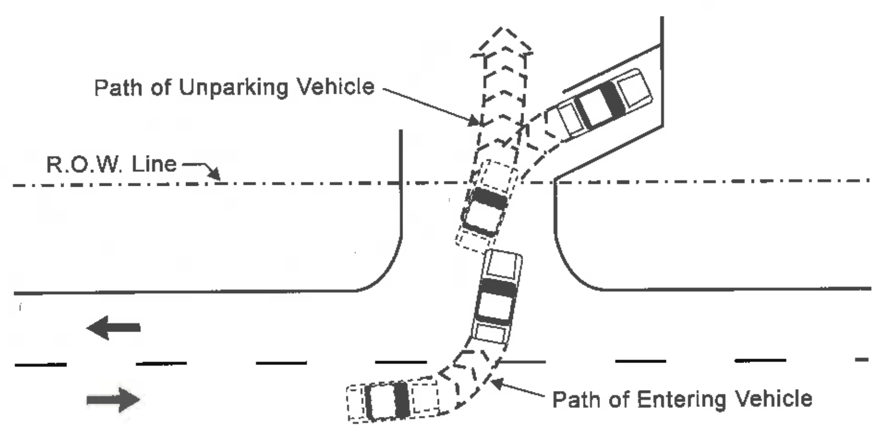
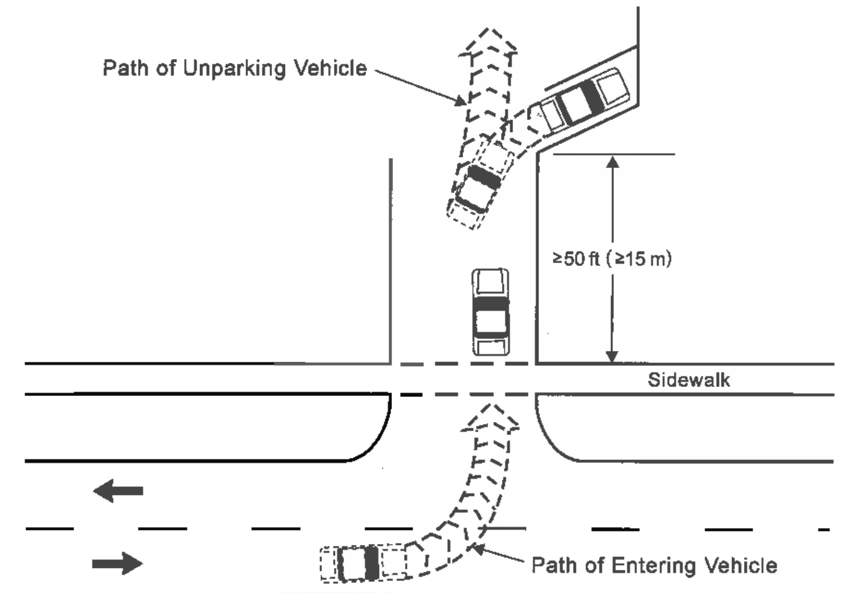
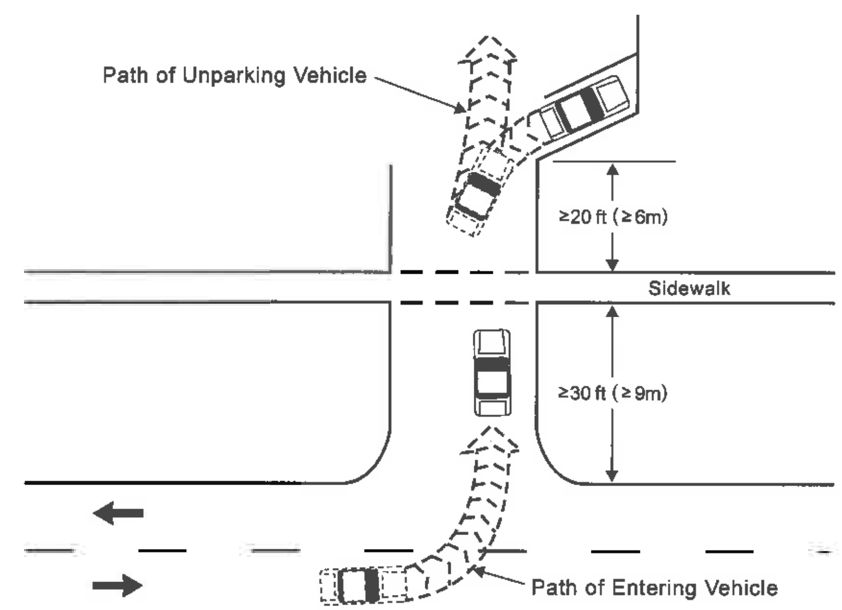


Figure 7–21. *Inadequate Throat Length with Parking Immediately on Entering the Site. An Unparking Vehicle Backs into the Driveway Throat and Blocks a Vehicle Attempting to Enter the Site.*



a. A driver of an entering vehicle stops after crossing the sidewalk and then waits for an unparking vehicle to clear the driveway throat.



b. Preferred design. The driver completes the left-turn entry maneuver, clears the through traffic lane and then stops before coming to the sidewalk when a pedestrian is present.

Figure 7–22. *Throat Length Needed for a Left Turn Into a Driveway to Stop Clear of the Through Traffic Lane*

It is suggested that a solid yellow line be used to separate the entry and exit sides of two-way access drives when the volume exceeds 100 vph (Figure 7–23). Left-turn capacity is low even with only moderate volumes (≥ 600 vph) on the abutting roadway. Therefore, a small number of left turns will cause substantial delay to right turns when the access drive has a single lane exit. Customer convenience is enhanced if left-turning vehicles need to be able to use all suitable gaps in the traffic streams and right turns do not have to wait for a preceding left turn to clear the driveway. Therefore, separate left- and right-turn lanes should be provided for all commercial driveways where left-turn exit maneuvers are permitted, as illustrated in Figure 7–24. Figure 7–25 is an example of such a design.

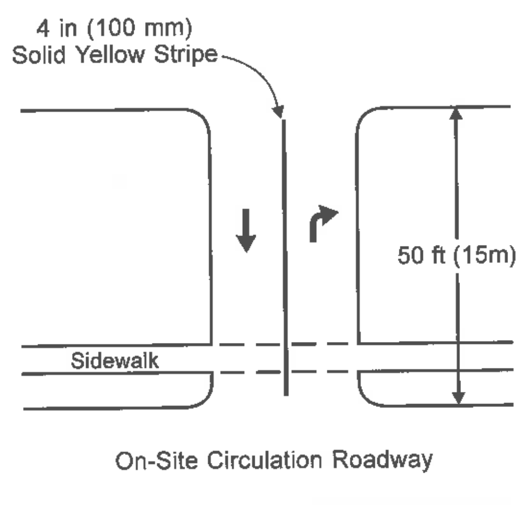
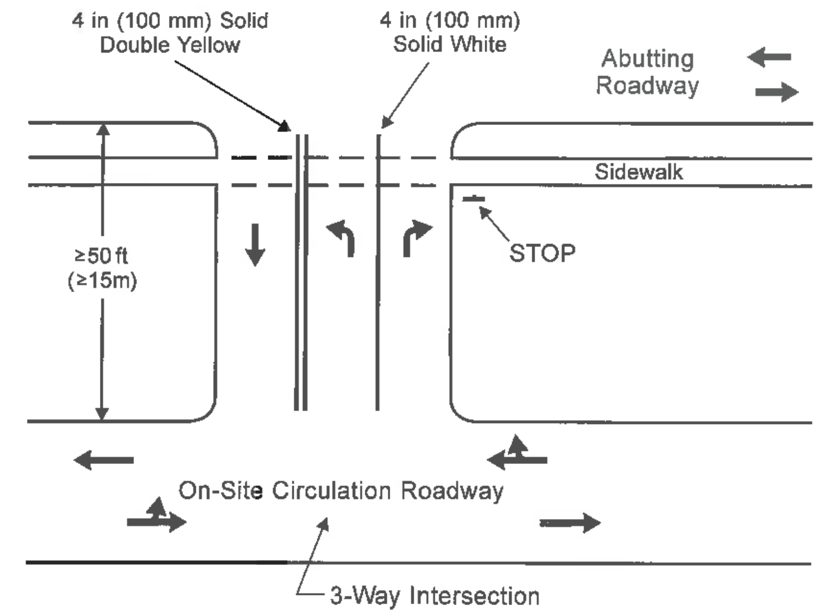


Figure 7–23. ***STOP-Controlled Commercial Drive, Single-Lane Exit; No Parking in the Vicinity of the Intersection of the Access Drive and On-Site Circulation***



Two exit lanes provide storage for exiting vehicles in each lane, increasing egress capacity, reducing egress delay; this requires a minimum throat length of at least 50 ft.

Figure 7–24. ***STOP-Controlled Two-Lane Exit; No Parking in the Vicinity of the Intersection of the Access Drive and the On-Site Circulation Roadway***

Figure 7–25. ***Example of a Good Design Two-Lane Exit on an Unsignalized Access Drive Serving an Office Development***

Source: Courtesy of Philip Demosthenes, Colorado DOT

Large developments require multiple exit lanes to serve the high volumes generated. Adequate throat length must be provided to accommodate the necessary weaving. Therefore, as the throat width becomes wider, the throat length must become longer to accommodate the increased amount of weaving that must occur on the outbound side of the access drive. Figures 7–26 through 7–30 illustrate the throat length that have been found to be appropriate for signalized access connections. These lengths have been observed to allow drivers to make the weaving maneuver and achieve minimum headways when crossing the curb line. This ability to achieve short headways is essential for accommodating high exiting traffic flow rates. The design illustrated in Figure 7–26 can serve retail development of up to 250,000 $ft.^2$, or office and other developments having comparable traffic generation. An access drive, such as that illustrated in Figure 7–27, has been observed to accommodate commercial development of as much as 500,000 $ft.^2$

The access drive shown in Figure 7–28 is one of the first, if not the first, example of an access drive that was located and designed with criteria comparable to the design of the intersection of two arterial streets. The original development of the 1 million $ft.^2$ shopping center was served by two such access connections. The design indicates that a throat length of 200 ft. is sufficient to achieve high exit flow rates. Queues back up onto the ringroad. On the green phase, drivers can weave through the intersection of the ringroad and the access drive and then accelerate before reaching the curbline so as to enter the intersection at near minimum headway. This produces high flow rates comparable to the signalized intersection of two urban arterials.

Figure 7–29 shows the principal access to a super regional shopping center (≥ 1.5 million $ft.^2$ gross leased area. This is one of the two principal exits (one of three total access connections). The exit has a single left-turn lane, two through lanes that merge into one lane before merging with the northbound lanes of I-15 and a right-turn lane. The throat length is 300 ft. Observation indicates that this separation of the on-site intersection of the ringroad and the access drive from the intersection of the access drive and the abutting arterial is sufficient to achieve efficient operation. A throat length of 300 ft. is probably the absolute minimum for a four-lane exit, such as the examples shown in Figures 7–29 or 7–30.

Throat lengths for unsignalized access drives and signalized access are summarized in Tables 7–8 and 7–9 respectively.

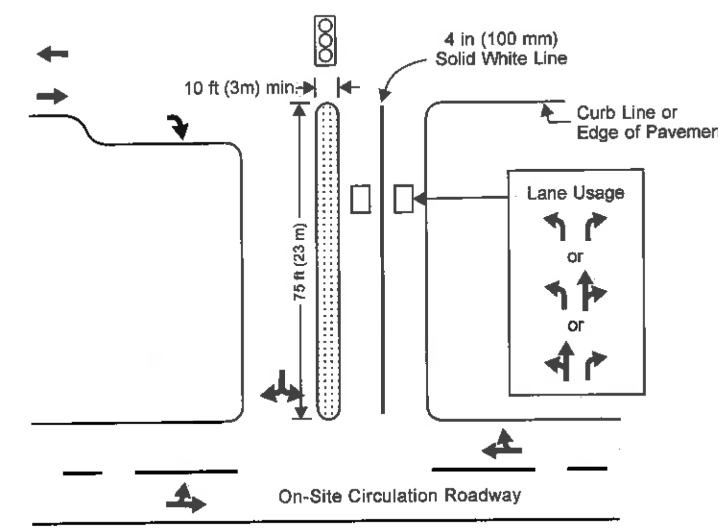


Figure 7–26. ***Signalized Connection***

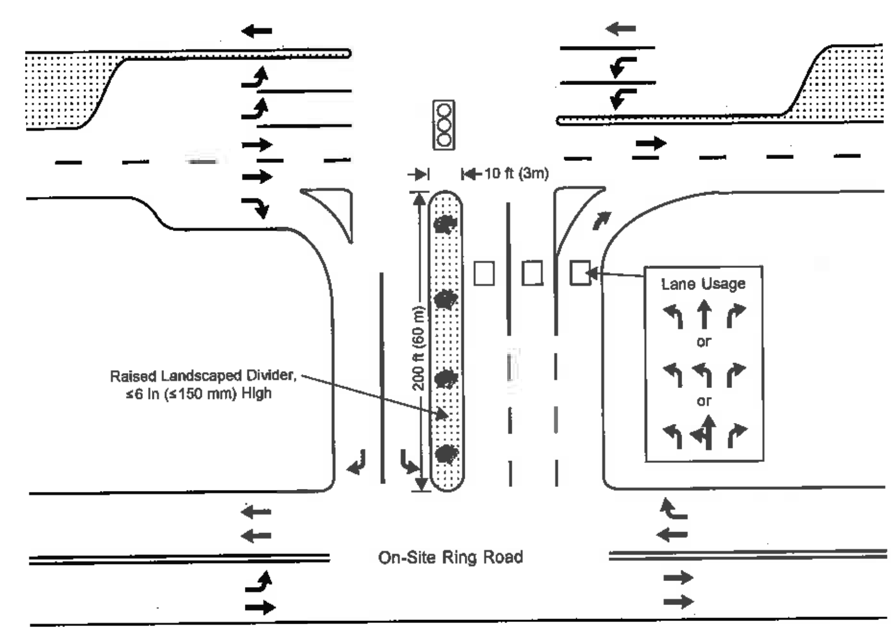


Figure 7–27. ***Signalized Connection, Three-Lane Exit with Right Turn***

Circa 1964

Circa 1990

This was perhaps the first development where an access drive was designed with criteria comparable to that of a major intersection. The throat length (approx. 180 ft.) allows exiting drivers to weave and then enter the intersection at short headways—and therefore a high flow rate. The sign, photograph circa 1964, provides excellent identification for drivers on the arterial roadway as they approach the site. The subsequent landscaping, photo circa 1990, improves the aesthetic quality somewhat but did not address the deficiencies of the intersection of the ringroad and the access drive. Removal of the sign reduces the visual cue as to the location of the intersections.

Figure 7–28. ***Access to a Regional Shopping Center (Wheaton Plaza, MD) that was Located and Designed as a Major Signalized Intersection***

Circa 1989

Circa 2001

This is the principal access drive for the North County Fair, Escondido, CA; it has a throat length of 300 ft. Observation of its operation indicates that this is adequate length for weaving on a four-lane exit.

Figure 7–29. ***Access to a Large Regional Shopping Center***

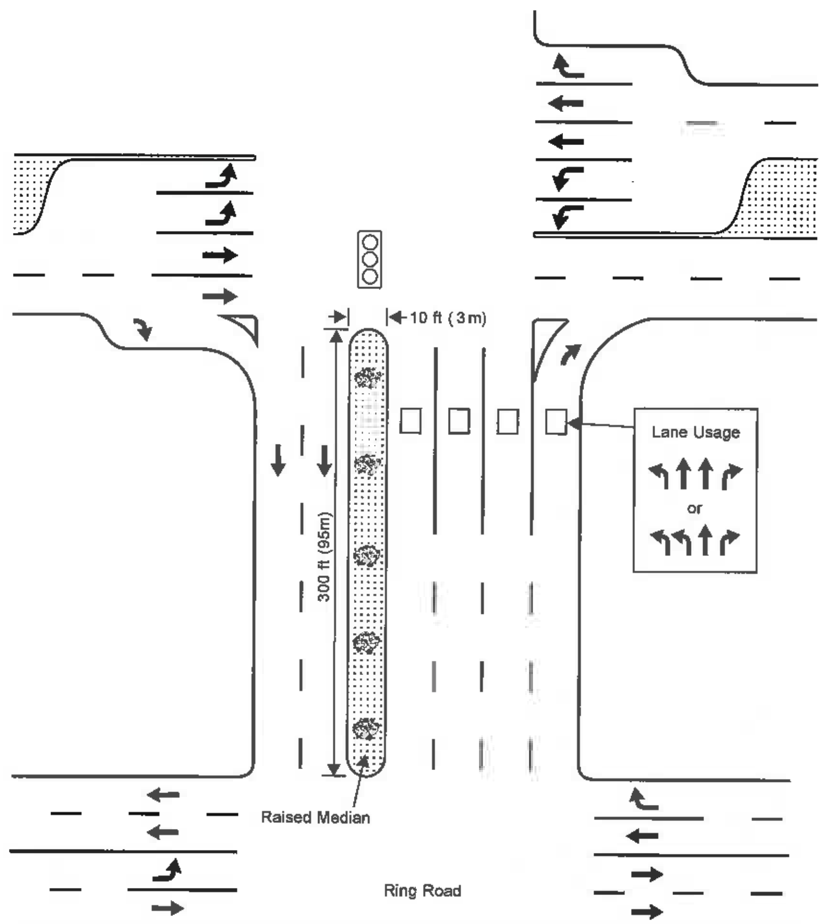


Figure 7–30. ***Signalized Connection, Four-Lane Exit with Right Turn***

High-Volume Driveways

For high-volume driveways, divisional islands should be used to prevent egress traffic from encroaching on the side of the drive used by ingress traffic. This ensures that the ingress traffic has the necessary maneuver space. The island, however, must not present a hazard. This can be accomplished by using one of the following designs:

1. A wide divider with a 4 in. to 6 in. (100 mm to 150 mm) curb. The divider needs to be of sufficient size, width and length, so as to be highly visible—10 ft. (3 m) wide, face-to-face of curb by 50 ft. (15 m) long are desirable dimensions. Appropriate landscaping will contribute to the visibility as well as the aesthetic qualities of the site. A width of at least 8 ft. (2.5 m) is needed to provide sufficient space for the landscaping to grow to a functional size. A wide separation can cause confusion and result in some drivers thinking that the access connection is two, two-way driveways. Widths greater than 12 ft. (3.7 m) are, therefore, to be avoided. The divider is also the preferred location for a sign to identify the development and aid the driver in locating the access point. Appropriate attention of course, must be given to the design and positioning of the sign to ensure that its location and design does not interfere with sight distance.
2. A narrow divider with a contrasting surface raised slightly above the driveway surface. The surface of the median should be no more than 2 in. (50 mm) higher than the driveway surface. Crushed limestone provides a good contrast with an asphalt surface; paving brick are a contrast with a Portland cement concrete surface. Reflectorized pavement buttons are desirable where snow removal is not a problem. Use of paving brick for the median also provides an attractive contrast. The minimum width should not be less than 2 ft. (0.6 m), preferably 4 ft. (1.2 m).

It is suggested that a raised divisional island be used on high-volume driveways to separate the entry and exit sides whenever any combination of egress and ingess lanes is three or more. (Paint lines may be adequate on low-volume driveways.)

Whenever a channelizing island is used at the terminus of a right-turn bay or lane, the inside curb return radius should be a minimum of 75 ft. This will provide an island of sufficient size to allow for landscaping and enhanced visibility. The absolute minimum radius necessary to provide for an island of minimum size is 50 ft. (15 m), in which case a painted island should be used.

A pair of two-way drives with limited turns (Figure 7–31) might be used in place of a single standard two-way drive or a pair of standard two-way drives. The median must be of sufficient width (at least 18 ft.) to allow construction of median openings designed to confine the movement to that intended and to store the left-turn egressing vehicle. This design eliminates the conflict between the left-in and left-out, thereby increasing the left-turn egress capacity. Attention must be given, however, to the on-site circulation system to ensure that the design can operate safely and efficiently.

Two, two-way driveways can also be used at signalized driveways as in the example shown in Figure 7–32. This permits two-phase operation, which is more efficient than three- or four-phase operation. Long throat length to separate the two intersections of the access drives and the on-site circulation roadway (ringroad) is essential for this design to function safely.

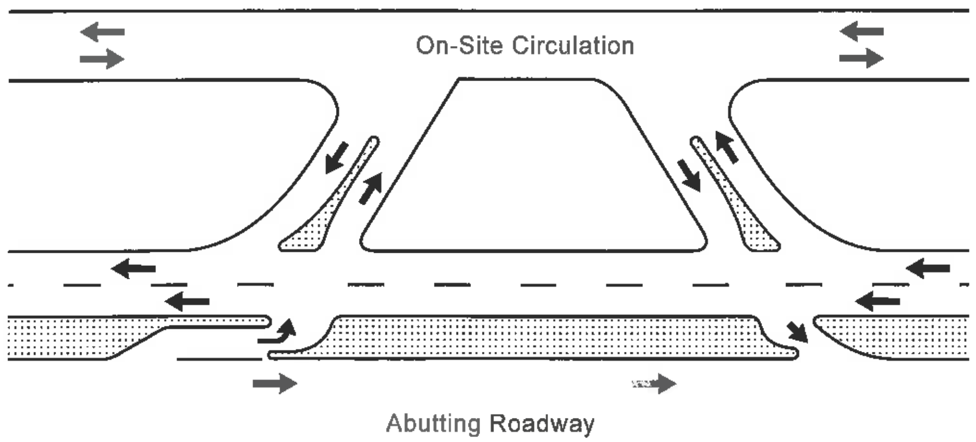


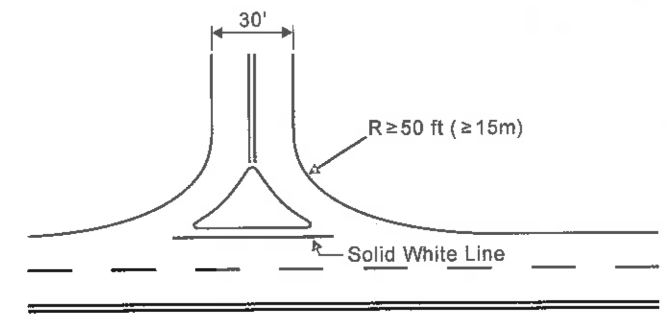
Figure 7–31. ***Two-Way Driveways with Limited Turns***

This design permits two-phase signal operation. A long throat length to obtain a large separation of the intersections of the access drives and the on-site circulation roadway (ringroad) is essential.
Crossgate Mall, Albany, NY. Circa 1996

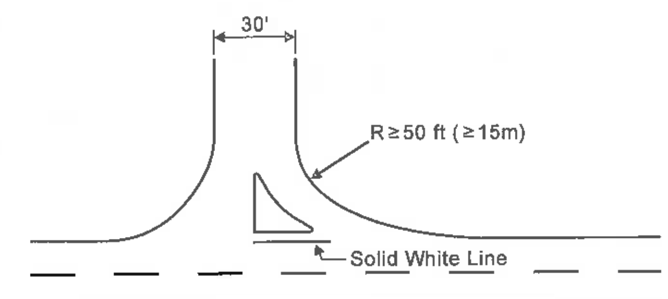
Figure 7–32. ***Example of a Development with Two, Two-Way Access Drives***

Designs to Restrict Left-Turn Movements

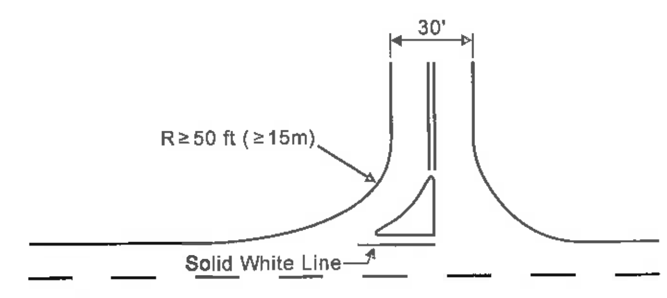
In some instances, it is desirable to prohibit some, or all, left turns. Channelizing islands in the driveway throat are often used (Figure 7–33) to do this. These features do not provide positive control and are often violated—in some locations on a very frequent and routine basis; Figure 7–34 illustrates two such locations. An extension, such as that illustrated in Figure 7–35, is only partially effective. Nevertheless, driveway channelizing islands should be considered on high-volume driveways (even where a median is present) to provide pedestrian refuge.



(a) Channelizing Island to Prohibit Left-Turn Maneuvers



(b) Channelizing Island to Prohibit Left-Turn Ingress Maneuvers



(c) Channelizing Island to Prohibit Left-Turn Egress Maneuver

Figure 7–33. ***Traditional Channelizing Islands Used to Discourage Left Turns***

a. The triangular island is ineffective in prohibiting left turns in absence of a nontraversable median. College Station, TX. Circa 1997

b. Observation shows that this design is violated several times per hour. The median needs to be extended to prevent the left-in maneuver. Wichita, KS. Circa 1999

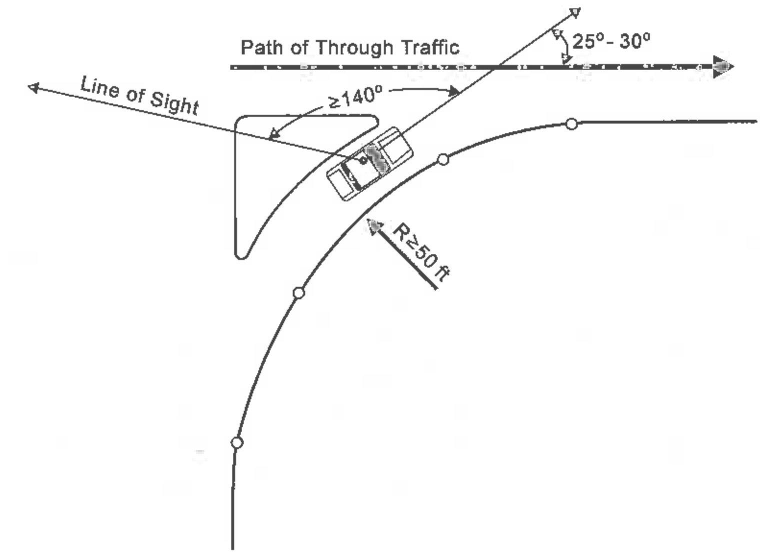
Figure 7–34. ***Examples of Driveway Channelizing Islands being Violated***

Observation at this location on State Highway 99 in Newburg, OR, indicates that in the absence of a nontraversable median, some drivers make u-turns to accomplish left-turn entry and exit maneuvers. Circa 1998

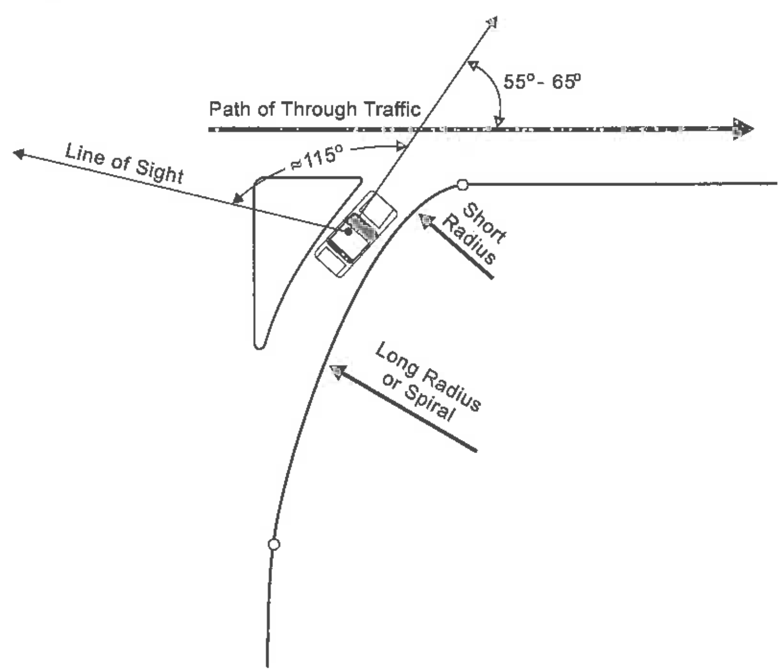
Figure 7–35. ***Extensions to the Triangular Channelizing Island are Intended to Restrict Movements to Right-In and Right-Out***

The traditional channelizing design illustrated in Figure 7–36a results in the right-turning vehicle being oriented at a "flat" angle just before completing the turn. This requires that the angle between looking straight ahead and the line of sight be approximately 140°. This traditional design also has been criticized as being "pedestrian unfriendly" because 1) the right-turning maneuver can be made at a relatively high speed, 2) drivers must scan a wide angle to look for pedestrians and 3) the large angle to view approaching traffic is difficult for drivers and diverts driver attention from seeing pedestrians approaching from the right. The common practice of placing the pedestrian cross-walk in the middle of the curve, however, affords drivers with excellent view of any pedestrians in the vicinity.

An alternative design, illustrated in Figure 7–36b, has been proposed as being more "pedestrian friendly." Its advantages are: 1) the angle between the axis of the right-turning vehicle and the through lane is relatively large (55°–60°), 2) drivers have a better view of the sidewalk area in the vicinity of the access connection, 3) speeds are relatively slow and 4) drivers can more easily see approaching through traffic. An example of such a design is shown in Figure 7–37. This island is much smaller than the traditional design and provides less space for pedestrian refuge. The smaller island size and higher angle of intersection with the through roadway also makes it much easier for drivers to make a left turn.



a. Traditional design: Requires driver to rotate head and body through a large angle to observe approaching vehicles.



b. Alternative design: Results in slower speeds and a less awkward angle to view approaching vehicles.

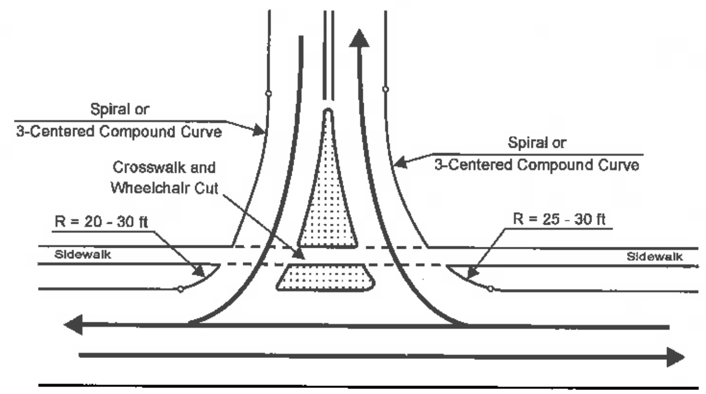
Figure 7–36. ***Schematic Comparison of the Traditional and Alternative Right-Turn Channelizing Island***

Figure 7–37. ***Example of the Alternative Right-Turn Channelization Island***

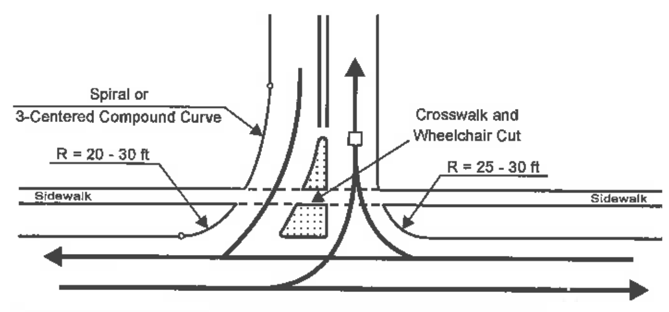
Source: Courtesy of Gary Sokolow, Florida DOT, 1998.

Although they might not be effective in eliminating undesired vehicular turning movements, triangular islands can provide pedestrian refuge. Therefore, islands such as those illustrated in Figure 7–38 should be used on all high-volume access drives. As illustrated, the sidewalk must be carried across the driveway without a change in direction. The minimum pedestrian refuge area is 5 ft. wide and at least 6 ft. long. Achieving a departure angle similar to that shown in Figure 7–36b requires different geometrics than the commonly used islands (Figure 7–33).

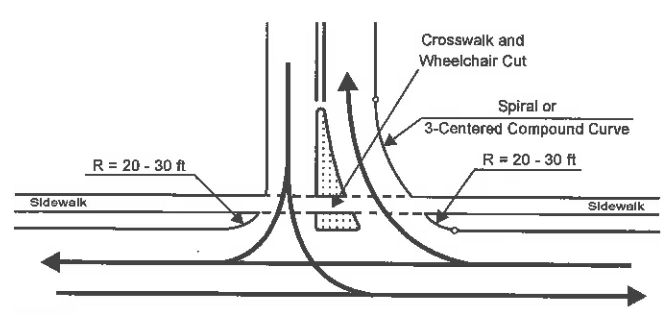
Where the distance from the back of curb permits, the sidewalk elevation can be maintained through the driveway. Elevating the driveway surface to the sidewalk elevation indicates that pedestrians have the right-of-way over vehicles. Such a design is possible where the distance between the back of curb and the sidewalk permits an acceptable change in grade between the roadway pavement cross-slope and the driveway apron (change in grade $\leq$ 8 percent on major roadways, $\leq$ 10 percent on minor roadways). Where this is not possible because of insufficient distance between the curb and sidewalk, a combination of lowering the sidewalk surface and raising the driveway surface is suggested.



a. Discourage left-in and left-out.



b. Discourage left-turn out.



c. Discourage left-turn in.

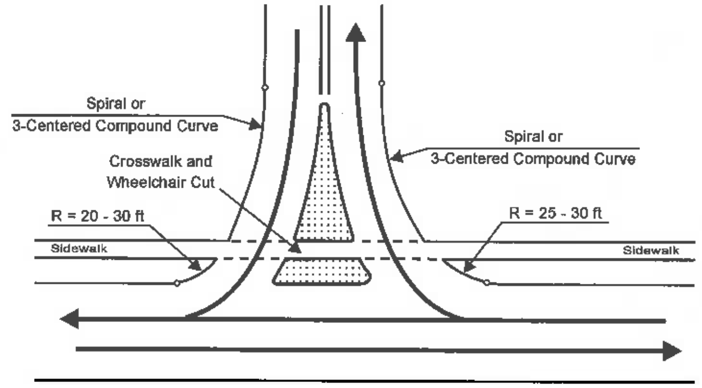
Figure 7–38. *Channelizing Islands Should be Used to Provide Pedestrian Refuge*

Driveway Profiles

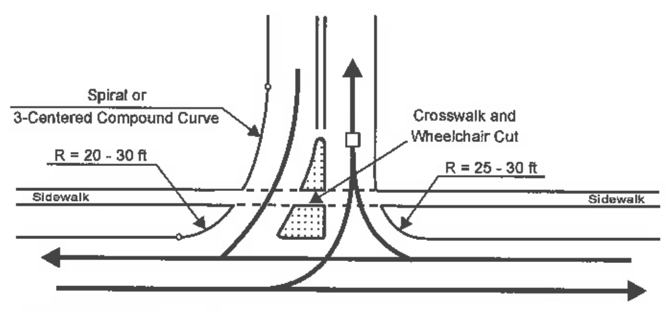
The change in grade between the roadway cross-slope and the slope of the driveway apron must permit drivers to make the transition between the highway and the abutting site. An excessive change in grade will cause the front or rear bumper to drag on the surfaces of the highway or the driveway. Drivers will then make the driveway maneuver at an angle instead of executing a 90° turn.

The ease with which the driveway maneuver should be made is a function of the character of the highway. Access drives to highways of statewide importance should enable the driver to execute a smooth, low-speed 90° turn maneuver. Recommended maximums for the change in grade between the roadway cross-slope and the driveway apron are given in Table 7–10. For example, with the common -2 percent cross-slope on a major urban arterial roadway, the apron slope should be between -6 percent and +2 percent (a 4 percent change in grade). Lower-class roadways commonly have steeper cross-slopes. With a -4 percent cross-slope on a collector or local street, a +12 percent maximum apron slope results in a 16 percent change in grade. Normal construction practice can result in a smooth transition between the pavement cross-slope and the driveway apron, as well as between segments of the driveway having different slopes when the change in grade is less than 5 percent. On driveway connections to roadways other than major arterials, "rounding" can provide an acceptable transition when the change in grade is 8 percent or less. Suggested practices are indicated in Table 7–11. Table 7–12 gives the length of vertical curves for extreme changes in grade between the pavement cross-slope and the driveway apron, and between changes in grade between driveway segments. Profiles are illustrated in Figures 7–39, 7–40 and 7–41.

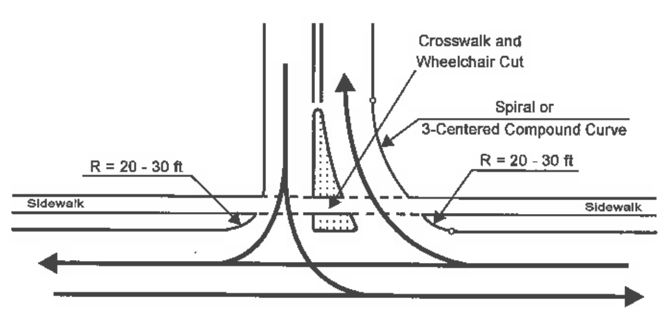
Care needs to be taken to prevent stormwater from flowing from the roadway onto the abutting property when the site is below the roadway elevation. On roadways having a curb and gutter, this can be accomplished by use of a verticle curve as illustrated in Figure 7–39. On uncurbed roadways, this can be accomplished by use of a swale at the edge of the shoulder (option 1) or at the foot of the driveway (option 2) to control stormwater runoff as illustrated in Figure 7–40.



a. Discourage left-in and left-out.



b. Discourage left-turn out.



c. Discourage left-turn in.

Figure 7–38. *Channelizing Islands Should be Used to Provide Pedestrian Refuge*

Driveway Profiles

The change in grade between the roadway cross-slope and the slope of the driveway apron must permit drivers to make the transition between the highway and the abutting site. An excessive change in grade will cause the front or rear bumper to drag on the surfaces of the highway or the driveway. Drivers will then make the driveway maneuver at an angle instead of executing a 90° turn.

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Table 7–10. *Suggested Maximum Change in Grade Between the Roadway Cross-Slope and the Driveway Slope*

	Driveway	
Roadway	High Volume	Low Volume
Major Arterial	5%	6%
Minor Arterial	6%	8%
Major Collector	7%	9%
Minor Collector	–	10%
Local	–	12%

Table 7–11. *Suggested Driveway Design Profile Design Practice*

Driveway Connection	Design
Arterial Roadways:	
A[1] ≤ 4%	"Rounding"[2]
A > 4%	Design Vertical Curve
Collector Roadways:	
A ≤ 8%	"Rounding"
A > 8%	Design Vertical Curve
Local Residential Streets:	
A ≤ 10%	"Rounding"
A > 10%	Design Vertical Curve

[1]A = change in grade between the pavement cross-slope and the driveway apron.

[2]Taking care to avoid an abrupt change in grade.

Table 7–12. *Length of Crest and Sag Vertical Curves for Extreme Changes in Driveway Profile*

Algebraic Change in Grade	Length of Vertical Curve (ft.) Sag	Crest
6%	15	5
8%	20	8
10%	25	10
15%	35	20
20%	45	30
25%	55	40

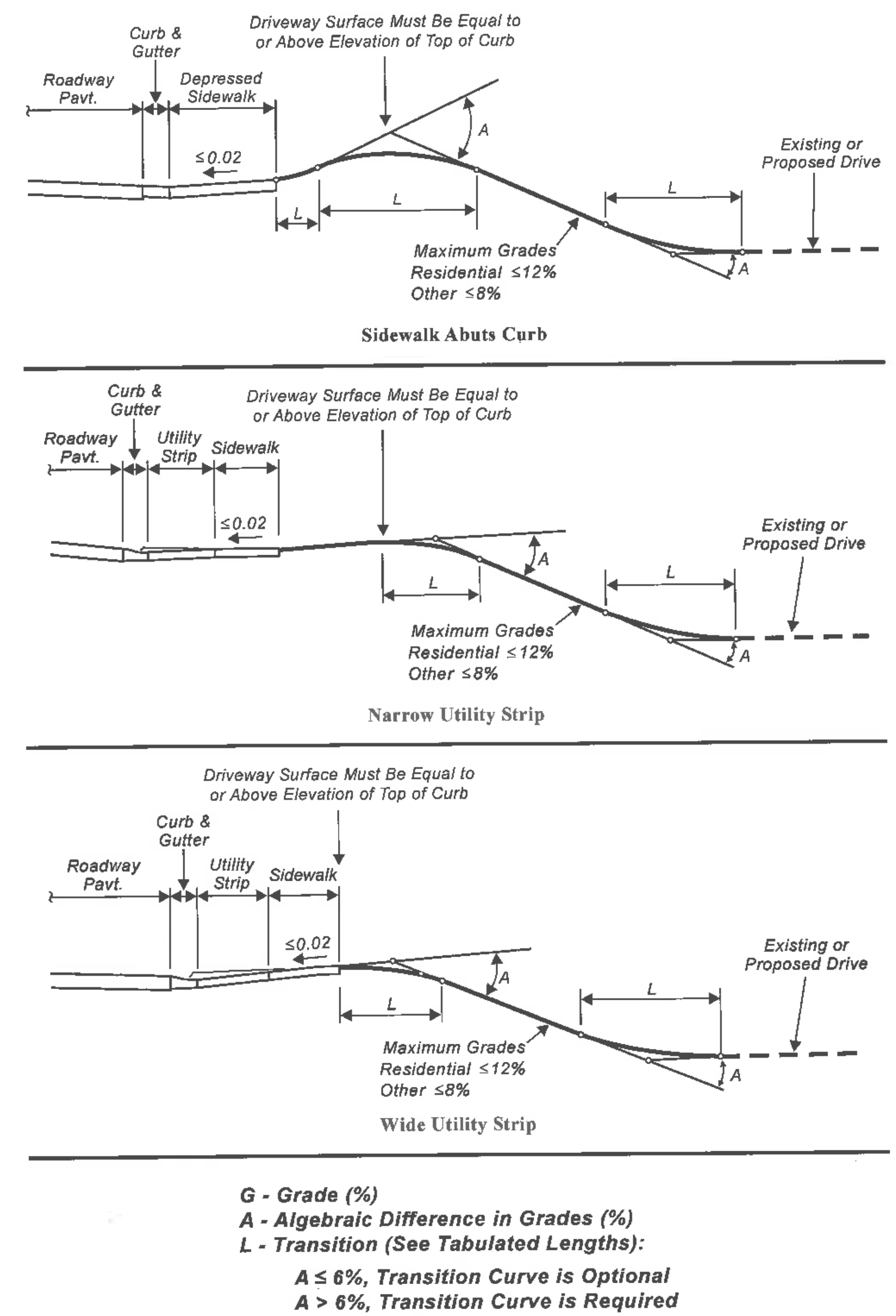
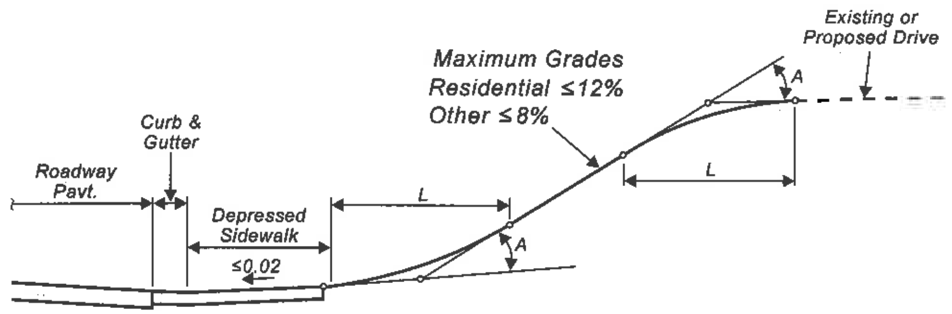
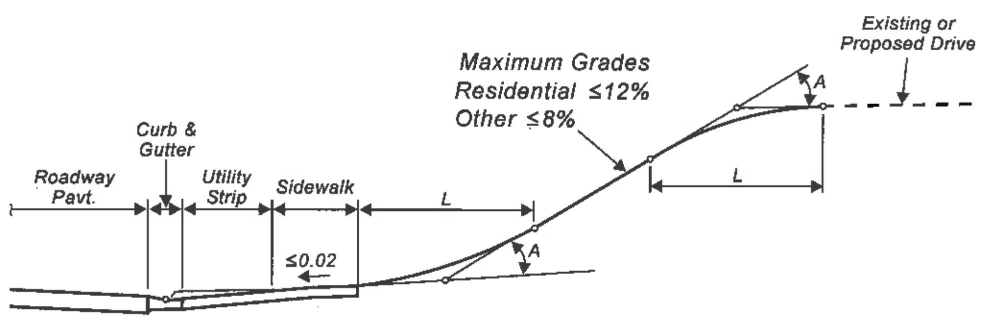


Figure 7–39. ***Urban Profile, Driveway on a Downgrade***

Source: Adapted from Oregon DOT.



Sidewalk Abuts Curb

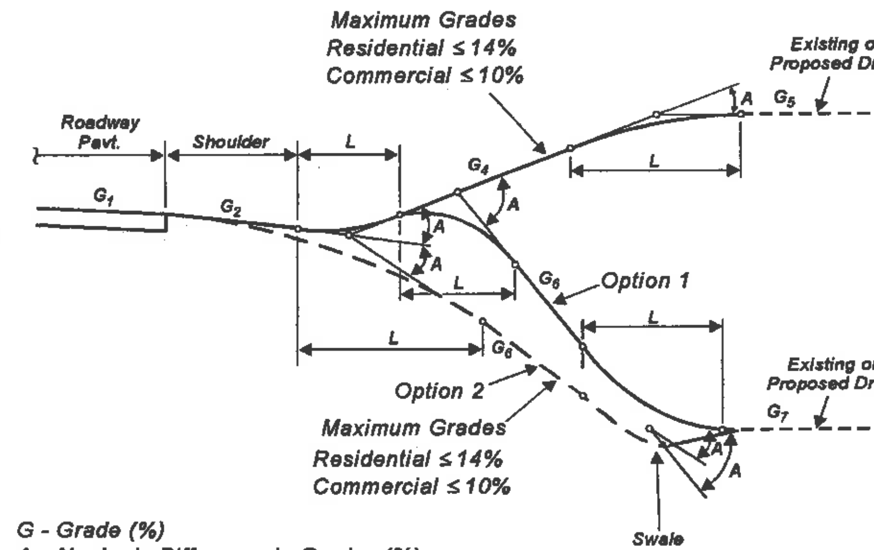


G - Grade (%)
A - Algebraic Difference in Grades (%)
L - Transition (See Tabulated Lengths):
A ≤ 6%, Transition Curve is Optional
A > 6%, Transition Curve is Required

Utility Strip Between Sidewalk and Curb

Figure 7–40. *Urban Profile, Driveway on an Upgrade*

Source: Adapted from Oregon DOT.



G - Grade (%)
A - Algebraic Difference in Grades (%)
L - Transition (See Tabulated Lengths):
A ≤ 6%, Transition Curve is Optional
A > 6%, Transition Curve is Required

Figure 7–41. *Rural Profiles*

Source: Adapted from Oregon DOT.

Driveways for Rural Residences and Small Rural Developments

Where adequate stopping-sight distance cannot be obtained at any point along the frontage and alternative access cannot be provided, consideration should be given to the purchase of the access rights and preferably purchase of property. Where this is not feasible, the risk involved in providing the access needs to be carefully evaluated. If the risk is very low, conditions as to the volume and types of vehicles permitted to use the access drive, and speed and volume on the abutting roadway, should be included as limitations as to the use of the access drive. If conditions on the abutting roadway change or use of the driveway changes, a new permit application should be required.

The distance from the edge of the shoulder to any gate should be sufficient for a vehicle to stop clear of the roadway; this is especially critical where large trucks, pickups pulling trailers or farm tractors pulling wagons might be encountered. In many cases, this requires that the gate be recessed some distance from the right-of-way line. Other considerations for rural driveways are: provision of adequate sight distances, width sufficient to accommodate large agricultural equipment and drainage design so that water does not flow across the highway or carry soil or sand onto the highway.

The permit should specify a variety of limitations and conditions, such as the driveway volume for which it is valid. Exceeding any limit or condition should invalidate the permit and require that a new application be submitted. Suggested conditions to be specified in the permit include: 1) maximum driveway volume, 2) mix of vehicles (i.e., percent trucks, percent cars) and 3) if additional development occurs, cross-parcel circulation and alternative access must be provided by the development. Unless turnbays are provided as part of the initial development, the access permit should state the traffic conditions where left- and right-turn bays are to be provided at the developer's expense. Additionally, a taper shown in Figure 7–43 will avoid the maintenance problem illustrated in Figure 7–42.

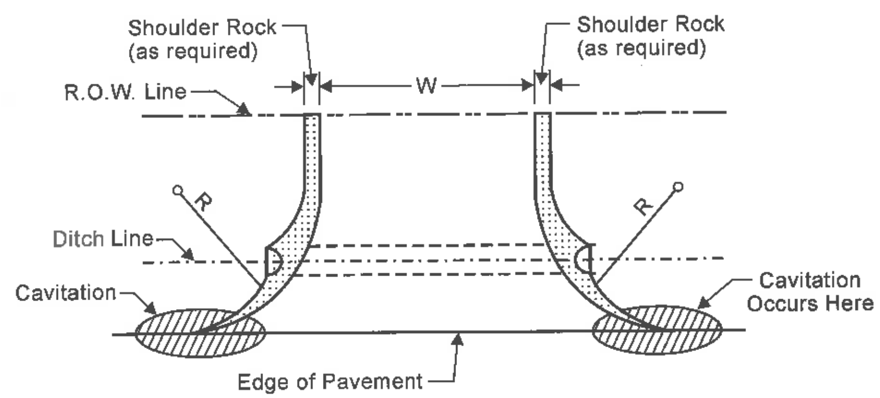


Figure 7–42. *Common Rural Approach Design: Maintenance Problems Occur Due to Cavitation Where the Radius Meets the Edge of the Pavement*

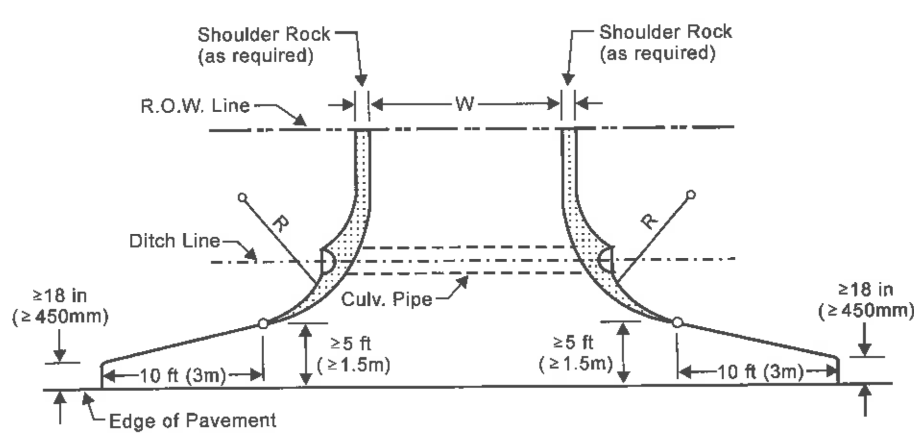


Figure 7–43. *Recommended Rural Approach Design*

The site plan submitted as part of the approach road application should ensure that: 1) ample storage is provided for traffic entering the site so that spill-back onto the abutting highway will not occur and 2) adequate intersection sight distance is provided at all commercial approach road connections.

A truck stop is not a small development, even though it might be located in a rural area. The permit should also limit the number of approach road connections to that stated in the permit and specify that future subdivision of the parcel will require joint and cross-access or provision of a supporting on-site roadway system.

Sight Distance Issues Related to Driveway Design

The site triangle, together with its dimensions, should be shown on the site plan. The site designer and the agency reviewer of the site plan need to check to ensure that the sight triangle does in fact provide for adequate intersection sight distance on the abutting roadway. This means that the vertical alignment as well as the plan view need to be checked. Review of the site plan must then ensure that no potential obstruction such as the following can occur within the sight triangle: buildings, parking, signs and vegetation over 24 in. (0.6 m) high. Periodic inspections and substantial penalties are needed to help ensure that visual obstructions are not placed within the sight triangle after the site has been developed. Failure to keep the sight triangle free of obstruction incurs liability for both the public agency as well as the property owner.

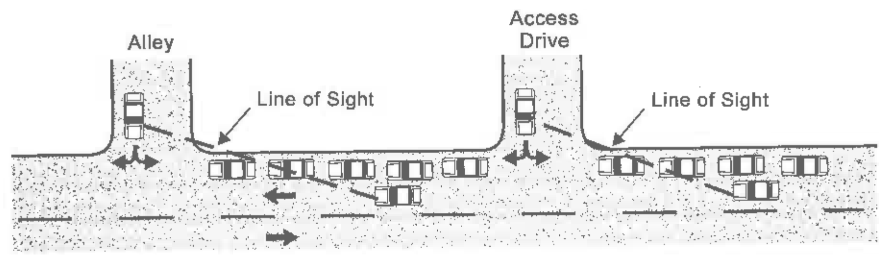
Situations That Commonly Result in Inadequate Sight Distance

As illustrated in Figure 7–44, on-street parking commonly results in inadequate intersection sight distance and often results in inadequate stopping sight distance as well. The problem is especially severe where sport utility vehicles, vans, pickups and trucks are parked or stopped at the curb.

The solution to this problem is to remove or prohibit parking within the sight triangle. Where there are frequent access drives, alleys and street intersections, parking often must be removed for the entire block frontages.

Inappropriate landscaping or inadequate landscape maintenance also are common obstructions to sight distances, as illustrated in Figure 7–45. Solutions to this problem include:

- Restrict landscaping within the sight triangle as part of the access connection permit. Landscaping must comply with an approved landscaping plan, including use of specified planting materials; and

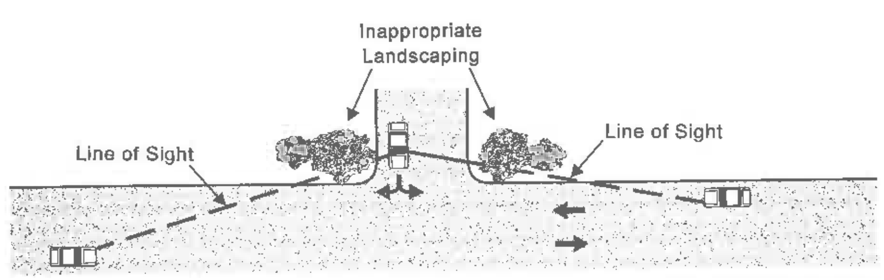


Not to Scale

a. Schematic illustration of on-street parking interfering with sight distance.

b. Sight distance leaving this high-volume municipal parking lot obstructs sight distance on a major roadway serving a commercial area. Danville, CA. Circa 2000

Figure 7–44. ***Sight Distance Obstructed by On-Street Parking***

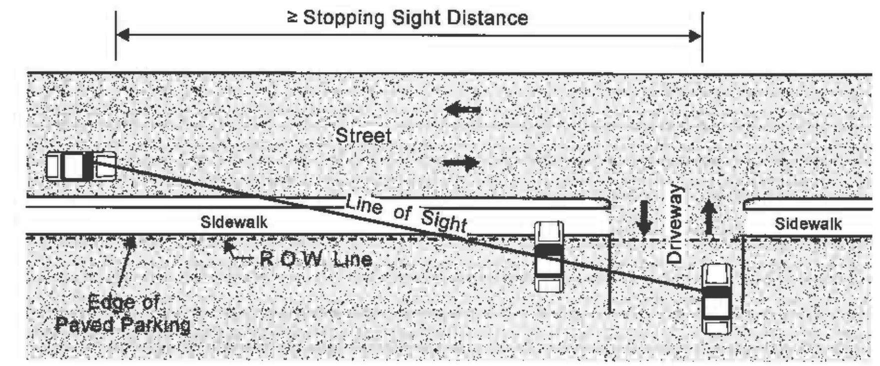


Not to Scale

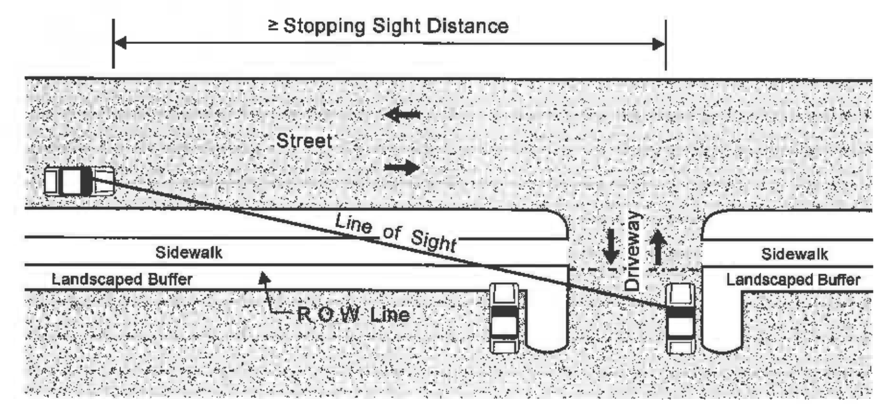
Figure 7–45. ***Inappropriate Landscaping or Inadequate Landscape Maintenance Results in Inadequate Sight Distance***

- Periodic inspection. Provide substantial penalties for violation. Remove inappropriate landscaping and bill property owners for cost or set fee.

Parking lots are often paved to the right-of-way and to the edge of the driveway. As illustrated in Figure 7–46a, a vehicle parked in the end stall, or a large sign located in the end stall, seriously interfere with the necessary minimum sight distance. A landscaped buffer between the right-of-way line and a landscaped border along the access connection, illustrated in Figure 7–46b, can be used to preserve sight distance and improve the aesthetics.



a. Sight distance obstructed by parking.



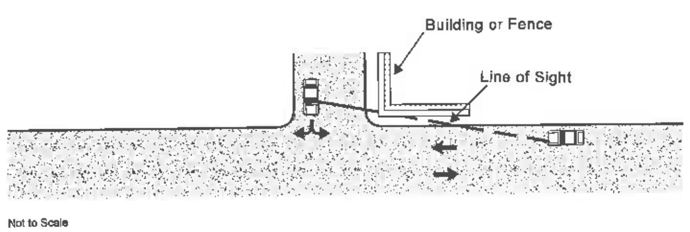
b. An appropriate buffer can be used to preserve the sight distance.

Figure 7–46. ***Sight Distance is Often Blocked When Parking Lot is Paved to Edge of Sidewalk or to Right-of-Way Line***

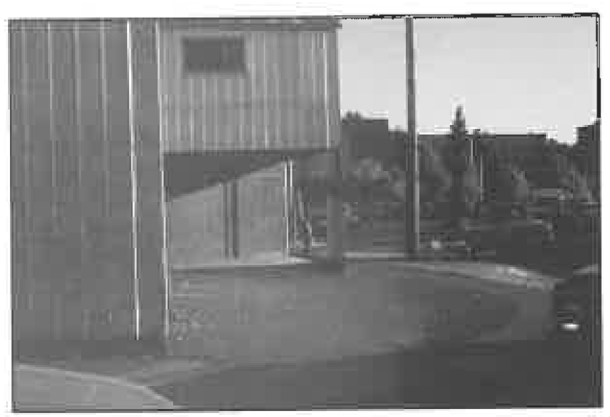
Inadequate building setbacks will result in structures encroaching into the sight triangle as schematically illustrated in Figure 7–47a. This problem is addressed by:

- Requiring that the building be located outside of the sight triangle if the traditional building line would allow the structure closer to the right-of-way; and
- Designing the building so that the floor does not encroach upon the sight triangle; the upper stories could extend over the sight triangle.

Figure 7–47b illustrates a case where a zero building line was permitted. This resulted in a sight distance that was considerably less than minimum stopping sight distance. Part of the structure had to be removed to rectify the situation.



a. Placing a structure at the right-of-way line will interfere with sight distance where the distance from the curb, or edge of pavement is limited.



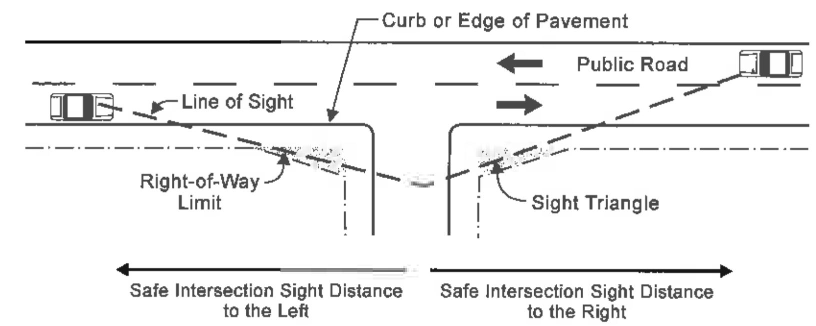
b. A portion of this building had to be removed to provide minimum sight distance. Speeds are 30 to 35 mph. The photograph was taken from the driver's seat. Note that the driver must stop over the cross-walk; even then, the sight distance is minimal for a speed of 25 mph. Corvalis, OR. Circa 1999

Figure 7–47. *Inadequate Building Setback Obstructs Sight Distance*

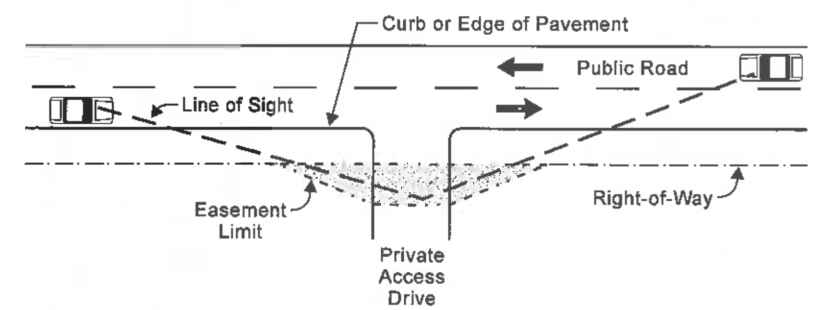
Preserving Sight Distances

A sight triangle that is sufficient to provide adequate intersection sight distance must be kept free of all obstructions that could interfere with the line of sight. The best way to ensure this is to require a dedication of the sight triangle as part of the right-of-way. The more common practice, however, is to attempt to keep the sight triangle free of obstructions through regulation.

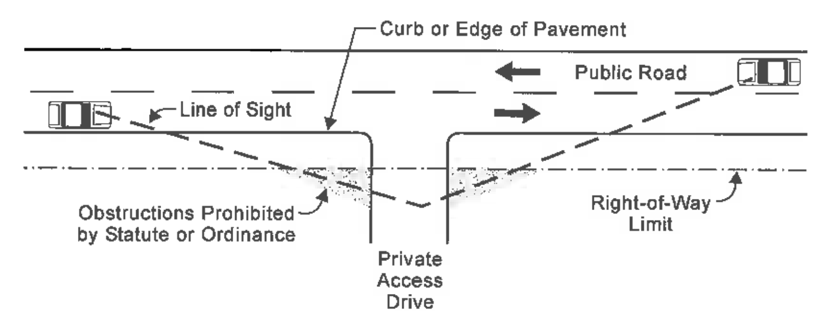
Adequate sight distances can be provided at the intersection of two public streets, alleys and private access drives by the three methods illustrated in Figure 7–48.



a. Sight triangle incorporated as right-of-way. This is the best way to ensure that the sight triangle remains free of obstruction that can interfere with sight distances.



b. Sight triangle protected by acquisition of use (easement). The easement gives the governmental agency control over the use of the private property within the sight triangle. Enforcement should be somewhat simpler than just regulating objects within the sight triangle.



c. Sight triangle protected by regulation. This method is the best of the three approaches to preserve sight distances. A well-written ordinance (city, county, or township) or regulation (state) must be developed and an aggressive, effective enforcement practice implemented.

Figure 7–48. *Methods of Preserving Intersection Sight Distance*

Visibility and Visual Cues

The location and geometrics of all connections must be clear to approaching drivers. Low contrast between driveways and the space between driveways reduces recognition of individual driveways. The problem is often compounded by extremely short throat lengths and paving the site to the sidewalk. Conditions such as those shown in Figure 7–49 cause drivers intending to enter a site to travel at a slow speed while attempting to locate the appropriate access drive. Continuous paving, as illustrated in Figure 7–50, makes it extremely difficult for drivers to identify driveway locations—especially at night.

The Portland Cement concrete sidewalk provides contrast between the asphaltic concrete surfaces of the street and the on-site parking areas. The access drives are, however, very poorly delineated and extremely difficult for the driver to identify. The spacing visible between the two drives in the foreground is prevalent along the entire street. The lack of contrast between the access drives and the space between them makes it very difficult to spot a driveway that is more than 150 to 200 ft. away. Even on a clear day, the low volume on this arterial is because the photo being taken on a Sunday morning.
Phoenix, AZ. Circa 1985

Figure 7–49. *Poor Delineation of Access Drives*

The continuous asphalt paving makes identification of access locations difficult in the daytime and nearly impossible at night. The gouges on the 9 in. (222 mm) high curb are clear evidence that drivers fail to identify the driveways. At night, the absence of contrast suggests open frontage (no curb). Big surprise! Circa 1977

Figure 7–50. *No Visual Cue Is Provided as to the Access Location*

A planter strip between the back of curb and the sidewalk, as illustrated in Figure 7–51, provides excellent contrast and makes it easy to identify an access drive location. This has the added benefit of providing a physical separation between pedestrians and the vehicular traffic and aesthetics.

The landscaped strip between the curb and the sidewalk produces excellent contrast, which enables drivers to easily identify the location and geometric of the access drive. The return radius (10 ft.) and throat width (25 ft.), in combination with a bike lane, permits drivers to make simultaneous entry and exit maneuvers at this apartment complex in Corvallis, OR. Circa 1998

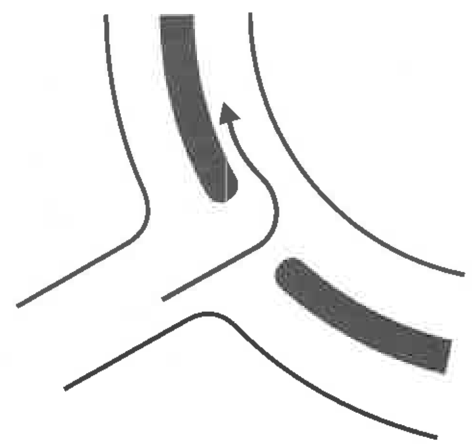
Figure 7–51. *Good Driveway Design*

Figure 7–52 illustrates a design of a median opening that was not coordinated with the location of an access drive located on the outside of a horizontal curve. The access drive, which serves a large multiscreen cinema, is on the outside of a horizontal curve. The median opening was designed with the geometrics of an opening on a tangent. Drivers leaving the cinema at night do not have good visibility of the median end and its location is within the area traversed when making a left turn from the cinema site. Figure 7–53 illustrates the "required" path that a driver needs to steer when making a left turn and the "natural" path that drivers attempt to use when making a left turn through the median opening as shown in Figure 7–52.

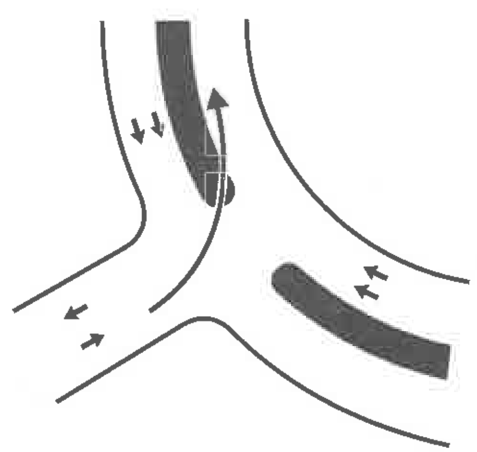
This median opening was not coordinated with the driveway located on the outside of the curve. The problem is compounded by an absence of contrast between the median surface and the pavement.

Damage and tire marks on the leading end of the median opening indicate that many drivers fail to see it when making a left turn from the driveway that is located on the outisde of the horizontal curve. Lee County, FL. Circa 1995

Figure 7–52. *Median Opening Serving an Access Drive on the Outside of a Horizontal Curve. Such Locations Require a Different Design than a Median Opening or a Tangent.*



"Required" Path of Left Front Wheel



"Natural" Path of Left Front Wheel

Figure 7–53. *Schematic Illustration of the Vehicle Path Required by the Median Opening Shown in Figure 7–54 and the Natural Path*

Had the problem been recognized in the site development phase, the problem could have been avoided by relocation of the access drive or realignment of the roadway. Once developed, however, the option is to replace the end of the 6 in. (150 mm) high curbed median with a slightly raised section about 2 in. (50 mm) high for a distance of 12 to 15 ft. (3.6 to 4.6 m) in advance of the full 6-in. (150 mm) media. Because snow is not a problem, reflectorized pavement buttons also would help provide visibility.

Signage as Visual Cues

Signage is, or should be, considered to be an integral part of access design. Figure 7–54 is an example of a problem of improper sign location. The sign should be located in the circular area adjacent to the driveway. However, this is a state highway right-of-way resulting from a very small remainder parcel and private signs are not permitted nor could the excess right-of-way be leased or sold. The distance between the access drive and the sign misleads motel clientele. On realizing that they have passed the driveway, a large number stopped in the traffic lane and then either backed up or made a u-turn. The problem was resolved by legislation that allowed the state DOT to either sell, lease, or allow private signs on "excess right-of-way."

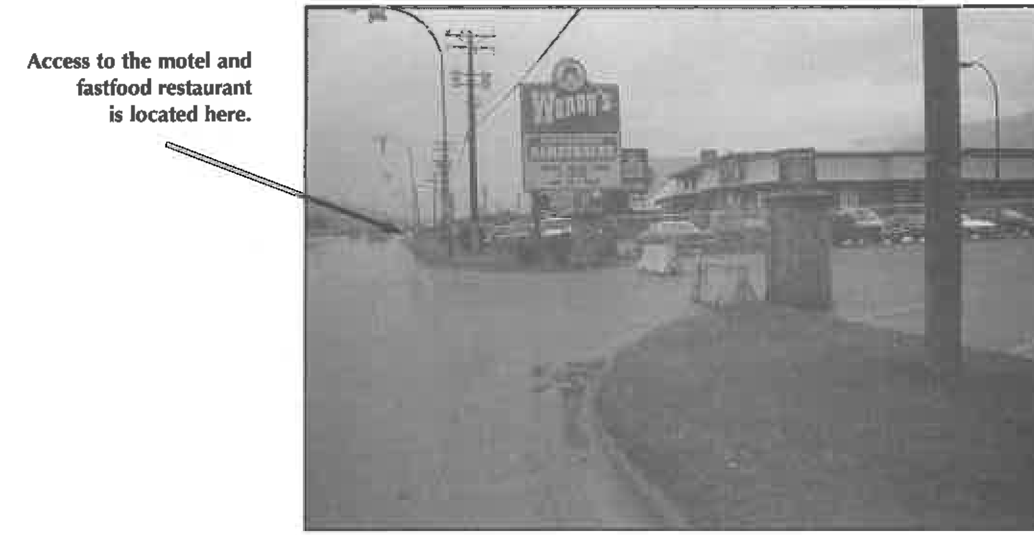
The proper sign location is the grass area adjacent to the driveway that was acquired by the Tennessee DOT because of its very small size and because the taking plus damages to the remainder was equal to the before value. A change in state law has allowed the sign to be relocated adjacent to the driveway.

Figure 7–54. *The Distance Between the Access Drive and the Sign Mislead Motel Clientele*

An access drive located on the inside of a horizontal curve, as shown in Figure 7–55, also requires careful attention because a vehicle's headlights does not illuminate the driveway connection at night. Signing and lighting must be designed to clearly communicate the driveway location and geometrics—especially if the site will be visited by patrons who are unfamiliar with the area. The visual cue misleads drivers approaching this regional shopping center at night. The vehicle's headlights do not provide good illumination for the access drive. This is compounded by the location of the sign and area lighting on the far side of the access drive which has a 24 ft. (8 m) inbound roadway, 10 ft. (3 m) grass divider and a 24 ft. (8 m) exit roadway. The shopping center is located in an area that has a very large number of winter visitors who might not be familiar with the site. Drivers frequently pass the entrance side of the driveway before they realize it, and then stop in the outside traffic lane while considering their predicament. Observation indicated that the vast majority back up and enter on the ingress side or enter by going the wrong way on the exit side of the drive; only a few continue to find another access. Figure 7–56 illustrates another example where improper sign location and access confuse drivers.

The visual cue misleads drivers approaching this regional shopping center at night. The vehicle's headlights do not provide good illumination of the access drive. This is compounded by the location of the sign and area lighting on the far side of the access drive, which has a 24 ft. (8 m) inbound roadway, 10 ft. (3 m) grass divider and 24 ft. (8 m) exit roadway. The shopping center is located in an area that has a very large number of winter visitors who may not be familiar with the site. Drivers frequently pass the entrance side of the driveway before they realize it and stop in the outside traffic lane while considering their predicament. Harlinger, TX. Circa 1989

Figure 7–55. ***Poor Access Design Misleads Drivers***



Access to the motel and fastfood restaurant is located a considerable distance (approximately 350 ft.) from the Wendy's sign. Location of the signs in close proximity to a driveway serving an adjacent property confuses patrons. Concrete barriers were placed in the driveway to discourage motel and restaurant patrons from entering the driveway serving the adjacent property.

Figure 7–56. ***Access, Sign Location and Site Layout Were Not Coordinated***

Driveway Construction

On roadways having a curb and gutter, the entire curb and gutter section should be removed and replaced as an integral part of the driveway apron as indicated in Figure 7–57. This provides structural integrity and helps prevent water seeping through the joint between the gutter and apron. With a little care, the manual surface finishing process will produce a vertical curve that will provide a suitable transition between the roadway cross-slope and the driveway profile, as shown in Figure 7–58.

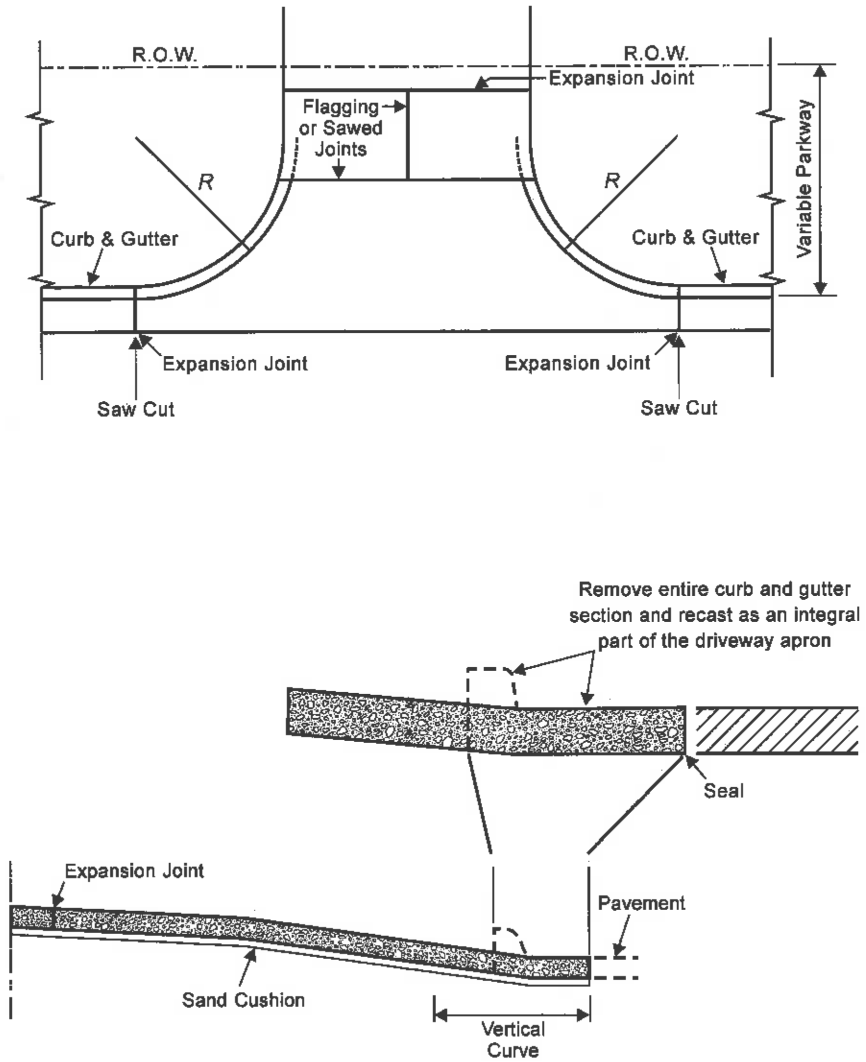


Figure 7–57. ***Sketch Illustrating Proper Removal of Curb and Gutter, and Correct Construction of Direct-Access Drive***

The change in grade is from a 2.5 percent cross-slope on the pavement to a 2.0 percent grade on the apron (a 4.5 percent change in grade). Stormwater flow through the driveway opening follows the gutter line. 29th Street, Bryan, TX. Circa 1994

Figure 7–58. ***Example Where the Curb and Gutter Were Removed and the Gutter Section Was Replaced as an Integral Part of the Driveway Apron***

Cited References

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5. Stover, V. G., W. G. Adkins and J. C. Goodknight, *Guidelines for Medial and Marginal Access Control on Major Roadways,* NCHRP Report 93, National Cooperative Highway Research Project, Highway Research Board, National Research Council, 1970.
6. Unpublished data from Project 5182, Texas Transportation Institute, 1979.