Access Control Issues Related to Urban Arterial Intersection Design

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The 1984 AASHTO Green Book replaced volume-based design with functional design. The Green Book also makes three significant statements relative to intersections: (*a*) driveway terminals are intersections, (*b*) a driveway should not be located within the functional boundary of an intersection, and (*c*) private drives should be designed using the same criteria as the equivalent public street intersections. The third statement implies that there is an equivalence between the intersection of a driveway and a street and the intersection of two public streets—or that such an equivalence needs to be established. The three statements taken collectively imply that there is a hierarchy of intersections. A generalized intersection hierarchy is presented. It is suggested that access control design on major urban arterials should begin with the establishment of optimum spacing criteria for signalized intersections. Minimum functional intersection limits are calculated for various speeds. Basic criteria for unsignalized access are also presented.

The adoption of the philosophy of functional design was a major contribution of the 1984 edition of the AASHTO Green Book (*1*, Chapter 1). However, neither the 1984 nor the 1990 edition effectively addresses access control as an element of design.

The design of urban arterial streets is essentially a matter of designing a hierarchy of intersections, which are connected by relatively short segments of tangents and curves, both horizontal and vertical. Thus the logic of functional design suggests that the urban arterial street design process should begin with the most important intersections and then, in turn, consider intersections that are successively lower in the functional hierarchy.

Major issues relative to access control in urban arterial intersection design include the following:

- Spacing of signalized intersections (private access as well as public streets) so that efficient traffic movement can be achieved on the arterial streets in both peak and off-peak periods;
- Establishment of a functional hierarchy of intersections;
- Determination of the functional boundary of intersections so that an intersection of lower functional classification is not located within the functional boundary of an intersection of higher classification;
- Establishment of comparability between the intersections of two public streets and intersections resulting from the connection of private access drives to public streets;
- Design of intersections (private drives as well as public streets) so that left- and right-turning vehicles do not cause serious interference with through traffic;
- Design of medians and median openings to provide access control at unsignalized intersections, public as well as private; and
- Visibility to the driver of the location and the geometries of each intersection.

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SIGNALIZED ACCESS SPACING

The need to efficiently move high volumes of traffic, especially during peak periods, must be a principal consideration in the planning and design of major urban arterial street systems. The first consideration in the control of access related to urban arterial intersections must then be the selection of an appropriate long and uniform interval for the spacing of signalized intersections. It is essential that high-volume intersections (including signalized private access) conform to the selected spacing or to multiples of this spacing.

The relationship between the speed of progression, cycle length, and signalized intersection spacing is shown in Figure 1, and similar information is presented in Table 1. The shaded areas in Figure 1 indicate the combinations of cycle lengths and desirable speeds for peak and off-peak conditions. Long cycle lengths are commonly used during peak traffic periods to minimize the time lost due to signal phase changes. Also, maximum flow rates are achieved at speeds of 30 to 35 mph (approximately 45 to 55 km/hr). Inspection of Figure 1 and Table 1 shows that a cycle length of 120 sec and a speed of 30 mph (48 km/hr) require a spacing of ½ mi (0.805 km) to achieve optimum progression efficiency.

Given a ½-mi spacing, for example, use of a 60-sec cycle would result in a speed of progression of about 58 mph (95 km/hr) as shown in Figure 2. Undoubtedly, the desired off-peak speed would be less. Use of a slower speed (50 mph or about 80 km/hr) and a 60-sec cycle would result in poor progression efficiency, and platoon movement on the arterial would be interrupted. As shown in Figure 2, a 70-sec cycle should be used for an off-peak speed of 50 mph (80 km/hr). This would maintain efficient progression of the desired speed on the arterial and will increase the delay for left-turning and crossing traffic on the minor street approaches to the arterial. The necessity (or at least the desirability) of providing efficient traffic flow in both the peak and off-peak periods therefore suggests the following for addressing signalized access to major arterial streets.

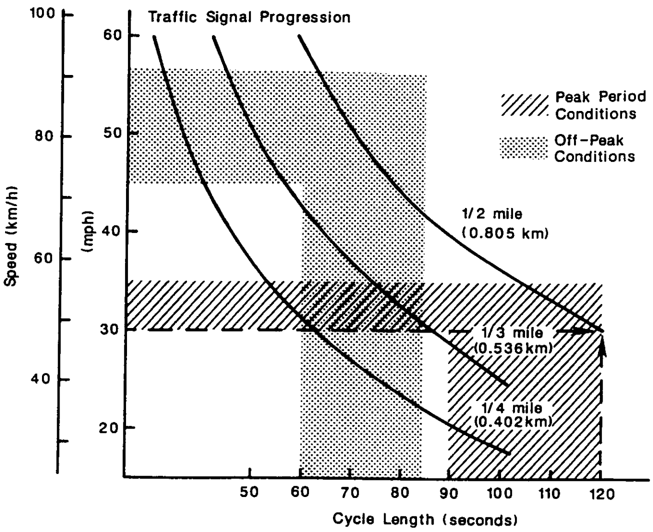
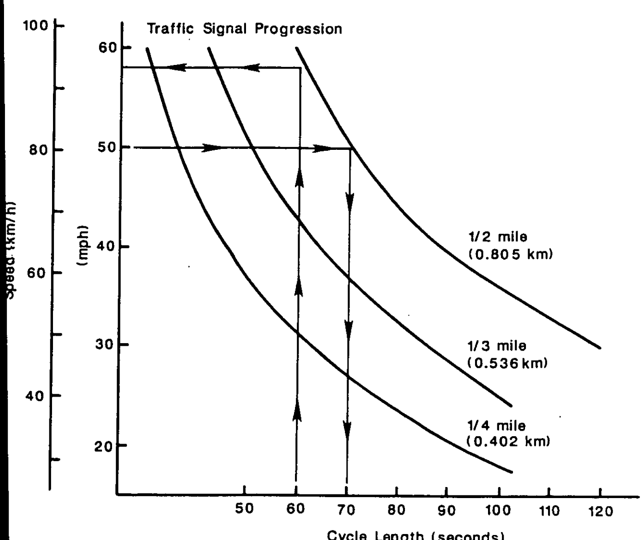


FIGURE 1 Relationships between progression speed cycle length and signal spacing (*2*, Figure 4-13).

TABLE 1 Optimum Signalized Intersection Spacings Needed To Achieve Efficient Traffic Progression at Various Speeds and Cycle Lengths (*3*, p. 29)

Cycle Length (sec)	Speed (mph)						
	25	30	35	40	45	50	55
60	1,100	1,320	1,540	1,760	1,980	2,200	2,430
70	1,280	1,540	1,800	2,050	2,310	2,500	2,820
80	1,470	1,760	2,050	2,350	2,640	2,930	3,220
90	1,630	1,980	2,310	2,640	2,970	3,300	3,630
120	2,200	2,640	3,080	3,520	3,960	4,400	4,840
150*	2,750	3,300	3,850	4,400	4,950	5,500	6,050

* Represents maximum cycle length for actuated signal if all phases are fully used.
One-half mile (2,640 feet) spacing applies where optimum spacing exceeds one-half mile.



IGURE 2 Selection of peak-period cycle length once a niform signalized intersection spacing has been established *¼*, Chapter 2).

• Adopt a signalized interval that will maximize efficiency at 30 mph (45 km/hr) with the anticipated future peak-period cycle lengths.

• Use the comprehensive urban plan and other development management tools to implement the desired signalized intersection spacing.

FUNCTIONAL HIERARCHY

The AASHTO Green Book recognizes that a functionally designed circulation system provides for the following distinct travel states: termination, access, collection, distribution, primary movement, and transition (*1*, pp. 1–3; *5*, pp. 1–3). It also indicates that, according to functional design concepts, each trip stage should be handled by a separate facility and that "the failure to recognize and accommodate by suitable design each of the different stages of the movement hierarchy is a prominent cause of highway obsolescence" (*1*, p. 2; *5*, p. 3). The AASHTO policy also indicates that the same principles of design should be applied to access serving development adjacent to arterials and collector streets.

Thus functional design principles recognize the following:

• All trips begin at the origin and end with termination at the destination end. However, all trips do not necessarily involve all the trip stages (i.e., primary movement).

• The design of each facility should be based on the degree to which it is to serve the functions of movement versus access.

As shown in Figure 3, the three principal functional classes are divided into various general design classes. These classes can be further subdivided into typical design groups (i.e., major arterials with at-grade intersections can be subdivided into typical cross sections such as six-lane divided and four-lane divided, which can be further subdivided by more detailed design elements such as median width/design, etc.).

The fact that driveways create intersections with the public street system is recognized by AASHTO (*1*, p. 888; *5*, p. 841). Though not clearly stated, the recognition of transition as a

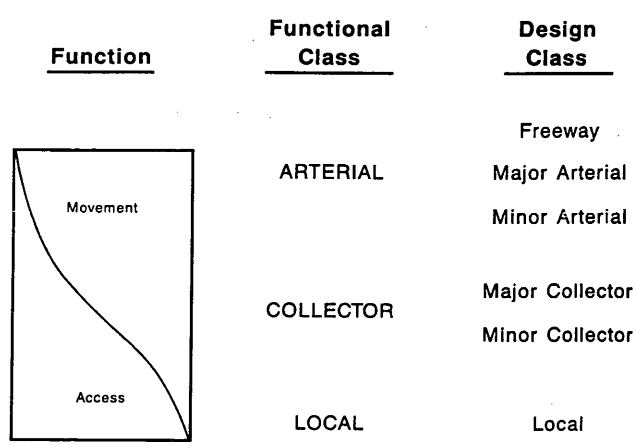


FIGURE 3 Hierarchy of facilities in a functionally designed street system.

separate trip stage combined with the concept of functional classification (the degree to which a given facility is to accommodate movement versus access) implies that there is a hierarchy in the provision of transitions between facilities intended to accommodate different degrees of access versus movement and that there is (or should be) a hierarchy in the design of intersections.

As shown in Figure 4, transition from or to a facility of lower functional design should be limited to a facility of the next higher design, that is, a local street should intersect with a minor collector or in some cases a major collector in carefully designed residential subdivisions. Major collectors should only intersect with an arterial, and only major at-grade arterials should interconnect with freeway-type facilities. Private access drives (the termination facilities) serving individual dwellings should intersect with local streets and minor residential collectors only. This concept of design is well recognized in the design of modern limited-access subdivisions, and municipal ordinances commonly prohibit private residential driveways and local streets from intersecting with arterials. However, this principle is not as well recognized in the provision of access between major streets and adjacent nonresidential development.

Though implied by functional design principles, there is very little literature addressing the hierarchy of intersections of public streets and their private access or on-site circulation equivalents. A suggested generalized hierarchy is given in Table 2. Two or more typical designs might be developed for each depending on the conditions commonly encountered by an agency. For example, the intersection of a major arterial and a major collector where the collector serves a residential development will experience different traffic conditions than an intersection of the same major arterial and a major collector servicing retail, office, or industrial development.

TABLE 2 Generalized Hierarchy of Intersections

High ↑	Freeway Main Lanes - Ramp
	Major Arterial - Freeway Ramp
	Major Arterial -
	Major Arterial - Minor Arterial
	Major Arterial - Major Collector
	Minor Arterial - Major Collector
	Major Collector - Major Collector
	Minor Collector - Local
↓ Low	Local - Residential Drive/Parking Place

Consequently, there should be at least two different typical designs for major arterial–major collector intersections. Moreover, there is an increasing awareness that some major arterials are of regional significance, whereas other major arterials are of significance to a portion of a large urban region. Thus there should be least five typical major arterial–major arterial intersections. In order of decreasing hierarchical importance these are (*a*) six-lane regional to six-lane regional, (*b*) six-lane subregional to six-lane subregional, (*c*) six-lane regional to four-lane subregional, (*d*) six-lane subregional to four-lane subregional, and (*e*) four-lane subregional to four-lane subregional. This also means that the hierarchy of intersections is much more complex than the generalized hierarchy presented in Table 2.

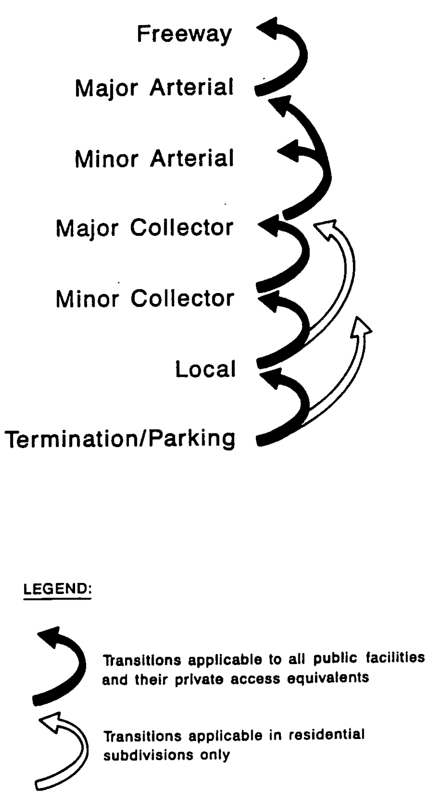


FIGURE 4 Functional hierarchy of intersections.

FUNCTIONAL BOUNDARY

AASHTO specifically states that "a driveway should not be located within the functional boundary of an intersection" (*1*, p. 888; *5*, p. 841). Whereas AASHTO does not present guidelines as to the size of the functional area of an intersection, logic indicates that it must be much larger than the physical area (see Figure 5). Logic also suggests that the functional area should be composed of the distance traveled during the PIEV time plus the distance required to move laterally and come to a stop plus any required storage length (see Figure 6). The minimum maneuver distance assumes that the driver is in the proper lane and only needs to move laterally into a right-turn bay (as shown) or a left-turn bay. Parameters that must be evaluated in the determination of maneuver distance include the following:

- d_1: The perception-reaction time required by the driver depends on driver characteristics. It may be assumed that for motorists frequently using the street this is a little more than the time required for preparing to brake. Strangers may not be in the proper lane to execute the maneuver and could require several seconds to react.
- d_2: Braking while moving laterally is a more complex maneuver than braking alone, perhaps one-half the deceleration rate used in d_3. Lateral movement under urban condi

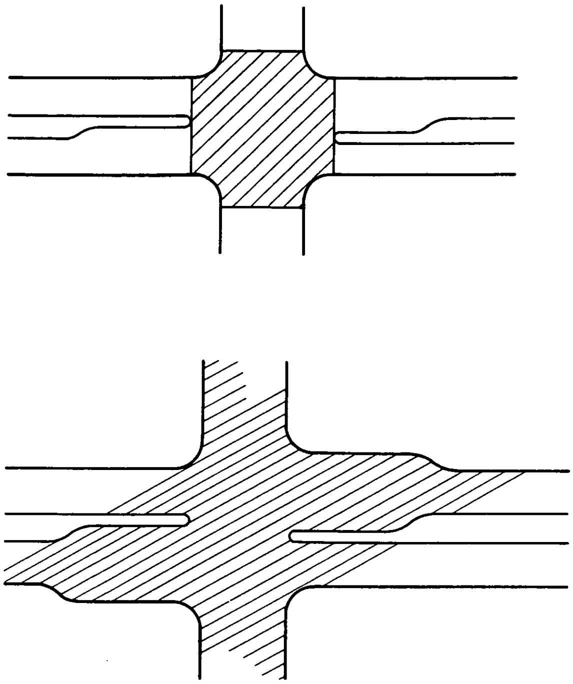


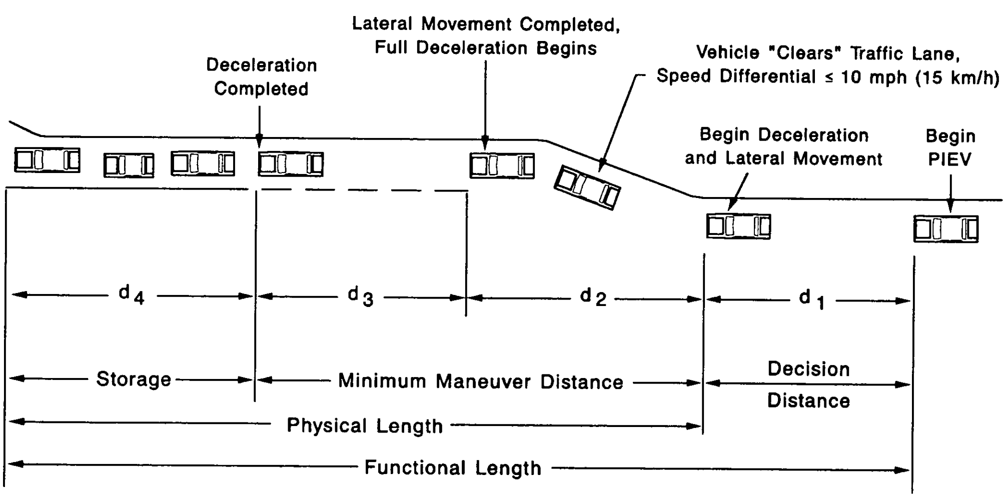
FIGURE 5 Intersection area: *top*, defined by physical area; *bottom*, defined by functional area (*2*, Figure 4-16).

tions is commonly assumed to be 4 ft/sec (1.2 m/sec). At low deceleration rates [less than about 7 ft/sec² (2 m/sec²)], the driver will have shifted laterally sufficiently far that a following vehicle can pass without encroaching on the adjacent lane before a speed differential of 10 mph (16 km/hr) occurs. At higher deceleration rates [more than about 7 ft/sec² (2 m/sec²)], the speed differential will exceed 10 mph (16 km/hr) before the turning vehicle clears the through-traffic lane.

- d_3: Deceleration after moving laterally into the turn bay should be a rate that will be used by most drivers. Studies (*6,7*) have found that most drivers (85 percent) will use a deceleration rate of 6 ft/sec² (1.8 m/sec²) or more; only about 50 percent can be expected to accept a rate of 9 ft/sec² (2.7 m/sec²) or greater.
- d_4: Queue storage should be of sufficient length to accommodate all turning vehicles most of the time.

Table 3 presents maneuver distances and total distances (maneuver plus PIEV distance, but excluding storage) for the conditions indicated in the footnotes. These distances represent the minimum functional length of an approach to an intersection since they exclude storage.

As indicated in Figure 6, the physical length of a turn bay excludes the distance traveled during the perception-reaction time. The difference in the maneuver distance required for peak and off-peak speeds will provide some storage. For example, using the desirable values, an off-peak speed of 55 mph (90 km/hr) and a peak speed of 30 mph (50 km/hr), a storage of about 450 ft (135 m) is built in. At 25 ft (7.7 m) per vehicle, measured front bumper to front bumper, a queue of about 18 cars can be accommodated. This will generally be sufficient to provide the necessary right-turn storage on arterial approaches at the intersections with minor arterials and major collectors serving residential areas. At high-volume intersections, the functional limits are commonly controlled by peak-period conditions since peak-period maneuver distance plus storage is longer than the maneuver distance plus storage needed in the off-peak. Consequently, the functional boundaries will be greater than the distances given in Table 3 or those developed from similar analyses.



d_1 = distance traveled during perception-reaction time

d_2 = distance traveled while driver decelerates and maneuvers laterally

d_3 = distance traveled during full deceleration and coming to a stop or to a speed at which the turn can be comfortably executed

d_4 = storage length

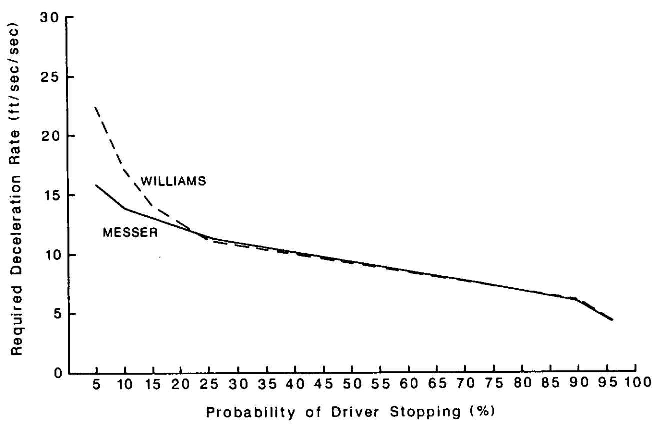
FIGURE 6 Elements of the functional area of an intersection.

TABLE 3 Calculated Upstream Maneuver Distances

	Minimum Maneuver Distance [1] in Feet (Metres)			
	Desirable Conditions [2]		Limiting Conditions [3]	
Speed mph (km/h) [4]	Deceleration[5]	Total[6]	Deceleration	Total[6]
30 (50)	225 (70)	325 (100)	170 (50)	215 (65)
35 (55)	295 (90)	425 (130)	220 (65)	270 (80)
40 (65)	375 (115)	525 (160)	275 (85)	335 (700)
45 (70)	465 (140)	630 (190)	340 (105)	405 (125)
50 (80)	565 (170)	750 (230)	410 (125)	480 (145)
55 (90)	675 (205)	875 (265)	485 (150)	565 (170)
60 (95)	785 (240)	1005 (305)	565 (170)	655 (200)

Source: Calculations by author.

(1) All values rounded to nearest 5 feet (5 metres).
(2) 2.5 second perception-reaction time; 3.5 fps² (1.1 mps²) average deceleration while moving laterally into turn bay and an average 6 fps² (1.8 mps²) deceleration thereafter 10 mph (15 km/h) speed differential.
(3) 1.0 second perception-reaction time; 4.5 fps² (1.4 mps²) deceleration while moving laterally into turn bay and an average 9.0 fps² (2.7 mps²) deceleration thereafter; 10 mph (16 km/h) speed differential
(4) Nearest 5 km/h for design
(5) Distance to decelerate from speed to a stop while maneuvering laterally into a left or right-turn bay.
(6) Deceleration distance plus distance traveled in perception-reaction time.



OBSERVED DECELERATION RATES

The inability to forecast turn volumes with any degree of reliability presents an additional issue in access control relative to urban arterial intersection design. This problem can be addressed by providing flexibility in the design and adoption of appropriate state access regulations and local ordinances. Design can provide flexibility by including dual left turns on all approaches of major arterial intersections. The possibility that it may be necessary to lengthen a turn bay (especially a left-turn bay) should also be considered in the event that demand turns out to exceed the projected turn volume. A major issue is that most states and most local governments have not enacted appropriate legislation or ordinances and standards necessary for implementation of access management of high-speed, high-volume arterials.

The placement of driveways within the functional boundary of an intersection may be expected to have an effect on intersection capacity as well as to increase accident rates. The research by McCoy and Heimann (*8*) suggests that the corner clearance required to diminish the effect on capacity is less than the maneuver distance. Additional research on the effect of corner clearance on intersection capacity over a range of speeds and design conditions is needed.

LIMITATION OF SPEED DIFFERENTIAL

It has long been recognized that a high speed differential between vehicles in the traffic stream is a major factor in traffic accidents (*9*). Research has shown that the forward speed of a vehicle making a turn at an intersection was very slow for all reasonable combinations of curb return radii and throat widths (*2*). As shown in Figure 7, the forward speed of the vehicle is 9 to 14 mph (14 to 22 km/hr). The speed vector parallel to the through traffic lane is only about 1.5 to 2.5 mph (2.4 to 4.0 km/hr). Thus the speed differential between a turning vehicle and through traffic is essentially the speed of traffic on the through lanes. A turn bay is therefore essential if the speed differential between turning vehicles and through traffic is to be limited to some reasonable magnitude.

The minimum physical length of a turn bay, exclusive of storage, for different speeds is given by the deceleration distances in Table 3. Distances similar to those for deceleration (the limiting conditions in Table 3) are included in the New Mexico regulations (*10*, Table 6), for example.

Dual left turn bays, or the provision for future dual left turn bays, should be provided at all major arterial–to–major arterial intersections. This will require a median of at least 30 ft (9 m). As in the case shown in Figure 8, the dual left-turn bay should be striped as a single left-turn bay until volumes warrant dual left operation.

The provision of a dual-left on the arterial street at arterial-collector intersections can be used to facilitate U-turns as shown in Figure 9. This practice provides access to adjacent properties without the provision for a median break.

The taper length in rural design is commonly a ratio that is a function of the design speed. It is suggested herein that the taper for urban arterial design should be a standard length. It is also suggested that the taper for a single left-turn and for a right-turn bay should be 120 ft (35 m) or less. This is only slightly shorter than the distance used by a driver moving laterally the width of one traffic lane at peak-period speed [(1.47) (30 mph) × (12 ft/4 ft/sec) = 132 ft]. This follows from the fact that urban arterials have two design conditions, namely peak and off-peak. With dual left-turn bays, a taper of 180 or 150 ft (55 or 45 m) is suggested. These taper lengths are slightly more abrupt than the natural trajectory used by drivers at peak-period speeds and thus help communicate that the increased cross section is an auxiliary lane (turn bay) rather than an additional lane.

COMPARABILITY OF PUBLIC AND PRIVATE ACCESS

AASHTO makes the following significant statement: "Driveway terminals are in effect at-grade intersections and should be designed consistent with the intended use" (*5*, p. 841). To implement design based on this principle, it is necessary to establish an equivalence between public streets and driveways. Such analogies are presented in Table 4.

UNSIGNALIZED INTERSECTIONS

Medial and marginal access to urban arterial streets may be provided as long as it does not jeopardize the primary (move-

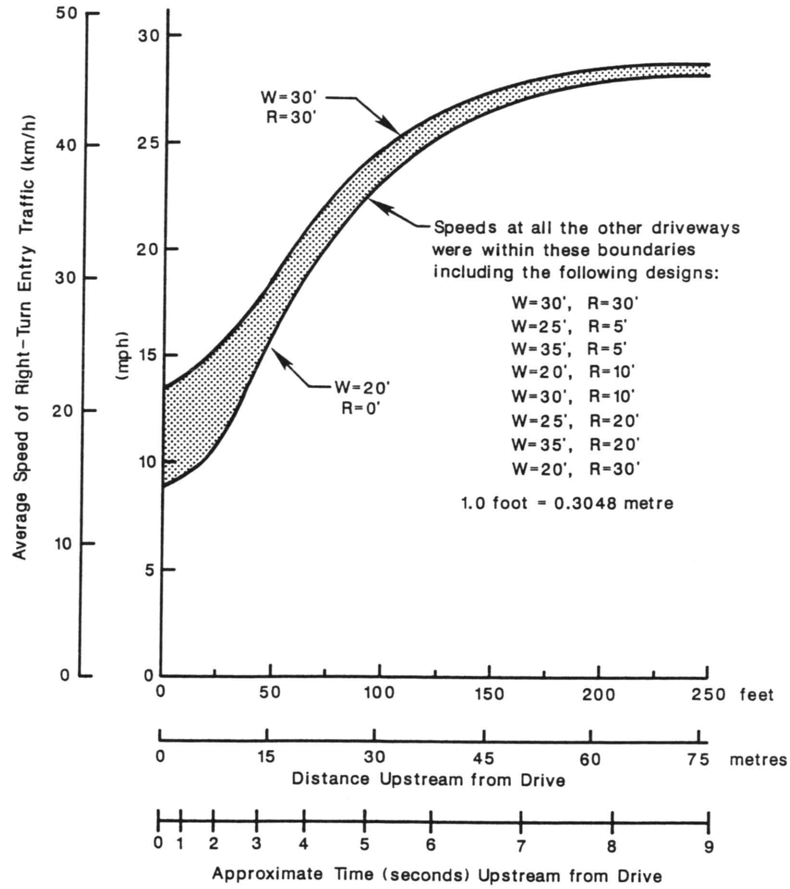


FIGURE 7 Vehicle speed as a function of driveway geometry (*2*, Figure 5-29).

FIGURE 8 When this roadway (Powers Boulevard, Colorado Springs, Colorado) was reconstructed as a multilane major arterial, long dual left-turn lanes (970 ft, including taper) were provided. The bay is currently striped to operate as a single left-turn lane until volumes require a dual left. Such a length will accommodate maneuvers at a 55-mph off-peak speed and ensure availability of maneuver plus storage space when the area fully develops.

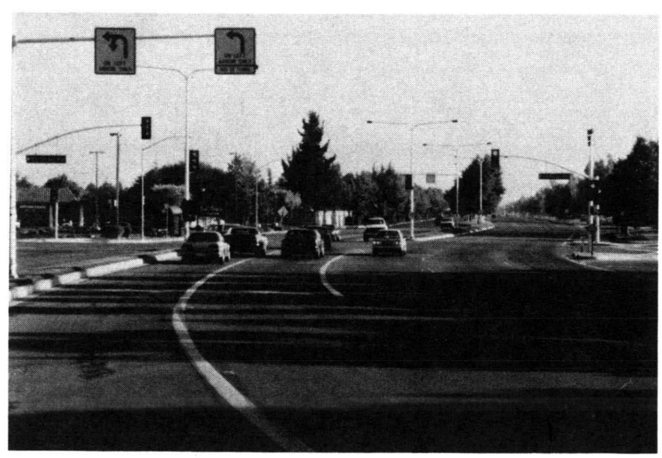


FIGURE 9 Allowing U-turns at low signalized intersections where the cross street has relatively low approach volumes (arterial-collector intersections) facilitates access to properties fronting on major street without the provision of median breaks. A 30-ft median is desirable for such designs. This provides for two turn lanes and a median nose of at least 6 ft.

TABLE 4 Comparability Between Public Streets and Circulation Elements of Private Development (2, p. 85)

Public Street	Private
Local	Aisle in parking lot; Driveway of convenience grocery
Minor Collector	Perimeter road in shopping center; Access drive of small commercial center (> 200,000 ft²)
Major Arterial	Access drive of a large retail development (> 1,000,000 ft²); Access drive of very large commercial or mixed use development (> 2,000,000 ft²)

ment) function of the arterial. Identification of the frontage where access can be provided is essentially a problem of determining the functional boundary of the adjacent intersections. It is suggested that the problem be addressed in two steps. First, establish the frontage along the arterial where access can be provided without interfering with adjacent intersections, especially signalized intersections. Second, identify the specific location and design of the access drive in conjunction with the design of adjacent property.

Figure 10 shows the region along the property frontage at which direct access might be permitted on the basis of the AASHTO policy that a driveway should not be situated within the functional boundary of an intersection. In locating the driveway it should be recognized that a turn bay is essential to limit the speed differential between a turning vehicle and through traffic. Therefore, the frontage on which the driveway throat can be located is shorter than the distance between the functional intersection boundaries.

Consolidation of access is another practice that minimizes access to arterial streets and increases corner clearances. Where the corner property is a separate parcel, a shared access point may be provided in the subdivision process. An example of this practice is shown in Figure 11. Where the adjacent property has already been subdivided, the adjacent property owners might be encouraged to consolidate access in a similar manner.

Medial access at unsignalized intersections should be designed to permit specific left turns (i.e., left-turn ingress or left-turn egress), and crossing movements should be positively eliminated by the design of the median opening. An example of a good design is shown in Figure 12.

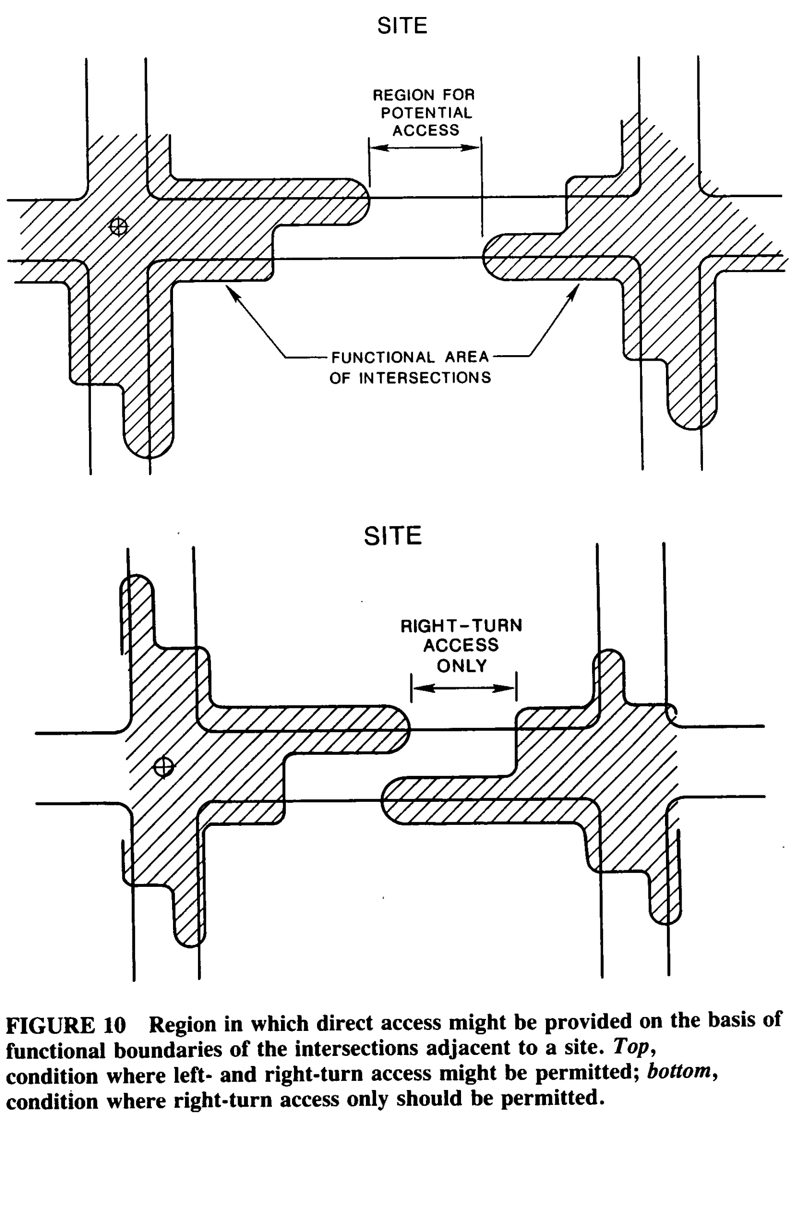
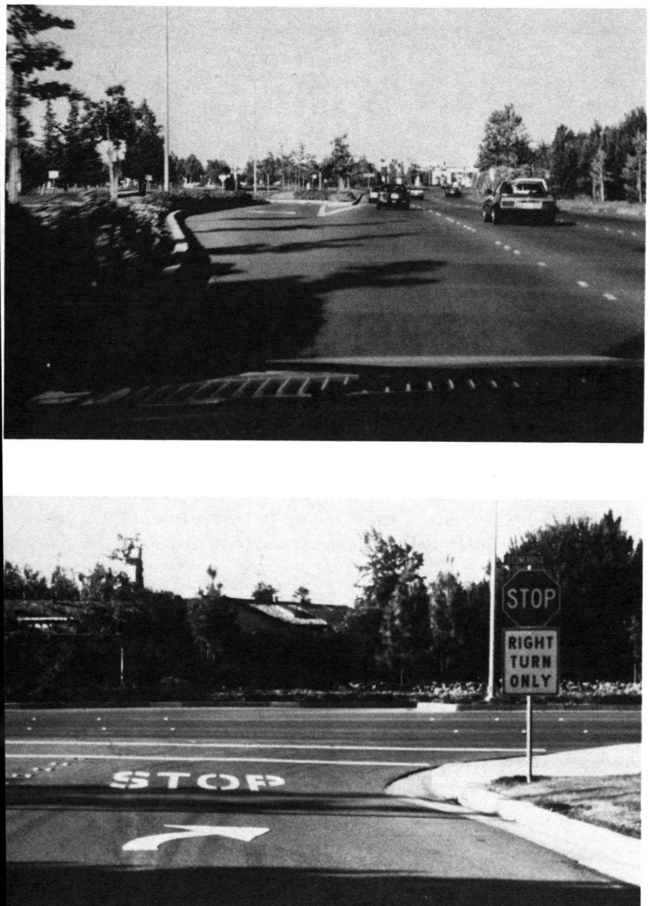


FIGURE 10 Region in which direct access might be provided on the basis of functional boundaries of the intersections adjacent to a site. *Top*, condition where left- and right-turn access might be permitted; *bottom*, condition where right-turn access only should be permitted.

FIGURE 11 Sharing of access will reduce the number of access drives and increase their spacing, or parcels with smaller frontage can be developed given a driveway spacing or corner clearance. In this example, a fast-food restaurant shares access with a 200,000-ft² shopping center. The centerline of the access drive is located on the property line. A reciprocal easement runs the length of the restaurant property. This is the only direct access to the restaurant.



IGURE 12 Examples of landscaping design to provide good elineation of a median break designed for left-turn egress only. *op*, driver's view on the approach to the left-turn bay; *bottom*, iew of the median treatment from the intersecting access.

VISIBILITY

The driver must be able to determine the location and the geometries of the intersection sufficiently far in advance so as not to be surprised either by the intersection itself or by other drivers making ingress or egress maneuvers. Greenberg (*11*) points out a serious issue in the use of the AASHTO Green Book, namely, that the sight distance criteria for minimum length of crest vertical curve is less than the intersection sight distance. Consequently, extreme care must be taken to ensure that an intersection (especially an unsignalized intersection with a public street or a private access drive) is not located beyond the crest of a vertical curve. Similarly, when the intersection itself is beyond the crest, the driver should be able to see a substantial portion of a left- or right-turn bay on the approach to a crest vertical curve.

Landscaping is essential to provide identification of the location of the median opening, the geometries of the intersection for the movement permitted, and clear definition as to which maneuvers are not permitted. Long left-turn bay tapers also need to be avoided to prevent misleading through traffic. Landscaping is also desirable to delineate the median nose where long left-turn bays are provided.

Delineation of marginal access at unsignalized intersections (public streets as well as private driveways) is also needed to inform drivers of the location and geometries. Visibility problems arise when adjacent development is allowed to pave to the back of the curb, the sidewalk is located immediately adjacent to the back of the curb, the intersection area is partly illuminated, and the entrance sign is placed downstream from the access drive.

The maneuver distances associated with high-speed urban arterials result in very long median noses. To enhance their visibility, landscaping should be provided, as shown in Figure 13.

FIGURE 13 A long median nose will result where a left-turn bay is designed to accommodate high off-peak speeds appropriate to major arterial streets or where long queues must be stored during peak periods. Landscaping helps delineate and enhance the visibility of these intersections. A width of at least 6 ft (preferably at least 8 ft), face-to-face of curb, is needed for pedestrian refuge as well as to accommodate landscaping. In this example, the planter boxes contain flowers, which represent a high-maintenance item. Selection of perennial plants will reduce the maintenance cost.

Figure 14 shows an example where development adjacent to the through traffic lanes was made in such a manner that the access drives are difficult to identify and locate. Development adjacent to a major street should not be permitted to pave the right-of-way. Also, sidewalks should not be located adjacent to the back of the curb. Rather, a landscape area should be required as part of the development adjacent to major streets. The area between the back of curb and the right-of-way line should be incorporated into the landscape scheme. The contrast between the paving and the landscaping will assist the driver in identifying the location and geometries of the access drive.

Median landscaping is also desirable to provide delineation of the median and inform drivers that left turns are prohibited by the median design, as in the example shown in Figure 15.

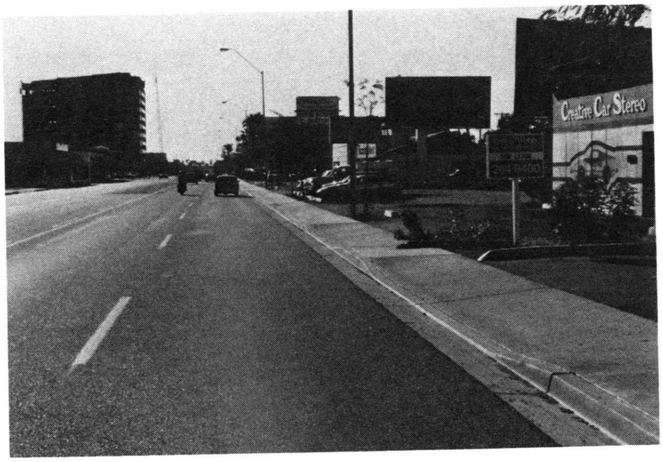


FIGURE 14 Placing sidewalks immediately adjacent to the bank of curb and allowing the owners of the adjacent properties to pave the right-of-way result in extremely poor delineation of the driveway location and geometry. A landscaped buffer in addition to the right-of-way should be required to enhance driveway identification.

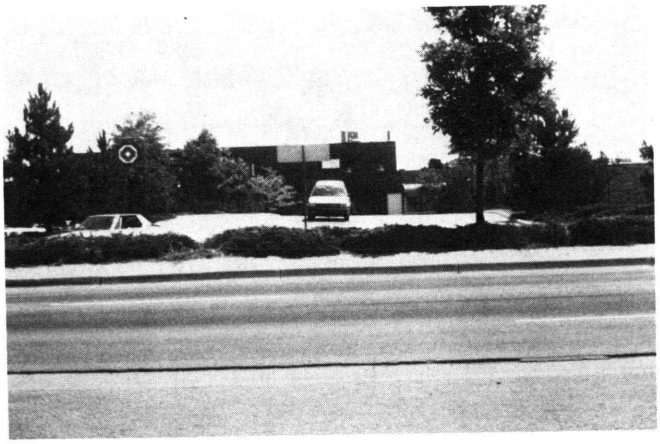


FIGURE 15 This section of US-36 in Boulder, Colorado, was reconstructed with a nontraversable, landscaped median. Movements are now restricted to right turns only. The landscaping adds aesthetics as well as function.

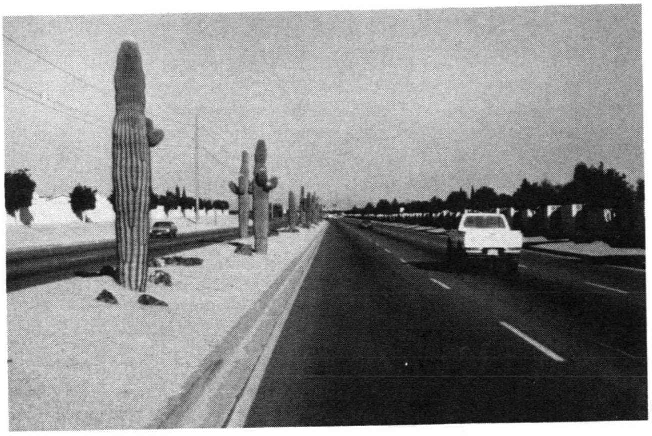


FIGURE 16 US-60/69 in Sun City, Arizona, is an example of medial landscaping using native materials resulting in low maintenance cost and providing good visibility.

FIGURE 17 Signing must be considered part of the design of intersections that provide access to development. The sign is located on the far side of a divided access drive to a regional shopping center. The problem is compounded by the intersection's location on a horizontal curve to the right. These two elements combine to lead drivers past the ingress drive. Many drivers miss the drive at night and stop in the traffic lane. Of those who stop, most either back up to enter on the ingress side or enter using the egress side of the drive.

Appropriate choice of landscaping materials helps control maintenance costs. Such an example is shown in Figure 16.

The location of signs is also an important feature of the design of intersections serving private development adjacent to major streets. Drivers approaching these intersections use the signs to help identify the location of the driveway. Special care must be taken where marginal access is located on a horizontal curve, such as the example shown in Figure 17.

REFERENCES

1. *A Policy on the Geometric Design of Highways and Streets*. American Association of State Highway and Transportation Officials, Washington, D.C., 1984.

2. V. G. Stover and F. J. Koepke. *Transportation and Land Development*. Institute of Transportation Engineers, Prentice Hall, Inc., 1988.
3. *Access and Spacing Standards for State Highways*. Urbitran Associates, Inc., Feb. 1990.
4. V. G. Stover et al. *City Street Design*. Short course notes. Texas Transportation Institute and Texas Engineering Extension Service, Dec. 1990.
5. *A Policy on the Geometric Design of Highways and Streets*. American Association of State Highway and Transportation Officials, Washington, D.C., 1990.
6. M. S. Chang, C. J. Messer, and J. Santigo. Timing Traffic Signal Change Intervals Based on Driver Behavior. In *Transportation Research Record 1027*, TRB, National Research Council, Washington, D.C., 1985.
7. W. L. Williams. Driveway Behavior During the Yellow Time Interval. In *Transportation Research Record 664*, TRB, National Research Council, Washington, D.C., 1977.
8. P. T. McCoy and J. E. Heimann. Effect of Driveway Traffic on Saturation Flow Rates of Signalized Intersections. *ITE Journal*, Feb. 1990.
9. D. Solomon. Accidents on Main Rural Roads Related to Speed, Driver and Vehicle. *Public Roads*, July 1964.
10. *Regulations for Driveways and Medial Openings on Non-Access Controlled Highways*. New Mexico State Highway and Transportation Department, June 9, 1989.
11. F. M. Greenberg. Design of Crest Vertical Curves: Proceed With Caution! *Public Works*, April 1986, pp. 42–43.

Publication of this paper sponsored by Committee on Geometric Design.