Intersection Design

6.1 Introduction

An intersection is the area where two or more streets join or cross at-grade. The intersection includes the areas needed for all modes of travel: pedestrian, bicycle, motor vehicle, and transit. Thus, the intersection includes not only the pavement area, but typically the adjacent sidewalks and pedestrian curb cut ramps. The intersection is defined as encompassing all alterations (for example, turning lanes) to the otherwise typical cross-sections of the intersecting streets. Intersections are a key feature of street design in four respects:

- **Focus of activity -** The land near intersections often contains a concentration of travel destinations.
- **Conflicting movements -** Pedestrian crossings and motor vehicle and bicycle turning and crossing movements are typically concentrated at intersections.
- **Traffic control -** At intersections, movement of users is assigned by traffic control devices such as yield signs, stop signs, and traffic signals. Traffic control often results in delay to users traveling along the intersecting roadways, but helps to organize traffic and decrease the potential for conflict.
- **Capacity -** In many cases, traffic control at intersections limits the capacity of the intersecting roadways, defined as the number of users that can be accommodated within a given time period.

This chapter describes the considerations and design parameters for intersections. The chapter begins by outlining definitions and key elements, and then describes the characteristics of intersection users, intersection types and configurations, capacity and quality of service considerations, geometric design elements, and other considerations.

6.3.3 Motor Vehicles

The following important characteristics of motor vehicles are considered in intersection design:

- **Design Vehicle -** The largest type of motor vehicle that is normally expected to be accommodated through the intersection.
- **Design Speed -** The motor vehicle speed selected on adjoining segments of roadway.
- **Motor Vehicle Capacity -** The number of motor vehicles that can be moved through an intersection under normal conditions.
- **Traffic Control -** Much like other users, motor vehicles are influenced by the type and timing of traffic control installed at an intersection, and number of other users. At roundabouts, STOP controlled, YIELD controlled, and uncontrolled intersections, motor vehicle capacity and delay are influenced by conflicting traffic streams. At signalized intersections, the time provided for each movement, conflicting turning movements, and the volume and mix of other users are key influences on both motor vehicle capacity and delay.

6.3.3.1 Design Vehicle

The design motor vehicle is the largest type of vehicle typically expected to be accommodated on the street. At intersections, the most important attribute of design vehicles is their turning radius, which in turn influences the pavement corner radius and therefore the size of the intersection. Lane width, another feature related to the design vehicle, has some impact on intersection design, but less than turning radius. The design vehicle may also affect the choice of traffic control device and the need for auxiliary lanes.

The design vehicle for intersections is the larger of the design vehicles selected for the intersecting streets. For example, at the intersection of a minor arterial and a local street, the appropriate design vehicle for the intersection is that required by the minor arterial (i.e., "larger" street). Exhibit 6-2, *Typical Design Vehicles at Intersections*, provides general guidance for selecting design vehicles appropriate for intersection design under conditions of normal traffic composition. At locations where collectors intersect with arterials experiencing high truck volumes, the appropriate truck design vehicle should be selected. Sample turning templates for these motor vehicles are provided in Exhibit 6-3.

Exhibit 6-2
Typical Design Motor Vehicles at Intersections

Functional Class of Major Road	Design Motor Vehicle (AASHTO Category) Typical for Intersection
Freeway	(No Intersections)
Major Arterial	Tractor-trailer Truck (WB-65)
Minor Arterial	Tractor-trailer Truck (WB-50)
Major Collector	Single-unit Truck
Minor Collector	Passenger Car (P)
Local Roads and Street	Passenger Car (P)

Notes: Design vehicles from AASHTO A Policy on Geometric Design of Highways and Streets, 2004
Passenger Car (P) applies to Light Trucks and SUV's
SU category can also be used for school and transit buses

6.3.4 Transit

The design vehicle appropriate for most types of transit service is the "City-Bus" as defined by AASHTO. This vehicle is 40 feet long, 8 feet wide, and has outer and inner turning wheel paths of 42.0 feet and 24.5 feet, respectively. The "mid-size" bus, typically accommodating 22 to 28 passengers, is also used in scheduled transit service. The turning path for the mid-size bus can be accommodated within the single-unit (SU) truck turning path diagram. Tracked transit vehicles, such as trolleys, have turning radii as specified by their manufacturer, and are not accounted for in AASHTO templates. Their interactions with other traffic elements must be taken into account where applicable.

Transit stops are often located at intersections either as a near-side stop on the approach to the intersection or as a far-side stop on the departure leg of the intersection. Location near intersections is particularly advantageous where transit routes cross, minimizing the walking distance needed for passengers transferring between buses.

A bus stop, whether near-side or far-side, requires 50 to 70 feet of curb space unencumbered by parking. On streets without parking lanes or bus bays, buses must stop in a moving traffic lane to service passengers. Passengers typically require 4 to 6 seconds per person to board a bus, and 3 to 5 seconds to disembark. The total amount of time a transit vehicle will block traffic movements can then be estimated using the number of boardings and alightings expected at a stop.

6.7.2 Pavement Corner Radius

The pavement corner radius—the curve connecting the edges of pavement of the intersecting streets—is defined by either the curb or, where there is no curb, by the edge of pavement. The pavement corner radius is a key factor in the multimodal performance of the intersection. The pavement corner radius affects the pedestrian crossing distance, the speed and travel path of turning vehicles, and the appearance of the intersection.

Excessively large pavement corner radii result in significant drawbacks in the operation of the street since pedestrian crossing distance increases with pavement corner radius. Further, the speed of turning motor vehicles making right turns is higher at corners with larger pavement corner radii. The compounded impact of these two measures—longer exposure of pedestrians to higher-speed turning vehicles—yields a significant deterioration in safety and quality of service to both pedestrians and bicyclists.

The underlying design control in establishing pavement corner radii is the need to have the design vehicle turn within the permitted degrees of encroachment into adjacent or opposing lanes. Exhibit 6-15 illustrates degrees of encroachment often considered acceptable based on the intersecting roadway types. These degrees of encroachment vary significantly according to roadway type, and balance the operational impacts to turning vehicles against the safety of all other users of the street. Although the Exhibit provides a starting point for planning and design, the designer must confirm the acceptable degree of encroachment during the project development process. The designer should use also use vehicle turning templates presented earlier in this chapter and in AASHTO's *A Policy on the Geometric Design of Highways and Streets* to confirm appropriate pavement corner designs.

At the great majority of all intersections, whether curbed or otherwise, the pavement corner design is dictated by the right-turn movement. Left turns are seldom a critical factor in corner design, except at intersections of one-way streets, in which case their corner design is similar to that for right turns at intersections of two-way streets. The method for pavement corner design can vary as illustrated in Exhibit 6-16 and described below.

- **Simple curb radius**: At the vast majority of settings, a simple radius (curb or pavement edge) is the preferred design for the pavement corner. The simple radius controls motor vehicle speeds, usually minimizes crosswalk distance, generally matches the existing nearby intersection designs and is easily designed and constructed.
- **Compound curves or taper/curve combinations**: Where encroachment by larger motor vehicles must be avoided, where turning speeds higher than minimum are desirable, or where angle of turn is greater than 90 degrees, compound curves can define a curb/pavement edge closely fitted to the outer (rear-wheel) vehicle track. Combinations of tapers with a single curve are a simple, and generally acceptable, approximation to compound curves.
- **Turning roadways**: A separate right-turn roadway, usually delineated by channelization islands and auxiliary lanes, may be appropriate where right-turn volumes are large, where encroachment by any motor vehicle type is unacceptable, where higher speed turns are desired, or where angle of turn is well above 90 degrees.

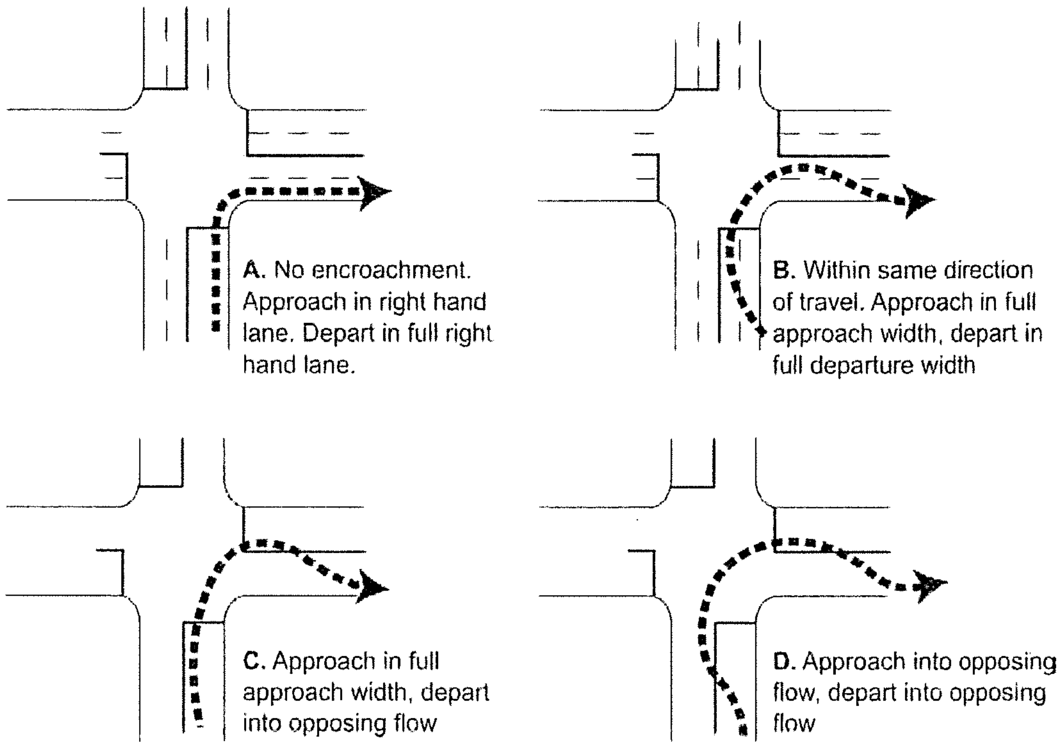
6.7.2.1 Simple Curb Radius

Pavement corner design at simple intersections is controlled by the following factors:

- The turning path of the design motor vehicle. Design motor vehicles appropriate for the various roadway types are summarized in Section 6.3.3 of this chapter.
- The extent (if any) of encroachment, into adjacent or opposing traffic lanes, permitted by the design motor vehicle determined from Exhibit 6-15.
- The "effective" pavement width on approach and departure legs is shown in Exhibit 6-17. This is the pavement width usable, by the design motor vehicle, under the permitted degree of encroachment. At a minimum, effective pavement width is always the right-hand lane and therefore usually at least 11-12 feet, on both the approach and departure legs. Where on-street parking is present, the parking lane (typically 7-8 feet) is added to the effective width on those legs (approach, departure or both) with on-street parking. Typically, legs with on-street parking have an effective pavement width of around 20 feet. The effective width may include encroachment into adjacent or opposite lanes of

traffic, where permitted. A maximum of 10 feet of effective width (i.e., a single lane of traffic) may be assumed for such encroachment.

Exhibit 6-15
Typical Encroachment by Design Vehicle



To (Departure Street)

From (Approach Street)	For Tractor/Trailer (WB 50)			For Single-Unit Truck (SU)			For Passenger Car (P)		
	Arterial	Collector	Local	Arterial	Collector	Local	Arterial	Collector	Local
Arterial (Art)	A	B	C	A	B	C	A	A	A
Collector (Col)	B	B	C	B	B	C	A	A	A
Local (Loc)	B	D	D	C	C	D	A	B	B

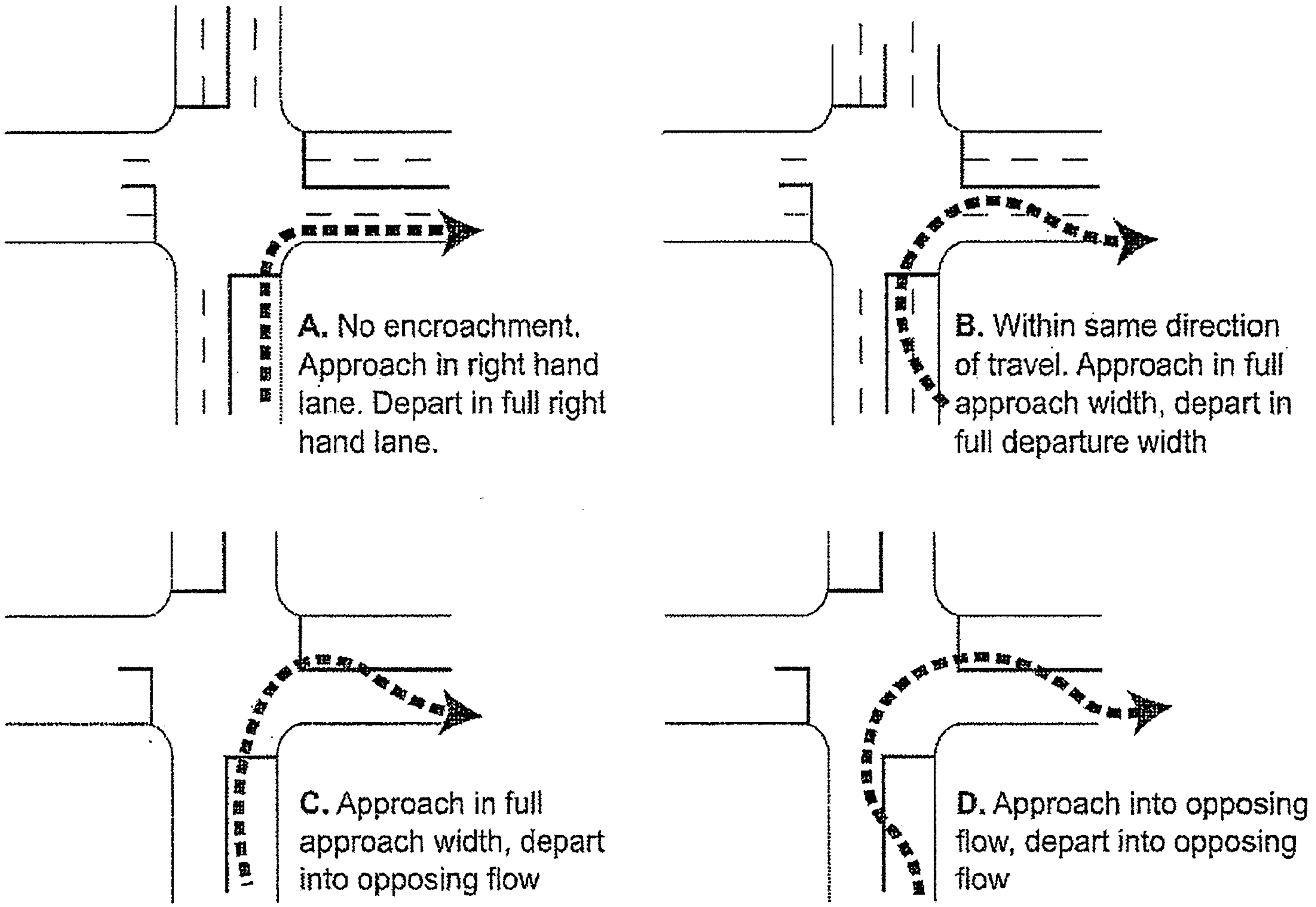
A, B, C, D defined in above diagrams.
Note: Cases C and D are generally not desirable at signal controlled intersections because traffic on stopped street has nowhere to go.
Source: Adapted from ITE Arterial Street Design Guidelines.

Exhibit 6-18 summarizes the simple curb radius needed for various design motor vehicles, reflecting the extent of encroachment and effective pavement width. General guidelines can be concluded for right-angle (90 degree) intersections:

- A 15-foot simple curb radius is appropriate for almost all right-angle (90 degree) turns on local streets. This radius permits passenger cars to turn with no encroachment and accommodates the single unit (SU) truck with acceptable degrees of encroachment. The occasional tractor/trailer truck (WB-50) can also negotiate the 15-foot corner radius within its acceptable degree of encroachment.
- Where the major street is a collector street, a 20-30 foot radius is likely to be adequate. Where parking is present, yielding an effective width of 20 feet, the typical design motor vehicle for the intersection (the SU truck) can turn with less than a 20 foot corner radius, without encroachment. On single lane approaches and departures, with no on-street parking, the SU vehicle can be accommodated with a 25-foot radius and an 8-foot encroachment (i.e., a 20 foot effective width) on the departure. At locations where no encroachment can be tolerated, a radius of 40 feet will permit the SU truck to approach and depart within a single lane.
- For arterial streets where the WB-50 truck is the design vehicle, a 35-foot radius is adequate under most circumstances of approach and departure conditions. However, with a single approach and departure lane, and with no encroachment tolerated, a radius as high as 75 feet is required. In this situation, a turning roadway with channelization island may be a preferable solution.

At skewed intersections (turn angle greater than 90 degrees), the simple radius required for the SU and WB-50 vehicle is significantly larger than that needed for 90 degree intersections. Curve/taper combinations or turning roadways may be appropriate in these situations.

Typical Encroachment by Design Vehicle



Source: Massachusetts Department of Transportation. <u>MassDOT Design Guide</u>, 2006. Chapter 6: Intersection Design, Pg. 6-40.