CHAPTER 6: INTERSECTION AND INTERCHANGES

6.1 Types of Intersection

Intersections are inevitable parts of any street system. A road or street intersection can be defined as the general area where two or more roads join or cross, including the roadway and roadside facilities for traffic movement within it (AASHTO, 2001). An intersection needs to be designed considering the efficiency, safety, speed, cost of operation, and capacity that it can offer to users. In general, there are three types of intersections:

(1) At-grade intersection

(2) Grade separated without ramps, and

(3) Interchanges

The common intersection is at-grade intersection where two or more highways join. The approaches are referred to as intersection legs. When it becomes necessary to accommodate high volume of traffic through intersections, intersections that are separated by grade are used, and these are generally referred to as interchanges. When two highways or streets cross each other at a different grade, with no connections, the arrangement is referred to as a grade separation.

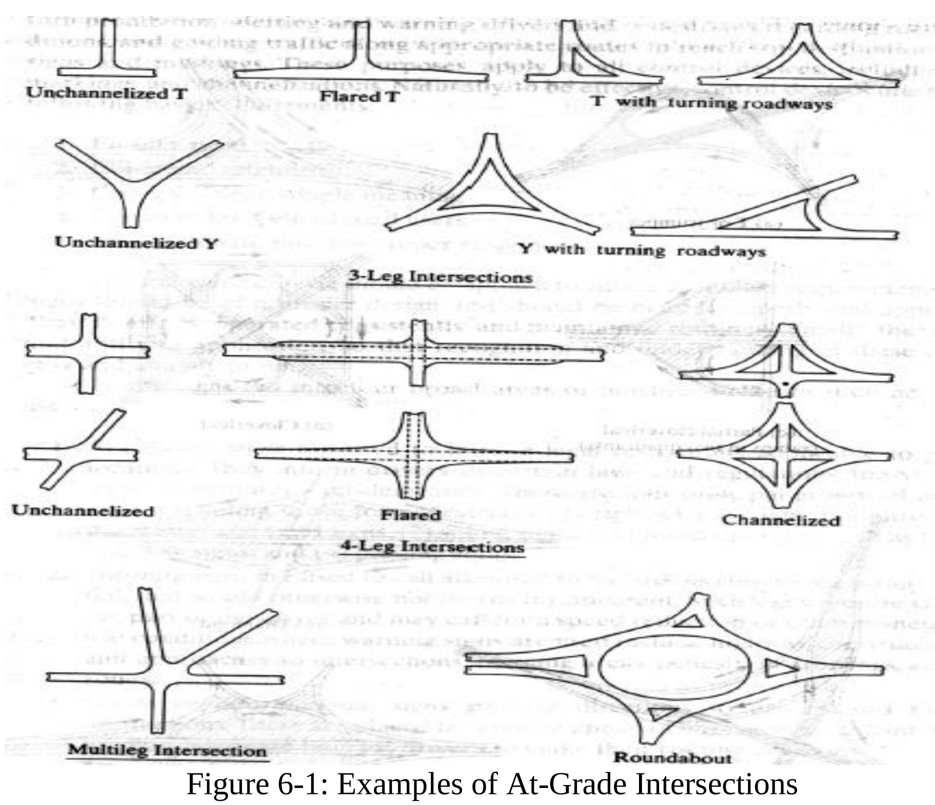


Figure 6-1: Examples of At-Grade Intersections

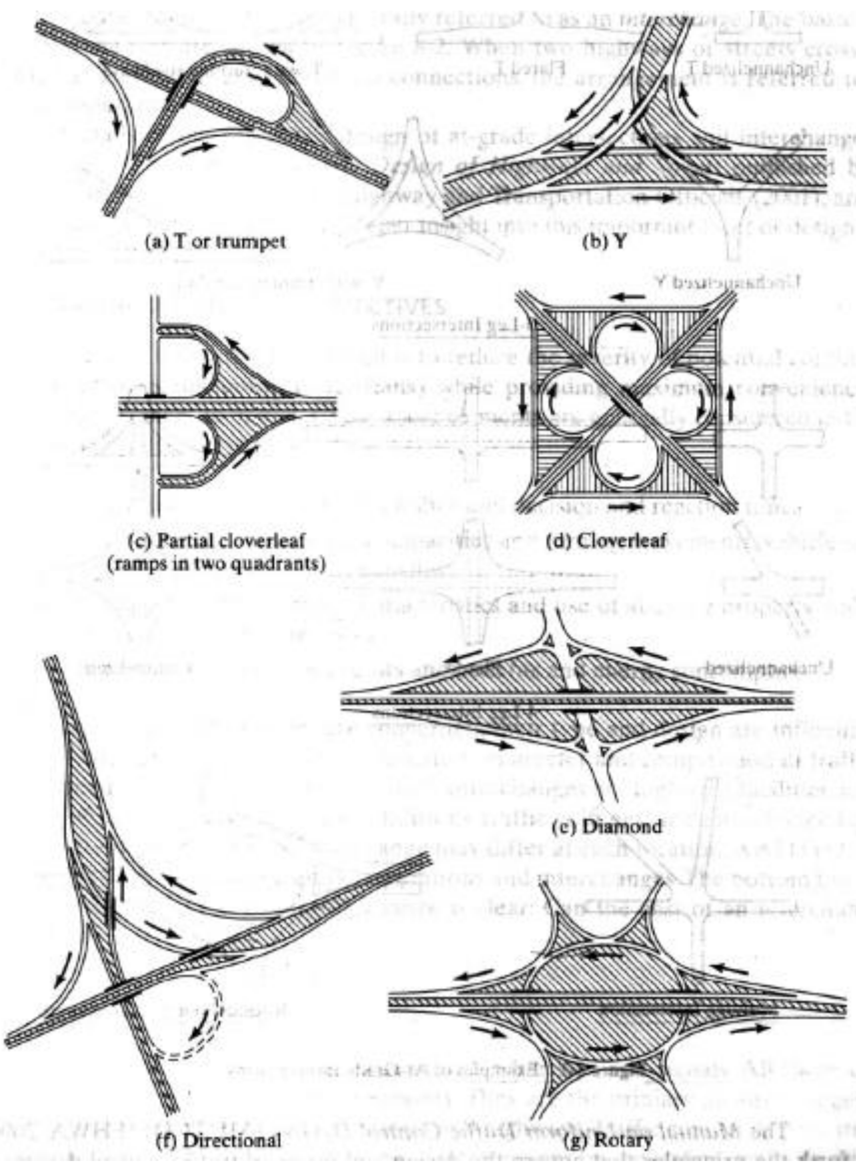


Figure 6-2: Types of Interchanges

6.2 Design Consideration and Objectives

The objective of intersection design is to reduce the severity of potential conflicts between vehicles (including pedestrians) while providing maximum convenience and ease of movement to vehicles. Four basic elements are generally considered in the design of at-grade intersections.

a. Human factor, such as driving habits and decision and reaction times
b. Traffic considerations, such as capacities and turning movements, vehicle speeds, and size and distribution of vehicles

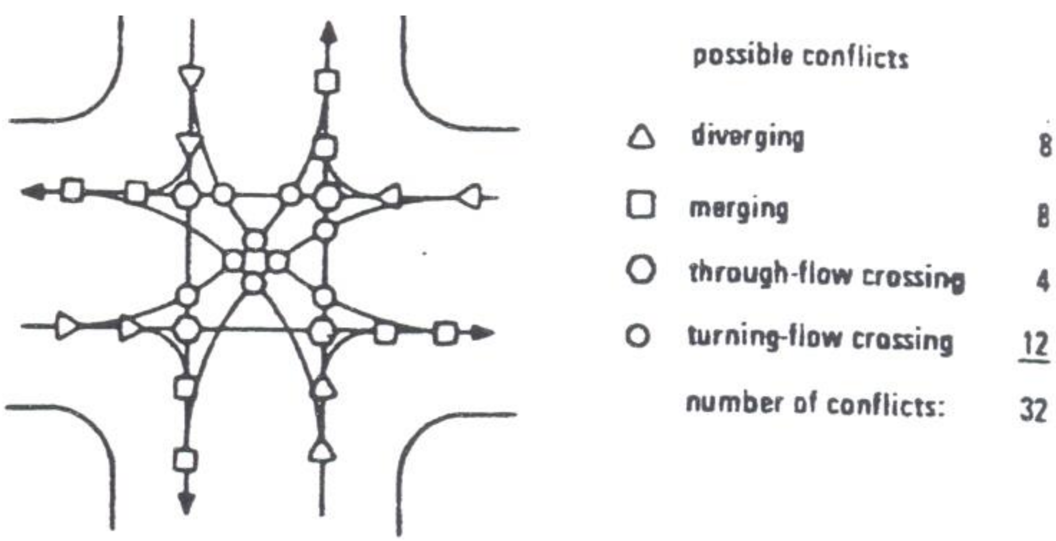
c. Physical elements, such as characteristics and use of abutting property, sight distance, and geometric features

d. Economic factors, such as costs and benefits and energy consumption

The design and type of interchanges is influenced by many factors, such as highway classification, character and composition of traffic, design speed, and degree of access control. Interchanges are high-cost facilities, and because of the wide variety of site conditions, traffic volumes, and interchange layouts, the warrants that justify an interchange may differ at each location. AASHTO (2001) provides details regarding grade separations and interchanges. The main important thing when considering interchanges is clearly the economic justification.

6.3 Conflict area at Intersection

Fig. 5.3 shows vehicle streams and the merging, diverging, and crossing maneuvers for a simple four-leg intersection, and for a more complicated staggered intersection. Such diagrams are useful because the number and type of conflicts may indicate the accident potential of an intersection. In the case of a regular two-lane, four-leg intersection there are 16 potential crossings conflict points, 8 merging and 8 diverging conflict points. The staggered T-intersection shown in the figure serves about the same function as the four-leg intersection, and consists of only six potential crossing conflict points, three diverging and three merging conflict points.



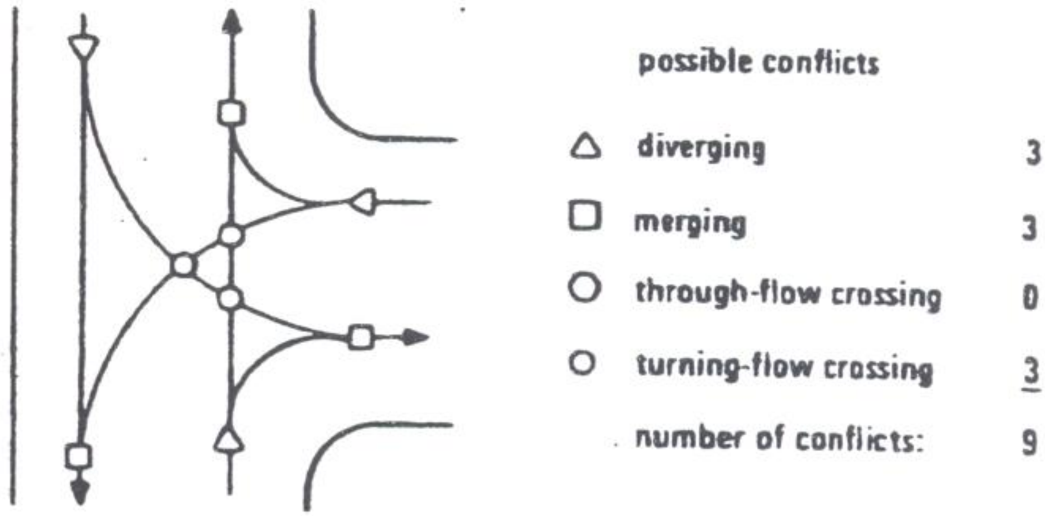


Figure 6-3 Vehicle Streams and the Merging, Diverging, and Crossing Maneuvers

6.4 Type of Intersection Control

There are at least six principal ways of controlling traffic at intersections, depending on the type of intersection and the volume of traffic in each of the vehicle streams. In an ascending order of control exercised at the intersection, these include no control, channelization, yield or stop signs, roundabouts and traffic signals. The FHWA, 2000 provides guidelines for adopting any particular type of intersection control, in the form of warrants.

6.4.1 Stop signs

Stop signs are warranted at intersections under the following conditions:

I. Intersection of less important road with a main road, where application of the normal right-of-way rule is unduly hazardous
II. Intersection of a county road, City Street, or township road with a state highway
III. Street entering a through highway or street
IV. Unsignalized intersection in a signalized area
V. Unsignalized intersection where a combination of high speed, restricted view and serious accident record indicates a need for control by the stop sign

Multiway (four way or all-way) stops can be used as a safety measure at some locations where the volume on the intersecting roads is approximately equal and following conditions exist:

I. An accident problem, as indicated by five or more reported accidents in a 12 month period, which may be corrected by a multiway stop installation

II. (a) The total vehicular volume entering the intersection from all approaches averages at least 500 vehicles per hour for any 8 hours of an average day, and (b) the combined vehicular and pedestrian volume from the minor street or highway averages at least 200 units per hour for the same 8 hours, with an average delay to minor street vehicular traffic of at least 30 seconds per vehicle during the maximum hour, but (c) when the 85th percentile approach speed of the major street traffic exceeds 40mph, the minimum vehicular volume warrant is 70% of the foregoing requirements.

III. Where traffic signals are warranted, the multiway stop control can be used as an interim measure while arrangements are being made for installation of the signal.

6.4.2 Yield Signs

Yield signs are established as follows:

i. On a minor road at the entrance to an intersection when it is necessary to assign the right-of-way to the major road, but where a stop is not necessary at all times, and where the safe approach speed on the minor road exceeds 10mph.

ii. On the entrance ramp to an expressway, where an adequate acceleration lane is provided

iii. Where there is a separate or channelized right-turn lane without an adequate acceleration lane

iv. At any intersection where a problem can be possibly corrected by a yield sign installation

v. Within an intersection with a divided highway, where a stop sign is present at the entrance to the first roadway, and further control is necessary at the entrance to the second roadway. Median width between roadways must exceed 30 ft.

6.4.3 Intersection Channelization

Channelization is the separation or regulation of conflicting traffic movements into definite paths of travel by traffic islands or pavement markings to facilitate the safe and orderly movements of both vehicles and pedestrians. Proper channelization increases capacity, improves safety, provides maximum convenience, and increases driver confidence. Channelization is frequently used along with stop or yield signs or at signalized intersections.

Some basic principles to help design channelized intersection are as follows:

i. Motorists should be provided with channel lines that are easy to follow.

ii. Sudden and sharp reverse curves should be avoided.

iii. Areas of vehicle conflict should be reduced as much as possible.

iv. Traffic streams that cross without merging and weaving should intersect at or near right angles.

v. Islands should be carefully selected and be as few as possible.

vi. Over channelization should be avoided, as it has proved to be counterproductive.

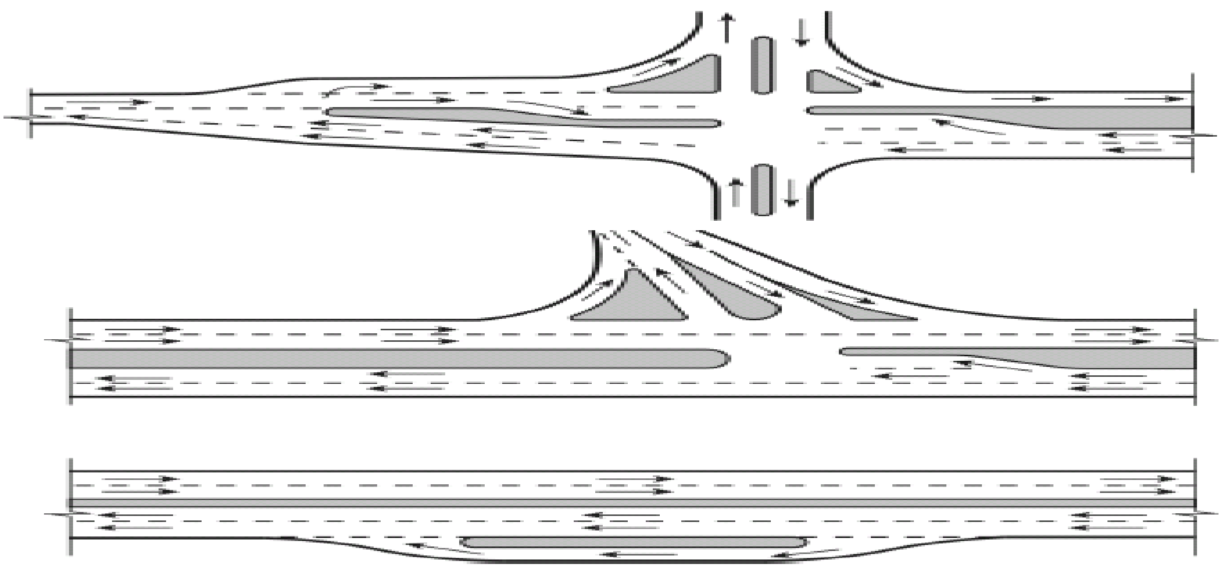


Figure 6-4: Typical Examples of Channelized Intersections (AASHTO, 2001)

Rotaries and Roundabouts

Rotaries and roundabout are channelized intersections comprising a central circle surrounded by a one-way roadway. The basic difference between rotaries and roundabouts is that rotaries are generally signalized, whereas roundabouts are not. Naturally, in the case of roundabouts, entering traffic yields to traffic within.

Roundabouts generally have good safety records and traffic does not have to stop when traffic volumes are low. A well-designed roundabout should deflect the path of vehicles passing through an intersection by the use of a sufficiently large central island, properly designed approach islands, and staggering the alignment of entries and exits.

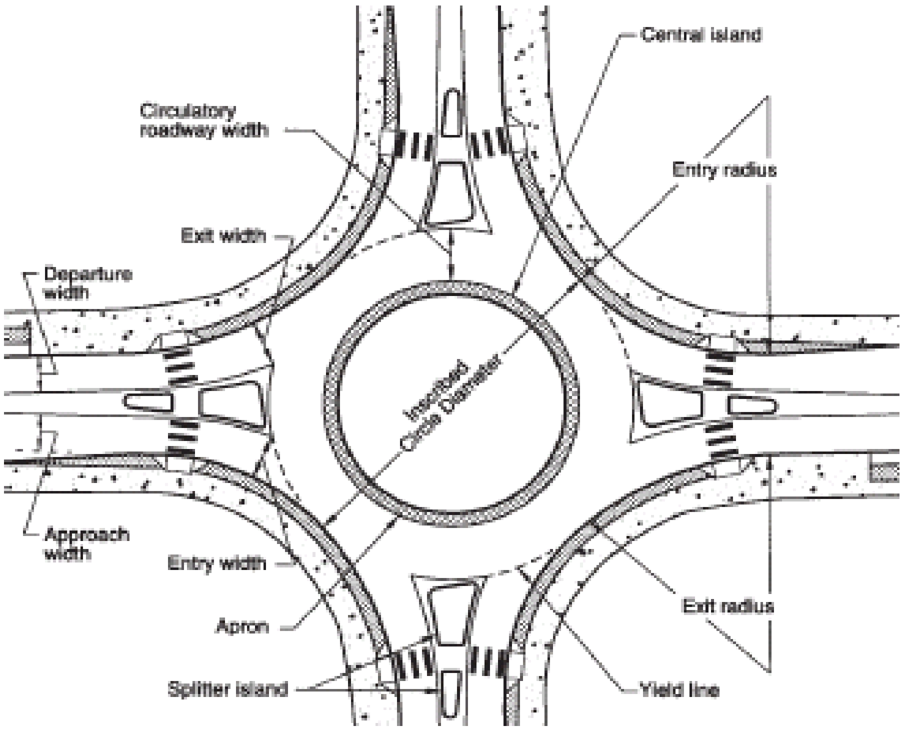


Figure 6-5: Parts of a Typical Roundabout

6.4.4 Traffic Signal

- It is the ultimate form of intersection control
- It can substantially reduce the number and nature of intersection conflicts because it alternately assigns right-of-way to specific movements
- At virtually all signals, some pedestrian-vehicle and bicycle-vehicle conflicts remain between legal movements (Thus, driver vigilance and judgment are still required)
- Due to their high cost and introduction of delay, their use must be last resort (thorough investigation required)

6.4.5 Uncontrolled Intersections

Where an intersection has no control device, the operator of a vehicle approaching an intersection must be able to perceive a hazard in sufficient time to alter the vehicle's speed, before reaching the intersection. The time needed to start decelerating is the driver's perception and reaction time and may be assumed to be 2.0 sec. In addition, the driver needs to begin braking some distance from the intersection. This distance from the intersection, where a driver can first see a vehicle approaching on the intersecting road, is that which is traversed during 2.0 seconds for perception and reaction, plus an additional 1.0 second to actuate braking or to accelerate to regulate speed.

By referring to Fig. 5.5, the sight triangle is determined by the minimum distances along the road. For instance, if highway A has a speed limit of 50 mph and highway B has one of 30 mph, it would require an unobstructed sight triangle, with legs extending at least 220 ft and 130 ft, respectively, from the intersection, based merely on the average distance traveled in 3 seconds.

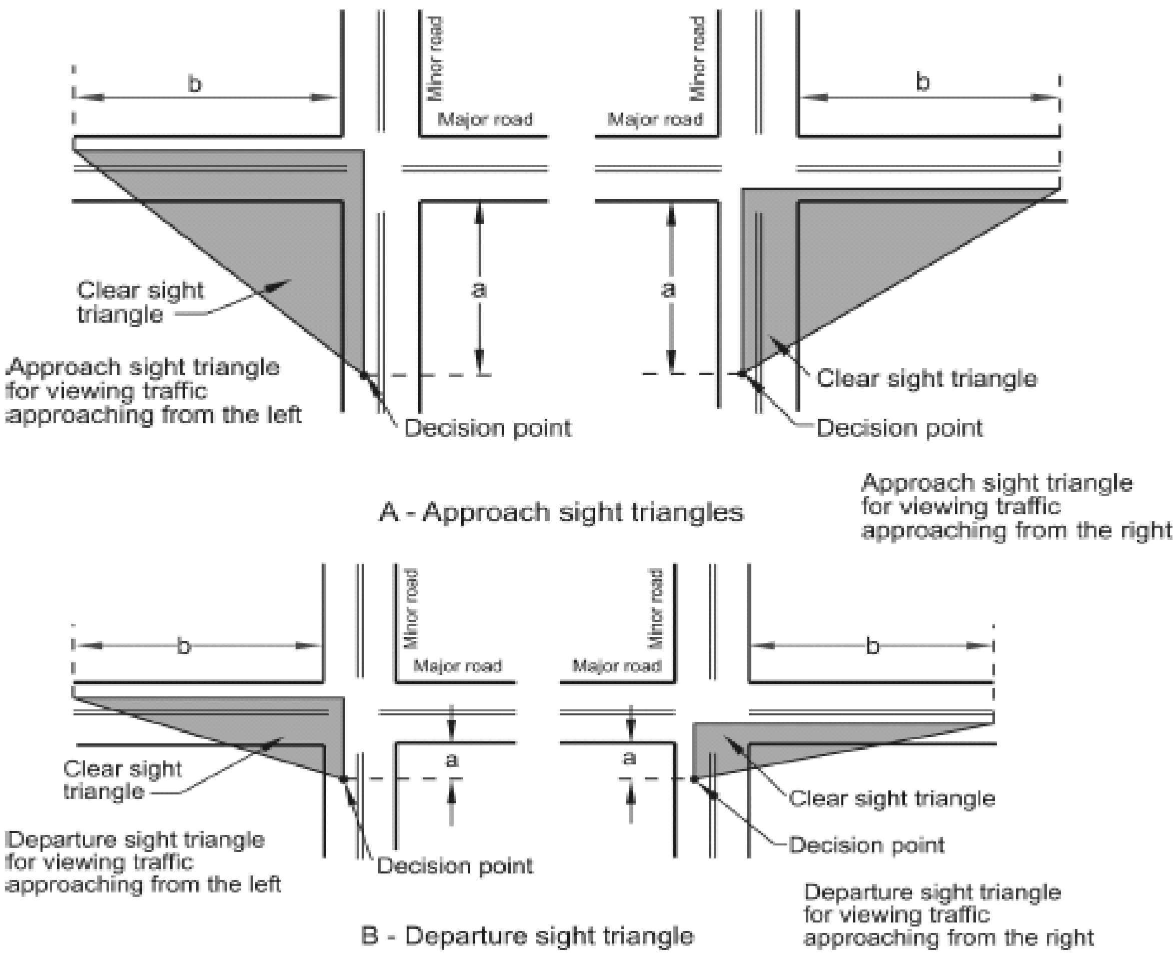


Fig. 6.6 Sight Triangle (AASHTO 2001)

These minimum distances will permit a vehicle on either road to change speeds before reaching the intersection, but this fact by itself does not imply that the intersection is safe. There can be potential danger to vehicle operators on such intersections, especially when successions of vehicles are approaching the intersection, when time is sufficient to avoid only a single vehicle. Because the distance covered in 3 seconds ranges from 70% of the safe stopping distance at 20 mph to only 36% at 70 mph, the use of sight triangles for design purposes must be approached with caution.

A safer design for such intersections should allow drivers on both highways to see the intersection and traffic in sufficient time to stop the vehicle before reaching the intersection. The safe stopping distances in this case are the same as those used for designing any other section of highway.

In essence, the responsibility for avoiding a potential conflict is assigned to the vehicle on the left. It is also often specified that through vehicles have the right-of-way over turning vehicles at uncontrolled intersections.

6.5 Interchanges

Interchanges are combinations of ramps and grade separations designed as a system of interconnecting roadways to separate the turning and through movements at the junction of two or more roads. They provide the greatest efficiency, safety and capacity for handling large volumes of traffic in these situations. Interchange design is a special form of intersection design. The traffic interchange is the best solution available to the problems encountered in intersections at grade, as it separates the major crossing movements and enables maximum traffic volumes to operate uninterrupted on at least the freeway.

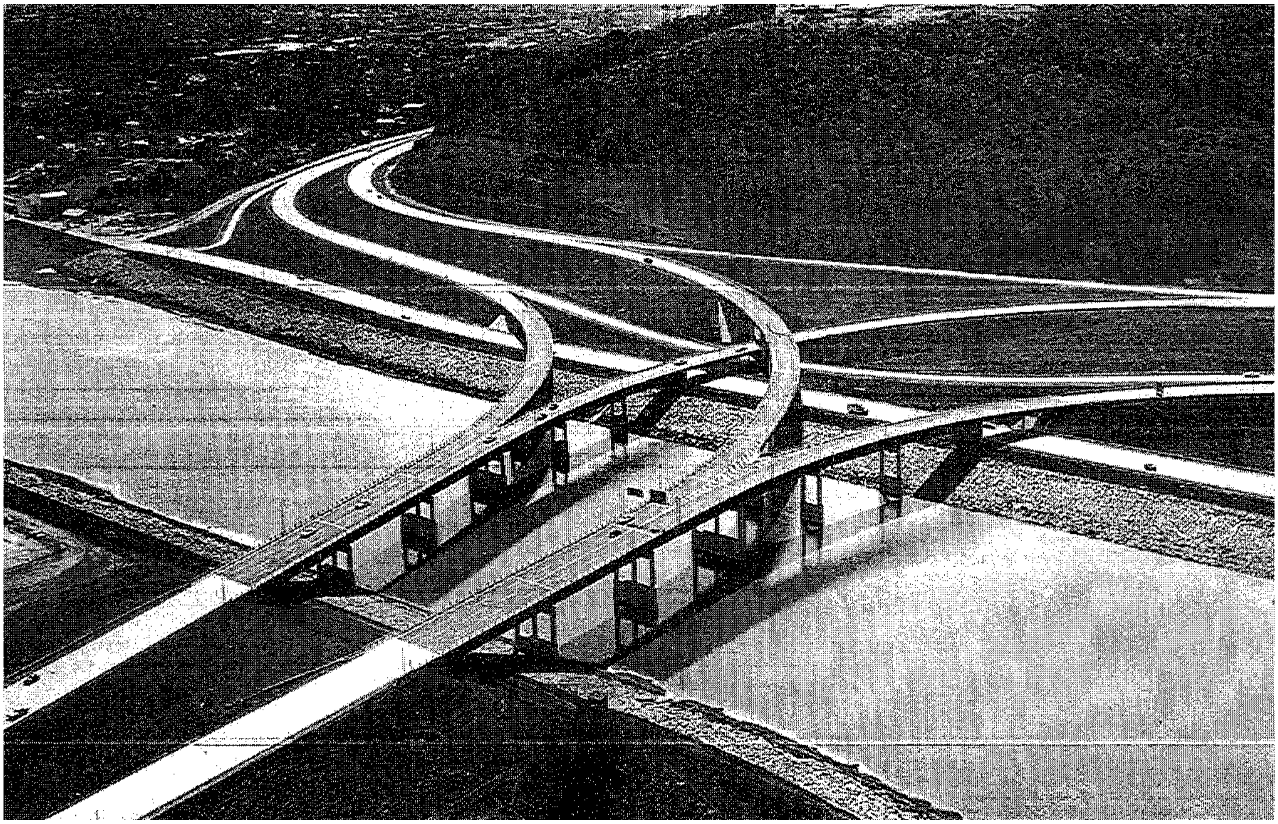


Figure 6-8: Three-leg interchange of a river crossing

Crossing conflicts are eliminated and turning conflicts are minimized depending on the type and degree of development of the interchange, and on the degree of access limitation imposed. Interchanges can be provided between freeways, between freeways and arterial roads, and between arterial roads. The general principles of design are similar but standards for clearance, curvature, sight distance and visibility depend on the standard and the design speed of the roadway to which the element of the interchange connects.

Each interchange is an individual problem and even standard types require customization to suit a particular site. Consistency of form assists in driver understanding and the design must be considered in conjunction with the design of adjacent interchanges. An interchange or series of interchanges on a route through an area may affect large adjacent areas or even the entire community. Interchanges should therefore be located and designed so that they will provide the best possible traffic service consistent with community interests. To this end all interchanges should provide for flexibility of operation and be subject to reasonably easy modification if required by future traffic patterns.

When interchanges are required at relatively close spacing, the weaving maneuvers between the interchanges may limit capacity. Weaving occurs when an entry ramp is followed by an exit ramp within a distance of about 1.5km. Weaving involves lane changing as well as merging and diverging. Longer distances between the entry and exit ramp results in freeway capacity being limited by merge and diverge capacity. The influence of lane changing is not the limiting factor as more opportunities to change lanes arise on longer stretches of road. Weaving may be reduced or eliminated by special design features. Freeway capacity may be modeled by use of the Highway Capacity Manual (either using manual calculation or HCS 2000 software).

Microscopic simulation software such as Paramics or Aimsun may also be used to assess freeway operating conditions under different traffic loadings and geometric layout options.