Chapter IV
Intersections and Interchanges

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Lecture Overview

- Introduction
- DESIGN CONCEPTS
- GEOMETRIC DESIGN
- SIGHT DISTANCE
- CHANNELIZATION
- ROUNDABOUTS
- GRADE SEPARATIONS AND INTERCHANGES

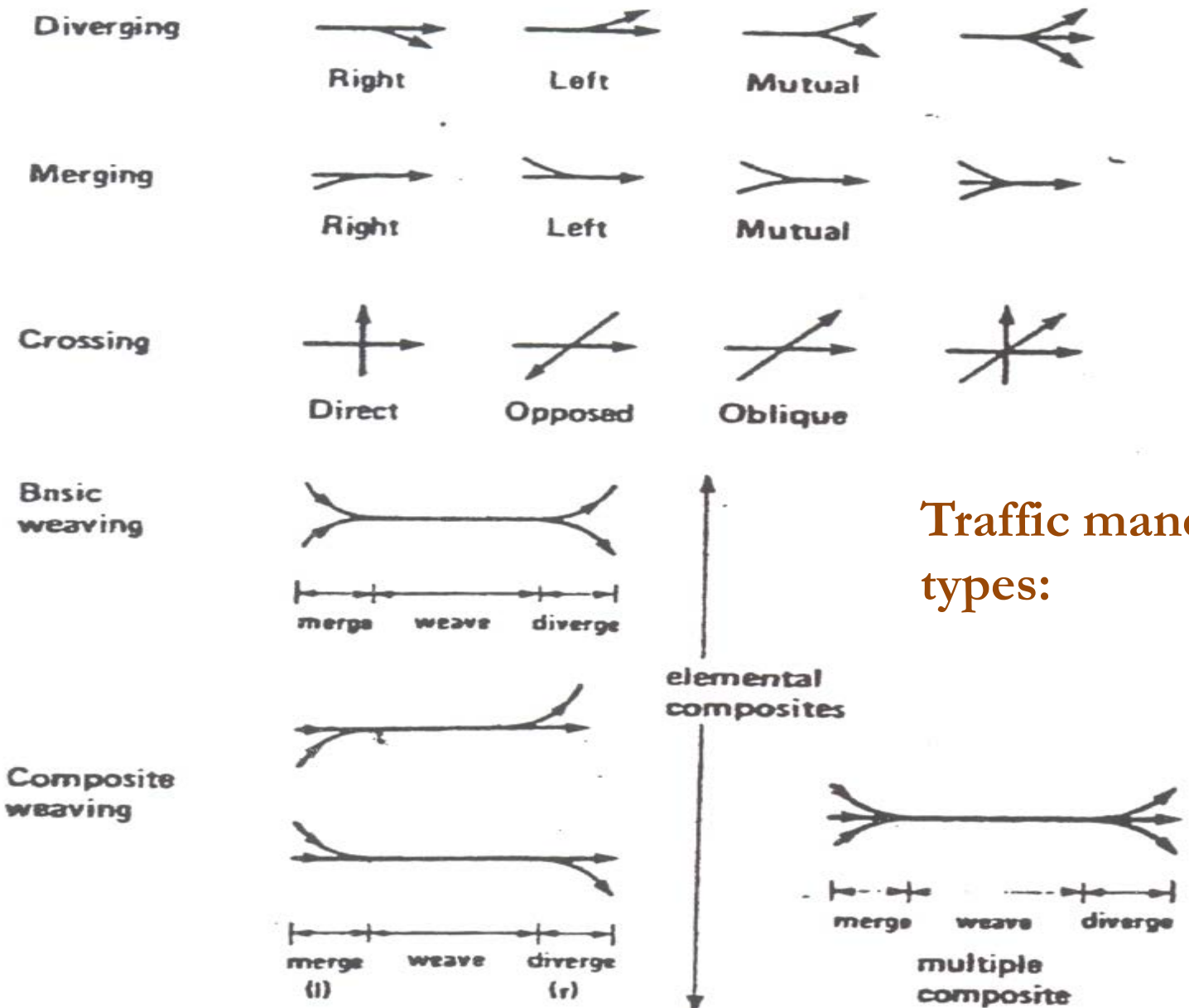
INTERSECTIONS

- An intersection is the area where two or more basic zone join or cross, including the roadway and the roadside facilities for traffic movements within the area.
- The efficiency, safety, speed, cost of operation, and capacity of road infrastructures depend on the design of intersections.
- A highway intersection is required to control conflicting and merging streams of traffic so that delay is minimized. This is achieved through choice of geometric parameters that control and regulate the vehicle paths through the intersection.

INTERSECTIONS

- The main objective of intersection design is to provide:
  - Safe and convenient operation for all road users, including cyclists and pedestrians;
  - Proper accessibility for road users with special requirements;
  - Adequate capacity for peak-hour demand on all movements;
  - Adequate manoeuvring space for design vehicles;
  - Resolution of conflicts between competing movements;
  - Storage for normal queuing of vehicles;
  - Uniformity of treatment with similar locations;
  - A safe environment for road users with special needs;
  - Adequate lighting for night-time operations;
  - Appropriate access to serve adjacent property development;
  - Minimum delay to all road users;
  - Ways to minimize pollution and emissions;

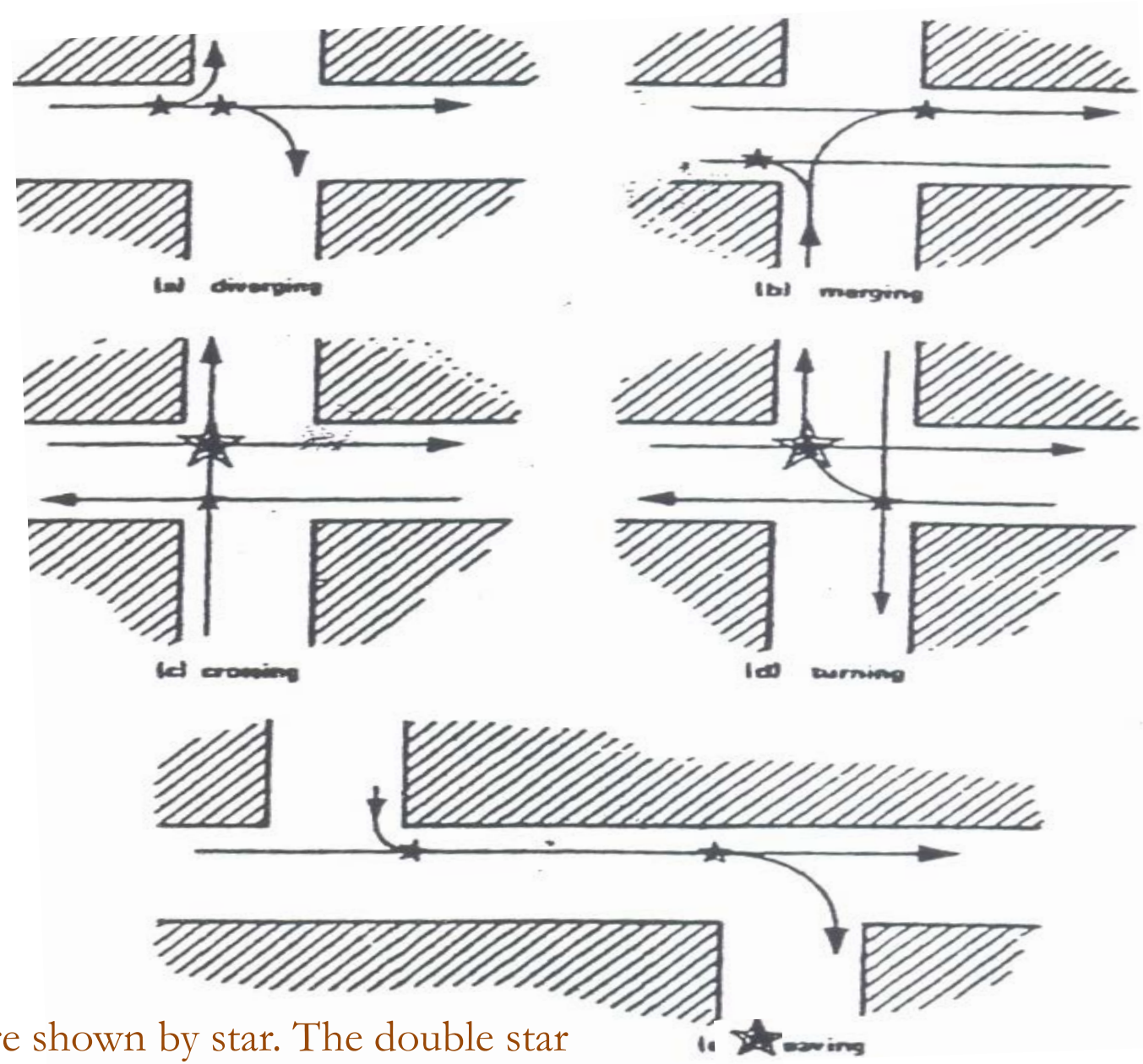
INTERSECTIONS



Traffic maneuvers types:

INTERSECTIONS

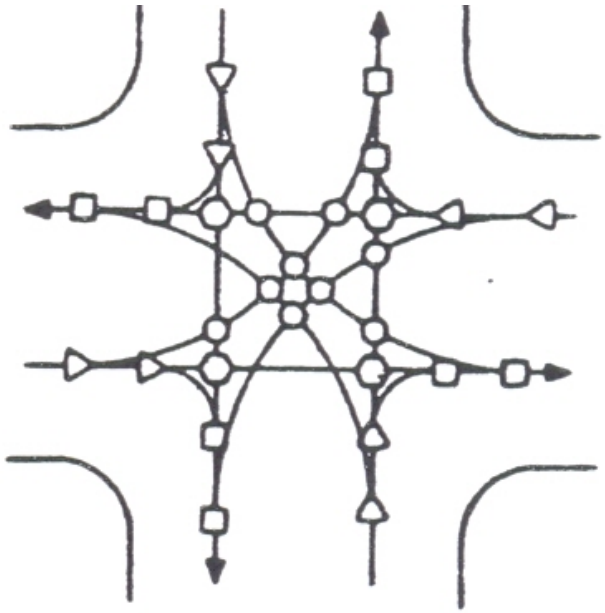
Basic types of intersection conflicts



The conflict points are shown by star. The double star indicates particularly hazardous conflicts

INTERSECTIONS

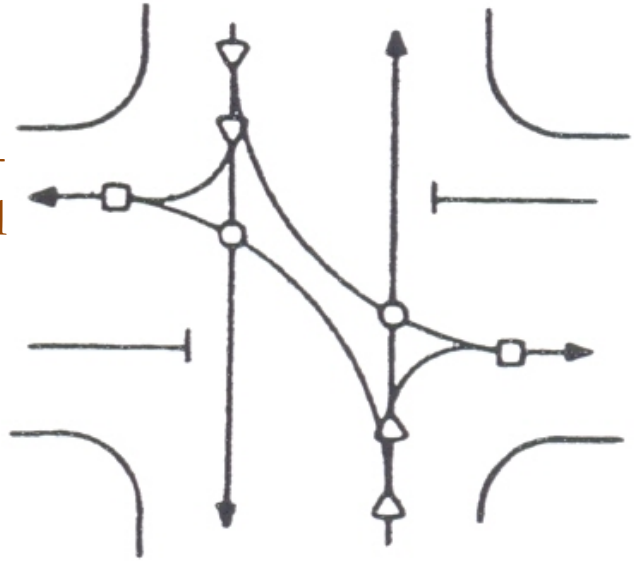
4-leg intersection single-lane approach no signal control



possible conflicts

△ diverging	8
□ merging	8
○ through-flow crossing	4
○ turning-flow crossing	12
number of conflicts:	32

4-leg intersection single-lane approach with signal control

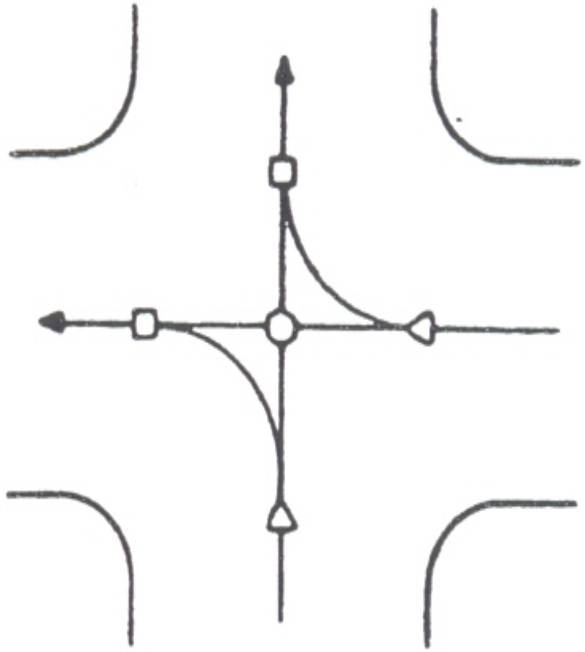


possible conflicts

△ diverging	4
□ merging	2
○ through-flow crossing	0
○ turning-flow crossing	2
number of conflicts:	8

INTERSECTIONS

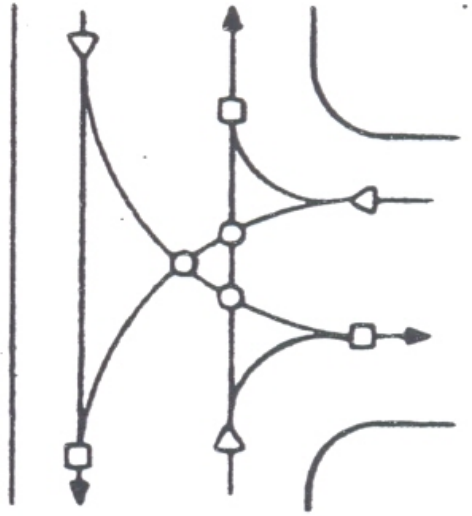
4-leg intersection one-way streets no signal controls



possible conflicts

△	diverging	2
□	merging	2
○	through-flow crossing	1
○	turning-flow crossing	0
	number of conflicts:	5

3-leg intersection single-lane approach no signal control



possible conflicts

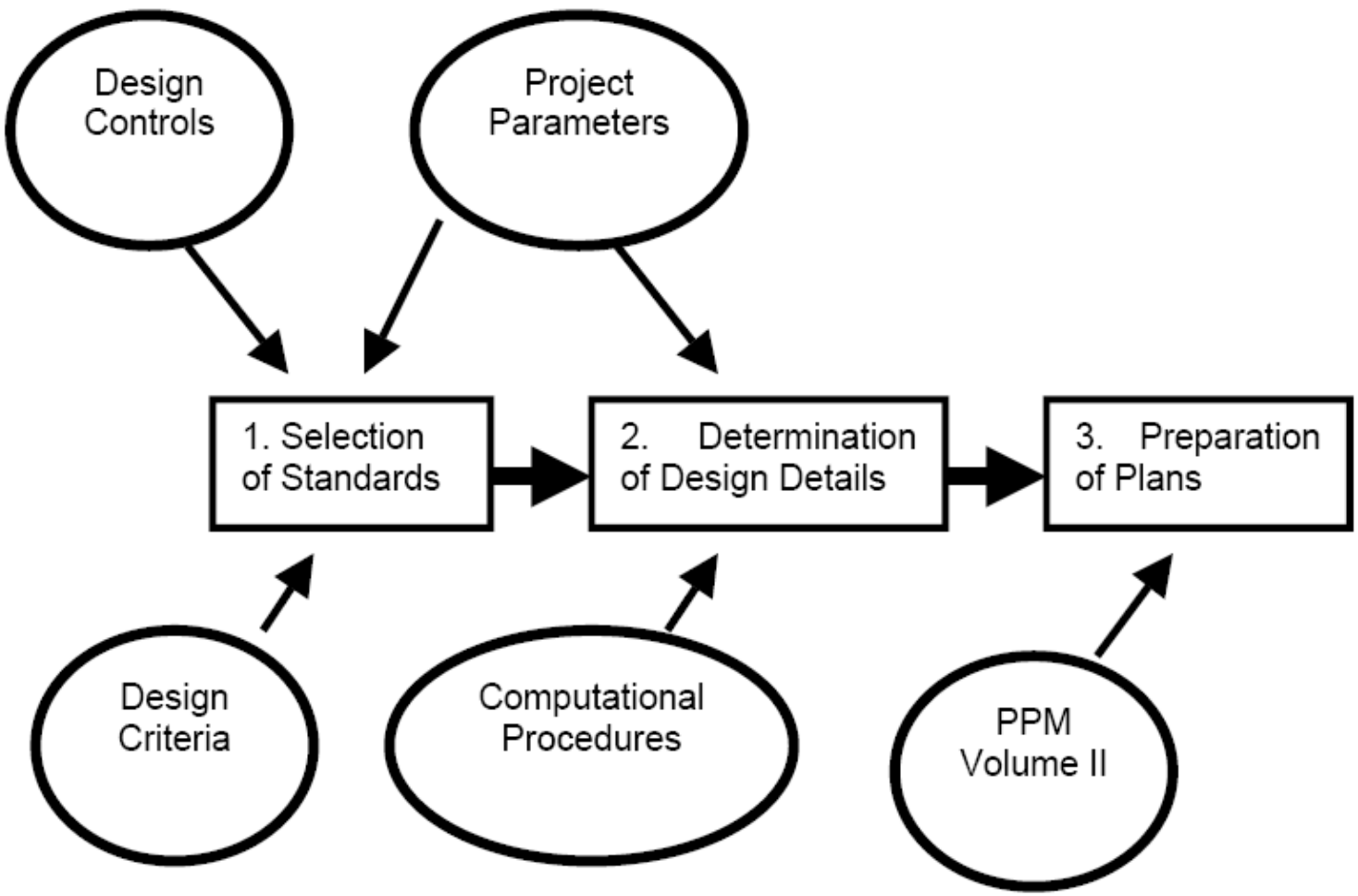
△	diverging	3
□	merging	3
○	through-flow crossing	0
○	turning-flow crossing	3
	number of conflicts:	9

INTERSECTIONS: DESIGN CONCEPTS

- Intersection design is founded on an extensive set of design criteria, controls, project parameters and standards.
- ***Selection of Standards***:
  - *Design Criteria:* Design criteria take the form of specific requirements, values or ranges of values or other conditions that are set forth in an authoritative reference ***such as the AASHTO guide***
  - *Design Controls:* Design controls are site-specific characteristics and conditions that influence or regulate the selection of the criteria for project standards. ***Examples of design controls include design year volumes, traffic composition, directional distribution, design speed, road user characteristics, etc.***
  - *Project Parameters:* Project parameters are the properties or specific conditions of a project ***that require the modification of design standards***.
- ***Development of Design Details***: The design details may be determined directly from the standards in some cases. It may, however, be necessary to apply ***additional computational procedures using other design controls***.
- ***Preparation of Plans***: When all of the design details have been determined they must be documented in the form of a design plan.

INTERSECTIONS: DESIGN CONCEPTS

- The design process steps and information flow



INTERSECTIONS: DESIGN CONCEPTS

INTERSECTION CHARACTERISTICS

Physical characteristics	Traveled roadway Curbs Sidewalks Medians Islands Drainage features Physical obstacles
Operational characteristics	Lane configuration and usage Traffic control mode Pedestrian control provisions Lane delineation Turn Prohibitions Crosswalk configuration Signal Phasing and timing Accessibility features
Traffic characteristics	Vehicular volumes Composition Peaking characteristics Pedestrian volumes Bicycle volumes
Site characteristics	Roadway classification Site location Roadside development Institutional proximity (schools, etc.)
Road User Characteristics	Age Special requirements

INTERSECTIONS: DESIGN CONCEPTS

- In the interest of safety, the conflict between two competing traffic movements must be resolved by a traffic control discipline that gives one movement priority over the other. When some movements are heavy, the priority must be assigned, alternated or distributed in some manner or at least one of the movements will fail.
- ***Most conflicts at intersections occur when two vehicles compete with each other for right of way.*** It is, however, important to recognize the conflicts that occur between two different types of road users. Inter-user conflicts may be characterized as:
  - ***Vehicle-pedestrian conflicts***: The Ethiopian traffic regulations assign the right of way to pedestrians crossing in crosswalks. Pedestrians crossing outside of crosswalks must yield to vehicles. Most pedestrian activity at intersections should be in crosswalks.
  - ***Vehicle-bicycle conflicts***: In the travelled roadway, a bicycle is always considered as a vehicle. In crosswalks, the cyclist is assumes the rights and duties of a pedestrian. The accommodations for bicycles at intersections must recognize this option.
  - ***Bicycle-pedestrian conflicts***: Because they assume the identity of a vehicle, bicycles on roadways are subject to the same rules indicated above for vehicle-pedestrian conflicts. When bicycles are on pedestrian facilities such as sidewalks, crosswalks, etc. they are required to yield to pedestrians.

INTERSECTIONS: DESIGN CONCEPTS

- **Traffic Control Disciplines:** The method of resolving conflicts between any two movements is referred to as the ***traffic control discipline***. The following traffic control disciplines are commonly employed at intersections:
  - ***Right of Way Rule***: The right of way rule applies in the absence of any other traffic control device.
  - ***Fixed Priority***: There are two cases of fixed priority: right of way to through vehicles in conflict with left turns and vehicles on approaches controlled by ***stop or yield signs***.
  - ***Alternating Priority (signals):*** The assignment of *right of way by traffic signals*.
  - ***Weaving Movements***: Vehicles proceeding in the same direction may also conflict with each other *if their respective origins and destinations cause their paths to cross*. Weaving movements are used by design for resolving conflicts at large traffic circles and some types of freeway interchanges.
  - ***Grade Separation***: The conflict between movements is automatically resolved *if the movements take place at different levels*. Grade separations are typically used to resolve conflicts between major movements at interchanges. It is important to note, however, that, except in the case of *extremely complex interchanges*, *one or more of the other disciplines* mentioned above will also be required to resolve some of the conflicts for turning movements.

INTERSECTIONS: DESIGN CONCEPTS

- The designer must be aware of *the roadway space requirements* and *the performance limitations of a typical vehicle*. The following considerations apply to vehicle requirements and constraints:
  - *Traffic Control Modes: A combination of traffic control disciplines are found at most intersections.*
  - One of the first steps in the intersection design process is to choose the most appropriate control mode from the following alternatives:
    - ***Uncontrolled***: where the right-of-way rule applies.
    - ***STOP control***: where *vehicles have to stop anyway*.
    - ***YIELD control***: where *vehicles have to give way to other vehicles*
    - ***Signal***: where the *right of way is given alternatively*
    - ***Roundabout***: where *one-way traffic is circulating around a central island*
- Normally, an engineering study of *traffic conditions, pedestrian characteristics and physical characteristics of the location* shall be performed *to determine whether installation of a traffic control signal or roundabout* is justified at a particular location.
- The provision of ***adequate capacity*** is one of the *primary design objectives*. The analysis of capacity is based on the *operational characteristics of conflicting vehicles separated by* ***the time constraints imposed by traffic control devices***.

INTERSECTIONS: DESIGN CONCEPTS

- The ***operation of an intersection*** may be represented by *four interacting components*: *the road user, the vehicle, the roadway, and the traffic control devices*.
  - ***The Design Vehicle***: used to determine a variety of geometric highway features, such as lane widths, minimum curb and corner radii and minimum turning radius.
  - ***Acceleration Performance***: The difference in acceleration capability is a major cause of inefficiency in mixed traffic streams.
  - ***Braking Performance***: A vehicle's braking performance is one of the most critical factors in highway safety and design and it is related to *the vehicle's braking system, type and condition of the tires and the condition and type of roadway surface --braking distance*.

INTERSECTIONS: DESIGN CONCEPTS

Vehicle Characteristics	Intersection Design Elements Affected
Physical Characteristics:	
Length	Lengths of storage lanes
Width	Widths of lanes
	Widths of turning roadways
Height	Placement of overhead signals and signs
Wheelbase	Nose placement
	Corner radius
	Widths of turning roadways
Operational characteristics	
Acceleration capability	Acceleration tapers and lane lengths
	Gap acceptance
Deceleration and braking capability	Lengths of deceleration lanes and tapers
	Stopping sight distance

INTERSECTIONS: DESIGN CONCEPTS

- The following considerations apply to ***road user requirements and constraints***:
  - **Perception and Reaction Time**: The perception of and reaction to a continuous series of visual and audio cues that are part of the driving task involve four actions on the part of the driver, characterized as: perception, identification, emotion and volition (PIEV time or perception-reaction time). PIEV time is a function of many factors. For intersection design purposes, a value of ***1.0 second*** is commonly used to account for ***the driver's reaction to a signal change interval*** and ***2.5 seconds*** is generally applied to more ***passive stimuli, such as a fixed warning sign***.
  - **Visual Acuity and Driving**: Drivers are normally tested only for static visual acuity, that is, the ability to see stationary objects and legend messages. However, other important measures are dynamic visual acuity, depth perception, glare recovery and peripheral vision. The three primary fields of vision that affect the driving task are: *the field of clear or acute vision, the field of fairly clear vision and the field of peripheral vision*
  - **Guidance Task**: Highway design and traffic operations have the greatest effect on guidance. Road user performance can be improved by paying the proper attention to *lane placement and road following, car following, overtaking and passing and other guidance activities*, (i.e., *merging, lane changing, avoidance of pedestrians and response to traffic control devices*, etc.).

INTERSECTIONS: DESIGN CONCEPTS

- **Human Error:** Improper operation and accidents may occur as a result of information-handling errors. These errors can be due to road user deficiencies and situational demands.
- **Cyclist Characteristics**: Knowledge of bicycle dimensions, operating characteristics and requirements is also necessary for providing adequate bicycle facilities. These factors determine *acceptable turning radii, grades and sight distances*.
- **Pedestrian Characteristics**: The safety of pedestrians, especially at intersections, is a very important consideration in the highway design process. Important pedestrian characteristics are: ***pedestrian crossing volumes, walking speeds and gap acceptance characteristics at crossing locations***.
- **Special Needs of Road Users**: Road users with physical, visual or hearing disabilities introduce controls that could modify standards (e.g., clearance time requirement).

Human factor	Design values	Design elements affected
Perception/reaction time	2,0 – 4,0 seconds	Intersection sight distance
Gap acceptance	5,5 - 7,5 seconds	Intersection sight distance
Driver height of eye	1,05 metres	Sight distance
Pedestrian walking speeds	1-1,5 metres/second	Pedestrian facilities

INTERSECTIONS: DESIGN CONCEPTS

- The roadway has its own set of requirements and constraints that must be considered. The most significant points include:
  - **Roadway Utilization**: The traffic regulations which govern roadway utilization.
  - **Driveways and Access Control**: The design and operation of driveway, and access management (driveways, side streets, and median openings).
  - **Drainage**: Drainage is usually more difficult and costly for urban areas. There is greater need to intercept concentrated storm water before it reaches the streets and to remove over-the-curb flow and surface water without interrupting traffic flow or causing a problem for vehicle occupants or pedestrians.
  - **Utilities**: It is important to note, that public and privately owned utilities are permitted to be accommodated within the right-of-way on the Highway System.

INTERSECTIONS: DESIGN CONCEPTS

- ***Data Requirement of Intersection***: The data requirements will depend on the nature of the design project. The following information will be required for most projects:
  - Approach volumes for each intersection approach,;
  - Existing geometrics (when improving an existing intersection);
  - Pedestrian and bicycle volumes, (where applicable);
  - Distances to other intersections;
  - Crash history (when improving an existing intersection);
  - Institutional locations: schools, etc.;
  - Speed along the intersecting roads;
  - Physical and right of way features and limitations;
  - Site development features: businesses, driveways, etc. and
  - Community considerations: need for parking, landscape character, etc.
- In addition, information on the following items may be needed, depending on specific design project objectives:
  - Anticipated growth based on governing comprehensive plan;
  - Traffic management strategies in the area;
  - Types of vehicles using the intersecting roadways;
  - Transit routes along intersecting roadway;
  - Adjacent land uses, especially if the design is proposed as a community enhancement project;
  - Access to adjacent properties;
  - Compatibility with adjacent intersections;
  - Availability of power and lighting and
  - The location of existing above-ground and below-ground utilities.

INTERSECTIONS: GEOMETRIC DESIGN

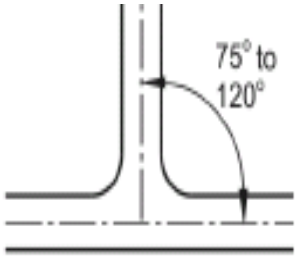
- **Design Considerations**: The design of an intersection involves four basic elements: *human, operational, physical and economic*. Other intersection design criteria are:
  - desirable traffic controls (none, signs, signals, pavement markings);
  - capacity analysis (level of service, number of approach lanes, turning movements and turn lanes);
  - degree of access control for highway facility;
  - pedestrian traffic;
  - bicycle traffic; and
  - lighting warrants.
- ***Intersection design should consider the following seven fundamental principles***:
  - ***Reduce number of conflicts.***
  - ***Reduce area of conflict***
  - ***Segregate non-homogeneous flows***
  - ***Intersection Spacing***
  - ***Control speed differentials***
  - ***Favour the heaviest and fastest flows***
  - ***Coordinate intersection design with the development of traffic control plans.***

INTERSECTIONS: GEOMETRIC DESIGN

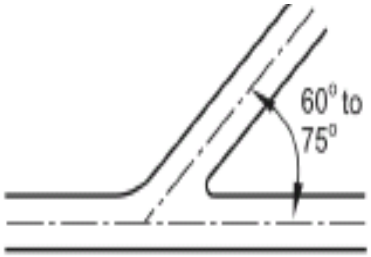
- Although the ***design of an intersection*** may be *influenced by constraints unique to its particular location or situation*, it conforms generally to the following design principles:
  - The design of intersections along a given street or highway ***should be as consistent as possible***.
  - The layout of the intersection should be as ***simple as is practicable***.
  - The design of all intersection elements should be ***consistent with the approach design speeds***.
  - The approach roadways should be ***free from steep grades or sharp horizontal or vertical curves***.
  - Intersections should be as ***close to right angle*** as practical.
  - Sight distance should be sufficient ***for crossing and turning manoeuvres***.
  - The intersection layout should ***encourage smooth flow and discourage wrong-way movements.***
  - Auxiliary turn lanes should be provided ***on high-speed and/or high-volume facilities***.
  - Acceleration lanes are desirable for ***entrance manoeuvres onto high-speed facilities***.
  - Design must give special attention to the provision of ***safe roadside clear zones and horizontal clearance***.
  - The intersection arrangement ***should not require sudden and/or complex decisions***.
  - The layout of an intersection should be ***clear and understandable***.
  - Special consideration should be given to requirements for ***accommodating bicycle and pedestrian movements***.

INTERSECTIONS: GEOMETRIC DESIGN

- ***Intersection types*** can be categorized by ***intersection basic type***, ***functional classification***, ***control type***, ***area type***, ***or a combination*** of these classifiers, depending on the element of design. At-grade intersection can be three-leg (T or Y), four-leg, multi-leg or circular.

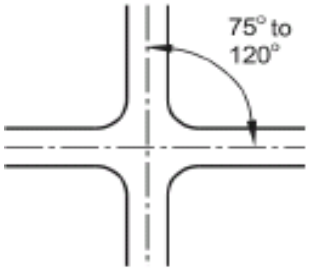


T-intersection

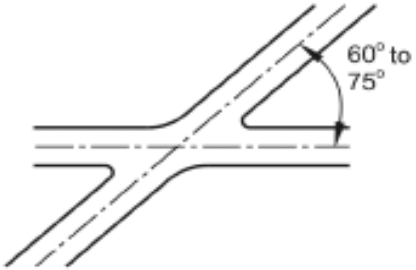


Y-intersection

Three-legged intersections



Right-angled

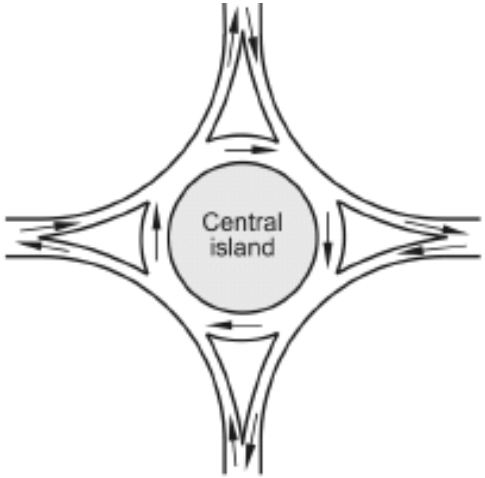


Oblique

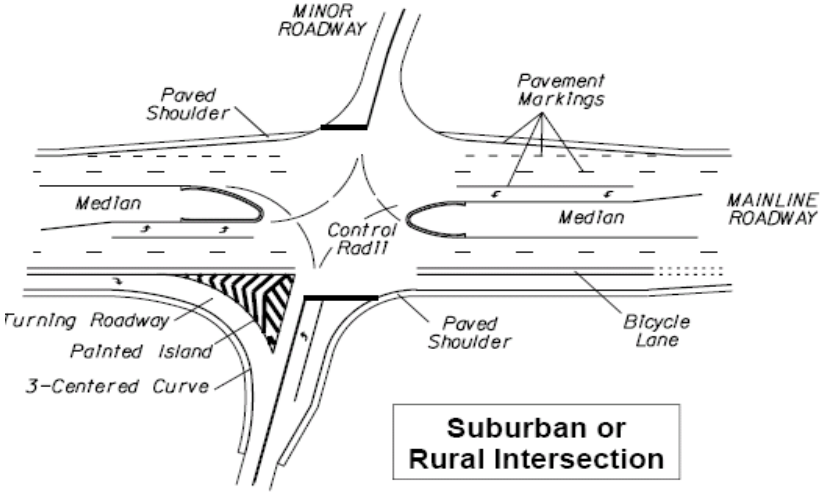
Four-legged intersections

Not recommended

Multi-legged intersection



Roundabout
(Rotary intersections)



Suburban or Rural Intersection

INTERSECTIONS: GEOMETRIC DESIGN

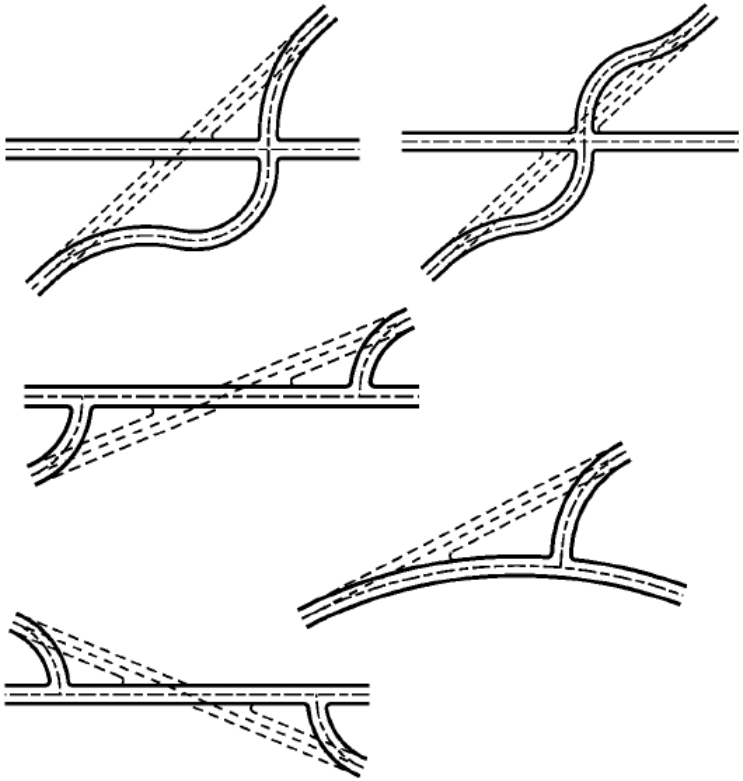
HORIZONTAL ALIGNMENT

- **Intersection Angle**: The angle of intersection of two highways can greatly influence the intersection's safety and operational characteristics. Both individual vehicle operations and the nature of vehicle/vehicle conflicts are affected by angle of intersection. Heavy "*skew*" *intersection angles produce large open pavement areas within the intersection*. Such intersections are not only more costly to build and maintain, but are undesirable operationally for the following reasons:
  - *Vehicles crossing the intersection are exposed for a longer time to conflicts* from crossing traffic. This may be a particularly *critical problem at STOP-controlled approaches on high speed highways*.
  - The road user's sight angle to one of the crossing legs becomes more restricted. This increases the difficulty of perceiving safe crossing gaps.
  - *Pedestrians and motorists are subjected to longer times* of exposure to conflicting vehicles.
  - *Vehicular movements are more difficult because of the skew*. Accommodation of large truck turns may necessitate additional pavement and channelization not otherwise called for.
- *Approaching roadways should intersect at right angles where practical*. Angles *less than 90 degrees, but greater than 75 degrees*, should be maintained normally. Angles *as low as 60 degrees may be acceptable* where costly or severe constraints occur.

INTERSECTIONS: GEOMETRIC DESIGN

- Where severe skew angles exist, the need to consider improvements should be assessed, with primary emphasis given to examination of crash rates and patterns. A high incidence of right angle crashes, particularly involving vehicles approaching from the acute angles, may be evidence of a problem attributable to the skew. Realignments such as those shown in the figure below whenever feasible.

Intersections on horizontal curves should be avoided. The curvature adds an extra element of complexity to the highway information that must be processed by the driver, thereby increasing the hazard. It also complicates the geometric design elements of *sight distance, channelization and superelevation.*



It may be impractical to provide the intersection on a tangent. In such cases, designers should consider realigning the minor highway to intersect the major highway perpendicular to a tangent at a point on the curve. However, this still has the disadvantage of difficult turning movements if the superelevation of the major highway is high.

INTERSECTIONS: GEOMETRIC DESIGN

Minimum radii for location of intersections on curves

Design speed (km/h)	Radius (m)
40	250
50	375
60	550
70	750
80	1 000
90	1 220
100	1 500
110	1 850
120	2 200
130	2 600

INTERSECTIONS: GEOMETRIC DESIGN

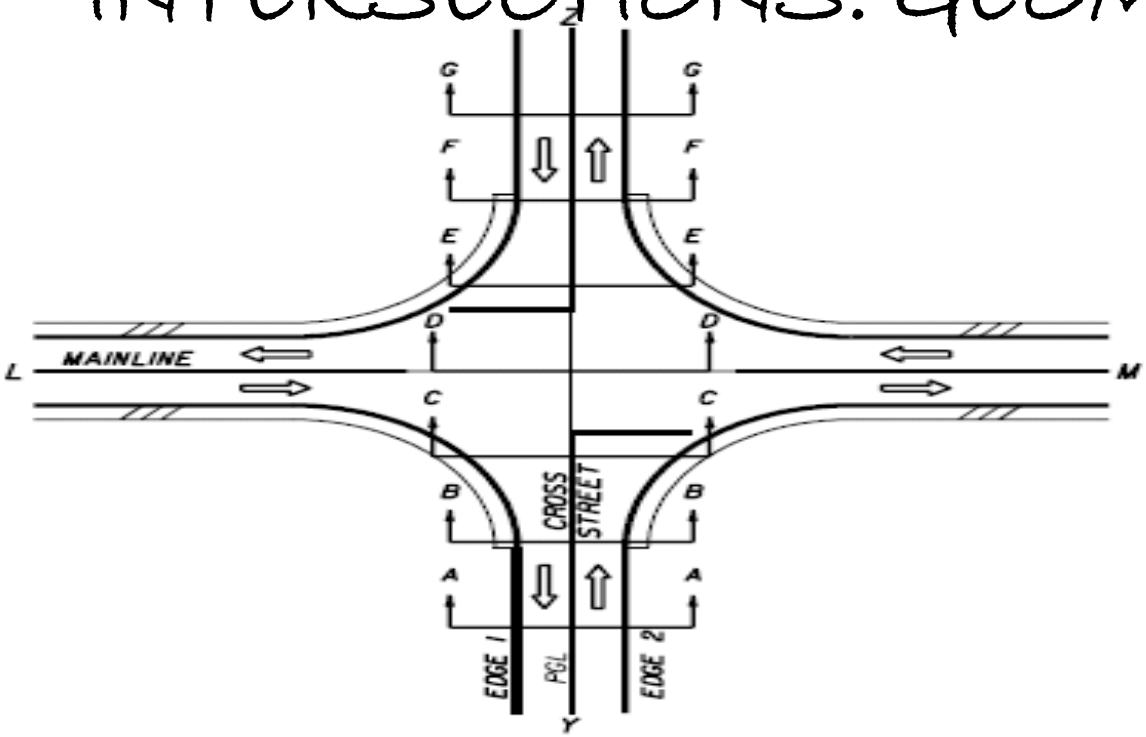
VERTICAL ALIGNMENT

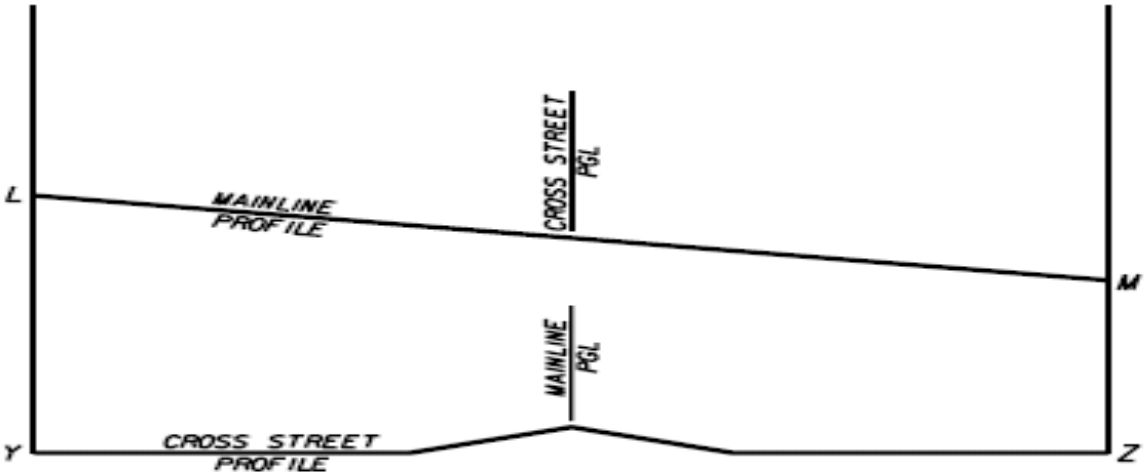
- As with other design elements, the characteristics of vertical alignment are influenced greatly by basic controls *related to design speed, traffic volumes, functional classification, drainage and terrain conditions*. Within these basic controls, several general criteria must be considered , including minimum and maximum grades, vertical curvature, maximum change in grade without vertical curves, vertical clearance and design high water.
- As a rule, the alignment and grades are subject to greater restrictions at or near the intersecting roads than on the open road. Their combination at or near the intersection must produce traffic lanes that are clearly visible to the road users at all times and clearly understandable for any desired direction of travel, ***free from sudden appearance of potential conflicts and consistent with the portions of the highway just travelled***.
- Combinations of grade lines that make vehicle control difficult should be avoided at intersections. ***The gradient of intersecting highways should be as flat as practical, but must consider cross slope and superelevation requirements***.

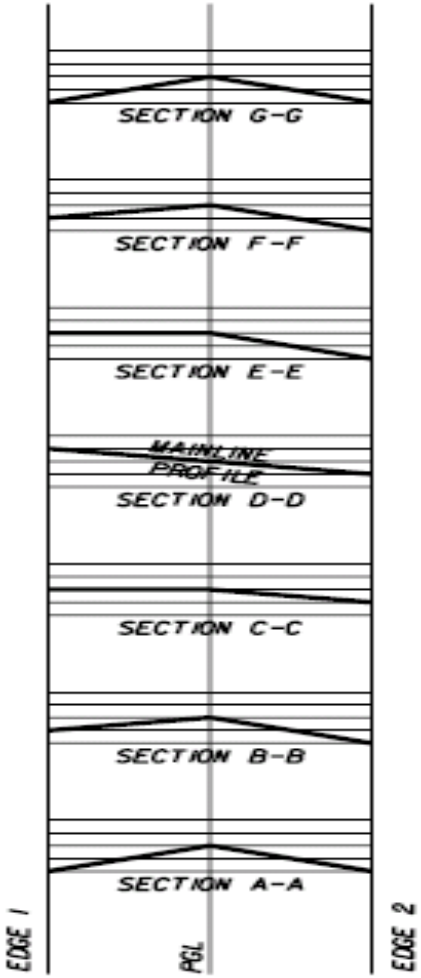
INTERSECTIONS: GEOMETRIC DESIGN

- Because most road users are unable to judge the increase and decrease in stopping or accelerating distance that is necessary because of steep grades, *grades in excess of* ***3% should be avoided on intersecting roads. Where possible, grades should not exceed 6%.***
- The profile grade lines and cross sections on the intersection legs should be adjusted for a distance back from the intersection proper to provide a smooth junction and proper drainage. *Normally, the grade line of the major highway should be carried through the intersection and that of the crossroad should be adjusted to it.*
- To ensure a safe, efficient, well drained and smooth roadway system, the profiles of some roadway elements requiring special analysis. These elements include pavement edges or gutter flow-line at street intersections, profile grade-line, intersection plateau, curb returns and roadway sections requiring special superelevation details.
- Plateauing refers to the transitioning of the roadway profiles and cross slopes at the approaches of an intersection.

INTERSECTIONS: GEOMETRIC DESIGN







INTERSECTIONS: GEOMETRIC DESIGN

INTERSECTION SIGHT DISTANCE

- Intersections are places of potential for several different types of traffic conflicts. These conflicts can be greatly reduced through the provisions of proper sight distances and appropriate traffic controls. The efficiency of traffic operations still depends on the judgement, capabilities, and response of each individual driver.
- The provision of SSD at all locations along each road, including intersection approaches, is fundamental to intersection operation. Vehicles are assigned the right-of-way at intersections by traffic-control devices or, where no traffic- control devices are present, by the rule of the road. Sight distance are provided at intersections to allow drivers to perceive the presence of potentially conflicting vehicles.
- The same principles of determining sight distance applies, but modified assumptions are made based on drivers behaviour at intersections.
- The areas along the approaches and across their included corners should be clear of obstructions that might block a driver's view of potentially conflicting vehicles which is known as sight triangles (can be either approach or departure sight triangle provided where traffic is controlled by STOP or YIELD sign). The dimensions of the sides of the sight triangles depend on the design speed of the intersecting roadways and the type of traffic control.

INTERSECTIONS: GEOMETRIC DESIGN

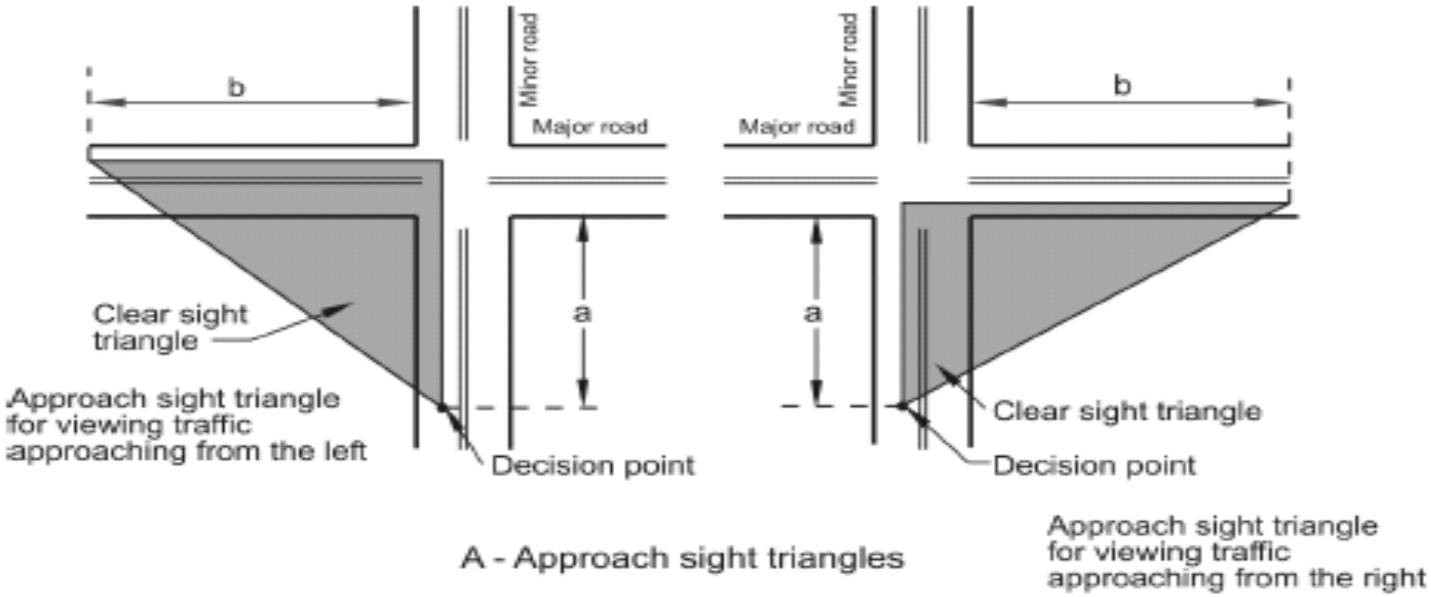
- Sight distance requirements at at-grade intersections are based upon the following five different cases of intersection control:
  - *Case I*— No control, but allowing vehicles to adjust speed,
  - *Case II*— Stop control, where traffic on the minor roadway must stop prior to entering the major roadway, (Rt turn from the minor road; Lt turn from the minor road; and cross manoeuvre from the minor road.
  - *Case III*— Yield control, where vehicles on the minor intersecting roadway must yield to vehicles on the major intersecting roadway, (crossing from the minor road, and left or right turn from the minor road)
  - *Case IV*— Signal control—where all legs of the intersecting roadways are required to stop by a stop sign or where the intersection is controlled by traffic signals and
  - *Case V*— intersections with all-way Stop control.

INTERSECTIONS: GEOMETRIC DESIGN

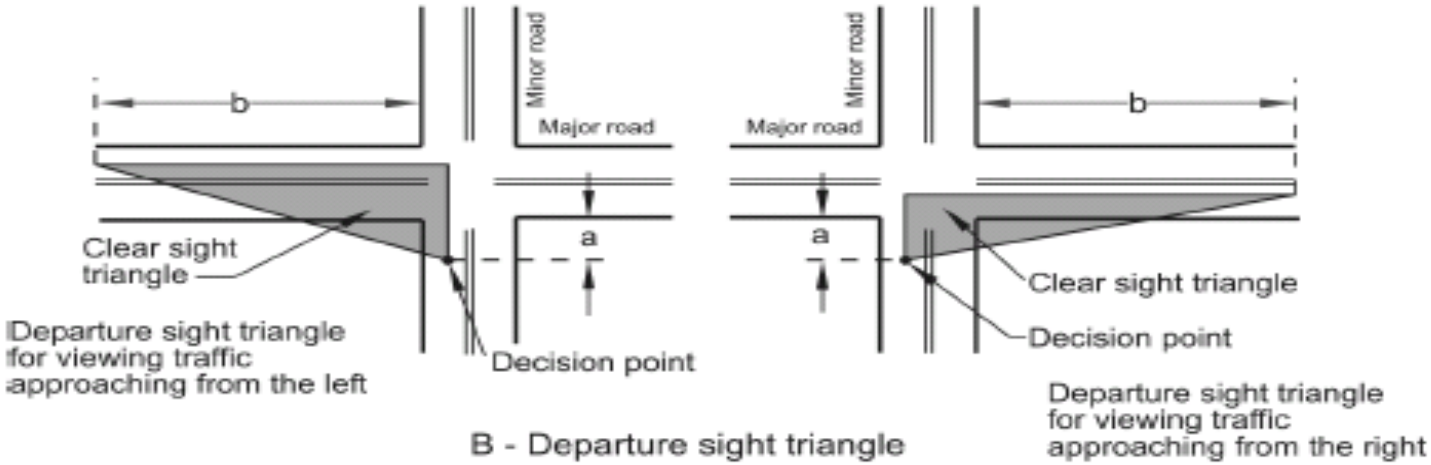
INTERSECTION SIGHT DISTANCE

SIGHT TRIANGLES

(Lt. hand drive)



A - Approach sight triangles



B - Departure sight triangle

INTERSECTIONS: GEOMETRIC DESIGN

INTERSECTION SIGHT DISTANCE

- *Intersections with no control:* Uncontrolled intersections are not used in conjunction with the main road network, but are common. In these cases, drivers must be able to see potentially conflicting vehicles on intersecting approaches in sufficient time to stop safely before reaching the intersection. Ideally, sight triangles with legs equal to stopping sight distance should be provided on all the approaches to uncontrolled intersections.
- If sight triangles of this size cannot be provided, the lengths of the legs on each approach can be determined from a model that is analogous to the stopping sight distance model, with slightly different assumptions.
- Field observations indicate that vehicles approaching uncontrolled intersections typically slow down to approximately 50 per cent of their normal running speed. This occurs even when no potentially conflicting vehicles are present, typically at deceleration rates of up to 1.5m/s^2. Braking at greater deceleration rates, which can approach those assumed in the calculation of stopping sight distances, begins up to 2,5 seconds after a vehicle on the intersecting approach comes into view.
- Where the gradient of an intersection approach exceeds three per cent, the leg of the clear sight triangle along that approach should be adjusted by multiplying the recommended sight distance. The following slide shows the recommended sight distance and grade adjustment factors.

INTERSECTIONS: GEOMETRIC DESIGN

INTERSECTION SIGHT DISTANCE

INTERSECTIONS WITH NO CONTROLS

- *Recommended sight distance which are less than the corresponding values of SSD for the same design speed*
- *Adjustment factors for sight distance based on approach grade*
- *If these sight distances cannot be provided, advisory speed signing to reduce speeds or installing Stop signs on one or more approaches should be investigated.*
- *Uncontrolled intersections do not normally require departure sight triangles because they typically have very low traffic volumes.*

Design speed (km/h)	Sight distance (m)
20	20
30	25
40	30
50	40
60	50
70	65
80	80
90	95
100	120
110	140
120	165

Approach gradient (%)	Design speed (km/h)									
	30	40	50	60	70	80	90	100	110	120
-6	1,1	1,1	1,1	1,1	1,1	1,2	1,2	1,2	1,2	1,2
-5	1,0	1,1	1,1	1,1	1,1	1,1	1,1	1,1	1,2	1,2
-4	1,0	1,0	1,1	1,1	1,1	1,1	1,1	1,1	1,1	1,1
-3 to +3	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
+4	1,0	1,0	1,0	0,9	0,9	0,9	0,9	0,9	0,9	0,9
+5	1,0	1,0	0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,9
+6	1,0	0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,9

INTERSECTIONS: GEOMETRIC DESIGN

INTERSECTION SIGHT DISTANCE

- *Intersections with Stop control on the minor road:* Departure sight triangles for intersections with Stop control on the minor road should be considered for three situations:
  - Right turns from the minor road;
  - Left turns from the minor road; and
  - Crossing the major road from the minor road approach.
- Left-turns from the minor road: Departure sight triangles for traffic approaching from either the right or left should be provided for left turns from the minor road onto the major road for all stop controlled approaches.
- The decision point of the departure sight triangle on the minor road (the typical position of the eye of the minor-road driver's eye at a stop position) varies from 4.4 to 5.4 m – assuming that the front of the stopped vehicle is 2 to 3 m from the travelled way of the major road, and the distance from the front of the vehicle to the position of the driver's eye is 2.4 m.
- The length of the sight triangle along the minor road, is the sum of the distance from the major road plus 1/2 lane width for vehicles approaching the left, or 1-1/2 lane width for vehicles approaching from the right.
- ISD along the major road is determined by:

  $$ISD = 0.278VT;$$

  where, T is the time gap as shown in the next slide.

INTERSECTIONS: GEOMETRIC DESIGN

INTERSECTION SIGHT DISTANCE

- *Time gap for left turn from stop onto a two lane road with no median and grades 3 % or less*

Design vehicle	Travel time (s) at design speed of major road
Passenger car	7,5
Single-unit truck	9,5
Semi-trailer	11,5
Adjustment for multilane highways: For right turns onto two-way highways with more than two lanes, add 0,5 seconds for passenger cars or 0,7 seconds for trucks for each additional lane, in excess of one, to be crossed by the turning vehicle. For left turns, no adjustment is necessary	
Adjustment for approach gradients: If the approach gradient on the minor road exceeds +3 per cent: ❑ Add 0,1 seconds per percent gradient for left turns ❑ Add 0,2 seconds per percent gradient for right turns	

Note: wherever median exist, it should be converted to equivalent lanes.

INTERSECTIONS: GEOMETRIC DESIGN

INTERSECTION SIGHT DISTANCE

Stop control on the minor road:

- Right-turn from the minor road: The ISD for the right turns is determined in the same manner as for left turn from the minor road, except the time gap should be adjusted.
- Field observations indicate that in making right turns, drivers generally accept gaps that are slightly shorter than those accepted in making left turns. The travel times shown in the preceding slide can be decreased by 1.0 to 1.5 seconds for right turn manoeuvres, where necessary, without undue interference with major-road traffic. When the recommended sight distance for a right-turn manoeuvre cannot be provided, even with a reduction of 1.0 to 1.5 seconds, consideration should be given to the installation of advisory speed signs and warning devices on the major road approaches.
- Crossing manoeuvre from the minor road: In most cases it can be assumed that the departure sight triangles for right and left turns onto the major road will also provide more than adequate sight distance for minor-road vehicles crossing the major road. However, it is advisable to check the availability of sight distance for crossing manoeuvres:
  - Where right and/or left turns are not permitted from a particular approach and crossing is the only legal manoeuvre;
  - Where the crossing vehicle has to cross four or more lanes; or
  - Where substantial volumes of heavy vehicles cross the highway and where there are steep gradients on the departure roadway on the far side of the inter section that might slow the vehicle while its rear is still in the intersection.
- The formula for ISD in case of left turning is used for crossing manoeuvre except that the time gaps are as shown in the following slide.

INTERSECTIONS: GEOMETRIC DESIGN

INTERSECTION SIGHT DISTANCE

- *Stop control on the minor road:*

  Time gap for right turning and crossing from stop on the minor road:

Design vehicle	Travel time (s) at Design speed of major road
Passenger car	6,5
Single-unit truck	8,5
Semi trailer	10,5
Adjustment for multilane highways: For crossing a major road with more than two lanes, add 0,5 seconds for passenger cars and 0,7 seconds for trucks for each additional lane to be crossed. In the case of dual carriageways with inadequate width of median for refuge, count the median as another lane to be crossed.	
Adjustment for approach grades: If the approach gradient of the minor road exceeds +3 %, add 0,2 seconds per percent gradient in excess of 3 %.	

INTERSECTIONS: GEOMETRIC DESIGN

INTERSECTION SIGHT DISTANCE

- *Intersections with Yield control on the minor road:* drivers approaching yield signs are permitted to enter or cross the major road without stopping, if there are no potentially conflicting vehicles on the major road.
- Departure sight triangles as described for Stop control must be provided for the Yield condition if conflicting vehicles are present. The sight distances needed by drivers on Yield-controlled approaches exceed those for Stop-controlled approaches because of the longer travel time of the vehicle on the minor road.
- For four-legged intersections with Yield control on the minor road, two separate sets of approach sight triangles should be provided: one set of approach sight triangles to accommodate right and left turns onto the major road and the other for crossing movements. Both sets of sight triangles should be checked for potential sight obstructions.
- *Crossing manoeuvres:* The lengths of the leg of the approach sight triangle along the minor road to accommodate the crossing manoeuvre from a Yield-controlled approach are as given

INTERSECTIONS: GEOMETRIC DESIGN

INTERSECTION SIGHT DISTANCE

- *Intersections with Yield control on the minor road:* drivers approaching yield signs are permitted to enter or cross the major road without stopping, if there are no potentially conflicting vehicles on the major road.
- Departure sight triangles as described for Stop control must be provided for the Yield condition if conflicting vehicles are present. The sight distances needed by drivers on Yield-controlled approaches exceed those for Stop-controlled approaches because of the longer travel time of the vehicle on the minor road.
- For four-legged intersections with Yield control on the minor road, two separate sets of approach sight triangles should be provided: one set of approach sight triangles to accommodate right and left turns onto the major road and the other for crossing movements. Both sets of sight triangles should be checked for potential sight obstructions.
- *Crossing manoeuvres:* The lengths of the leg of the approach sight triangle along the minor road to accommodate the crossing manoeuvre from a Yield-controlled approach are as shown in the following slide.
- The distances are based on the same assumptions as those for Case of no control except that, based on field observations, minor-road vehicles that do not stop are assumed to decelerate to 60 per cent of the minor-road design speed rather than to 50 per cent. The distances and times should be adjusted for the gradient of the minor road approach, using the factors. The length of the leg of the approach sight triangle along the major road to accommodate the crossing manoeuvre (distance "b“) should be calculated using the following equations:

INTERSECTIONS: GEOMETRIC DESIGN

INTERSECTION SIGHT DISTANCE

$$t_g = t_a + (w + L_a)/(0.167V_{minor});\ b = 0.278V_{major}t_c$$

where: t_g = travel time to reach and clear the major road in a crossing manoeuvre (sec)

b=length of leg of sight triangle along the major road (m)

t_a= travel time to reach the major road from the decision point for a vehicle that does not stop (sec) (use appropriate value for the minor road design speed from adjusted for approach grade, where appropriate)

W=width of intersection to be crossed (m)

L_a=length of design vehicle (m)

V_{minor}=design speed of minor road (km/h)

V_{major}=design speed of major road (km/h)

Design speed (km/h)	Distance along minor road (m)	Travel time from decision point to major road (t_a)[a,b]
30	30	3,4
40	40	3,7
50	50	4,1
60	65	4,7
70	85	5,3
80	110	6,1
90	140	6,8
100	165	7,3
110	190	7,8
120	230	8,6

a For minor-road approach gradients that exceed +3 per cent, multiply by the appropriate adjustment factor from Table 6.6.

b Travel time applies to a vehicle that slows before crossing the intersection but does not stop.

INTERSECTIONS: GEOMETRIC DESIGN

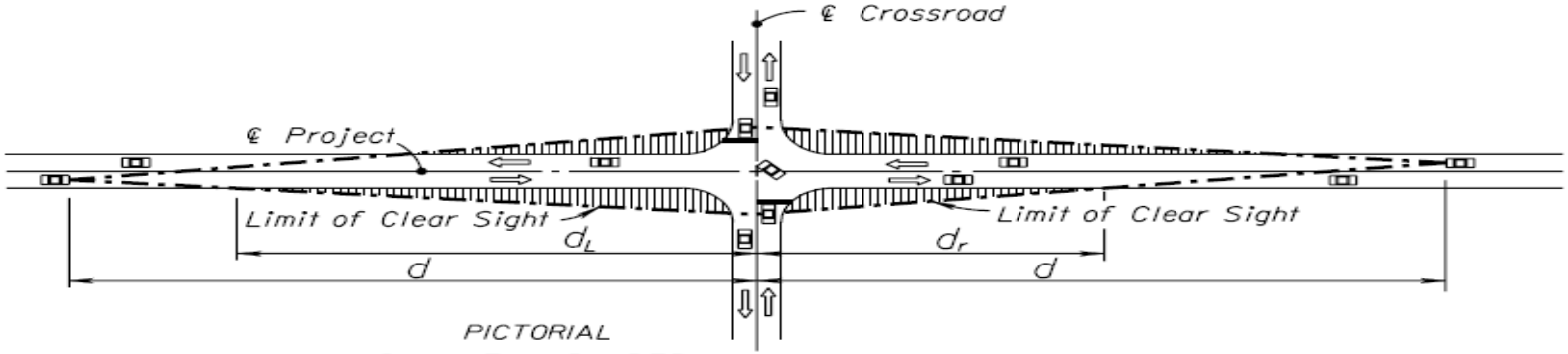
INTERSECTION SIGHT DISTANCE

- *Left and right-turn manoeuvres:* To accommodate left and right turns without stopping, the length of the leg of the approach sight triangle along the minor road should be 25 metres. This distance is based on the assumption that drivers making right or left turns without stopping will slow to a turning speed of 15 km/h.
- The length of the leg of the approach sight triangle along the major road is similar to that of the major-road leg of the departure sight triangle for Stop-controlled intersections. For a Yield-controlled intersection, the travel times for Stop-controlled intersections should be increased by 0,5 seconds.
- Departure sight triangle like those provided for stop-controlled approaches should also be for Yield-controlled approaches to accommodate minor-road vehicles that stop at the yield signs to avoid conflicts with the major-road traffic.
- *Intersections with traffic signal control:* In general, approach or departure sight triangles are not needed for signalised intersections. However, traffic signals may fail from time to time. Furthermore, traffic signals at an intersection are sometimes placed on two-way flashing operation under off-peak or night time conditions. To allow for either of these eventualities, the appropriate departure sight triangles for Yield-controlled intersections, both to the left and to the right, should be provided for the minor-road approaches.

INTERSECTIONS: GEOMETRIC DESIGN

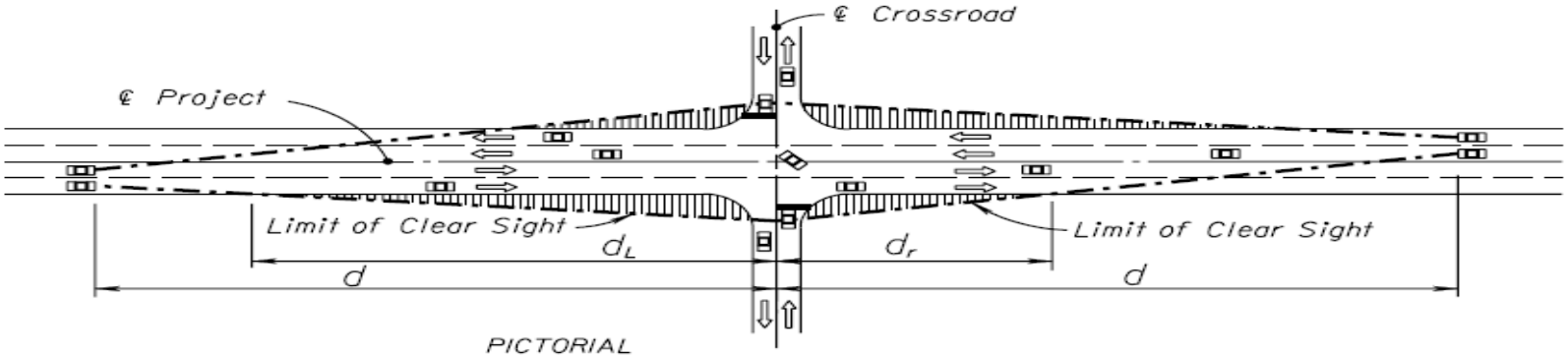
INTERSECTION SIGHT DISTANCE

- *Intersections with all-way Stop control:* At intersections with all-way Stop control, the first stopped vehicle on each approach would be visible to the drivers of the first stopped vehicles on each of the other approaches. It is thus not necessary to provide sight distance triangles at intersections with All-way Stop control. All-way Stop control may be an option to consider where the sight distance for other types of control cannot be achieved. This is particularly the case if signals are not warranted.
- *Effect of skew on sight distance:* The alignment of intersecting highways should be as close to 90 deg as possible. Significant deviation can increase the hazard and decrease the efficiency of the intersection as oblique angle intersections adversely affect sightline sight distance and turning movements. Therefore, sight distance calculations must be adjusted for oblique-angle intersections.
- Each of the sight triangles described are applicable to oblique-angle intersections (see the AASHTO Exhibit 9-69)



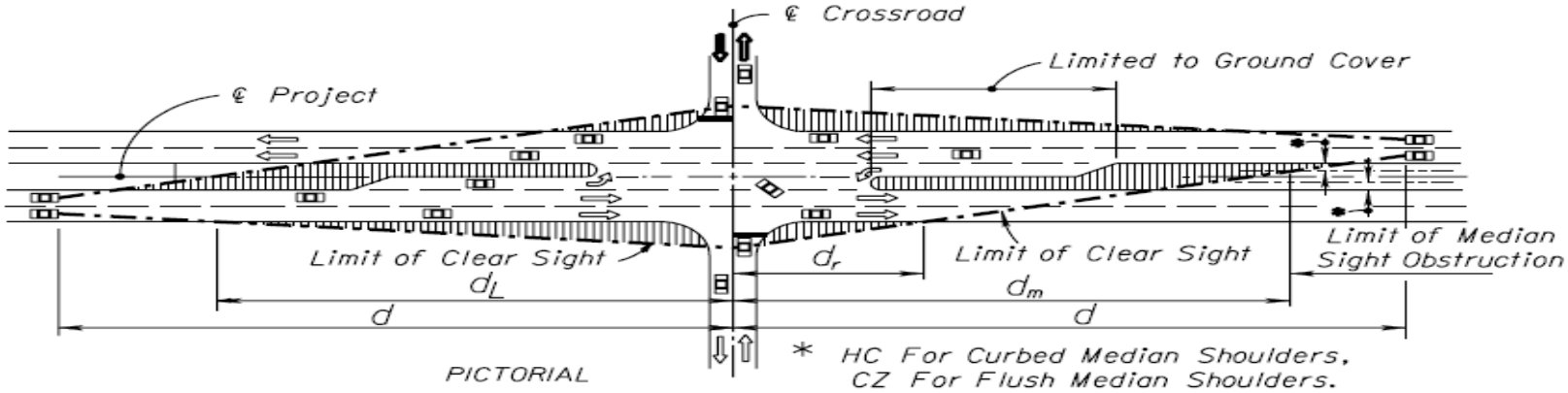
PICTORIAL

2 LANE UNDIVIDED



PICTORIAL

MULTILANE UNDIVIDED



* HC For Curbed Median Shoulders,
CZ For Flush Median Shoulders.

PICTORIAL

MULTILANE DIVIDED

LEGEND

Areas Free of Sight Obstructions

INTERSECTIONS: GEOMETRIC DESIGN

CHANNELIZATION

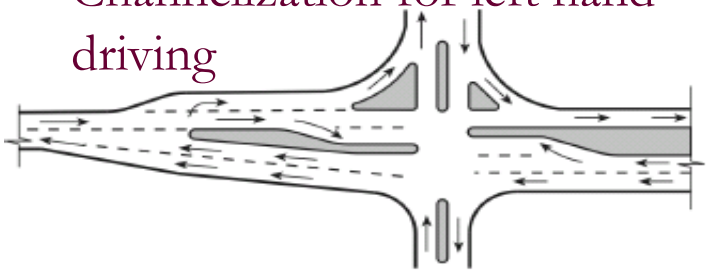
- Channelization is the separation or regulation of conflicting traffic movements into definite paths of travel by traffic islands or pavement markings to facilitate the orderly movement of both vehicles and pedestrians. Proper channelization increases capacity, provides maximum convenience, and instils driver confidence.
- Channelization of intersections is considered for one or more of the following factors:
  - To confine paths of vehicles
  - To control the angle and locations of merge, diverge or cross conflicts
  - Reduce paved area and thereby decrease vehicle wander and narrows the area of conflict
  - To indicate clearly for the proper paths of movements
  - To give priority for the predominant movement
  - To give area of refugee for pedestrians
  - To provide separate storage lanes for waiting vehicles to turn left
  - To provide space for installing traffic control devices where they can be clearly seen
  - To control prohibited turns
  - To restrict the speed of vehicles to some extent

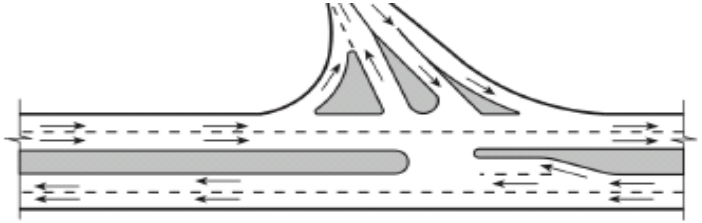
INTERSECTIONS: GEOMETRIC DESIGN

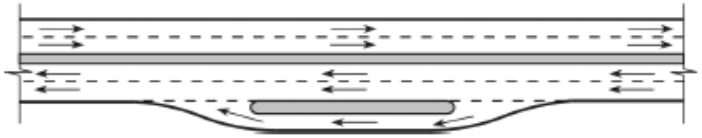
CHANNELIZATION

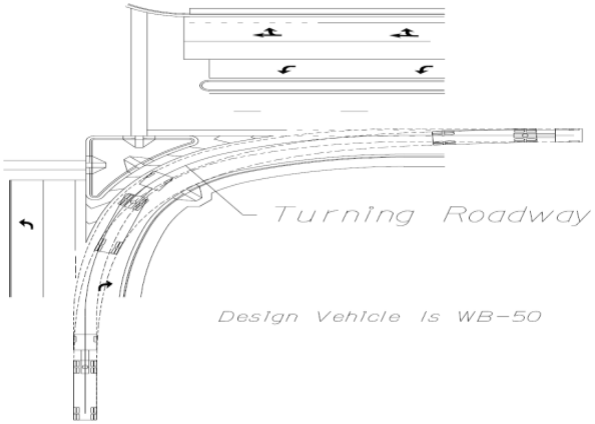
- The three main functions islands are:
  - channelization - to control and direct movements, usually turning;
  - Division - which can be of opposing or same direction, usually through, movements; and
  - Refuge - either of turning vehicles or of pedestrians.
- Channelizing islands: Islands are included in intersections for one or more of the following purposes:
  - Separation of conflicts;
  - Control of angle of conflict;
  - Reduction of excessive pavement areas;
  - Regulation of traffic and indication of the proper use of the intersection;
  - Arrangement to favour a predominant turning movement;
  - Protection of pedestrians;
  - Protection and storage of turning vehicles; and
  - Location of traffic control devices.
- Directional islands are typically triangular with their dimensions and exact shape being dictated by:
  - The corner radii and associated tapers;
  - The angle of skew of the intersection; and
  - The turning path of the design vehicle.

Channelization for left hand driving









INTERSECTIONS: GEOMETRIC DESIGN

CHANNELIZATION

- Auxiliary lanes are used at intersections preceding median openings for left-turning movements and preceding and following right-turning movements. The function of auxiliary lanes at intersections is to accommodate speed changes and manoeuvring of turning traffic. They may also be added to increase capacity through an intersection.
- The length of the auxiliary lanes consists of three components:
  - (1) deceleration length,
  - (2) storage length and
  - (3) entering taper
- Deceleration Length: The required total deceleration length is that needed for a safe and comfortable stop from the design speed of the highway.
- Storage (Queue) Length: The auxiliary lane should be sufficiently long to store the number of vehicles likely to accumulate during a critical period. The storage length should be sufficient to avoid the possibilities of turning vehicles stopping in the through lanes or the entrance to the auxiliary lane being blocked by vehicles queuing in the through lanes.
- Taper: on high speed roads it is common practice to use a taper rate that is between 8:1 and 15:1 (longitudinal :transverse).

INTERSECTIONS: GEOMETRIC DESIGN

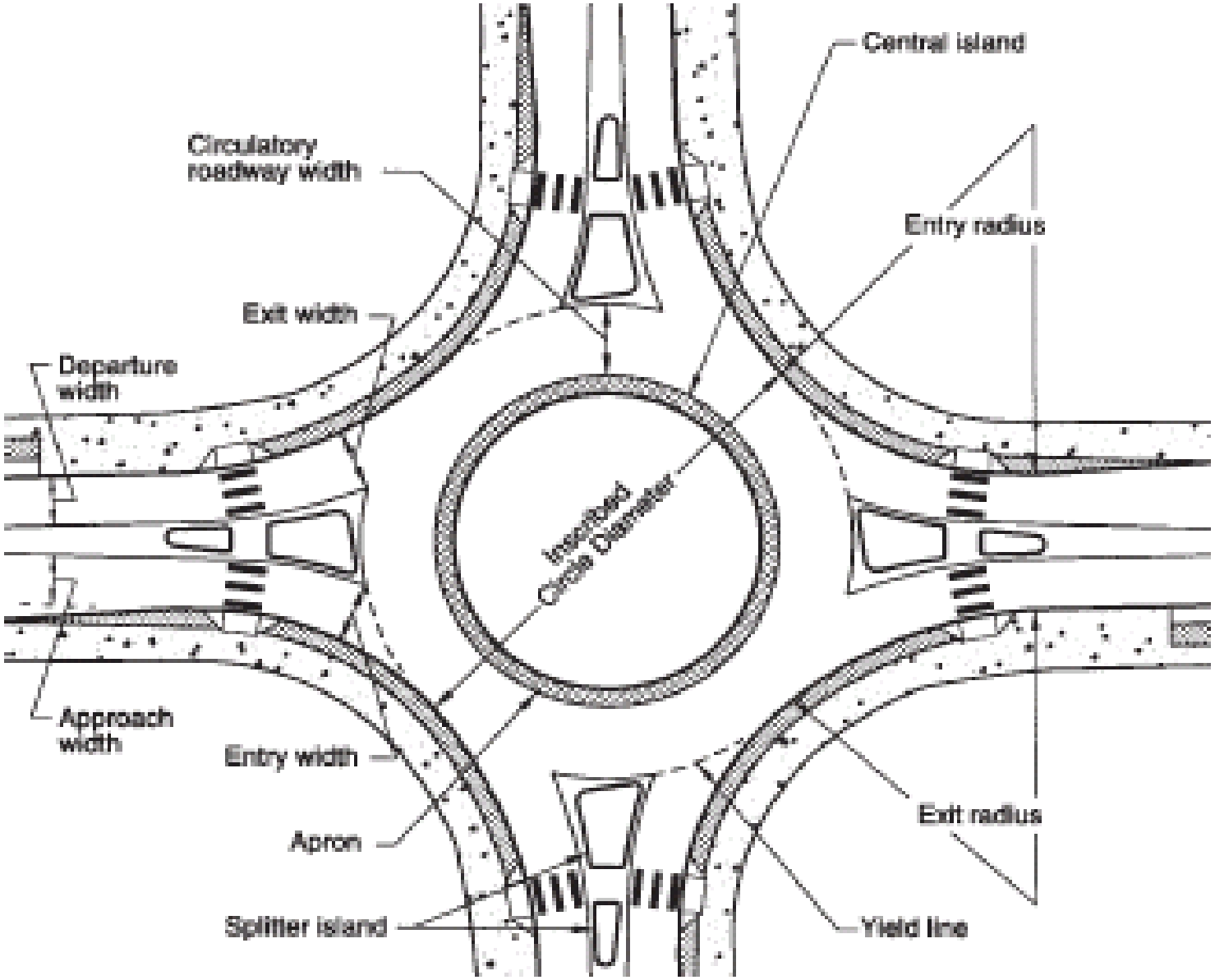
Control	Primary arterial	Secondary arterial	Collector road	local street
Traffic signals				
Primary arterial	A	A	O	X
Secondary arterial		A	O	X
Collector road			X	X
local street				X
Roundabouts				
Primary arterial	O	O	X	X
Secondary arterial		O	O	X
Collector road			A	O
local street				A
STOP OR GIVE WAY signs				
Primary arterial	X		A	A
Secondary arterial			A	A
Collector road			A	A
local street				A

Legend:

A Most likely to be an appropriate treatment
O May be an appropriate treatment
X Usually an appropriate treatment

INTERSECTIONS: GEOMETRIC DESIGN

ROUNDABOUTS



INTERSECTIONS: GEOMETRIC DESIGN

ROUNDABOUTS

- Circular intersections were first introduced in the ***U.S. in 1905***. The prevailing designs enabled high-speed merging and weaving of vehicles. ***Priority was given to entering vehicles, facilitating high-speed entries***. *High crash experience and congestion in the circles led to rotaries falling out of favour in America after the mid-1950's*. Internationally, the experience with traffic circles was *equally negative, with many countries experiencing circles that locked up as traffic volumes increased*.
- In 1966, the United Kingdom adopted a mandatory "***give-way***" rule at all circular intersections, which required entering traffic to give way, or yield, to circulating traffic. *This rule prevented circular intersections from locking up, by not allowing vehicles to enter the intersection until there were sufficient gaps in circulating traffic*.

INTERSECTIONS: GEOMETRIC DESIGN

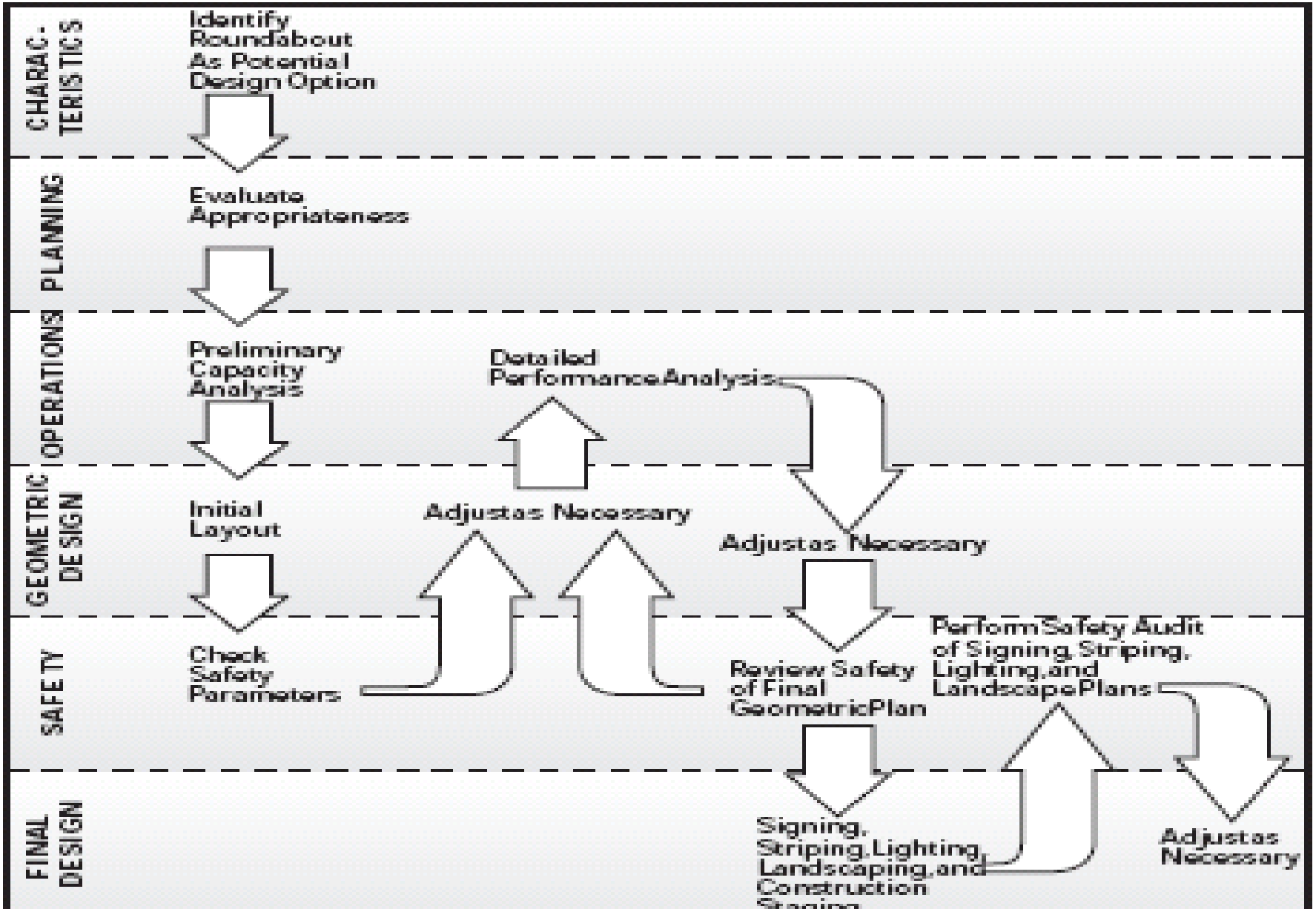
ROUNDABOUTS

- Modern roundabouts provide substantially better operational and safety characteristics than older traffic circles and rotaries. Therefore, many countries have adopted them as a common intersection form and some have developed extensive design guides and methods to evaluate the operational performance of modern roundabouts.
- Roundabouts operate ***most safely when their geometry forces traffic to enter and circulate at slow speeds***. Horizontal curvature and narrow pavement widths are used to produce this reduced-speed environment. Conversely, the capacity of roundabouts is negatively affected by these low-speed design elements. Thus, designing a roundabout is a process of determining the optimal balance between safety provisions, and operational performance accommodation.

INTERSECTIONS: GEOMETRIC DESIGN

ROUNDABOUTS

- Roundabout design is an iterative process.



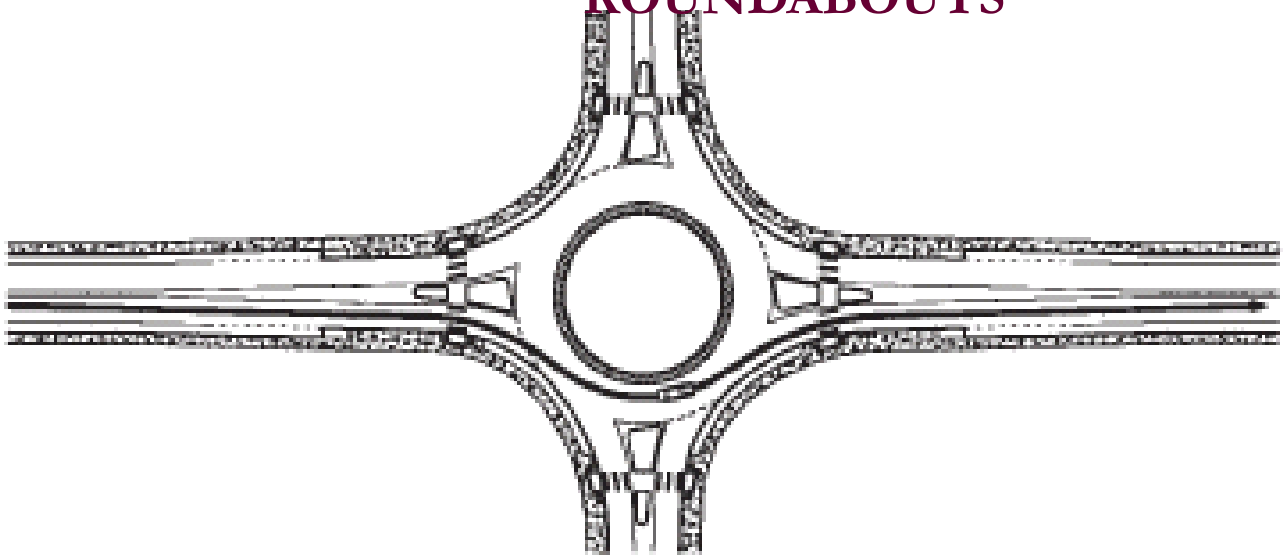
INTERSECTIONS: GEOMETRIC DESIGN

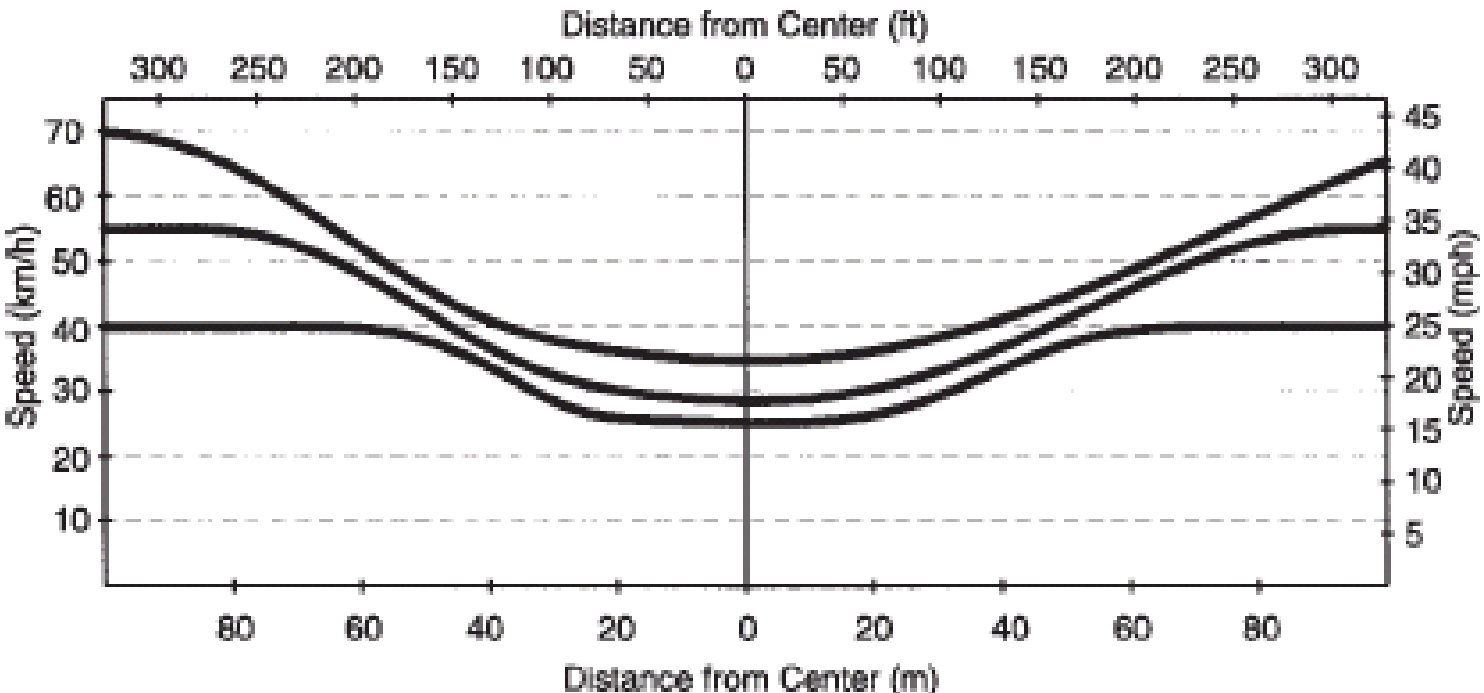
ROUNDABOUTS

- Before the details of the geometry are defined, ***three fundamental elements*** must be determined in the preliminary design stage:
  - The optimal roundabout size;
  - The optimal position; and
  - The optimal alignment and arrangement of approach legs.
- Design speed: Because it has profound impacts on safety, achieving appropriate vehicular speeds through the roundabout is the most critical design objective.
- A well-designed roundabout reduces the relative speeds between conflicting traffic streams by requiring vehicles to negotiate the roundabout along a curved path.

INTERSECTIONS: GEOMETRIC DESIGN

ROUNDABOUTS





INTERSECTIONS: GEOMETRIC DESIGN

ROUNDABOUTS

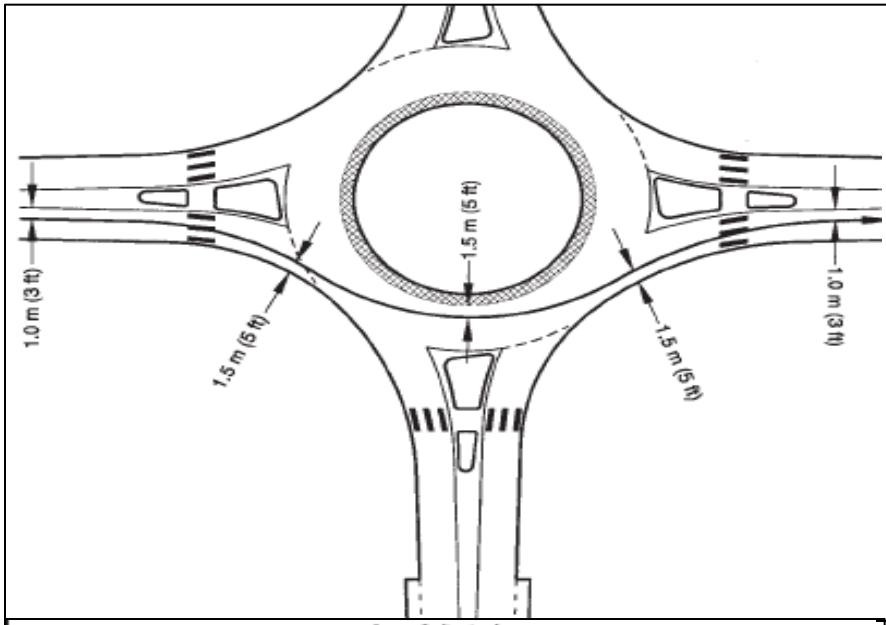
- International studies have shown that increasing the vehicle path curvature decreases the relative speed between entering and circulating vehicles and ***thus usually results in decreases in the entering-circulating and exiting-circulating vehicle crash rates***.
- However, increasing vehicle path curvature creates greater side friction between adjacent traffic streams and result in more vehicles cutting across lanes and higher potential for ***sideswipe crashes at multilane roundabouts***. Thus, for each roundabout, there exists an optimum design speed to minimize crashes.

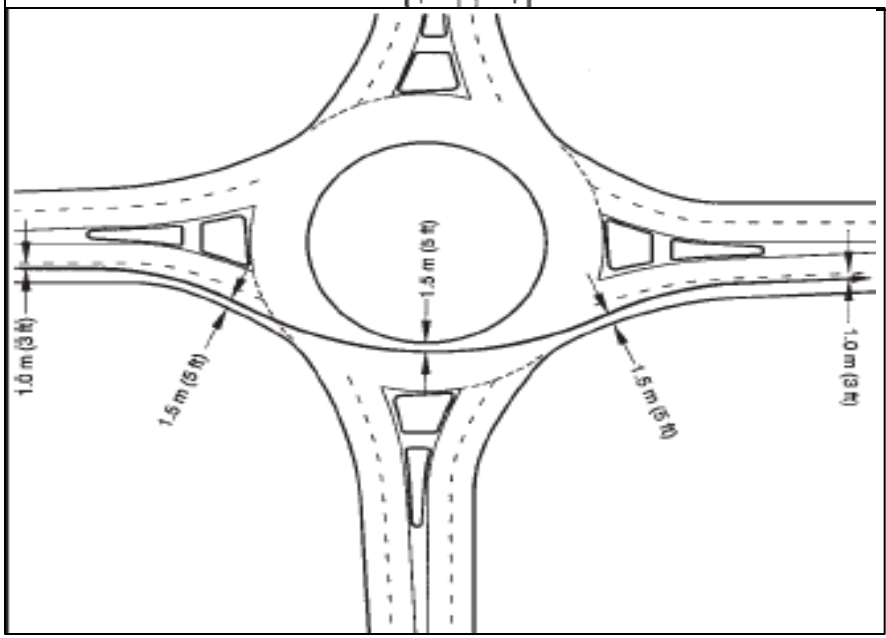
Site Category	Recommended Maximum Entry Design Speed
Mini-Roundabout	25 km/h (15 mph)
Urban Compact	25 km/h (15 mph)
Urban Single Lane	35 km/h (20 mph)
Urban Double Lane	40 km/h (25 mph)
Rural Single Lane	40 km/h (25 mph)
Rural Double Lane	50 km/h (30 mph)

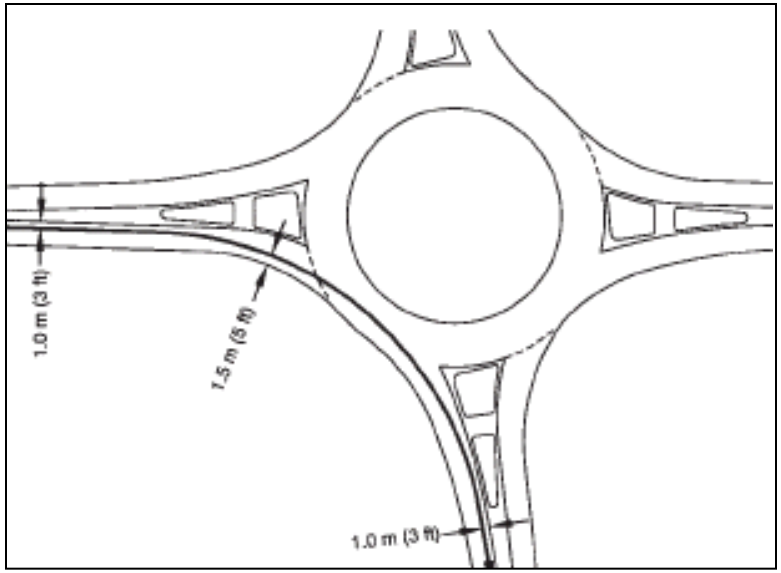
INTERSECTIONS: GEOMETRIC DESIGN

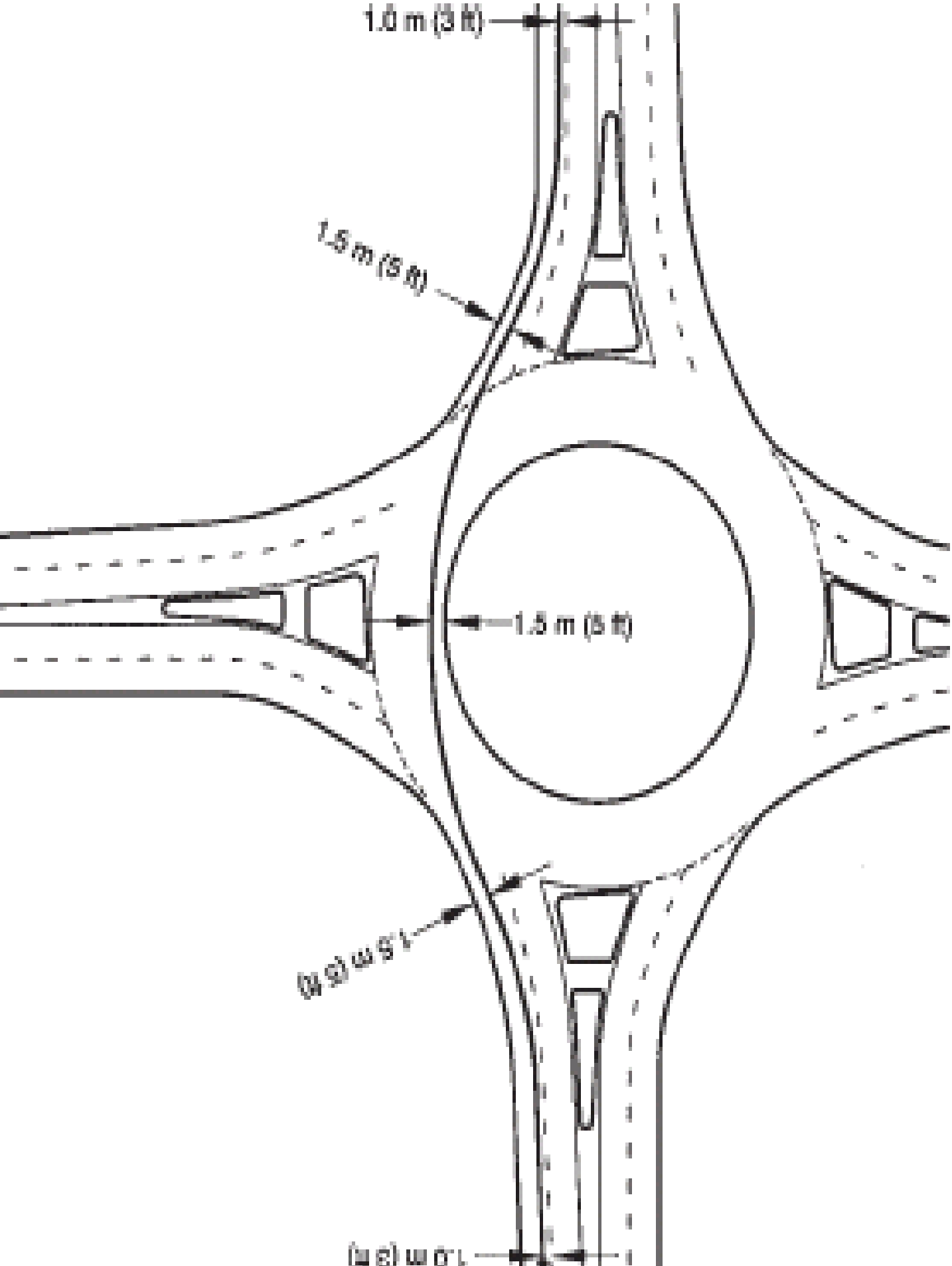
ROUNDABOUTS

- Roundabout speed is determined by the fastest path drawn with the following distances to the particular geometric features:
  - 1.5 m (5 ft) from a concrete curb,
  - 1.5 m (5 ft) from a roadway centreline, and
  - 1.0 m (3 ft) from a painted edge line.
- Through movements are usually the fastest path, but sometimes right turn paths are more critical.








1.0 m (3 ft)
1.5 m (5 ft)
1.5 m (5 ft)
1.5 m (5 ft)
1.0 m (3 ft)

INTERSECTIONS: GEOMETRIC DESIGN

ROUNDABOUTS

- As shown on the previous slide, the fastest path for the through movement is a series of reverse curves (i.e., a curve to the right, followed by a curve to the left, followed by a curve to the right).
- The design speed of the roundabout is determined from the smallest radius along the fastest allowable path. The smallest radius usually occurs on the circulatory roadway as the vehicle curves to the left around the central island.
- However, it is important when designing the roundabout geometry that the radius of the entry path (i.e., as the vehicle curves to the right through entry geometry) not be significantly larger than the circulatory path radius.
- The speed-curve relationship holds

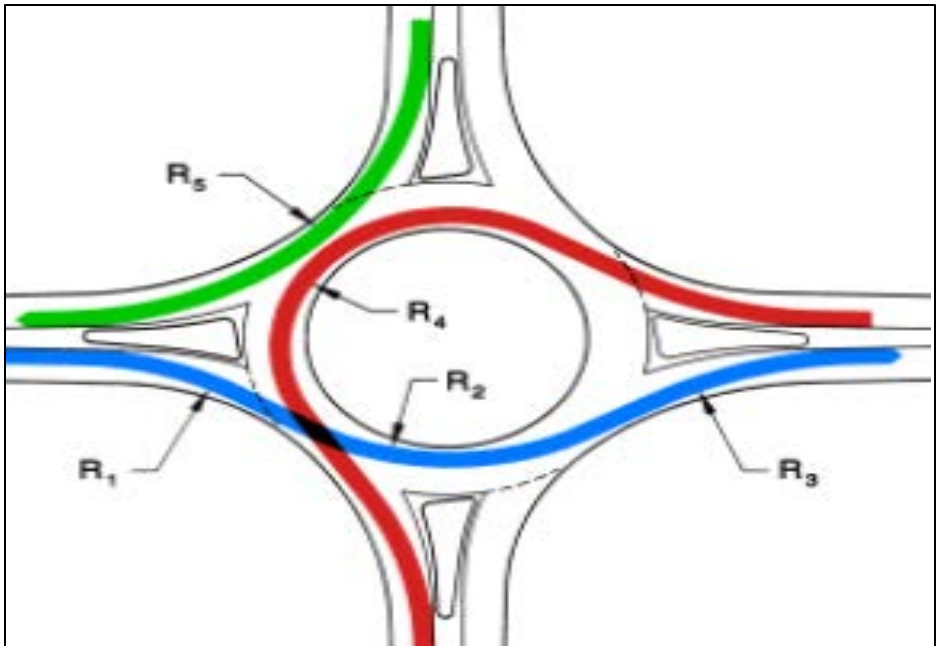
$$R = \frac{V^2}{127(e + f)}$$

  The value of e is usually 0.02 at the entry and exit curves as well as around the central island.
- In addition to achieving an appropriate speed reduction, another important objective in roundabout design is to achieve consistent speeds for all movements. This objective has the following implications:
  - The relative speeds between consecutive geometric elements should be minimized; and
  - The relative speeds between conflicting traffic streams should be minimized.

INTERSECTIONS: GEOMETRIC DESIGN

ROUNDABOUTS

- As shown in the figure below, five critical path radii must be checked for each approach.
  - R1 , the entry path radius, is the minimum radius on the fastest through path prior to the yield line.
  - R2 , the circulating path radius, is the minimum radius on the fastest through path around the central island.
  - R3 , the exit path radius, is the minimum radius on the fastest through path into the exit.
  - R4 , the left-turn path radius, is the minimum radius on the path of the conflicting left-turn movement.
  - R5 , the right-turn path radius, is the minimum radius on the fastest path of a right-turning vehicle.



INTERSECTIONS: GEOMETRIC DESIGN

ROUNDABOUTS

- On the fastest path, it is desirable for R1 < R2 < R3 . This ensures that speeds will be reduced to their lowest level at the roundabout entry and will thereby reduce the likelihood of loss-of-control crashes.
- It also helps to reduce the speed differential between entering and circulating traffic, thereby reducing the entering-circulating vehicle crash rate.
- At sites where it may not be possible to achieve an R1 value less than R2 due to right-of-way or topographic constraints, it is acceptable for R1 to be greater than R2 , provided the relative difference in speeds is less than 20 km/h (12 mph) and preferably less than 10 km/h (6 mph).
- At single-lane roundabouts, it is relatively simple to reduce the value of R1 . However, at double-lane roundabouts, this can cause the natural path of adjacent traffic streams to overlap. When path overlap occurs, i***t may reduce capacity and increase crash risk***. Therefore, care must be taken when designing double-lane roundabouts to achieve ***ideal values for R1 , R2, and R3*** .
- At single-lane roundabouts *with pedestrian activity, exit radii may still be small* (the same or slightly larger than R2) in order to minimize exit speeds. However, at *double-lane roundabouts, additional care must be taken to minimize the likelihood of exiting path overlap*.

INTERSECTIONS: GEOMETRIC DESIGN

ROUNDABOUTS

- Where no pedestrians are expected, the exit radii should be just large enough to minimize the likelihood of exiting path overlap. Where pedestrians are present, tighter exit curvature may be necessary to ensure sufficiently *low speeds at the downstream pedestrian crossing*.
- The radius of the conflicting left-turn movement, R4 , must be evaluated in order to ensure that the maximum speed differential between entering and circulating traffic is no more than 20 km/h (12 mph).

- The left-turn movement is the critical traffic stream because it has the lowest circulating speed. Large differentials between entry and circulating speeds may result in an increase in single-vehicle crashes due to loss of control.
- Generally, R4 can be determined by adding 1.5 m (5 ft) to the central island radius. Based on this assumption, the table on the right sides have approximate R4 values circle diameters.

	Approximate R_4 Value		Maximum R_1 Value	
Inscribed Circle Diameter (m)	Radius (m)	Speed (km/h)	Radius (m)	Speed (km/h)
Single-Lane Roundabout				
30	11	21	54	41
35	13	23	61	43
40	16	25	69	45
45	19	26	73	46
Double-Lane Roundabout				
45	15	24	65	44
50	17	25	69	45
55	20	27	78	47
60	23	28	83	48
65	25	29	88	49
70	28	30	93	50

GRADE SEPARATIONS AND INTERCHANGES

- Grade separations ***without ramps*** may be constructed because of
  - Insignificant traffic demand or when major arterials intersecting existing highway must be kept open for access but carry only low traffic volume;
  - When sufficient traffic demand exist; to avoid having interchanges so close, to eliminate interference with large highway traffic volumes, and to increase safety and mobility.
  - The topography of the site may be more favourable for grade separation than at-grade intersection, and ramp connection could be difficult and expensive.

INTERCHANGES

- There are several basic interchange configurations to accommodate turning movements and the choice depends on: *the number of intersecting roads, expected volume of through and turning traffic, type of truck traffic, topography, culture, design controls, and proper signing.*
- Signing and operations are major considerations in the design of the interchanges. The need to simplify interchange design from the standpoint of signing and driver understanding cannot be overstated.
- Usually several alternatives are prepared and compared on the following principles***: capacity, route continuity, exit patterns, with or without weaving, potential for signing, availability of right-of-way, potential for stage construction, and compatibility with the environment***.

GRADE SEPARATIONS AND INTERCHANGES

- **Three-Leg Designs**: Three-leg interchanges should only be considered when future *expansion to the unused quadrant is either impossible or modify* in the future. Three-leg interchanges
  - Trumpet pattern (Exhibit 10-9 a and b)
  - Three-leg single-structure interchange for both turning movements.
  - High type interchanges with more than one structure

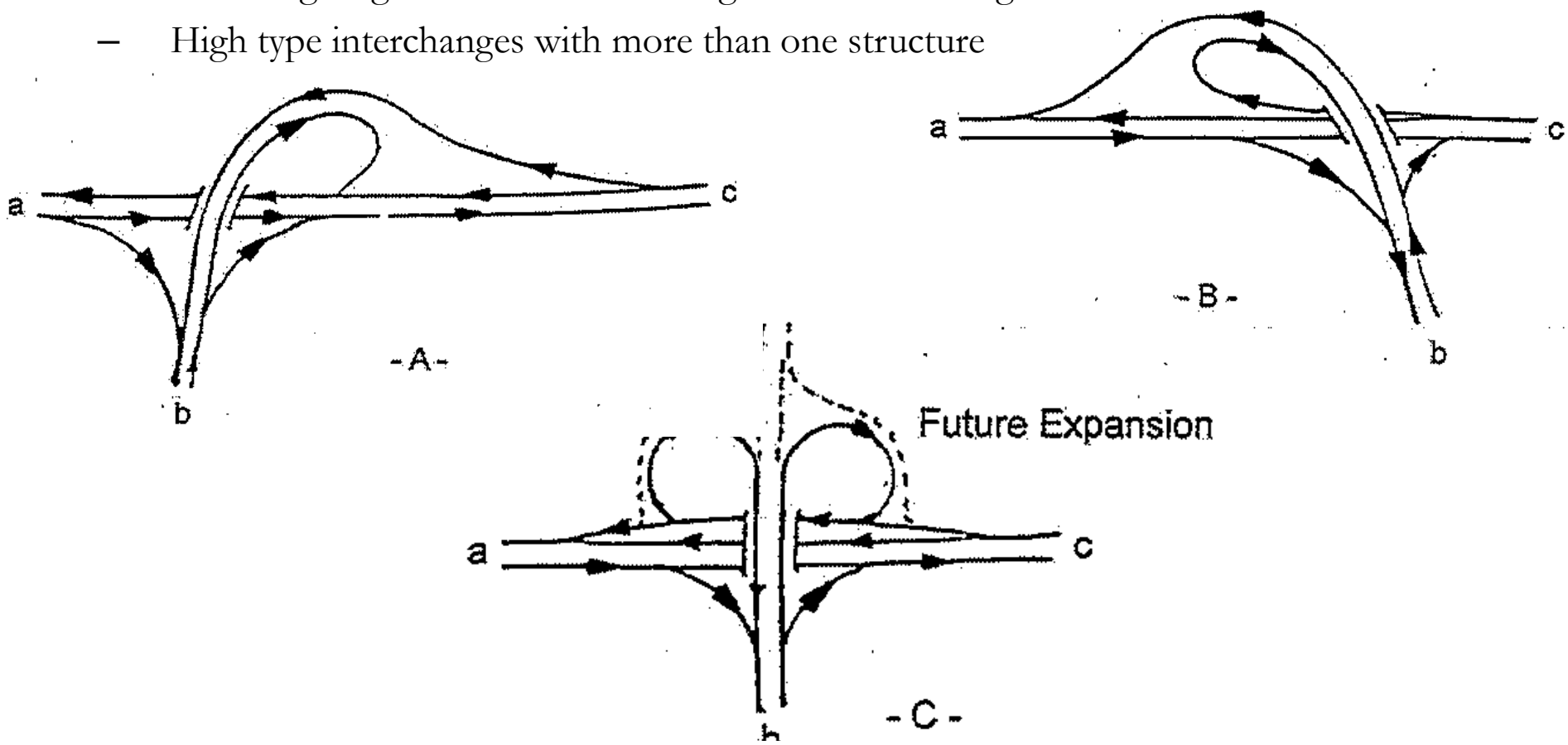
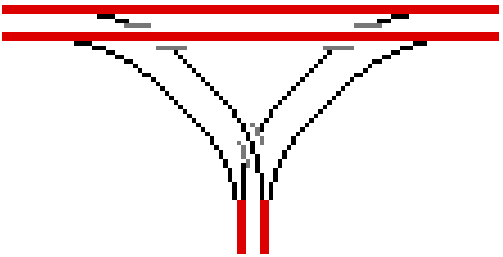
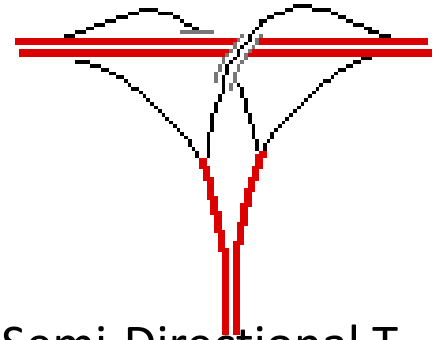


Exhibit 10-9. Three-Leg Interchanges with Single Structures

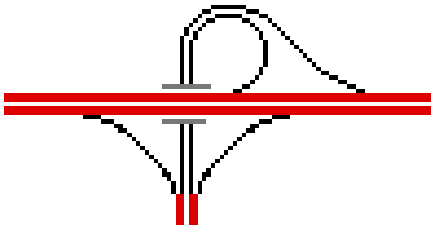
GRADE SEPARATIONS AND INTERCHANGES



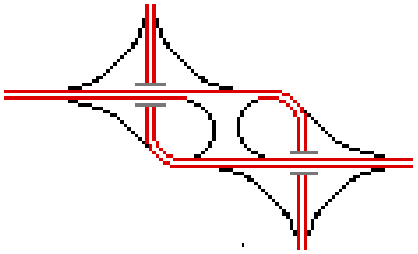
Directional T



Semi-Directional T



Trumpets



Fused Trumpet

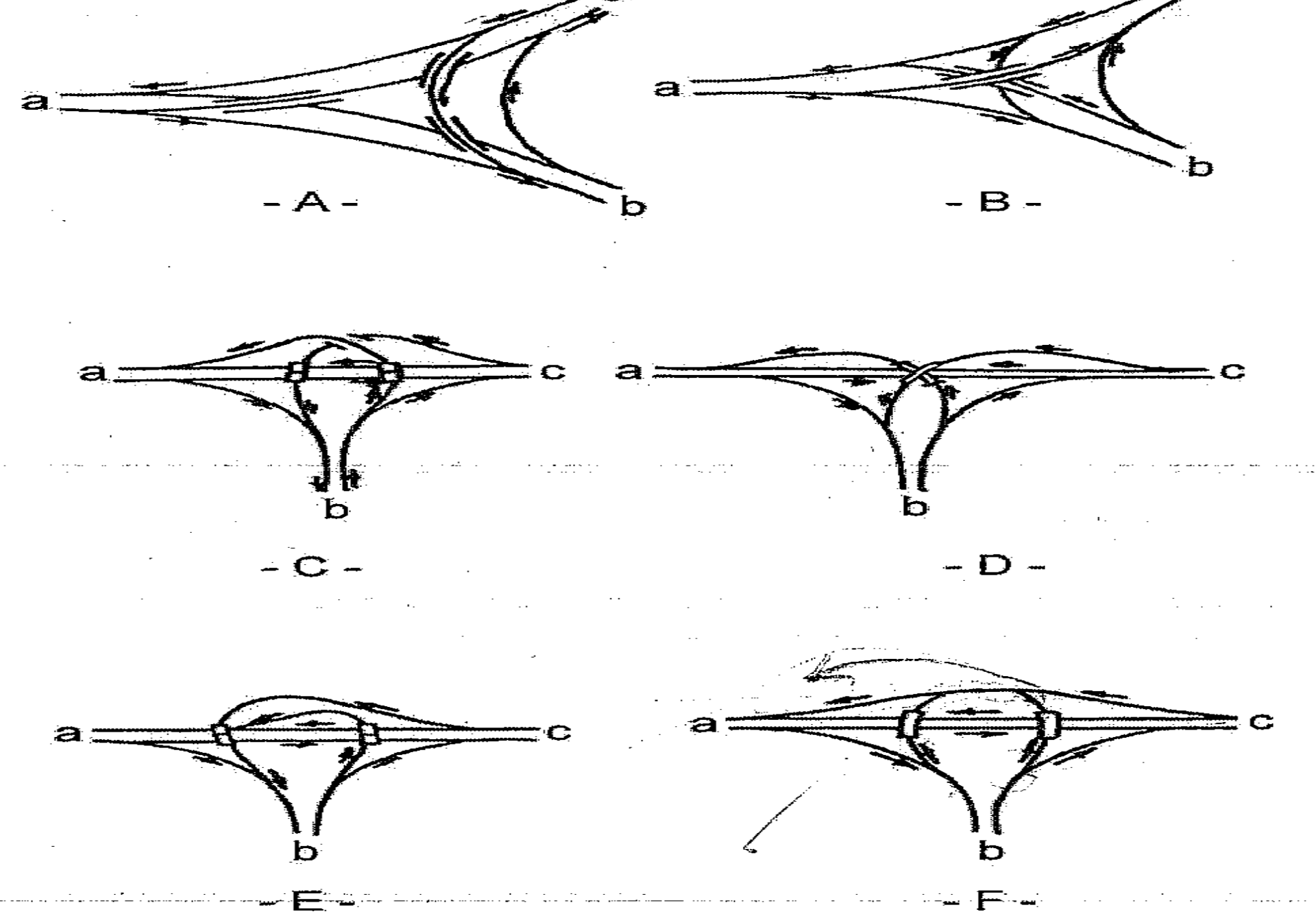


Exhibit 10-10. Three-Leg Interchanges with Multiple Structures

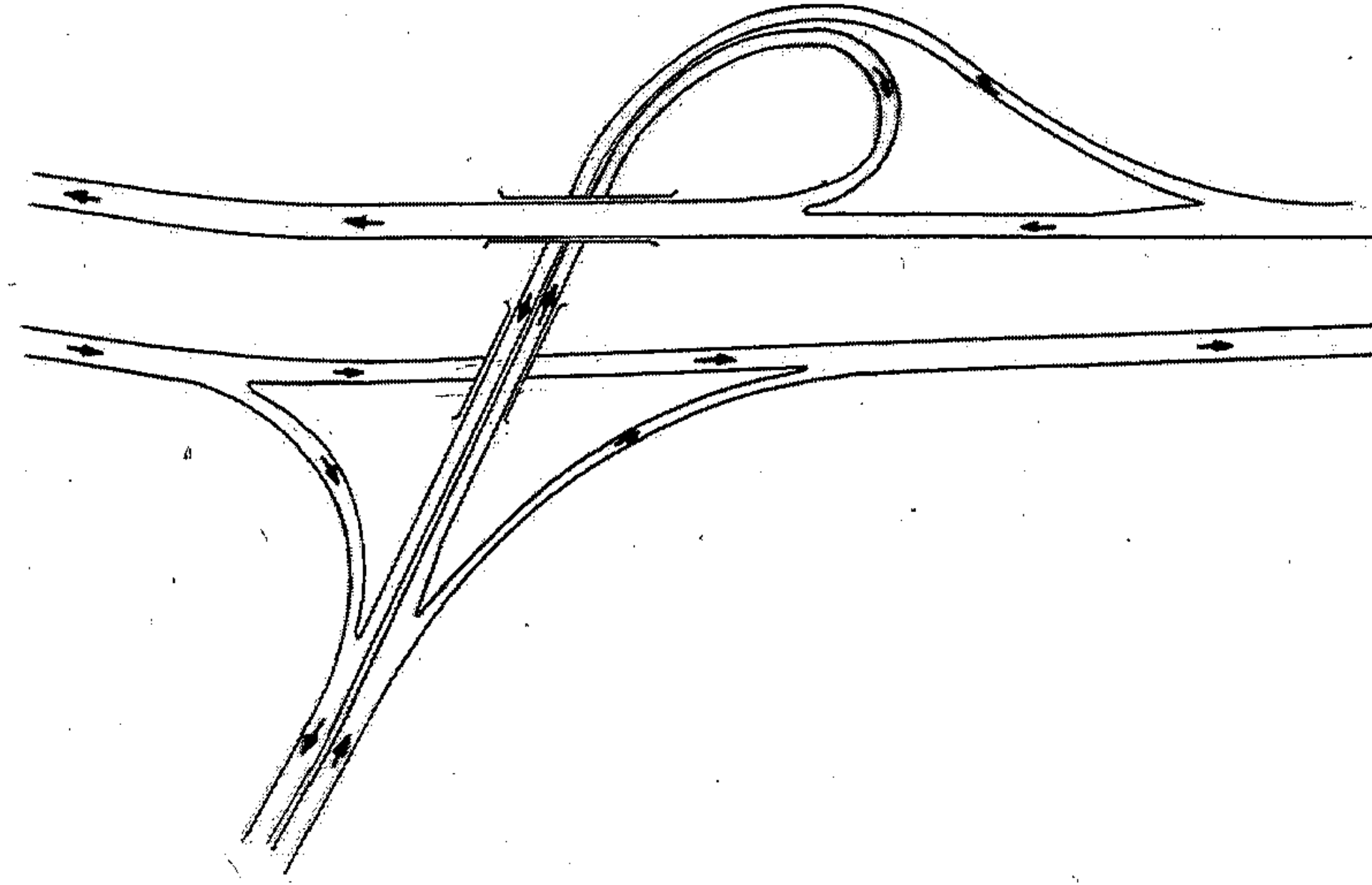


Exhibit 10-11. Three-Leg Interchange (T-Type or Trumpet

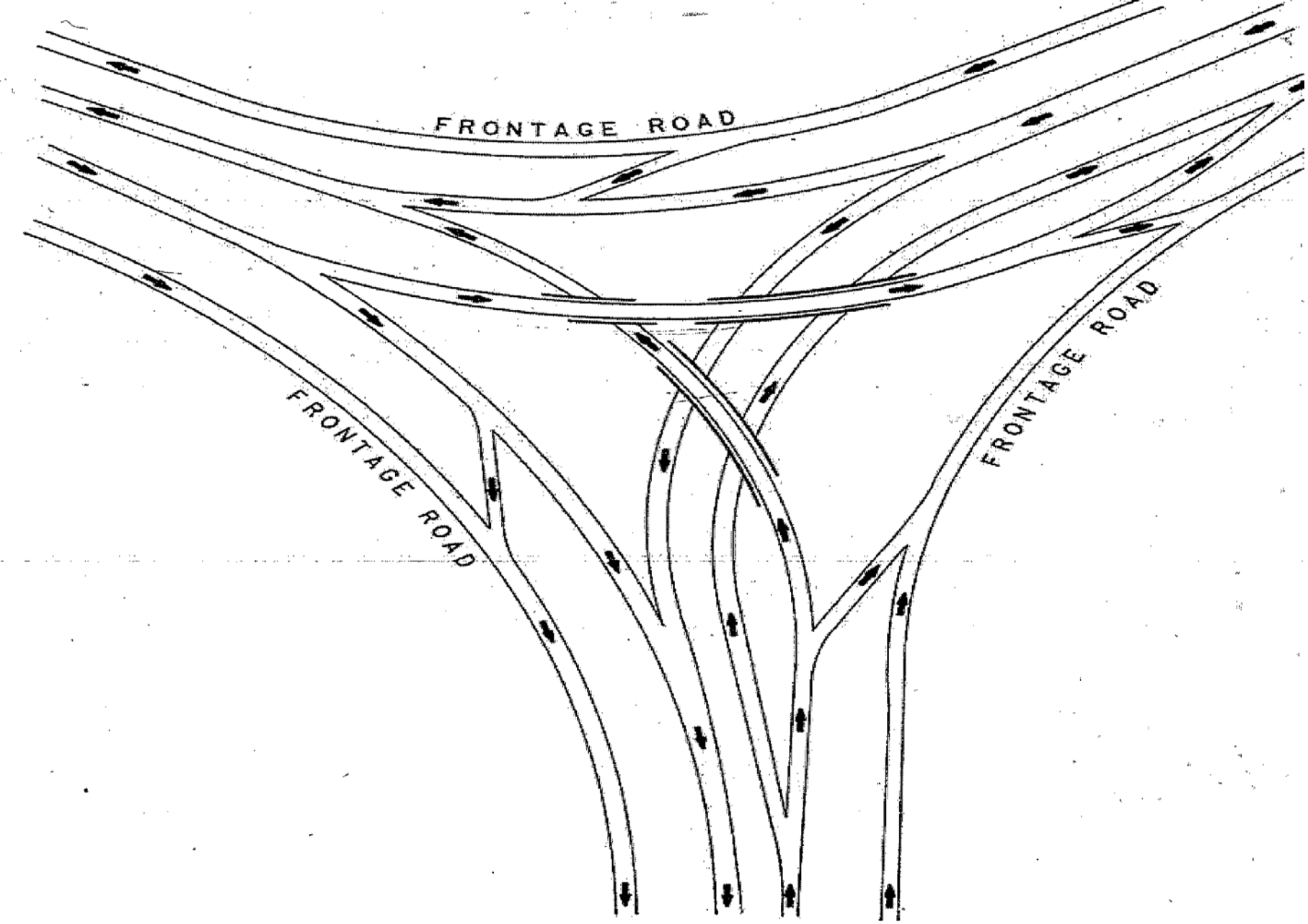


Exhibit 10-12. Three-Leg Interchange Semidirectional Design

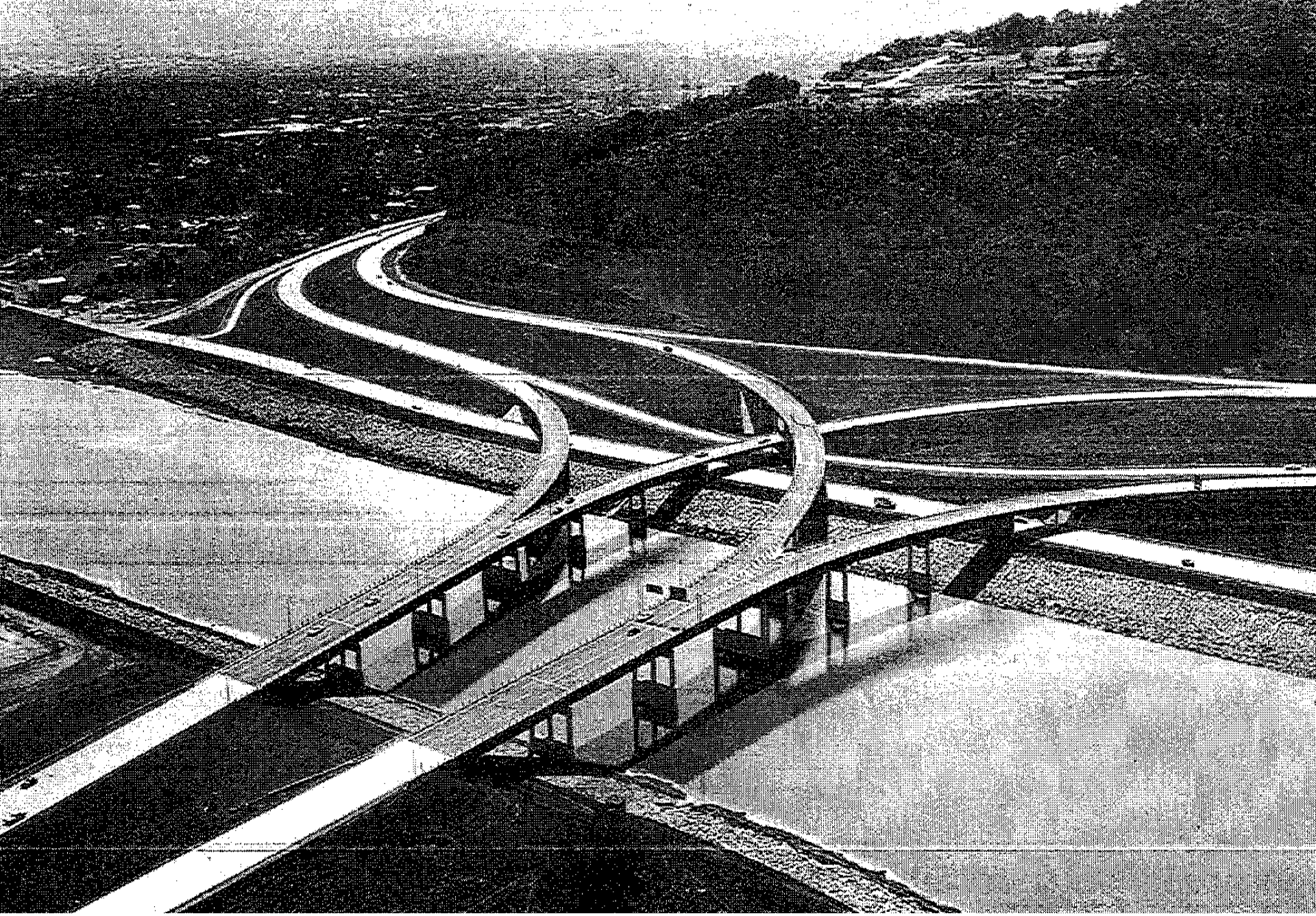
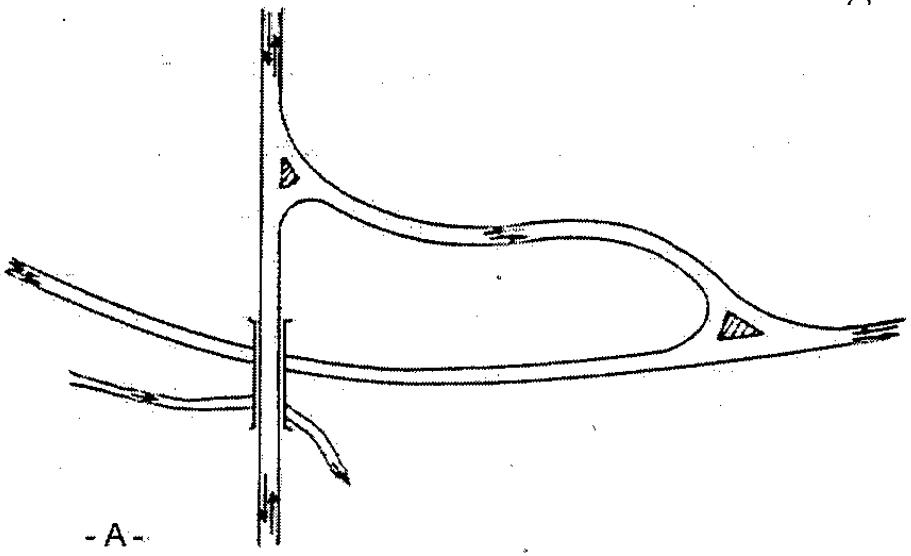


Exhibit 10-13. Directional Three-Leg Interchange of a River Crossing

GRADE SEPARATIONS AND INTERCHANGES

- **Four-leg interchanges :-**
  - Ramps in one quadrant
  - Diamond interchanges
  - Single point urban interchanges
  - Full or partial cloverleaf's
  - Interchanges with direct and semi-direct connections
- ***Ramps in one quadrant***: have application for an intersection of roadways with low traffic volumes. Also can be used in a stage construction.



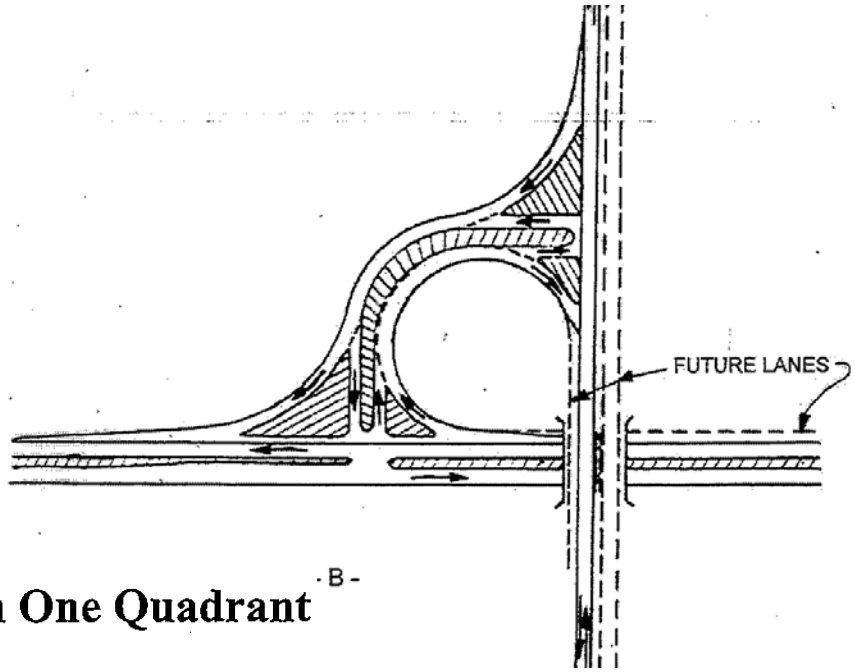
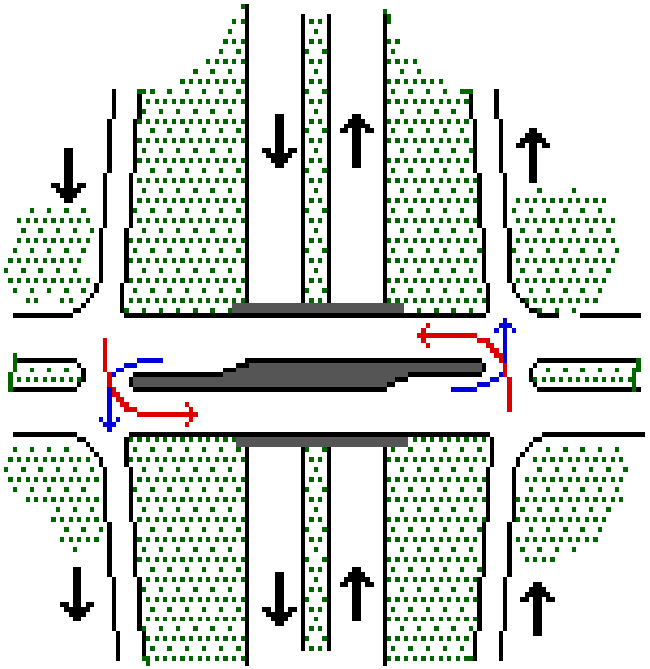


Exhibit 10-15. Four-Leg Interchanges, Ramps in One Quadrant

GRADE SEPARATIONS AND INTERCHANGES

- ***Diamond Interchange***: It is the simplest and perhaps most common interchange configuration. A full diamond interchange is formed when a one-way diagonal ramp is provided in each quadrant.
- It is applicable in both rural and urban areas, and they are particularly adaptable to major crossings where left turns at grade on the minor roads are fitting and can be handled with minimal interference to traffic approaching the intersection from either direction.



Diamond interchange.

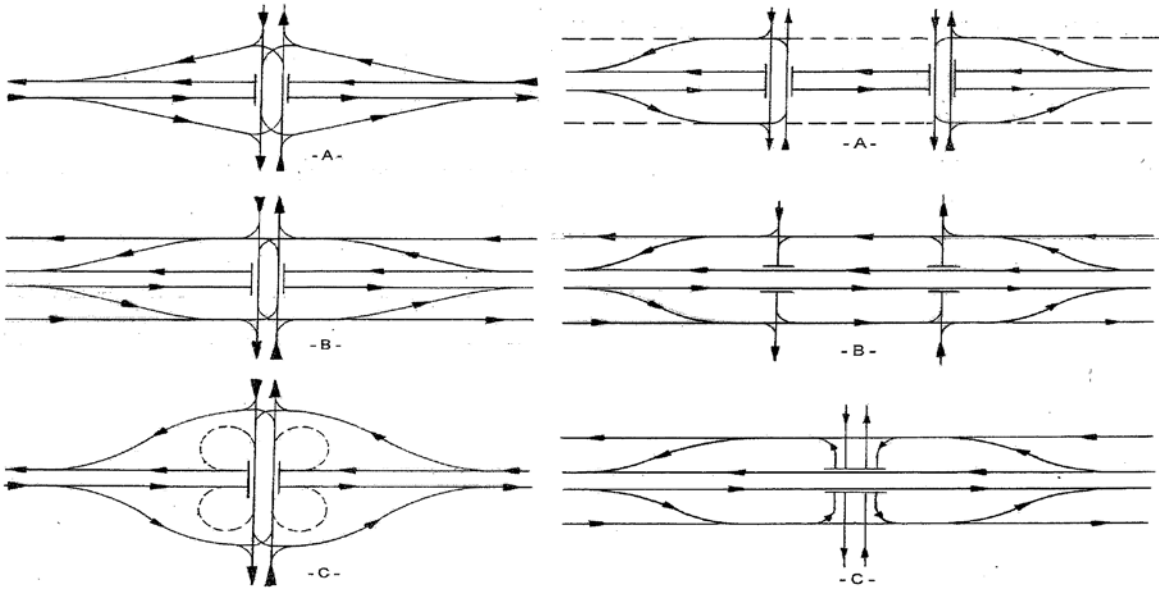


Exhibit 10-16 & 10-17: Diamond Interchanges, conventional arrangements and Arrangements to reduce traffic conflicts respectively

GRADE SEPARATIONS AND INTERCHANGES

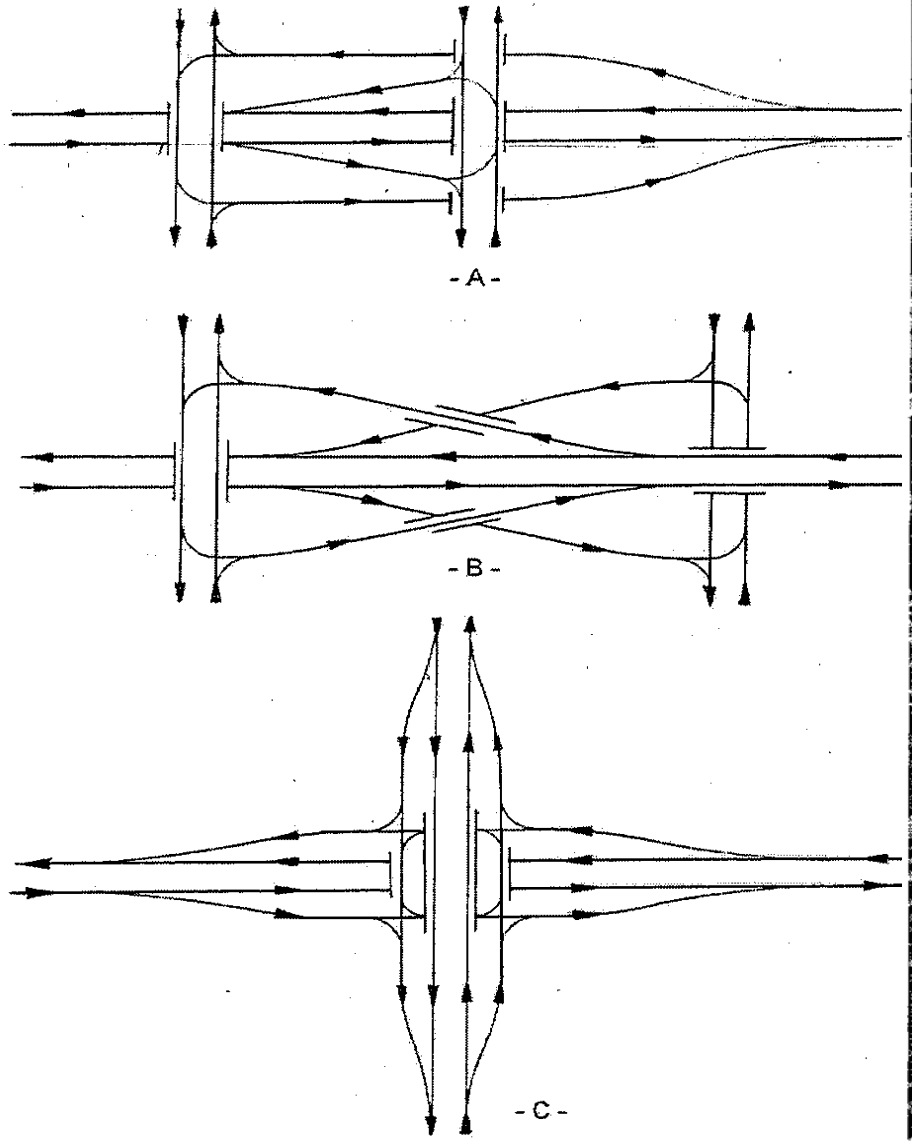


Exhibit 10-18. Diamond Interchanges with Additional Structures

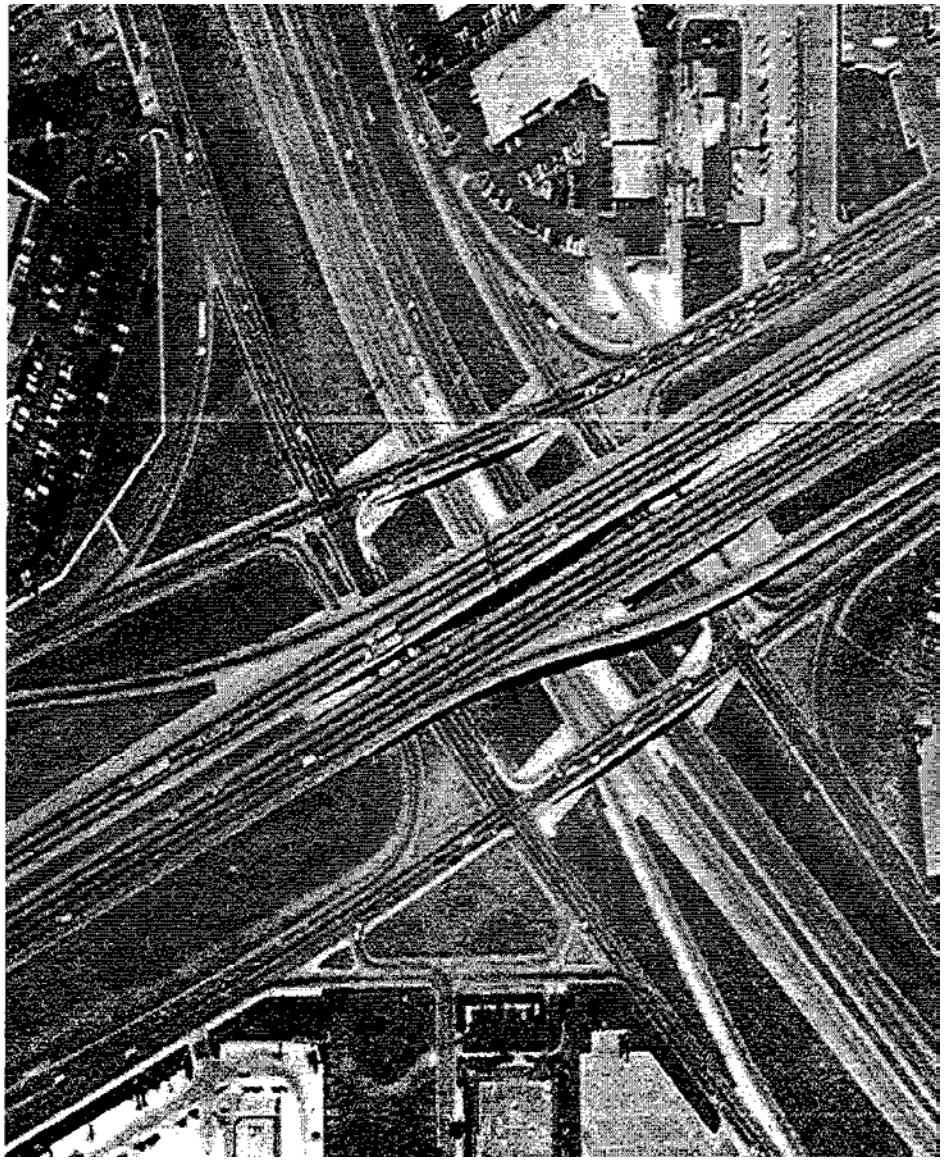


Exhibit 10-19. Freeway with a Three-Level Diamond Interchange

GRADE SEPARATIONS AND INTERCHANGES

- It may be beneficial to consider the use of "X" pattern ramps at diamond interchanges in urban areas. ➔ can improve traffic flow characteristics for the through roadways around diamond interchanges.

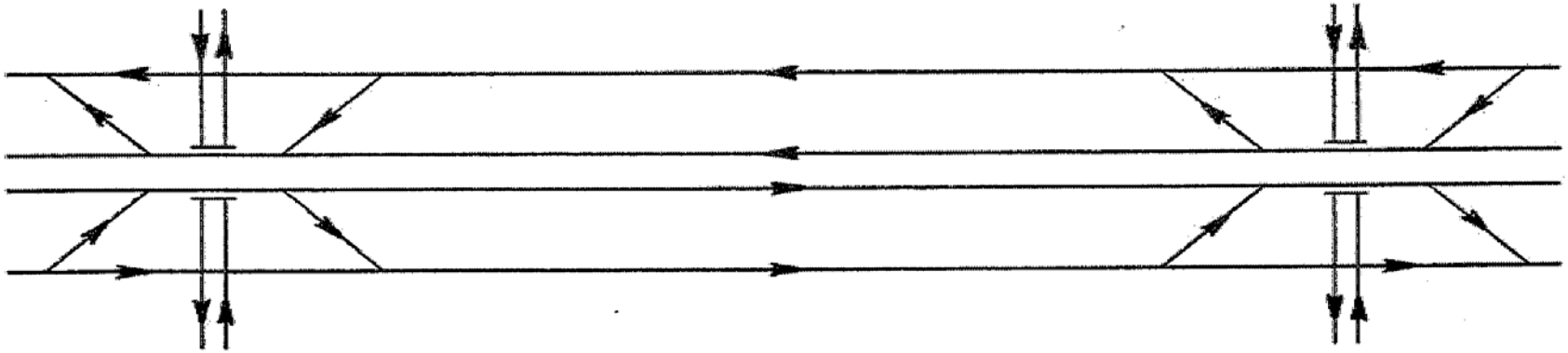
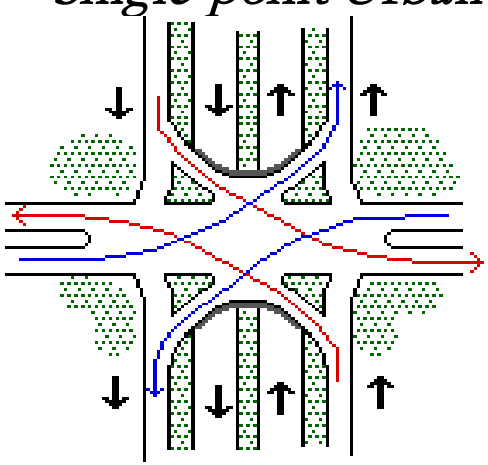


Exhibit 10-21. X-Pattern Ramp Arrangement

- ***Single-point Urban Interchanges***:



Single-point Urban Interchange

The single-point urban interchange (SPUI) is a relatively recent development in interchange design with the first SPUIs being constructed in the early 1970s.

•Is also known as urban interchange or a single-point diamond interchange

• all four turning moves are controlled by a single traffic signal and opposing left turns operate to the left of each other

• SPUIs are typically characterized by narrow right-of-way, high construction costs, and greater capacity than conventional tight diamond interchanges. ➔ can be constructed with or w/o frontage road

GRADE SEPARATIONS AND INTERCHANGES

- SPUIs reduce traffic signal needed from four-phase to three-phase
- Curve radii for left-turn movement through the intersection are significantly flatter than at conventional intersections and, therefore, the left turns move at higher speed. ➔ which result in ***higher capacity*** than a conventional tight diamond interchange.
- The ***primary disadvantage of SPUIs is high construction costs associated with bridges.*** ➔ overpass SPUIs need long bridges to span the large intersection below.
- The second potential problem encountered with SPUIs is the length and geometry of the path for left-turning vehicles through the intersection

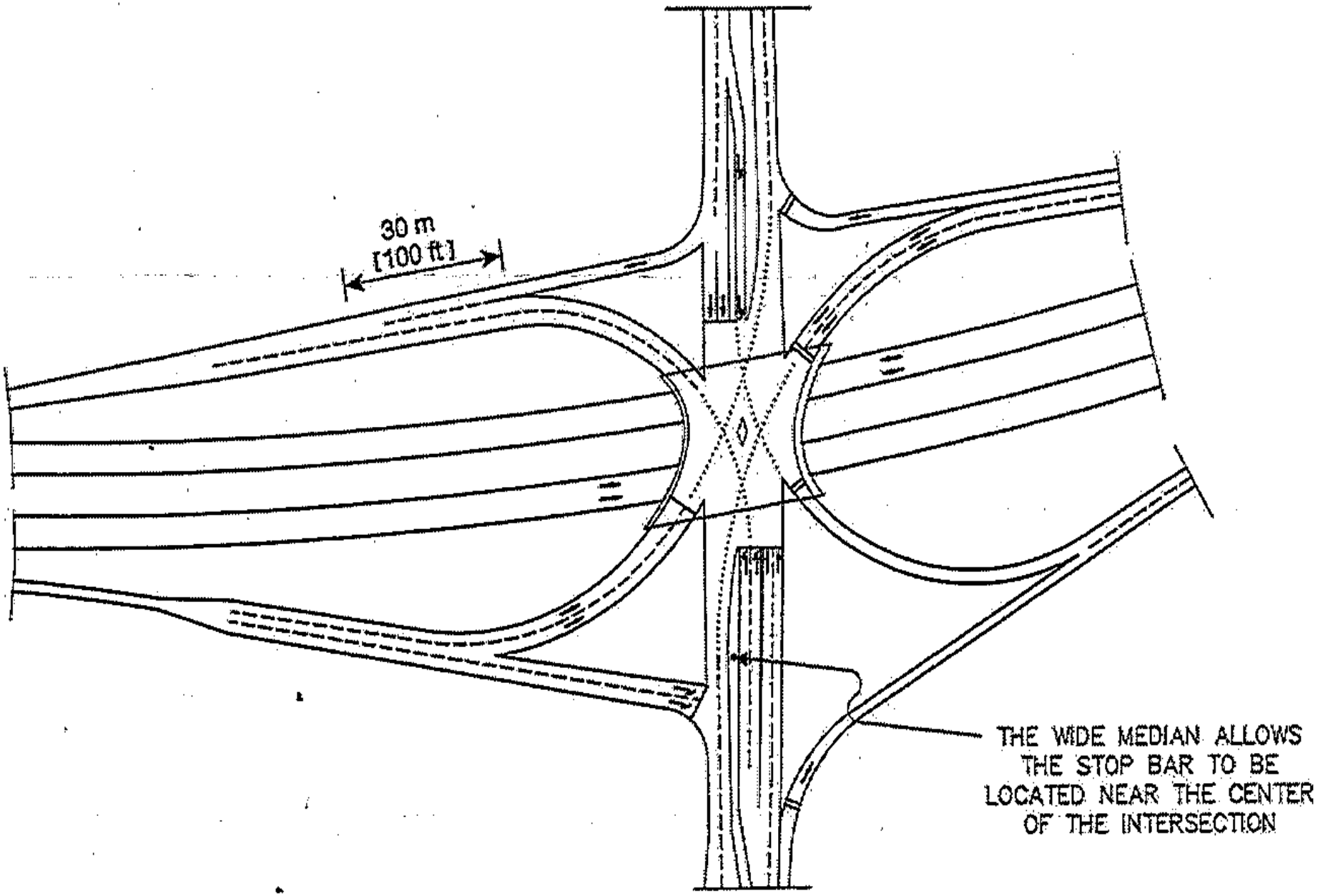


Exhibit 10-22. Underpass Single Point Urban Interchange

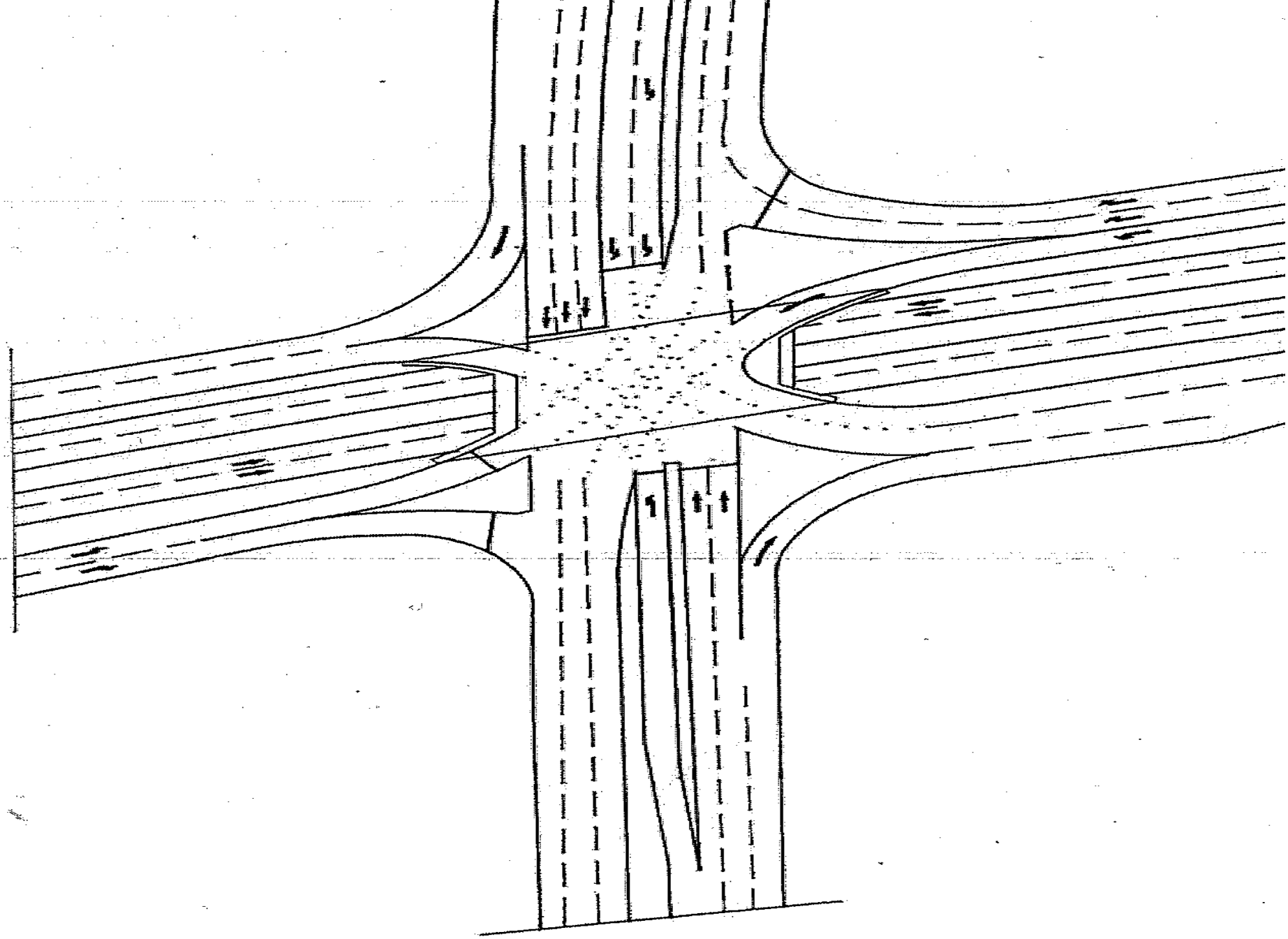


Exhibit 10-23. An SPUI Underpass in Restricted Right-of-Way

GRADE SEPARATIONS AND INTERCHANGES

- **Cloverleafs:** Cloverleafs are four-leg interchanges that employ loop ramps to accommodate left-turning movements.
  - Interchanges with loops in all four quadrants are referred to as "full Cloverleafs" and all others are referred to as "partial Cloverleafs."
  - The principal *disadvantages* of the cloverleaf are:
    - The additional travel distance for left turn, the weaving manoeuvre generated, the very short weaving length typically available, large right-of-way are requirement
    - When *collector-distributor roads are not used*, weaving on the main line, the double exit on the main line, and problems associated with signing for the second exit.
    - *More expensive than diamond interchanges* ➔ less common in urban areas and are better adapted to suburban or rural areas where space is available.

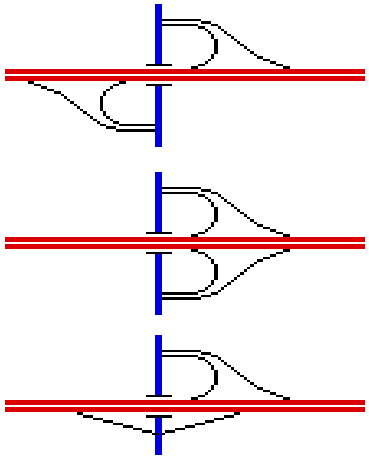
•The *capacity of the loop is limited to 800 to 1200vph* provided that the design speed for the ramp is *50kph or higher and there is no truck*.

•*Loop ramp capacity* is, therefore, a major control in cloverleaf designs

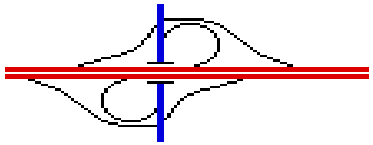
•*Two lane cloverleaf* is generally *uneconomical* due to high ROW requirement and more converging or diverging lanes requirements ➔ considered exceptional cases

GRADE SEPARATIONS AND INTERCHANGES

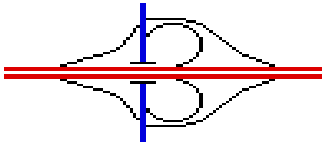
- **Partial Cloverleaf Ramp Arrangements:** The site conditions at some sites may offer a choice of quadrants to use partial cloverleaf.
  - The following guidelines should be considered in the arrangement of the ramps at partial cloverleafs:
    - The ramp arrangement should enable major turning movements to be made by right-turn exits and entrances
    - Where through-traffic volume on major highways is decidedly greater than that on the intersecting minor road, preference should be given to an arrangement placing at the right turns, either exit or entrance, on the major highway even though it results in a direct left turn off the crossed.



4-ramp partial cloverleaf variants.



Six-ramp partial cloverleaf.

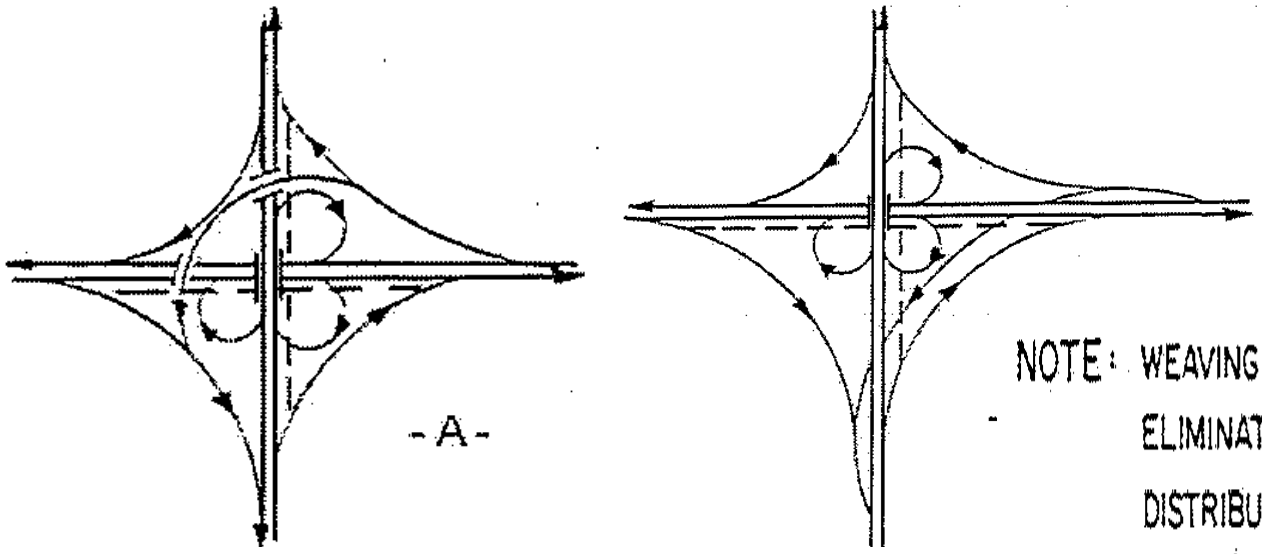


Variant favoring traffic to/from the left.

GRADE SEPARATIONS AND INTERCHANGES

- **Directional and Semi-directional Interchanges**
  - Direct or semi-direct connections are used for important turning movements to reduce travel distance, increase speed and capacity, eliminate weaving, and avoid the need for out-of direction travel in driving on a loop.
  - A direct connection is defined as one-way roadway that does not deviate greatly from the intended direction of travel.
  - Interchanges that use direct connections for the major left-turn movements are directional interchanges.
  - When one or more interchange connections are indirect in alignment yet more direct than loops, the interchange is described as semi-directional.
  - On direct or semidirect interchanges usually more than one highway grade separation is involved.
  - In comparison to loops, direct or semidirect connections have ***shorter travel distance, higher speeds of operation, and a higher level of service, and they often avoid the need for weaving***. ➔ appropriate in major urban intersection or on two or more expressway intersection.

GRADE SEPARATIONS AND INTERCHANGES



NOTE: WEAVING ADJACENT TO THE THROUGH LANES IS ELIMINATED BY PROVIDING COLLECTOR-DISTRIBUTOR ROADS AS SHOWN BY DOTTED LINES.

Exhibit 10-31. Semidirect Interchanges with Weaving

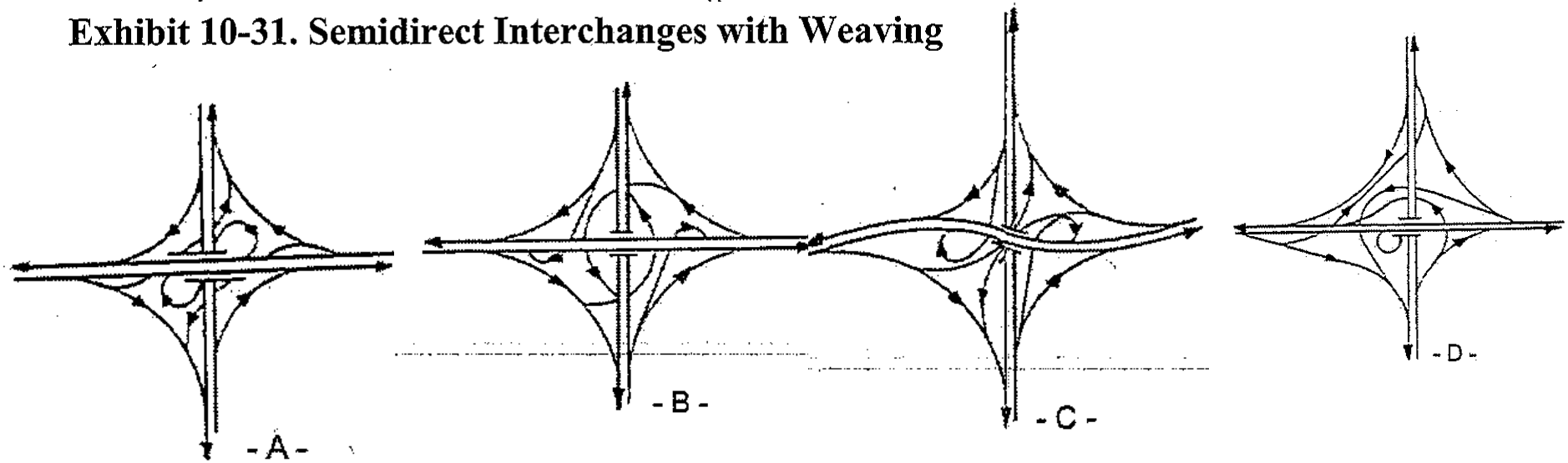


Exhibit 10-32. Semidirect Interchanges with No Weaving

GRADE SEPARATIONS AND INTERCHANGES

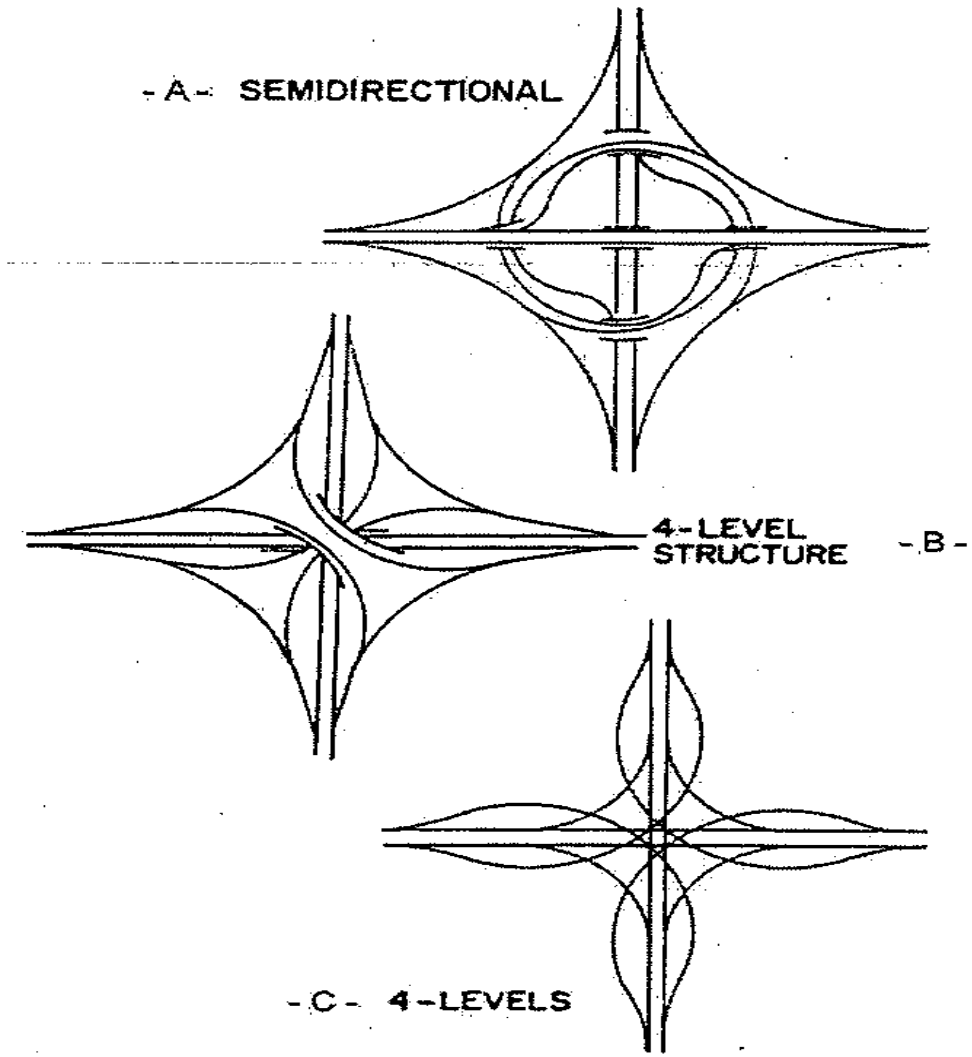


Exhibit 10-33. Semidirectional and Directional Interchanges—Multilevel Structures

GRADE SEPARATIONS AND INTERCHANGES

GRADE SEPARATIONS AND INTERCHANGES

GRADE SEPARATIONS AND INTERCHANGES

Thank You!