B.Sc - Road & Railway Design I. *Lecture 4.*

JUNCTIONS, INTERSECTIONS & INTERCHANGES

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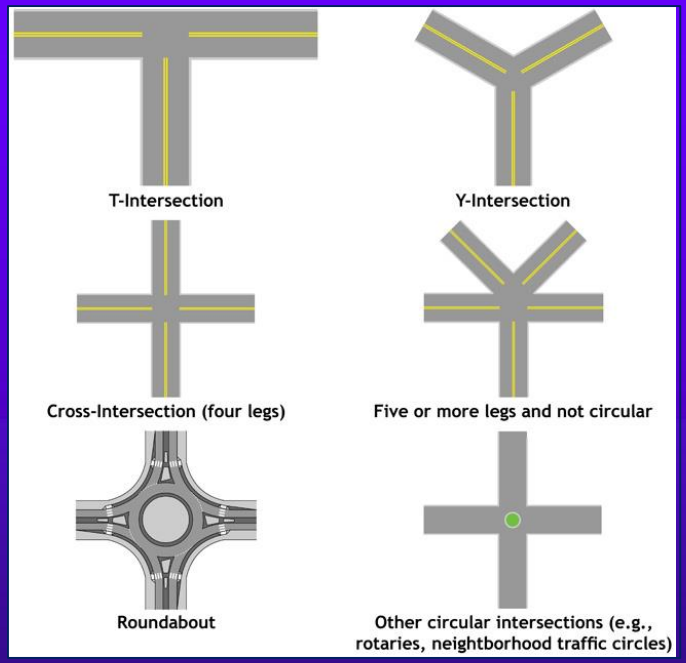
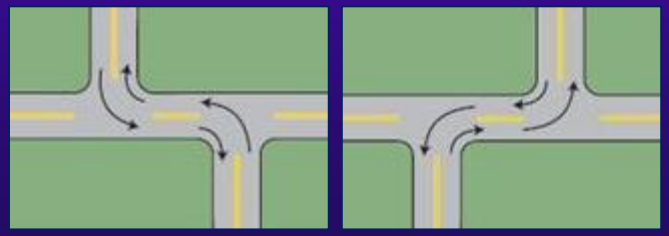
JUNCTIONS

- Roads meet or cross outside or inside of existing settlements at *junctions*
- As road networks increased in density and traffic flows followed suit, *managing* the flow of *traffic across the junction* became of increasing importance, to minimize delays and improve safety
- The most basic distinction among *junction types* is whether or not the roads cross at the same or different elevations
- At *intersections*, roads cross *at-grade* (on the same level), while at *interchanges* roads pass above or below each other, using *grade separation* and *slip roads* or *ramps*

CLASSIFICATION 1

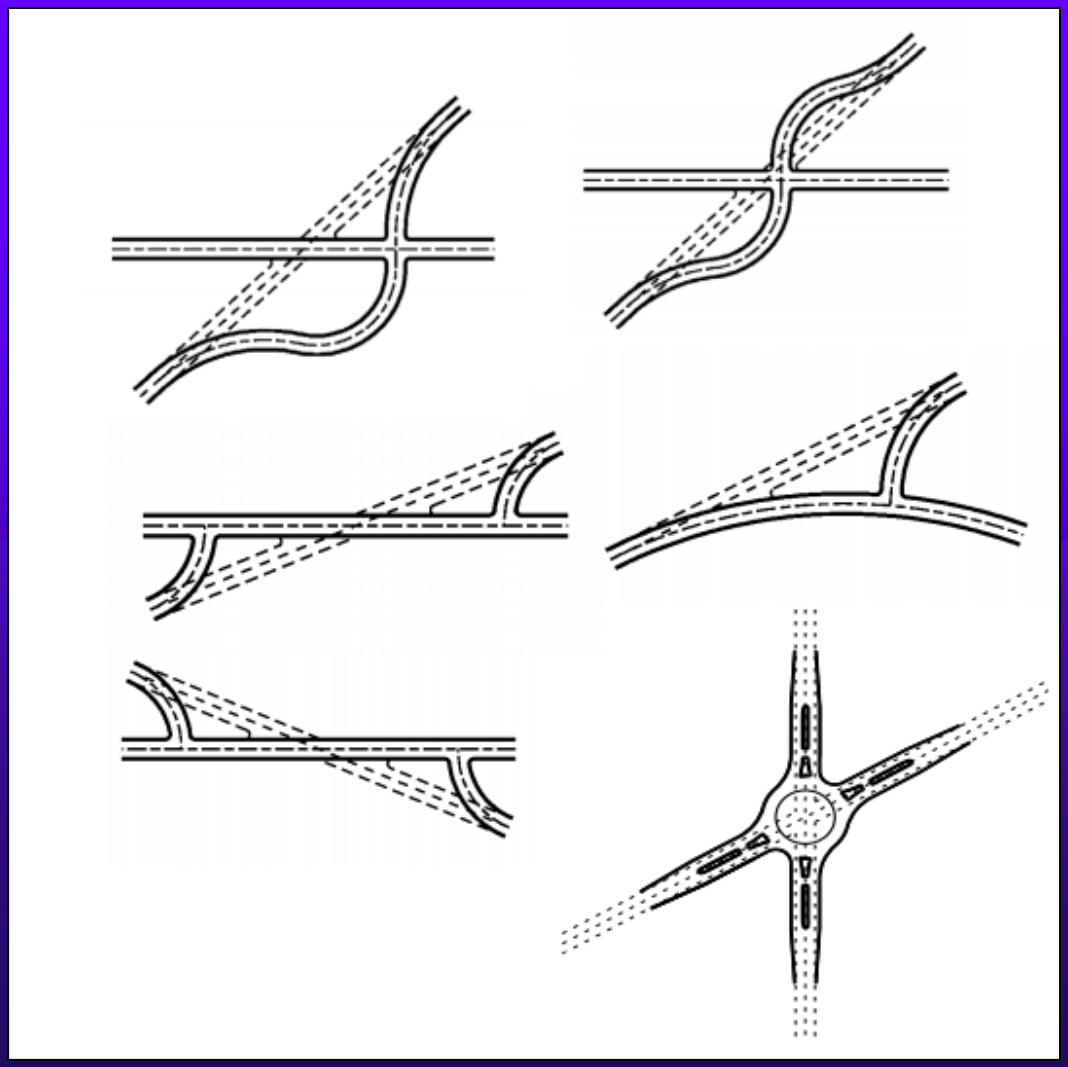
- **By the number of road segments (arms) that are involved:**
  - ***3-WAY INTERSECTION* – A junction between three road segments (arms) is a T junction (two arms form one road) or a Y junction (bifurcation)**
  - ***4-WAY INTERSECTIONS* usually involve a crossing over of two streets or roads; two roads may cross at a different angle (preferably >60^{o})**
  - ***5 (OR MORE)-WAY INTERSECTIONS* should be avoided, i. e. replaced by *staggered* intersections, or a *roundabout* (circular intersection in which traffic flows almost continuously in one direction around a central island)**





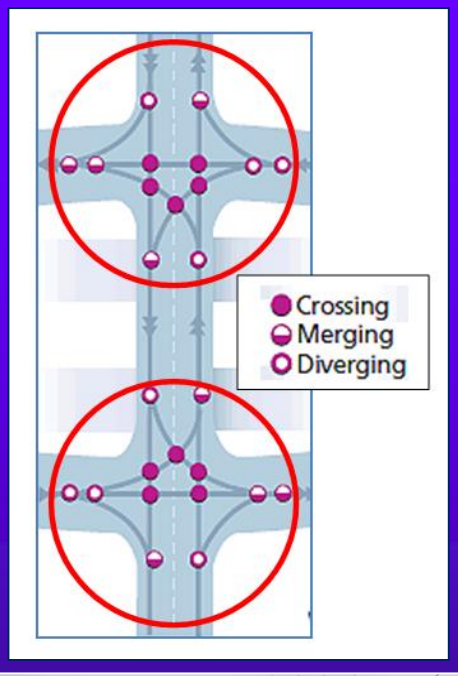
Staggering

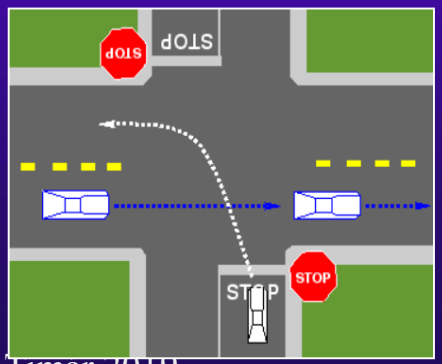
INTERSECTION RECONFIGURATIONS

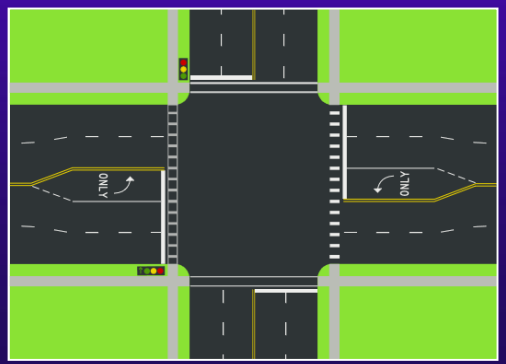


CLASSIFICATION 2

- **By traffic control technology:**
  - ***UNCONTROLLED*** **intersections, without signs or signals -** ***priority*** **(right-of-way) rules may vary by country, but most often traffic** ***from the right*** **has priority**
  - ***SIGN CONTROLLED*** **intersections (with YIELD/GIVE-WAY, or STOP signs)**
  - ***SIGNAL-CONTROLLE*****D intersections depend on traffic signals (usually electric), which indicate which traffic is allowed to proceed at any particular time**



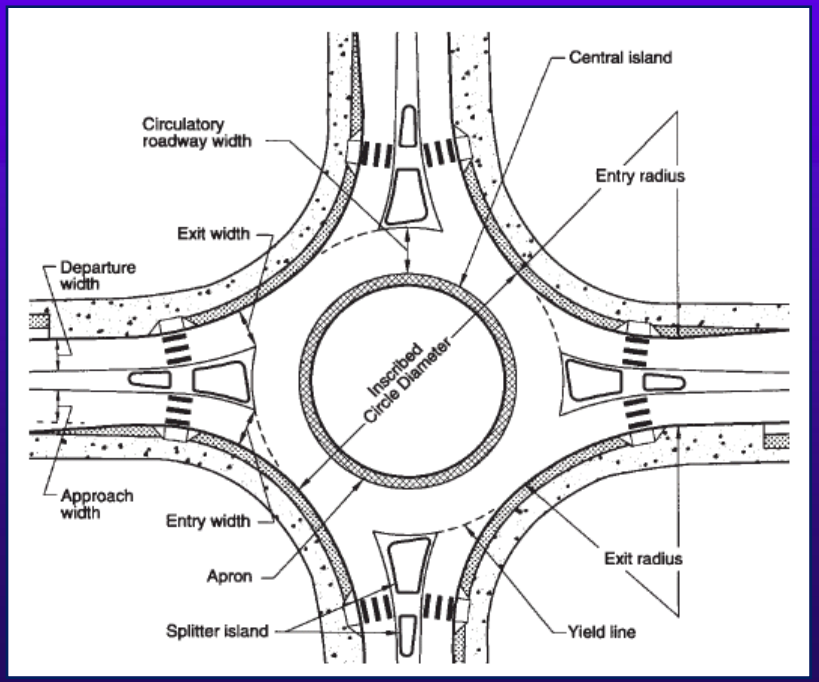


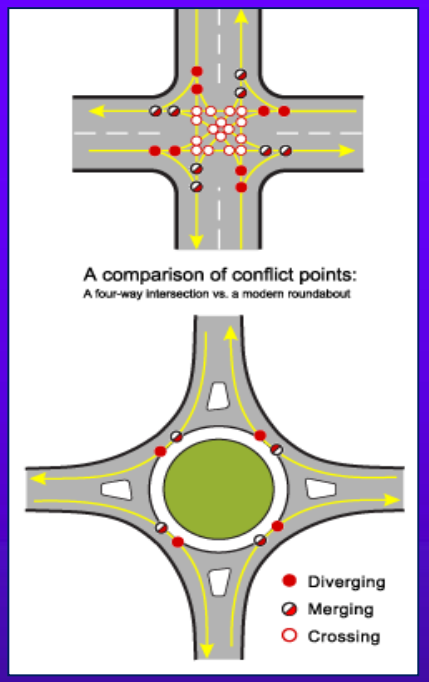


ROUNDABOUT OR ROTARY CIRCLE

ADVANTAGES:

- Continuous traffic movement from all legs
- Accidents are likely to be less serious
- Where more than 4-legs are involved, the design layout may be simplified
- The cost of this type may be considerably less than that of grade separation structures



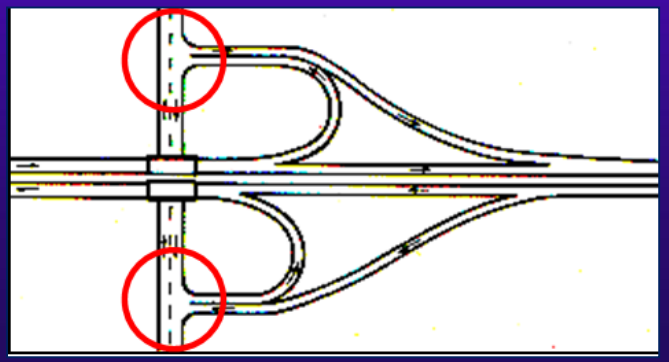


DISADVANTAGES:

- Requires large area
- Costs are more than other at-grade intersections
- It is not suitable for large pedestrian movements
- Needs long weaving sections to ensure smooth flow

CLASSIFICATION 3

- By the number of levels:
  - *AT-GRADE* intersections on „ordinary” roads
  - *PARTIALLY GRADE SEPARATED* interchanges on expressways
  - *GRADE SEPARATED* interchanges with *ramps* on motorways



Partially grade separated interchanges:
diamond and *partial cloverleaf*
(at-grade intersections in red circles)

AT-GRADE INTERSECTION

Square *Étoile - Charles de Gaulle* in Paris – it *is not* a roundabout!

GRADE-SEPARATED INTERCHANGES

Interchange CA 110/I – 110 **and** ***Interchange 10 - CA 60***
in Los Angeles (USA; „*spaghetti*” interchanges))

INTERSECTION DESIGN REQUIREMENTS

1. Safe and convenient operation for all road users, including cyclists and pedestrians
2. Proper accessibility for pedestrians with special needs
3. Adequate capacity for peak-hour demand on all movements
4. Adequate maneuvering space for design vehicles
5. Resolution of conflicts between competing movements
6. Reasonable delineation of vehicle paths
7. Adequate visibility of conflicting traffic
8. Storage for normal queuing of vehicles
9. Appropriate access management application
10. Minimum delay and disutility to all road users
11. Proper drainage of storm water
12. Accommodation for all utilities, both above and below the ground
13. Necessary regulatory, warning and informational messages for all road users
14. Suitable advance warning of all hazards
15. Uniformity of treatment with similar locations; and,
16. Minimal consumption of resources

AT-GRADE INTERSECTION DESIGN OBJECTIVES

- Need to meet two conflicting objectives:
  - Provide for the smooth flow of traffic (*design hourly volume*) across the intersection
  - Minimize the severity of *potential conflicts* among different streams of traffic and between pedestrians and turning vehicles
- Adequate *pavement width* (traffic lanes) and *approach sight distances* must be provided
- Operating characteristics of both the vehicles and pedestrians should be *duly considered*

AT-GRADE INTERSECTION DESIGN CONSIDERATIONS

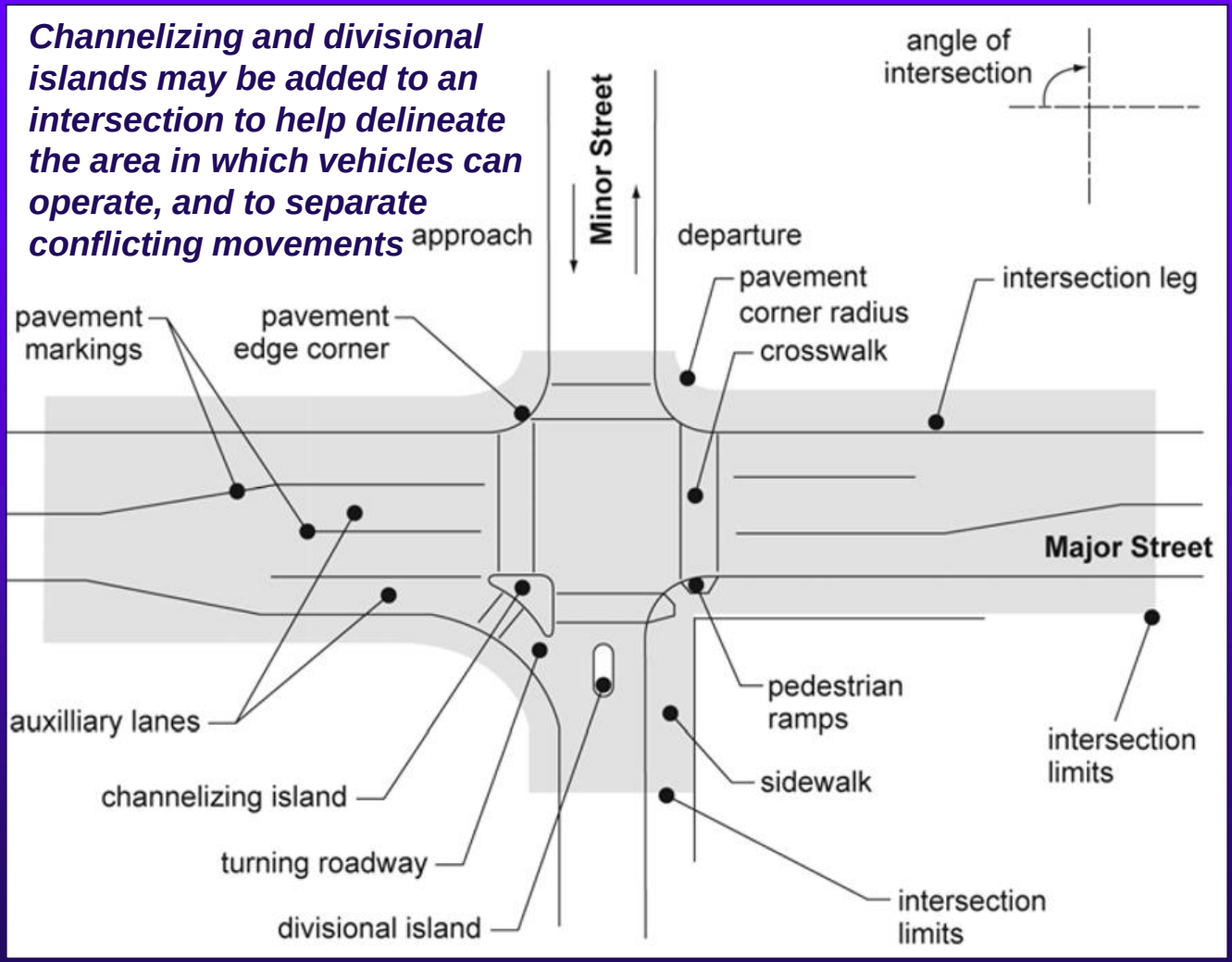
- Definition of *traffic volumes* by streams/flows and suitable channelization system for the traffic pattern comes first, followed by the *geometric design*
- Alignment and profile design is to be coordinated: look for the *angle* (plan) and *grades (profile)* of intersecting roads
- Minimum required widths of roadways where vehicles are turning (angle of turns 60º to 120º) should be provided
- Adequate sight distance for the type of traffic control used (no control, Yield, Stop, Signal)

INTERSECTION TERMINOLOGY

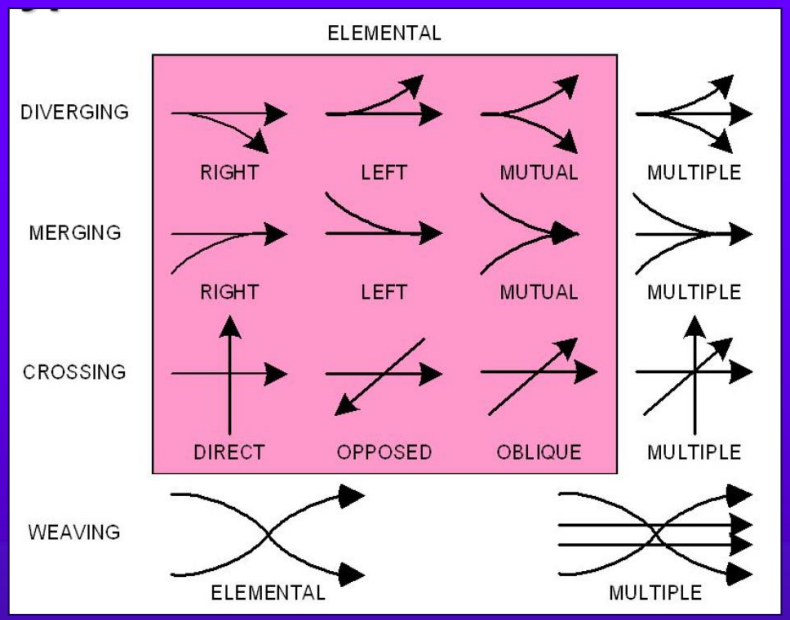
- The major road is typically the intersecting road with greater traffic volume, larger cross-section and higher functional class

- The minor, or cross road is the intersecting road likely to have less traffic volume, smaller cross-section and lower functional classification than the major road

Channelizing and divisional islands may be added to an intersection to help delineate the area in which vehicles can operate, and to separate conflicting movements



TYPES OF MANEUVERS & TRAFFIC CONFLICT POINTS



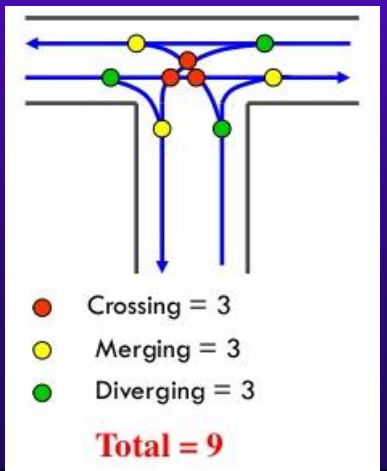
- A *channel* is called *traffic lane*; its width is determined by design standards, e. g. in

Germany:	3.75 m
UK	3.62 m
USA	3.60 m
France, Italy	3.50 m

- Depending upon environmental and traffic conditions in urban areas traffic lanes are narrower: 3.00-3.25m

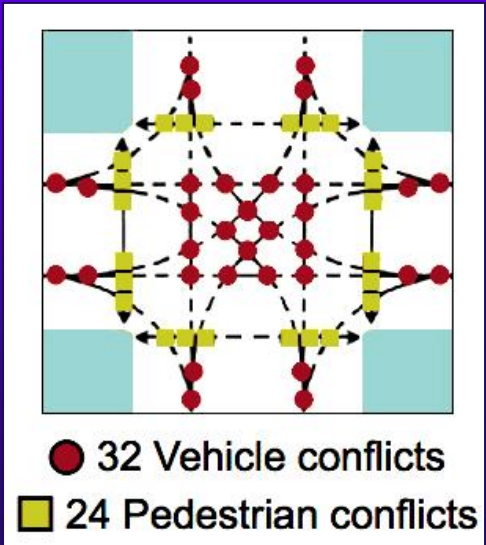
***SAFETY OBJECTIVES*:**

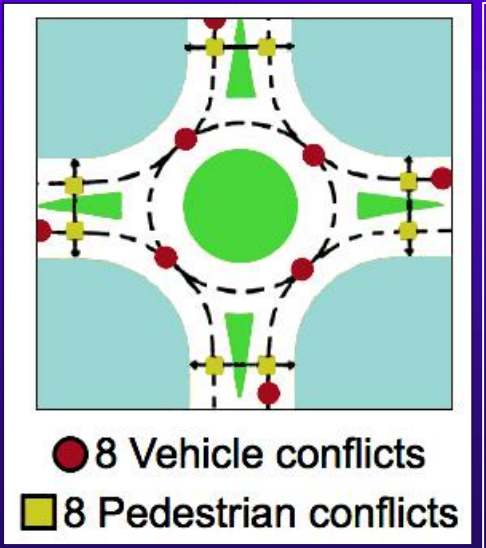
- Minimize traffic *conflict points* (locations)
- Minimise *weaving* movements
- Provide sufficient *sight distances*

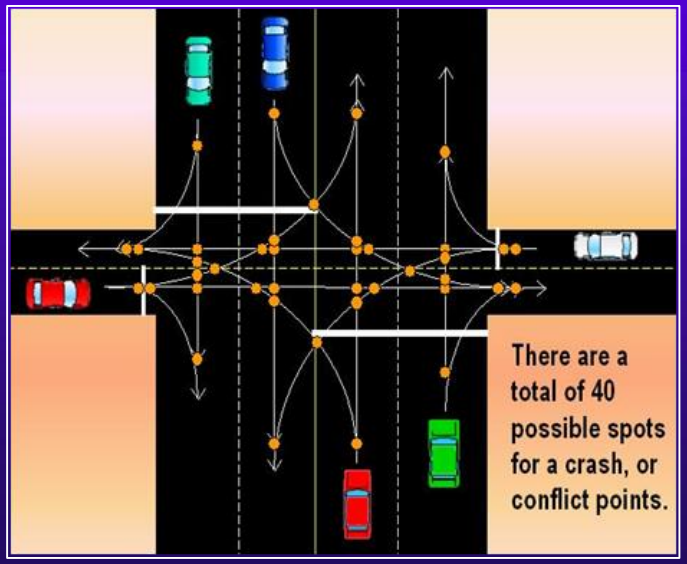


CONFLICT POINTS

- A driver must be able to see a potentially conflicting vehicle or pedestrian in time to implement an avoidance manoeuver (*sight distance* related), and
- The existing and forecast traffic volumes levels must present reasonable opportunities for a safe manoeuver to take place (*gap availability* related)

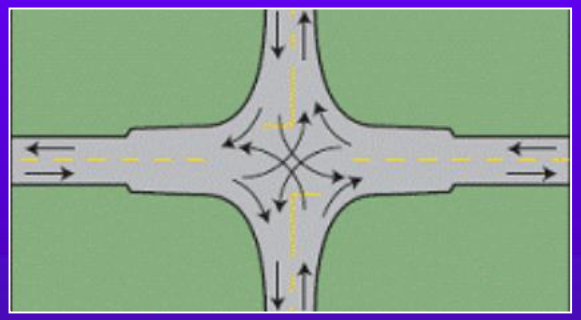




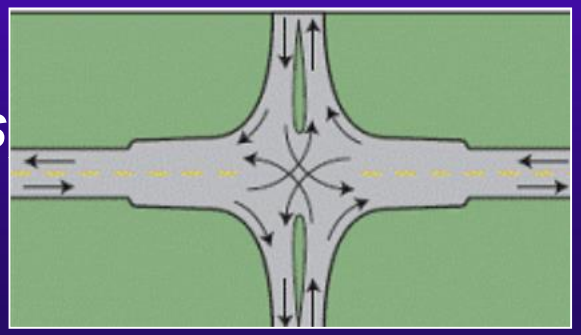


CHANNELIZATION

- Vehicles approaching an intersection are directed to definite paths by islands, marking etc. and this method of control is called *channelization*
- Intended to
  - Segregate traffic flows from each other and reduce the area of conflict between different intersecting traffic streams/flows
  - Provide junction angles to give good visibility
  - Define driving patterns and indicate clearly which road has priority at a junction
- Carried out by using *traffic islands* or/and *road markings*
  - Minor road channelization
  - Left-turn lanes
  - Passing lanes
  - Full channelization



Unchannelized crossroad



Channelized crossroad

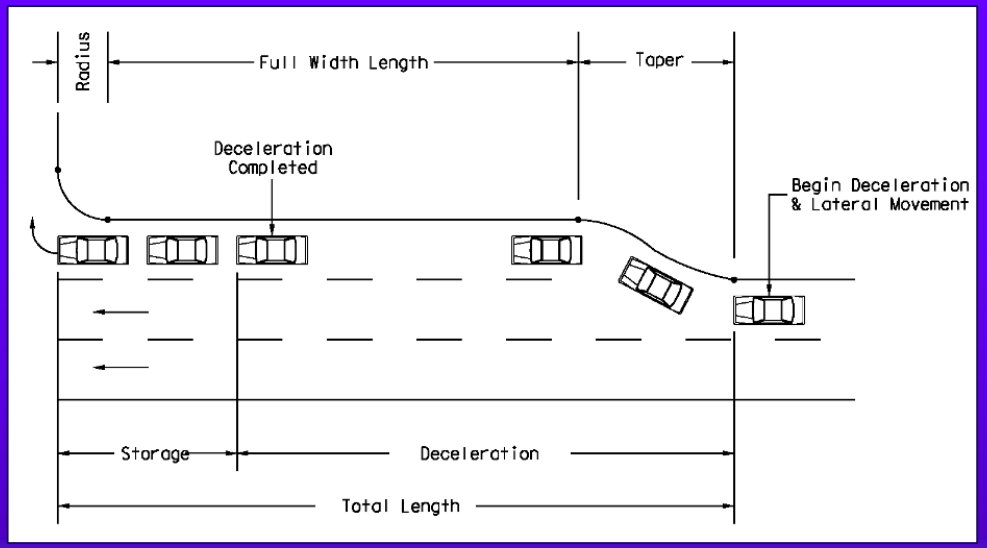
CHANNELIZATION CONSIDERATIONS

- Drivers should not be required to make more than one decision at a time
- Sharp reverse curves and turning paths greater than 90 degrees should be avoided
- Merging and weaving areas should be as long as possible, but other areas of conflict between vehicles should be reduced to a minimum
- Crossing traffic streams which do not weave or merge

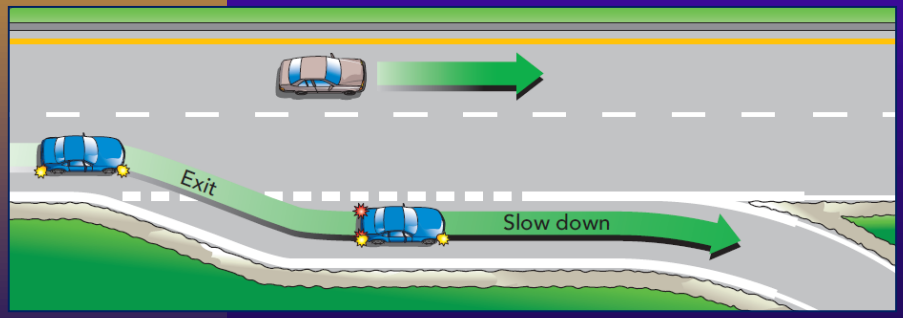
  should intersect at 90 degrees although a range of 60-120 degrees is acceptable
- The intersecting angle of merging streams should be such that adequate sight distance is provided
- Refuge/storage areas for turning vehicles should not interfere with the movement of through vehicles
- Prohibited turns should be blocked wherever possible and duly sign-posted
- Decisions on the location of essential traffic signs and control devices should be a component of the intersection design process

SPEED CHANGE OR TURN LANES 1

- Allow turning traffic to *accelerate* or *decelerate*
- Removes traffic from through lane
- Allows storage of vehicles through peak periods (in urban areas)



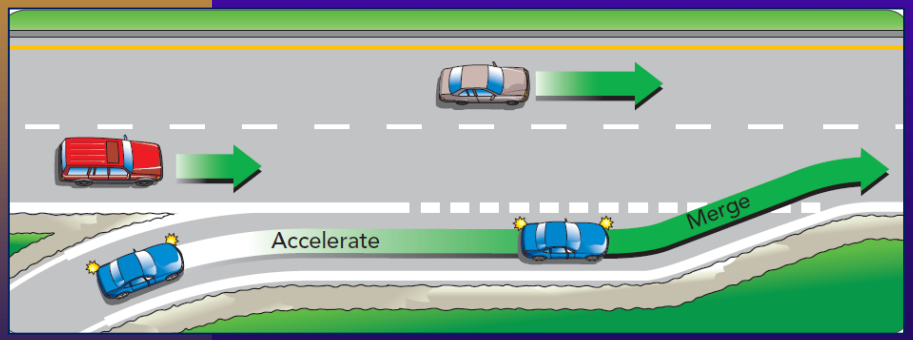
Mainlane Design Speed (km/h)	Taper Length (m)[1]	Deceleration Length (m)[2]	-	Design Turning ADT (vpd)	Minimum Storage Length (m)
50	15	50	-	150	15
60	15	65	-	300	30
70	30	85	-	500	50
80	30	105	-	750	75
90	30	130	-	-	-
100	45	200	-	-	-
110	45	240	-	-	-
120	45	290	-	-	-
130	45	330	-	-	-

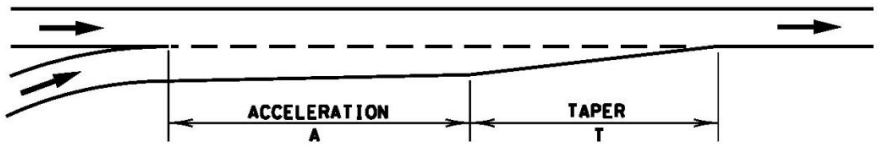


Deceleration lane, storage and taper lengths for design (USA)

SPEED CHANGE OR TURN LANES 2

- *Acceleration lanes* for turning vehicles are not customary at urban intersections, but desirable on multi-lane rural roads and mandatory on express- and motorways
- Entrance gives you appropriate distance to match your speed to the vehicles already on the motorway





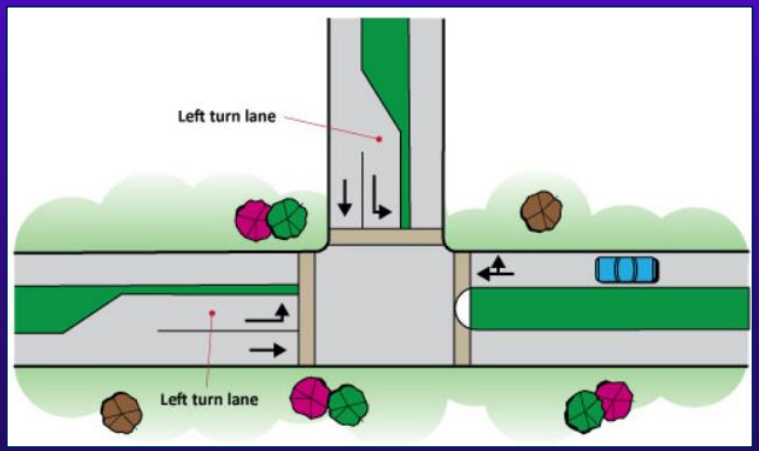
HIGHWAY DESIGN SPEED (km/h)	MINIMUM LENGTH OF TAPER T (m)	ACCELERATION LENGTH, A (m) FOR ENTRANCE CURVE DESIGN SPEED (km/h)							
		STOP CONDITION	20	30	40	50	60	70	80
		AND INITIAL SPEED (km/h)							
		0	20	28	35	42	51	63	70
50	45	60	50	30	-	-	-	-	-
60	55	95	80	65	45	-	-	-	-
70	60	150	130	110	90	65	-	-	-
80	70	200	180	165	145	115	65	-	-
90	75	260	245	225	205	175	125	35	-
100	80	345	325	305	285	255	205	110	40
110	90	430	410	390	370	340	290	200	125
120	100	545	530	515	490	460	410	325	245

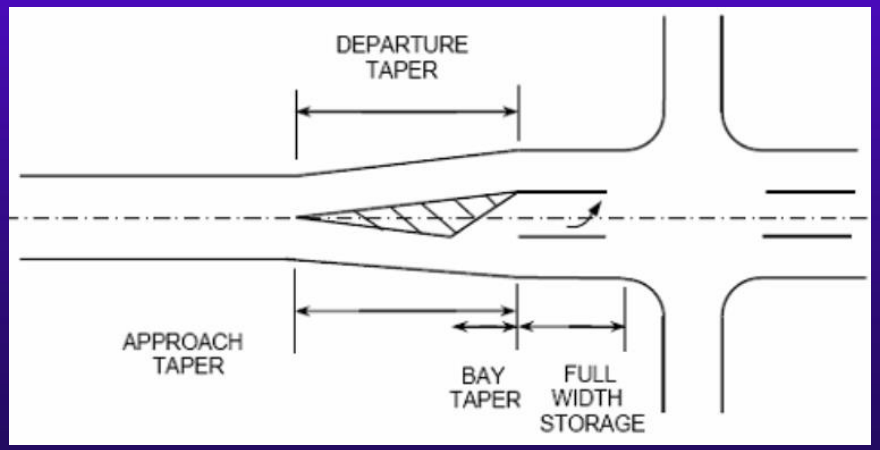
Note: Uniform 50:1 to 70:1 tapers are recommended where lengths of acceleration lanes exceed 400 m.

Acceleration lane and taper lengths for design (USA)

LEFT TURN LANES

- The design of left turn lanes should consider the intended function and the characteristics of the roadway: it is often necessary to widen the existing roadway to introduce the left turn lane
- All vehicles approaching the turn lane are shifted to the right; the left turning traffic is then shifted back into the lane, while through traffic returns to its original lane beyond the intersection





Basic design elements of left turn lanes (symmetrical shift)

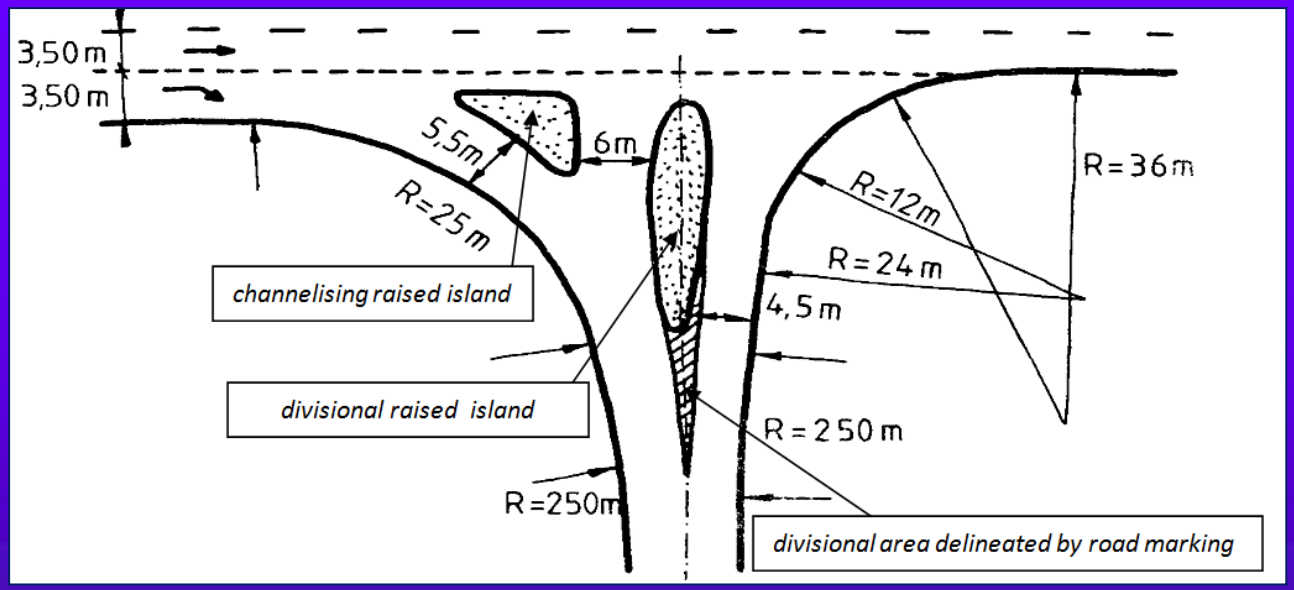
RAISED ISLANDS

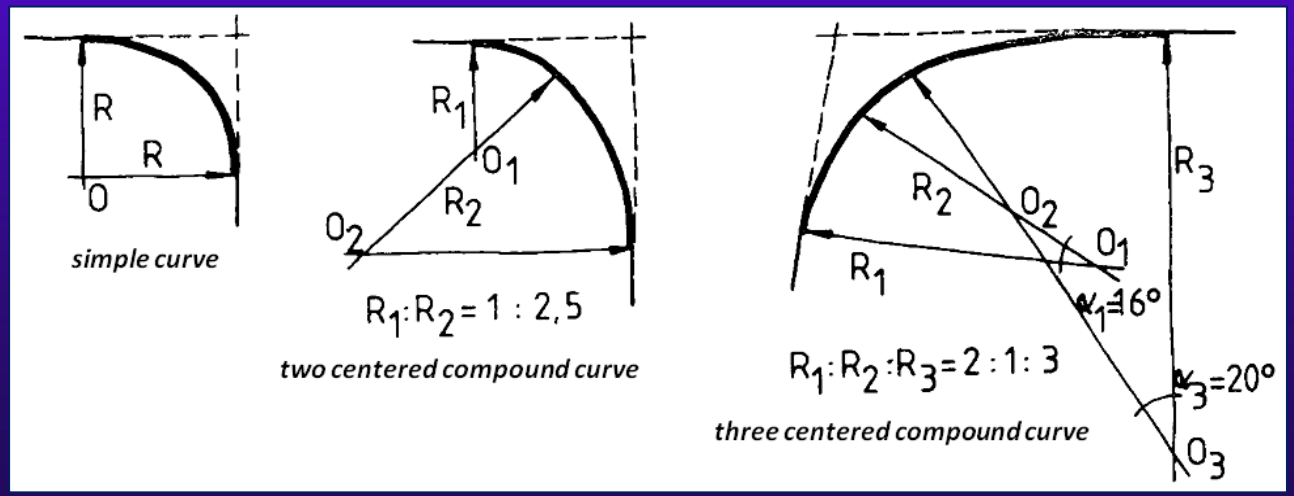
- Islands are an important form of intersection channelization that is often needed to prohibit undesirable movements, define the paths of allowed movements, and provide a refuge area for pedestrians
- Painted sidelines or islands (*road markings*) are an effective means to direct the paths of vehicular movement; however, raised islands are more effective and allowed where public lighting is available
- Raised islands should be offset (minimum 0.4 m) from the edge of the adjacent travel lane on all sides
- When raised islands are adjacent to roadways with posted speed limits of 80 km/h or greater, the island shall be offset from the edge of the roadway by a minimum distance of 1.0 m

PROFILE & CURVES

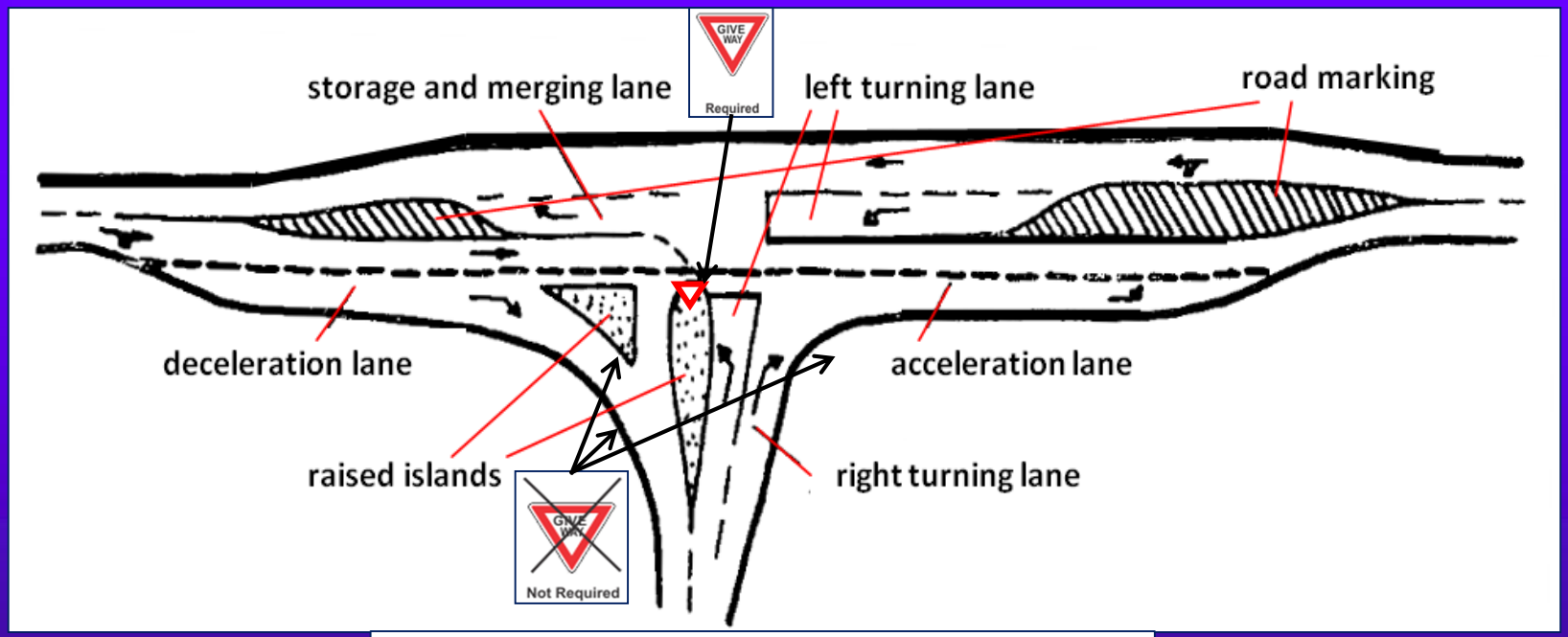
- Make it as flat as possible and avoid approach grades in excess of 3%
- Avoid grade changes at intersections:
  (crest ⇒ sight distance problems)
  (sag ⇒ drainage problems)
- The grade line of the major road should be carried through the intersection
- Adjust the grade for the normal crown of the crossroad to an inclined cross section at its junction with the major road
- When turning speed is <25 km/h, curves of the pavement edges are to be conform at least the minimum turning path of the design vehicle

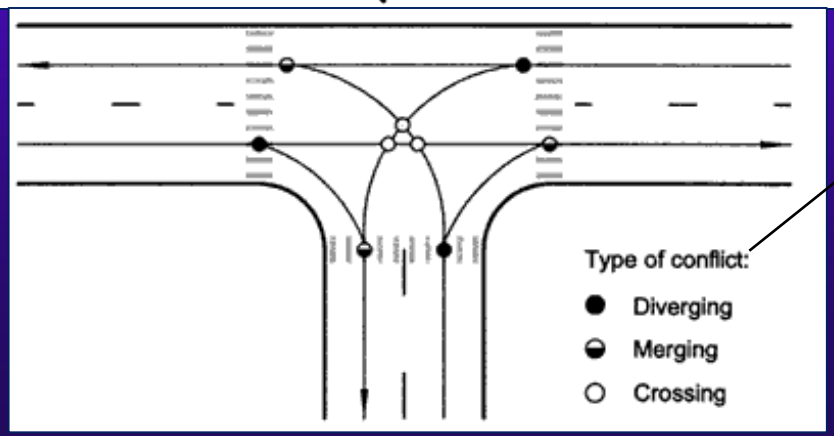
CHANNELIZING ELEMENTS AT MINOR ROAD (T-JUNCTION)



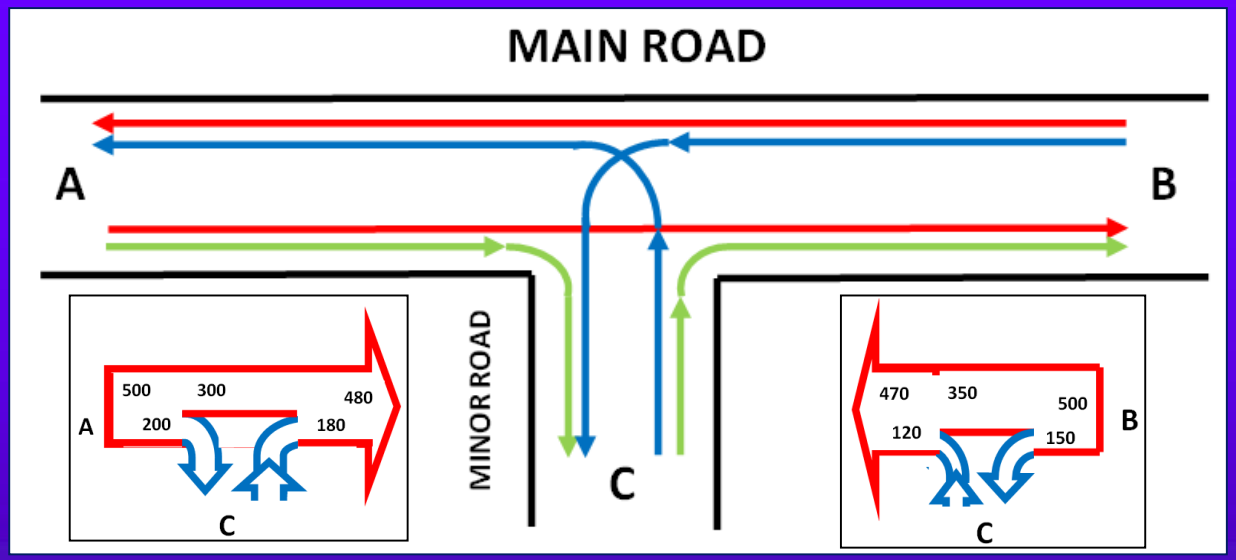


CHANNELIZING ELEMENTS AT A 3-LEG INTERSECTION





T-JUNCTION TRAFFIC PLANNING



Six traffic flows to be defined by appropriate counts at a T-junction

ORIGIN \ DESTINATION	A	B	C	TOTAL
A		300	200	500
B	350		150	500
C	120	180		300
TOTAL	470	480	350	1500

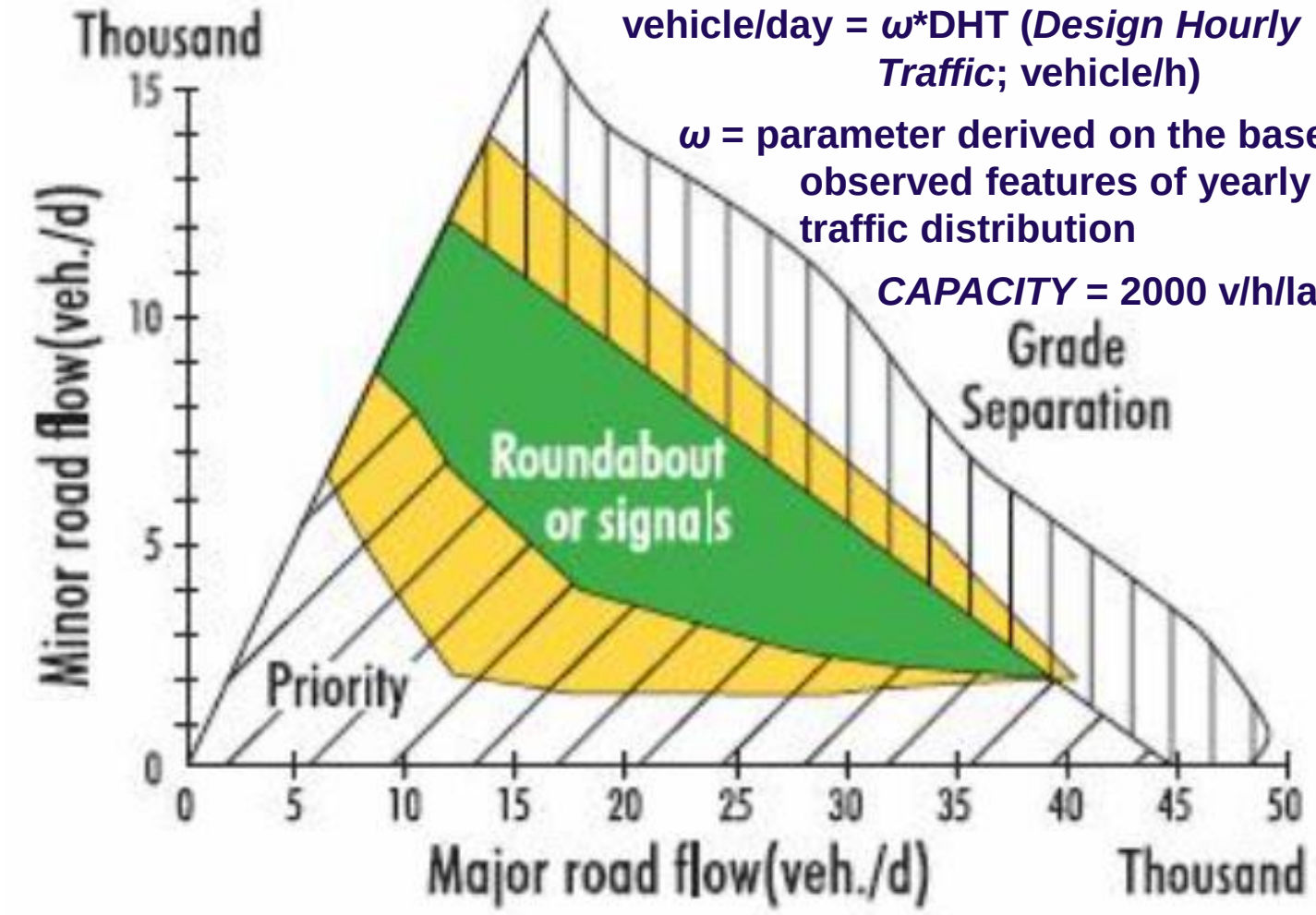
Traffic flows calculated on the base of counts (*design hourly volume*, vehicle/hour): O-D TRAFFIC MATRIX

SELECTION OF JUNCTION-TYPE

vehicle/day = *ω**DHT (*Design Hourly Traffic*; vehicle/h)

ω = parameter derived on the base of observed features of yearly traffic distribution

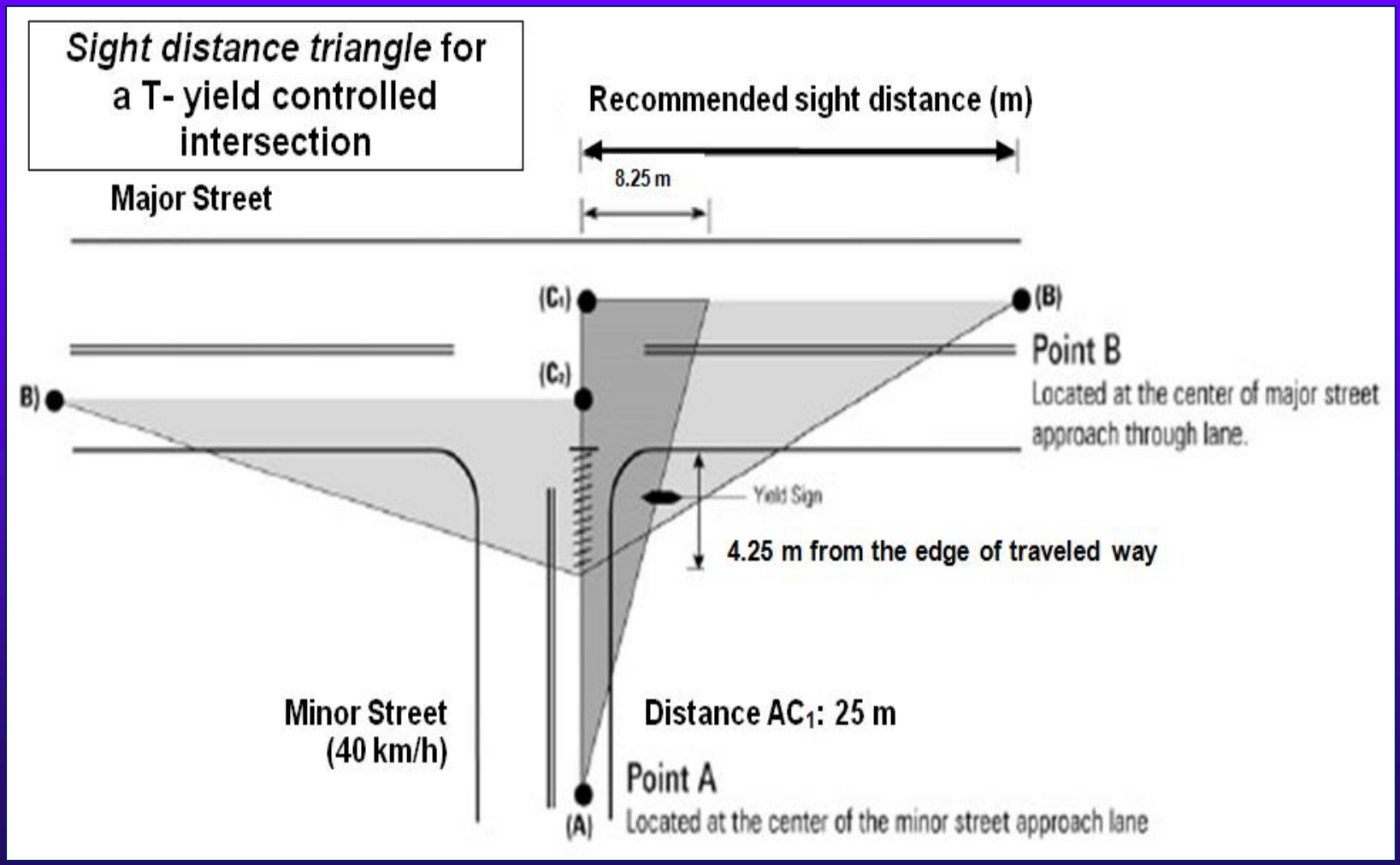
CAPACITY = 2000 v/h/lane



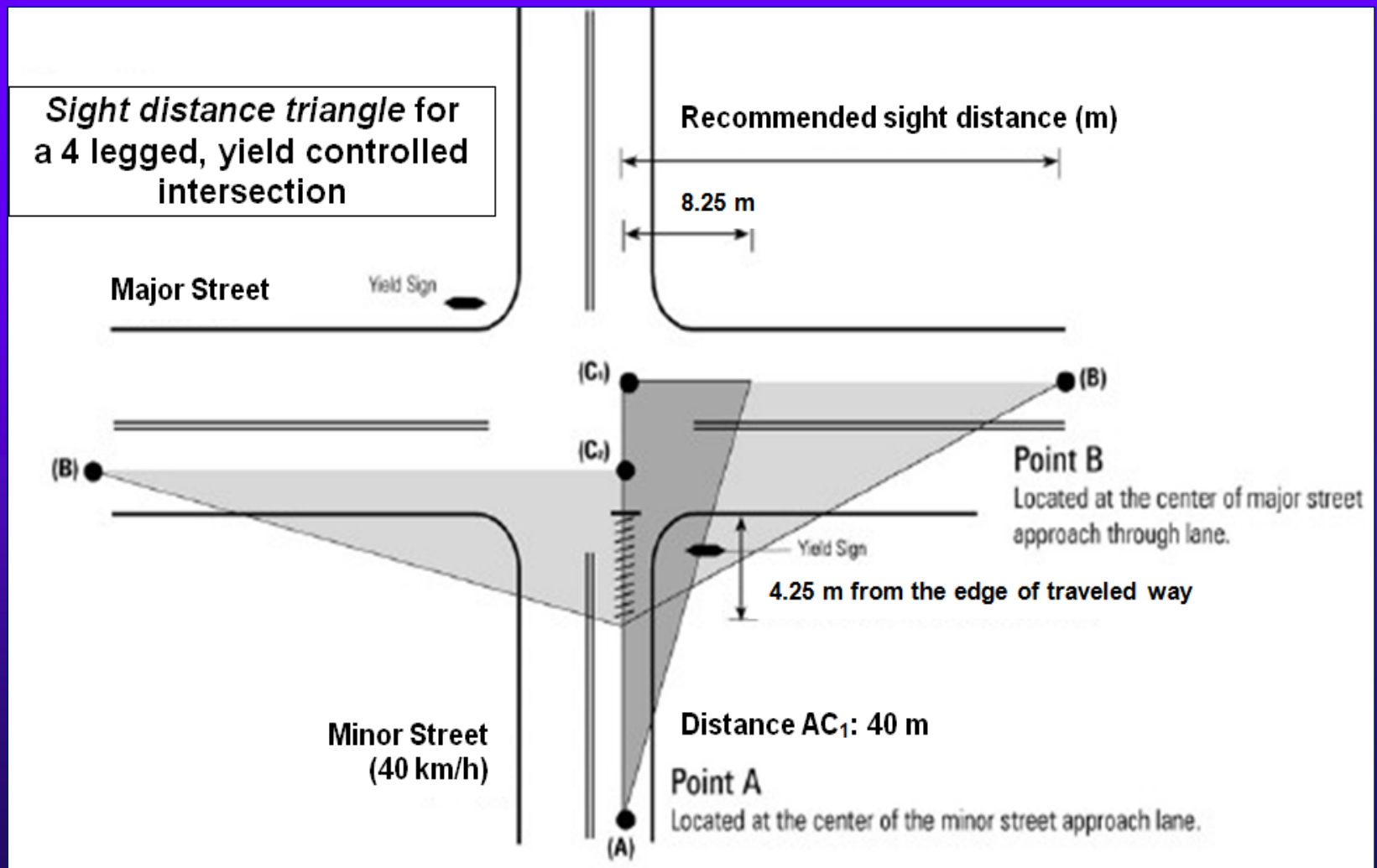
INTERSECTION SIGHT DISTANCE

- Intersection sight distance needs to be provided so that drivers approaching an intersection have an unobstructed view of the intersection and traffic signs and/or control devices, along with sufficient length along the intersecting streets to anticipate and minimize potential conflicts
- The area needed to be clear of site obstruction for safe turning movements is called the "sight distance triangle"
- Required sight distance represents how far (on the major road) the driver should be able to see so as to safely exit a minor road or to make a right turn at a non signal-controlled intersection

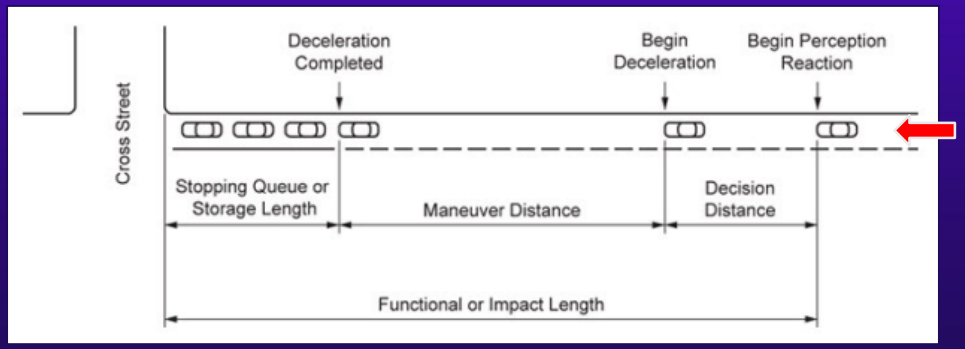
SIGHT DISTANCE TRIANGLE 1



SIGHT DISTANCE TRIANGLE 2



SIGHT DISTANCE TRIANGLE 3

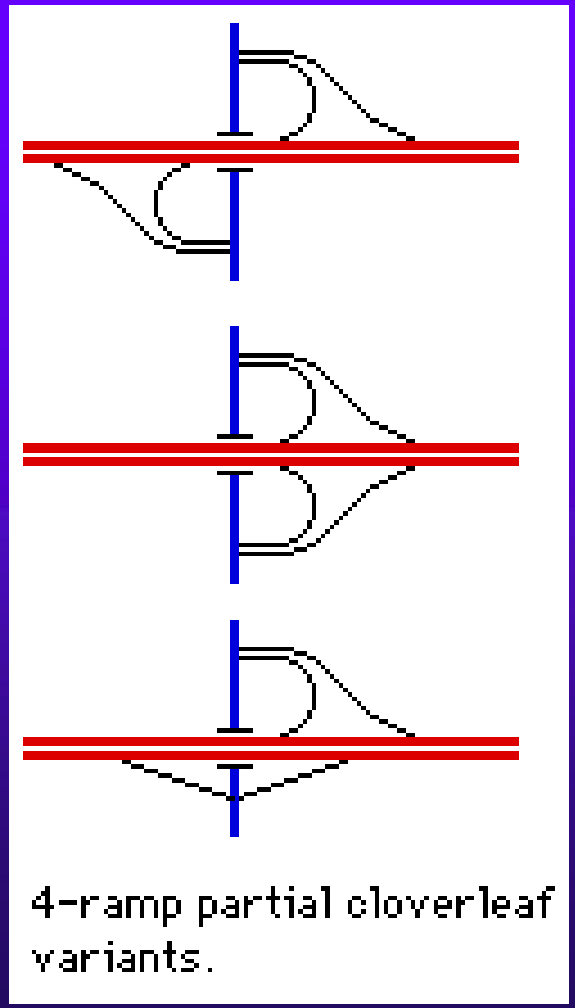


- Elements of the functional area of an intersection

INTERCHANGE CONFIGURATIONS

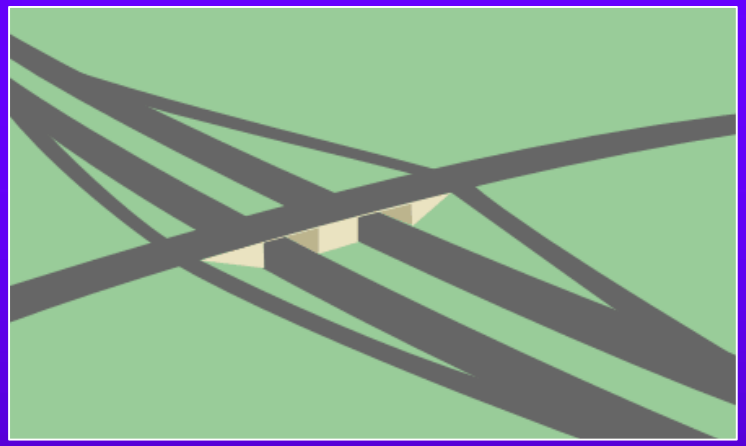
- Grade-separated interchanges have many different possible configurations
- The configuration chosen for the design of any particular interchange must be appropriate for
  - the volumes of traffic making specific turning movements at the interchange
  - the alignments of the roadways being connected
  - the surrounding terrain
  - the adjacent development, and
  - physical constraints such as existing rivers, railroads and roadways

TYPES OF *PARTIALLY GRADE-SEPARATED* INTERCHANGES

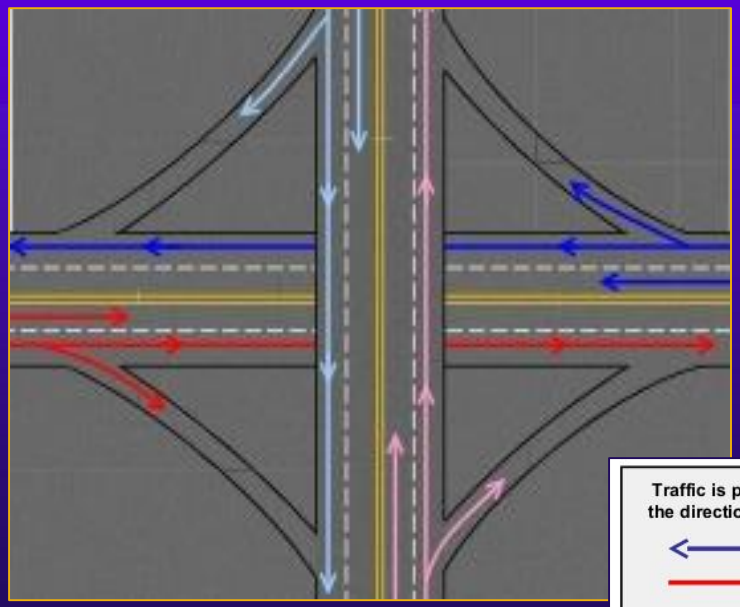


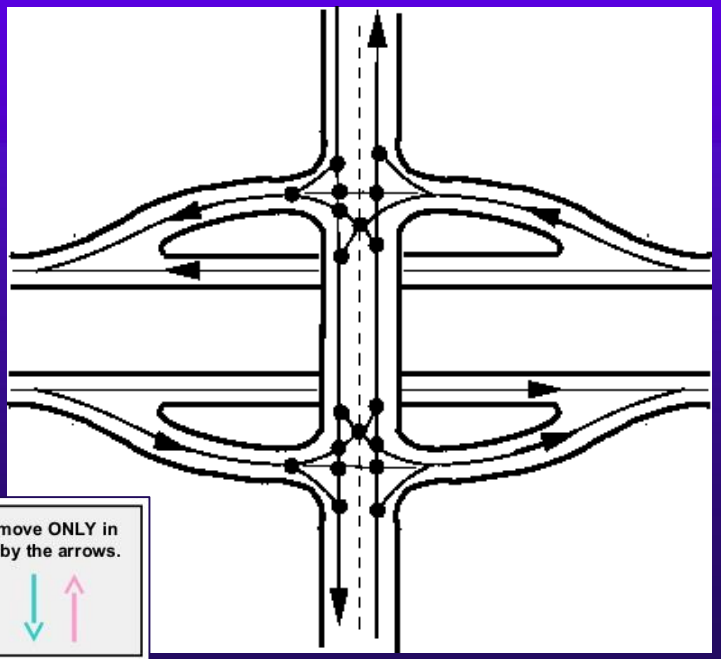
4-ramp partial cloverleaf variants.

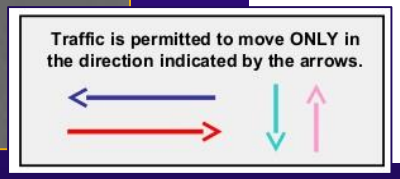
CLASSIC DIAMOND 1



A *diamond* interchange is designed to be used when a road with slower design speed crosses a busy expressway or motorway

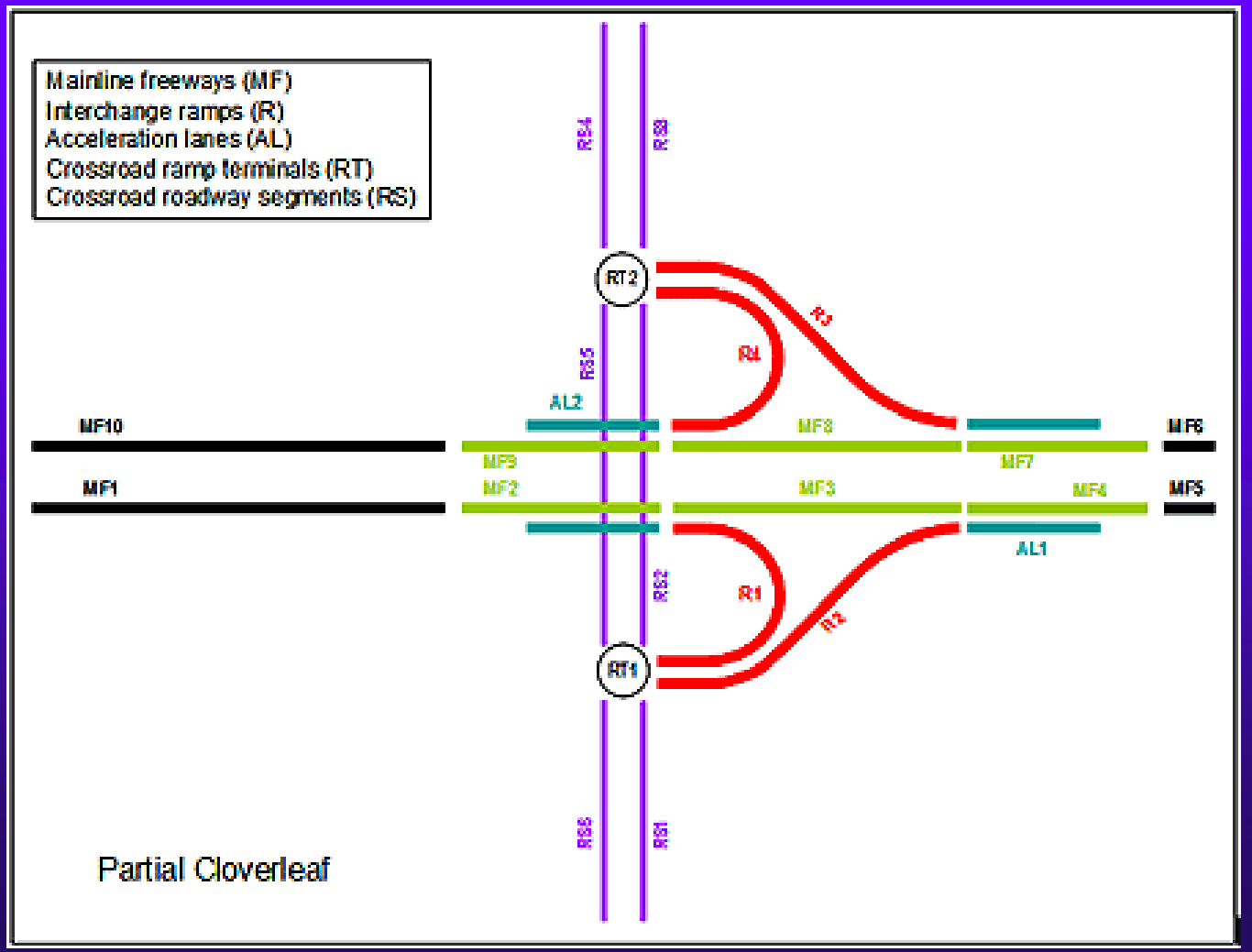






CLASSIC DIAMOND 2

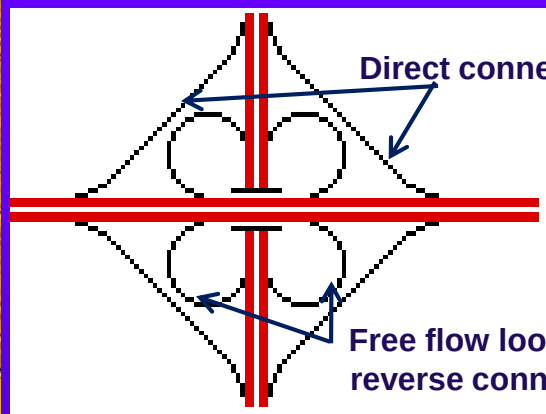
FOUR RAMP PARTIAL CLOVERLEAF 1



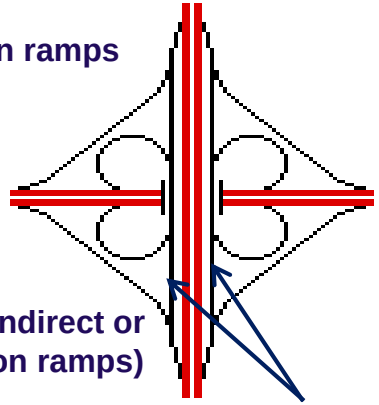
FOUR RAMP PARTIAL CLOVERLEAF 2

Motorway maintenance centre at a four ramp partial cloverleaf interchange

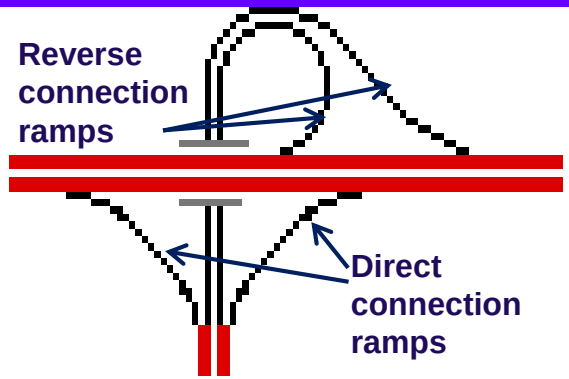
TYPES OF *FULL GRADE-SEPARATED* INTERCHANGES



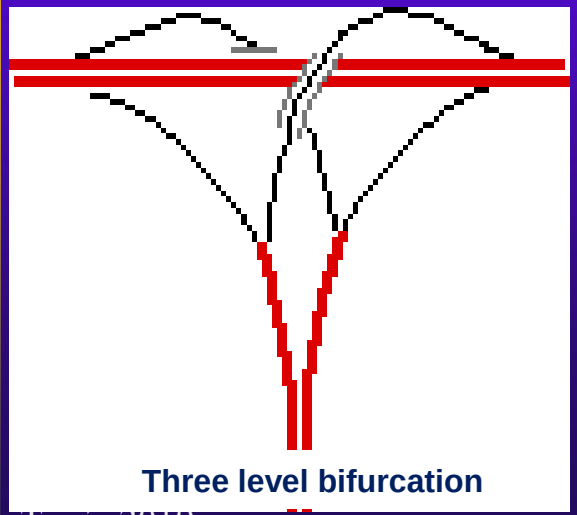
Full cloverleaf



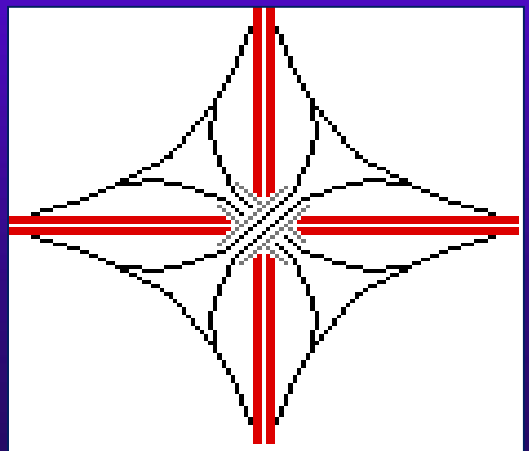
Full cloverleaf with collector an distributor roads



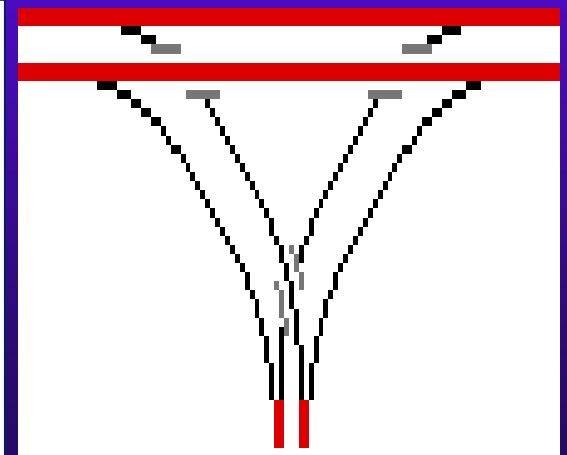
Trumpet



Three level bifurcation

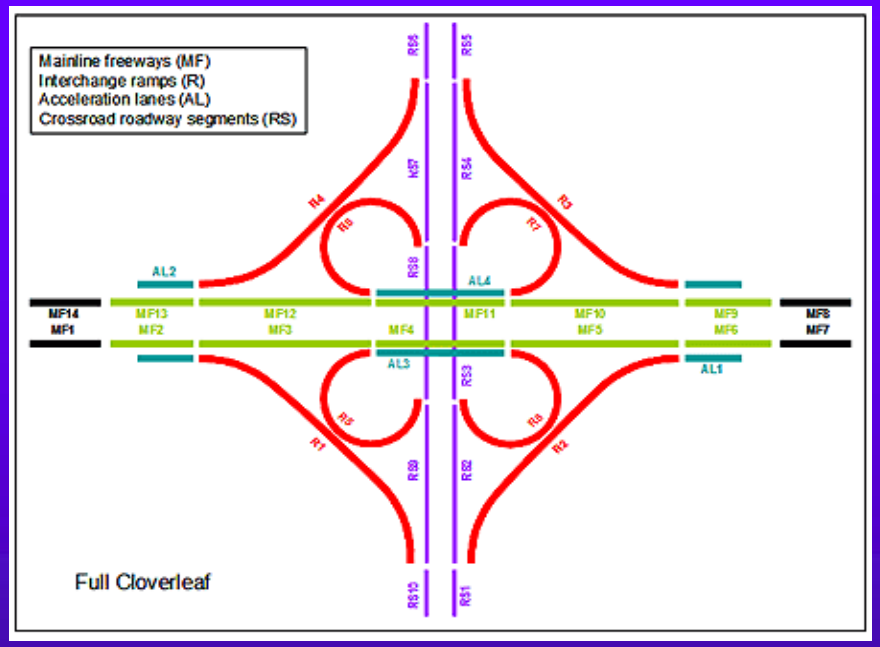


All directional, multi-level

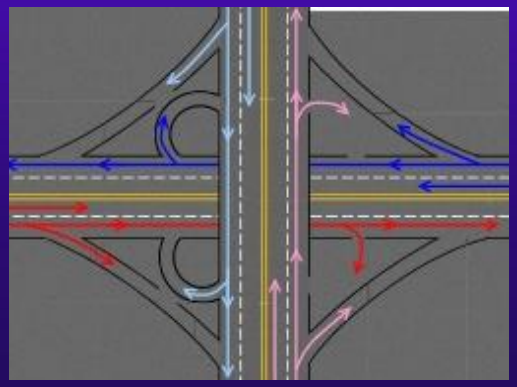


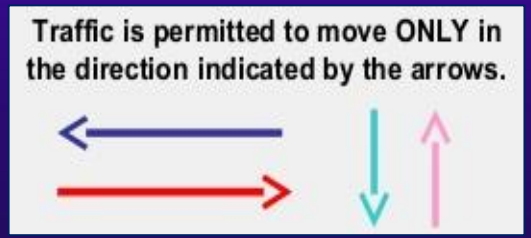
Two level bifurcation

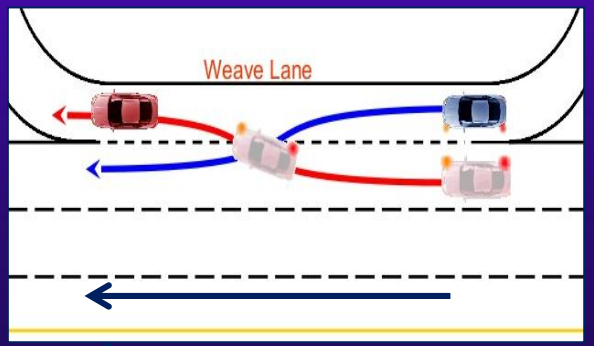
FULL CLOVERLEAF 1



Cloverleaf **interchange has a series of *shared entrance and exit (wave lane)*, as well as direct and indirect (reverse) *connection ramps*, that resemble the outline of a four leaf cloverleaf**

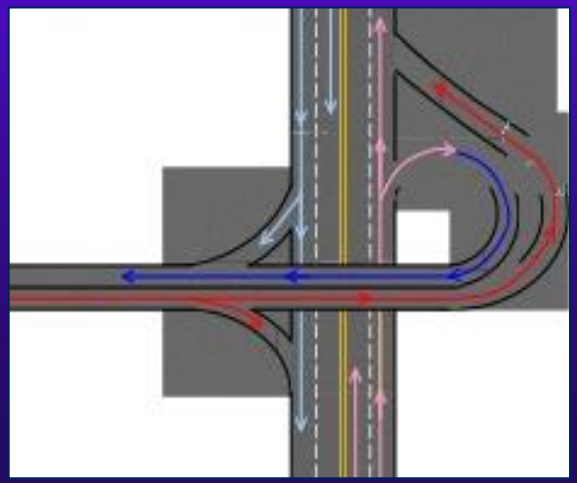




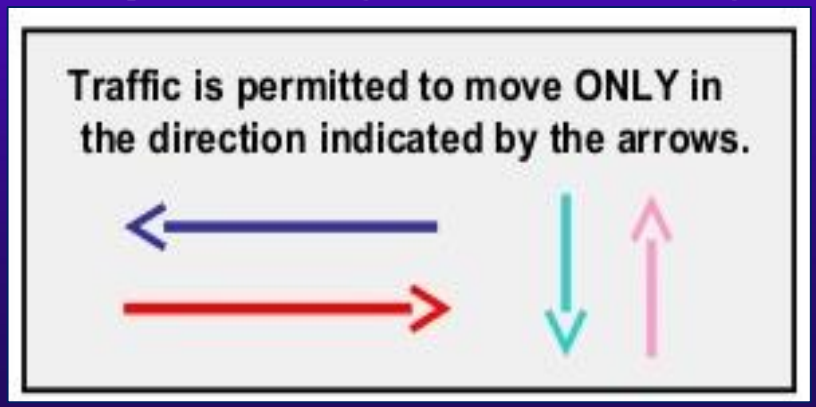


FULL CLOVERLEAF 2

TRUMPET INTERCHANGE

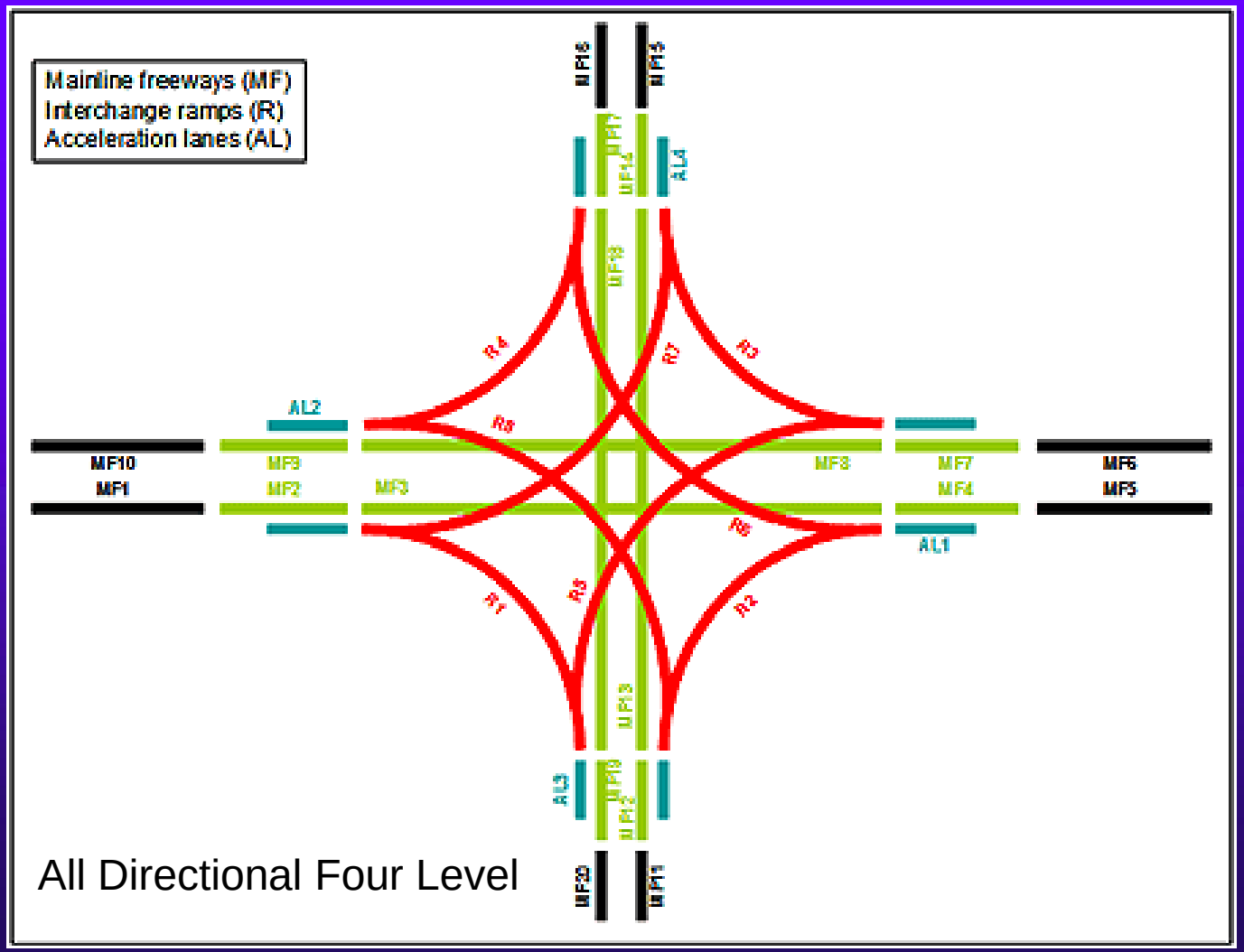


- Trumpet interchange is used when an intersecting side road forms a T-junction with an expressway or motorway
- Allows for traffic on a secondary two-way road to merge onto a multiple lane expressway or motorway



TRUMPET INTERCHANGE

ALL DIRECTIONAL FOUR LEVEL INTERCHANGE 1



ALL DIRECTIONAL FOUR LEVEL INTERCHANGE 2