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# Highway & Traffic Engineering

## INTERSECTION DESIGN PRINCIPLES & CONTROL SYSTEM

by  
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# Chapter Description

## Aims

This chapter provides students on the understanding of intersection design principles using stated method.

## Expected Outcomes

- Explain intersection characteristics comprising of at grade and grade separated intersections and interchanges
- Design appropriate signalized intersection using Arahan Teknik Jalan 13/87

# Contents

- Intersection Design Principles
- Types of intersections
- Traffic Conflicts at Intersection
- Traffic Signal
- Traffic Signal Controllers
- Guide for Signal Installation Warrants
- Basic Terminologies of Traffic Signal Design
- Traffic Signal Timing Design

# Intersection Design Principles

- Intersection is the area where two or more roads join or cross each other
- The objective of intersection design:
  - to regulate traffic operation and ensure safety of road users
  - to maintain design speed and maximize the capacity of intersection

# Guiding principles in intersection design

- Human Factors
  - Accommodate reasonable road user characteristics for example design should follow proper geometric layout so that hazardous movements by drivers are eliminated
- Traffic considerations
  - Minimized the number of conflict point by separating some of the crossing, merging and diverging conflicts
- Functional Intersection area
  - Provide adequate space at the junction (deceleration and acceleration zones and queuing area)
- Physical Elements
- Economic Factors

# Types of intersections

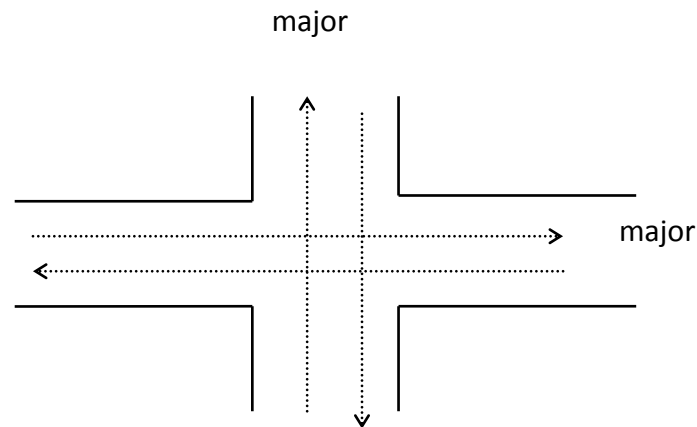
- At-grade intersection
  - where intersecting roads meet at a common level
- Grade separated intersection/Interchanges
  - where intersecting roads are at different elevations;

# At - Grade Intersection

- An intersection where all roadways join or cross at the same level.
  - i. Uncontrolled junction
  - ii. Priority junction
  - iii. Space sharing junction
  - iv. Time sharing junction
  - v. Channelization

# Uncontrolled junction

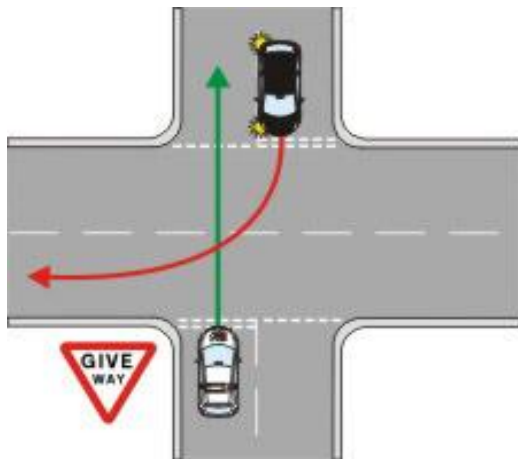
- Where the join or intersecting roads are more or less ***equal important*** and there is ***no established priority visibility*** should be provided, provided that a driver approaching the intersection from either road must be able to perceive a hazard.



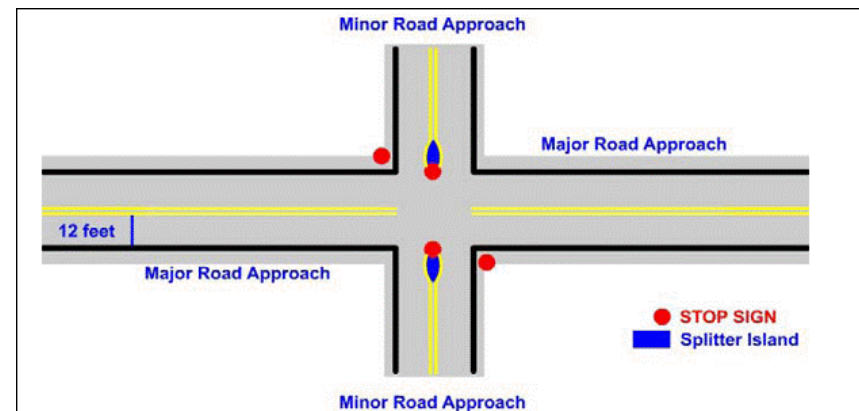


# Priority junction

- Intersections involving a **major road and minor road**, it is customary to **control traffic on the minor road** by STOP (when obstructed and poor inter-visibility) or GIVE WAY (when good inter-visibility) signs on road markings.



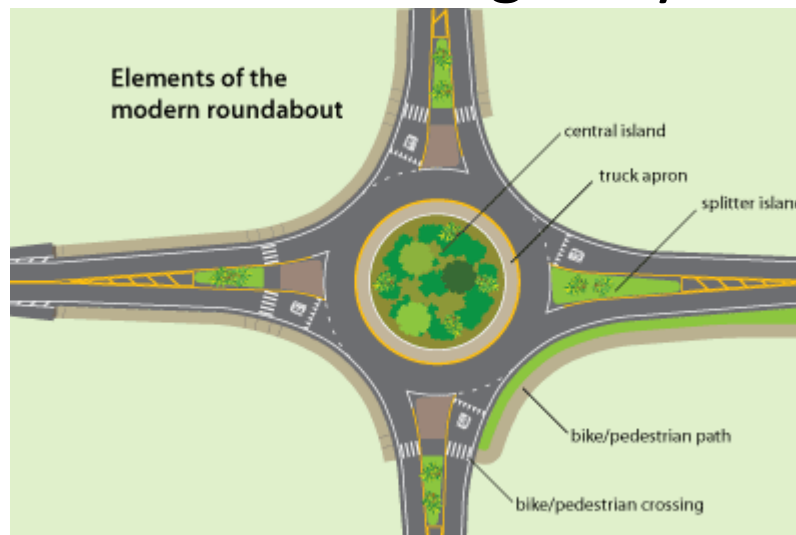
<https://sites.google.com/site/drivinginstructorm44/learning-to-drive/learnig-to-drive/crossroads>



<https://www.fhwa.dot.gov/publications/research/safety/08063/>

# Space sharing junction

- Example: roundabout;
- Number of traffic slightly equal at junction;
- Traffic streams share spaces at the same time;
- Suitable for 3 or 4 highways.



<https://www.co.mchenry.il.us/county-government/departments-j-z/transportation/roundabouts>

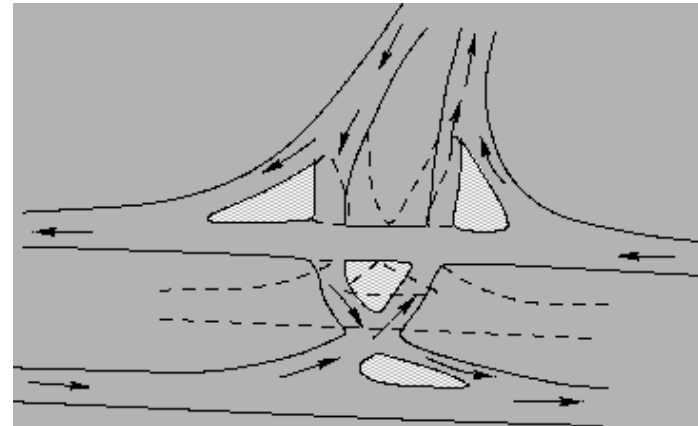
# Time sharing junction

- Example: traffic light
- Benefits:
  - Control traffic flow;
  - Reduce conflict at the junction;
  - Safer for pedestrian;
  - Less area used compare to roundabout.

# Channelization

## Definition:

Separation of conflicting movements at intersection to definite paths of traffic flow by means of lane markings islands, road curbs and others



[http://nptel.ac.in/courses/105101008/565\\_Channel/point11/point.html](http://nptel.ac.in/courses/105101008/565_Channel/point11/point.html)

## Functions of Channelization:

- ✓ To reduce possible area of conflicts at the intersection
- ✓ To control angle of conflict
- ✓ To regulate speed of vehicle entering and leaving the intersection
- ✓ Protection of traffic and pedestrians
- ✓ Location of traffic control devices

# Grade Separated Intersection/Interchanges

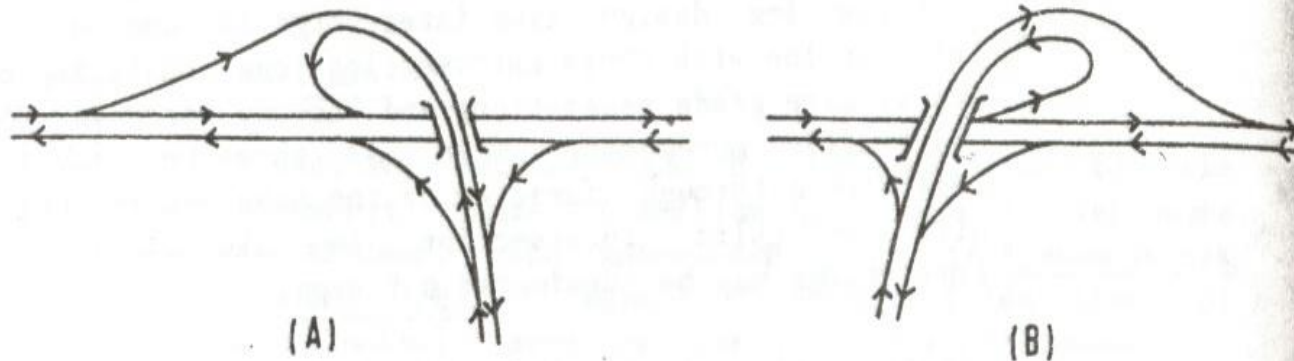
Grade separated intersection is the most expensive type of intersection. As such it is recommended in certain situations such as:

- i. on **high type facilities** (expressway) that serve high traffic volume and design speed more than 90km/hr
- ii. at-grade intersections which have reach **maximum capacity**
- iii. At **locations of bad accident history** when functioning as at-grade junction
- iv. at junction where the **traffic volume is heavy** and it is more economic to provide grade separator compare to the delays and loss due to not providing that
- v. at certain specific rolling or hilly topography
- vi. road crossing has four through lanes or more.

# Types of interchange

1. Three leg design
2. Four leg design
  - ramps in one quadrant
  - diamond interchanges
  - cloverleaf
  - directional and Semi-Directional Design
  - rotary Design

# Three Leg Design

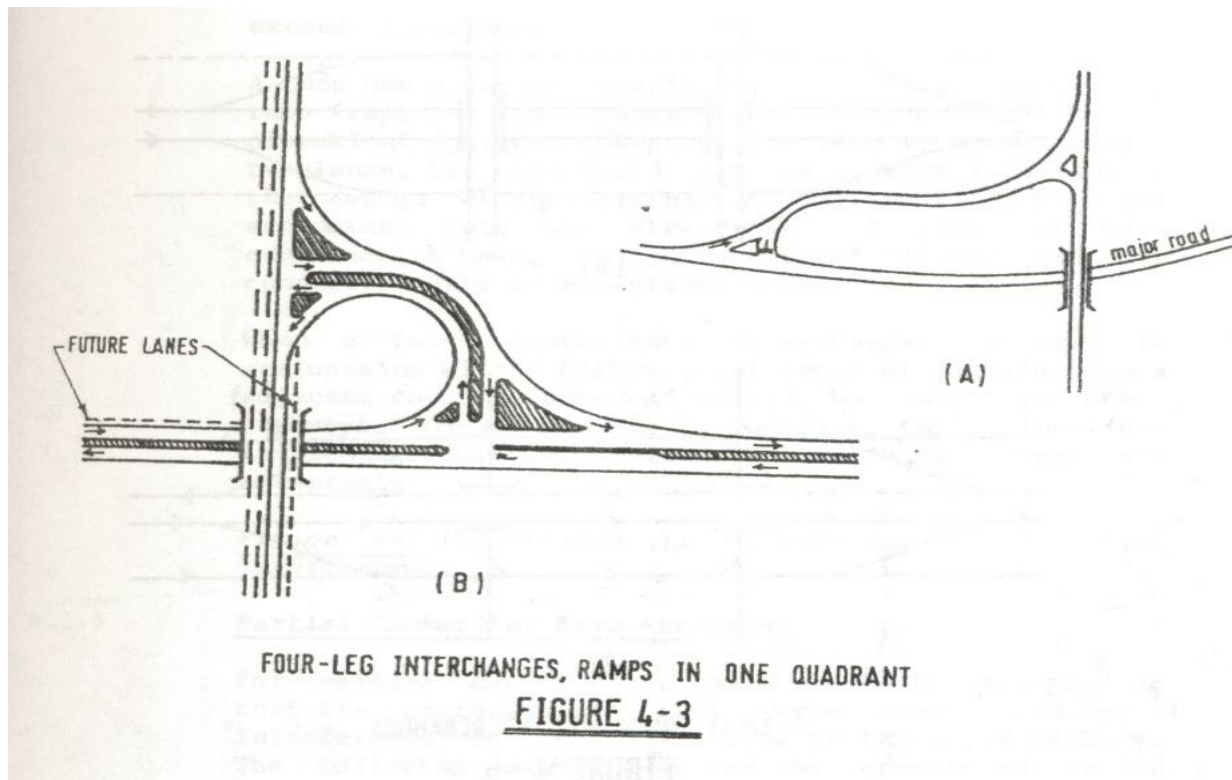


THREE-LEG INTERCHANGES WITH SIMPLE STRUCTURES

FIGURE 4-1

# Four leg design :Ramps in one quadrant

- apply for intersections with low volumes



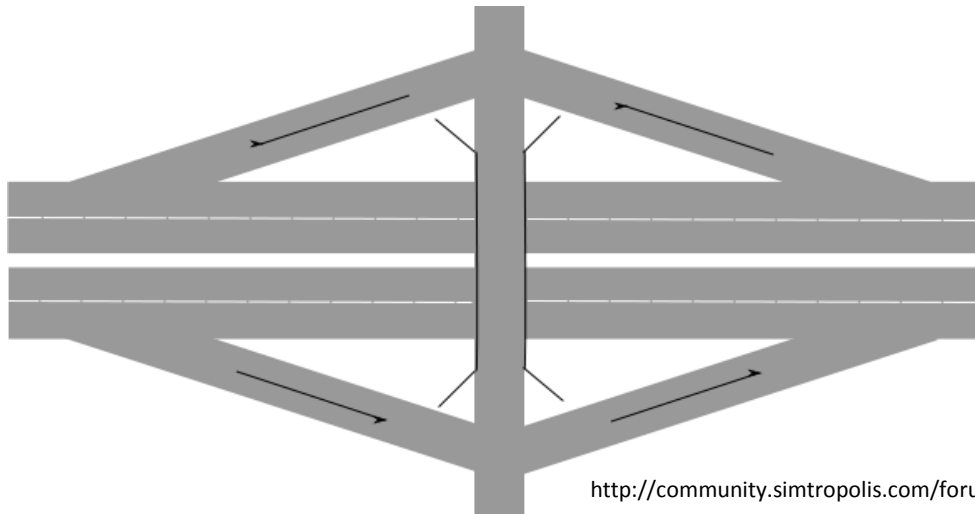


# Four leg design : Diamond interchanges

- simplest and most common type
- A full diamond interchange is formed when a 1-way diagonal type ramp is provided in each quadrant.

## Advantages:

- all traffic can enter and leave the major road at relatively high speed;
- right turning movement entail little extra travel; and
- relatively narrow band or right of way is required



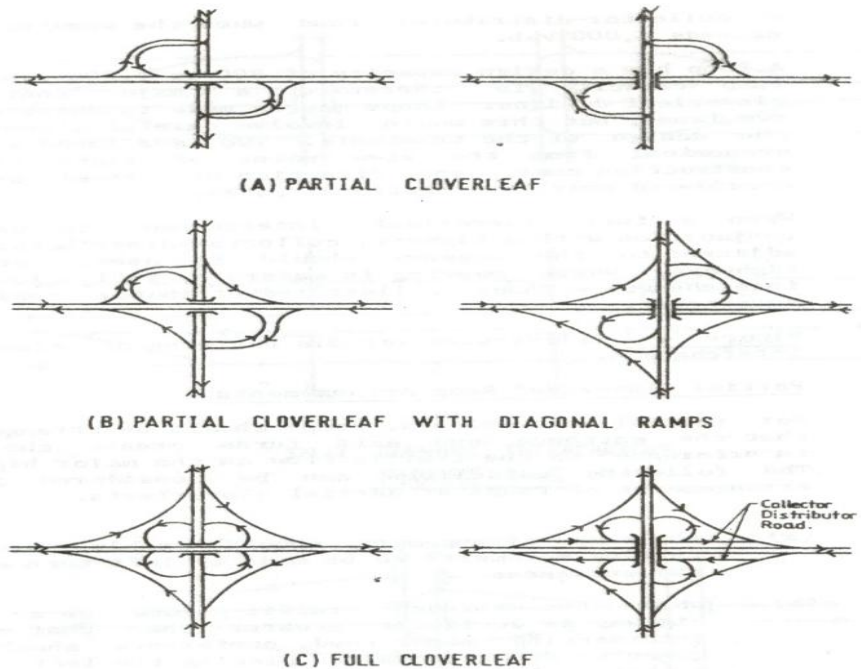
<http://community.simtropolis.com/forums/topic/28264-rhw-interchange-guide/>

# Four leg design : Cloverleaf

- Cloverleaf are four-leg interchanges which employ loop ramps to accommodate right-turning movements.
- More expensive than diamond interchanges.

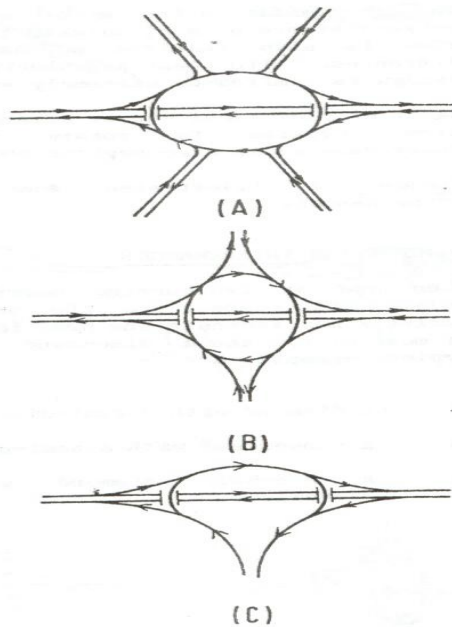


<http://www.modot.org/stlouis/links/SPUIFrequentlyAskedQuestions.htm>



# Rotary Design

- A rotary interchange is a roundabout with the major through highway grade-separated.



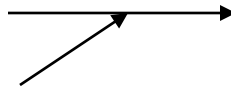
[https://www.revoly.com/main/index.php?s=Rotary%20\(interchange\)&item\\_type=topic&sr=50](https://www.revoly.com/main/index.php?s=Rotary%20(interchange)&item_type=topic&sr=50)

# Traffic Conflicts at Intersection

Traffic conflicts could be classified into:

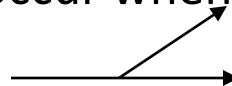
i) Merging Conflicts

- merging conflicts occur when vehicles enter a traffic stream;



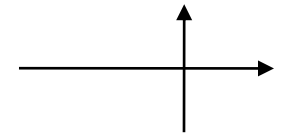
ii. Diverging Conflicts

- diverging conflicts occur when vehicles leave the traffic stream;



iii. Crossing Conflicts

- crossing conflicts occur when they cross paths directly.

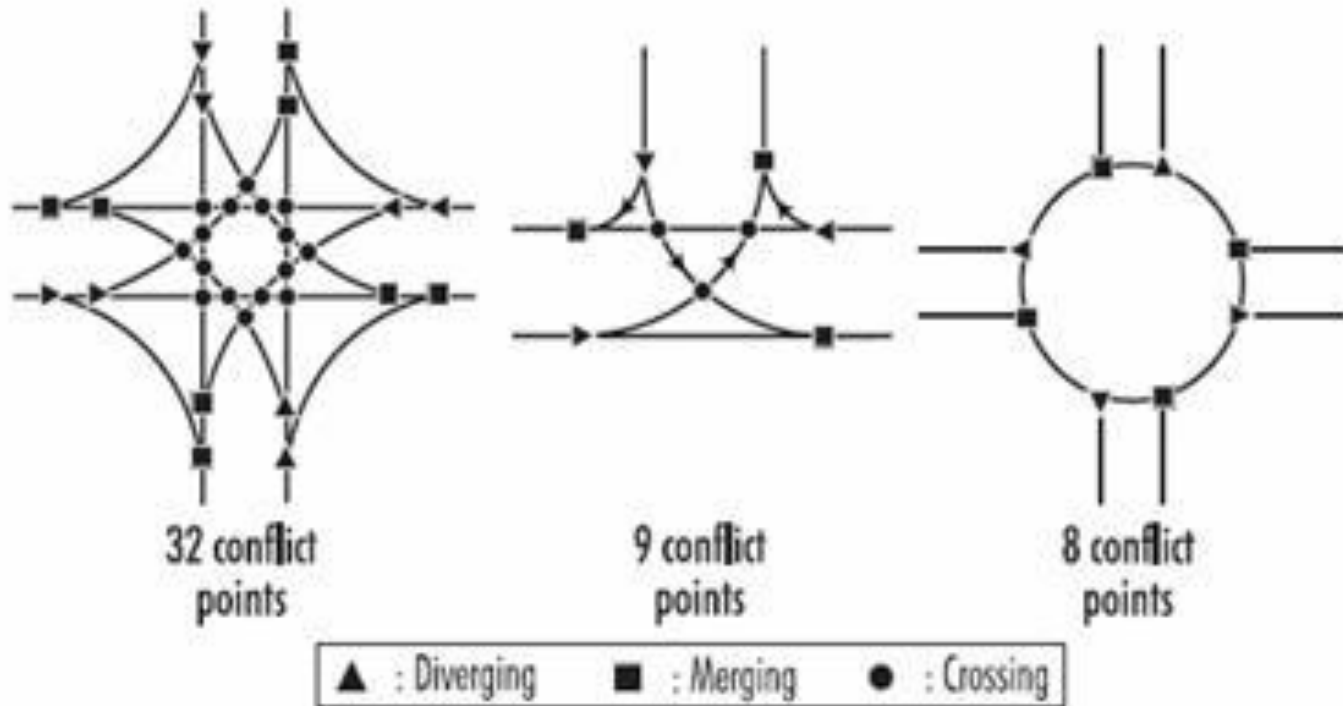


iv. Weaving Conflicts

- weaving conflicts occur when vehicles cross paths by first merging and then diverging



# Traffic Conflicts



Type of Conflicts points

[https://ec.europa.eu/transport/road\\_safety/specialist/knowledge/road/getting\\_initial\\_safety\\_design\\_principles\\_right/junctions\\_en](https://ec.europa.eu/transport/road_safety/specialist/knowledge/road/getting_initial_safety_design_principles_right/junctions_en)

# Traffic Signal

- Traffic signals are control devices that operate traffic by assigning right of way to various movements at the intersection
- Installation of traffic signal are follow guidance and principle by public work department [Arahan Teknik (Jalan) 13/87 (JKR, 1987)].

# Objectives of traffic signal

- To provide orderly movements of traffic at intersection
- To reduce number of conflict points
- To reduce delay and certain types of accidents

# Activity



## Advantages and disadvantages of traffic signal control?





# Advantages and Disadvantages

ADVANTAGES	DISADVANTAGES
Provide orderly movement of traffic	Can caused delay especially during off-peak
Reduce frequency of certain type of accident especially right angle type and pedestrian accident	Red runners
Can be used to interrupted heavy traffic at intervals to permit other traffic/pedestrian to cross or enter the main street flow	Accident frequency especially rear end may increased
Reduces number of conflicts point	Requires regular maintenance

# Traffic Signal Controllers

- Fixed Timed/ Pre-timed : signal timing same throughout the day
- Actuated : the sequence and timing of SOME or ALL green indication may change on a cycle-by-cycle basis in accordance with the demand from vehicle or pedestrian

# Signalised Intersection Warrant

Guide for installing signalised intersection based on the following warrant:

- i. Vehicle Operations
- ii. Pedestrian Safety
- iii. Accidents Record.

Traffic control signals should be installed if one or more warrants above are met.

# Warrant 1 : Vehicular Operations

## a) Total Volume

- traffic volume for each of any 8 hour of an average day meets the minimum requirements in table below

Number of Lanes Each Approach			Minimum Requirements (PCU)			
			Major Road (1)		Minor Road (2)	
Major Road	Minor Road	Urban	Rural	Urban	Rural	
1	1	500	350	150	105	
2 or more	1	600	420	150	105	
2 or more	2 or more	600	420	200	140	
1	2 or more	500	350	200	140	

(1) Total volume of both approaches

(2) Higher volume approach only

# Warrant 1 : Vehicular Operations

## b) Peak Hour Volume

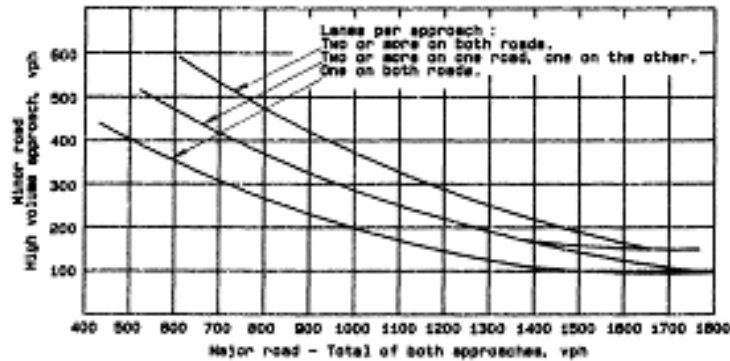


FIGURE 2.1 : PEAK HOUR VOLUME WARRANT - URBAN OR LOW SPEED

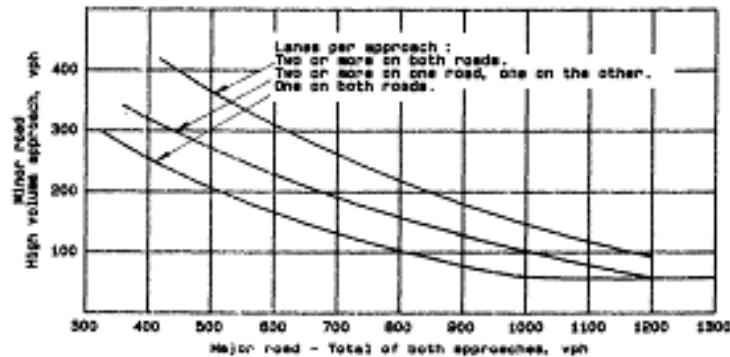


FIGURE 2.2 : PEAK HOUR VOLUME WARRANT - RURAL OR HIGH SPEED

# Warrant 1 : Vehicular Operations

## c) Progressive Movements

- at location desirable to install a signal to maintain a proper grouping or platooning of vehicles and regulate group speed even though the intersection. does not satisfy other warrants for signalisation

## Warrant 2 :Pedestrian Safety

- a) traffic volume  $\geq 600$  veh/hour on a major road for both direction or where there is a raised median island 1.2 m or more in width, 1,000 or more veh/hour, and
- b) 150 or more pedestrian/hour crossing the major road

# Warrant 3 : Accident Record

- The requirements are satisfied (based on at least 3 years accident records) when:
  - i. No other method found to reduce the accident frequency.
  - ii. There exist a record of 5 of more accidents in a year
  - iii. There exist a volume of vehicular and pedestrian traffic not less than 80% of the requirements specified in warrants 1 and 2.
  - iv. The signal installation will not seriously disrupt progressive traffic flow



# Basic Terminologies of Traffic Signal Design

## 1. Approach

- A lane or groups of lanes through which traffic enters the intersection

## 2. Traffic phase

- A part of the cycle time allocated to any traffic movement or any combination of traffic movements receiving the right of way. Any change in the right of way allocation marks the beginning of a new phase.

## 3. Intergreen time

- The time between the end of the green period of the phase losing the right of way and the beginning of the green period of the phase gaining the right of way. Thus, it includes amber time plus any all-red time between the two green periods.

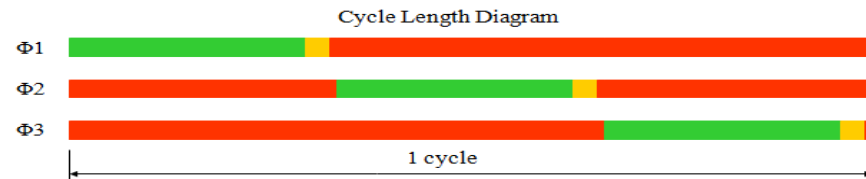
## 4. Lost time

- Time during which the intersection is not effectively using any approach. This time occurs during the change intervals when the intersection is cleared and at the beginning of each green indication as the first few vehicles in the standing queue experience start-up delay.

# Basic Terminologies of Traffic Signal Design

## 5. Optimum cycle time, C

- The total time for the signal to complete one sequence of signal indication cycle.



## 6. Saturation Flow, S

- The maximum flow that could pass through the intersection from a given approach if that approach were allocated all of the cycle time as effective green time with no lost time.

## 7. All red Interval

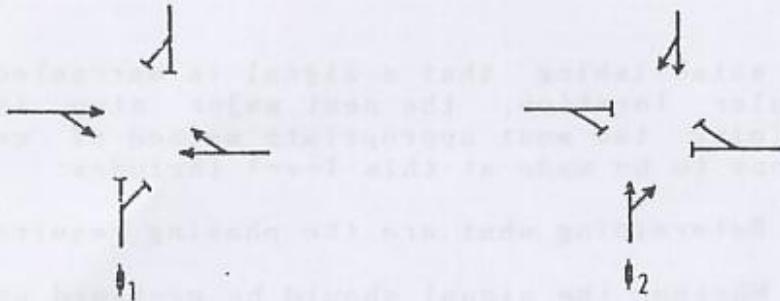
- the display of red indication for all approaches (pedestrian crossing)

## 8. Effective Green Time

- time effectively used by the signal for traffic movement

# TYPE OF PHASE

FIGURE 3.1: TWO PHASE CYCLE



- THROUGH MOVEMENTS ARE SEPARATED BUT THE RIGHT-TURN MOVEMENTS MUST YIELD TO OPPOSING TRAFFIC (TURNING ONLY WHEN THERE IS ADEQUATE GAP)

FIGURE 3.2: THREE PHASE CYCLE

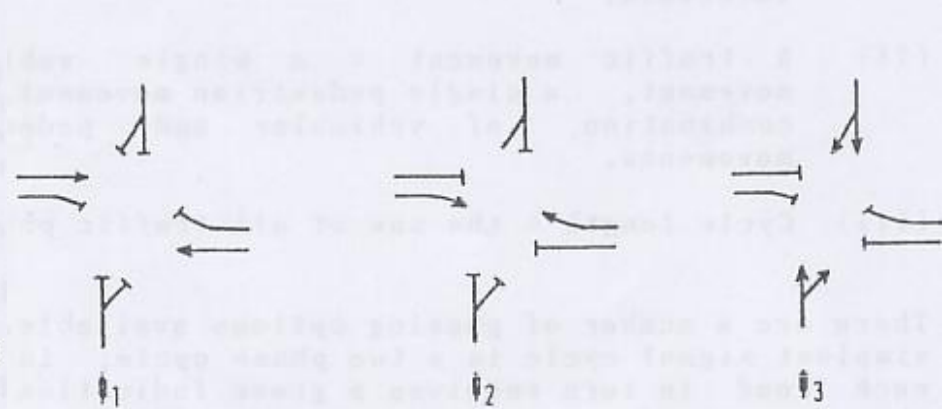
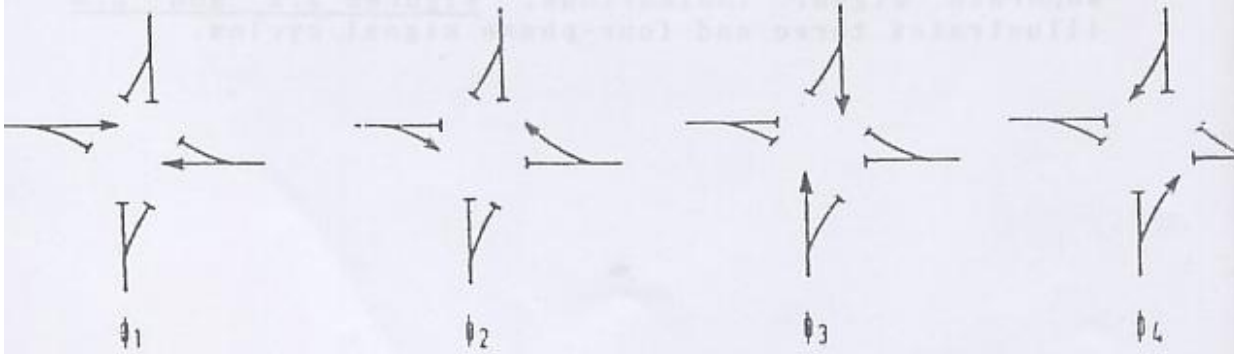


FIGURE 3.3: FOUR PHASE CYCLE



# Traffic signal timing design

## 1. Determination of saturation flow, s

- Effective approach width,  $W \geq 5.5$  m, therefore  $S = 525 W$  (pcu/hr)
- Where  $W < 5.5$  m, therefore S refer to table below:

w ( m )	3.0	3.25	3.5	3.75	4.0	4.25	4.5	4.75	5.0	5.25
s ( pcu/h )	1845	1860	1885	1915	1965	2075	2210	2375	2560	2760

# Traffic signal timing design

## 2. Determination of y value.

- $y = q / s$

where  $y$  = ratio of flow to saturation flow

$q$  = actual flow ( pcu/hr)

$s$  = saturation flow for the approach (pcu/hr)

- $Y_{max}$  should be less than 0.85

# Traffic signal timing design

## 3. Integreen Time

- $I = R + a$  where  $R = \text{allred}$   
 $a = \text{amber}$

## 4. Total lost time per cycle

- where  $a = \text{amber}(3\text{sec})$   
 $I = \text{IntergreenTime}$   
 $l = \text{driverreactiontime}$   
(normally set as 2 sec : 0-7 sec)

# Traffic signal timing design

## 5. Optimum cycle time

$$C_o = \frac{1.5L + 5}{1 - Y}$$

Note:

$C_o$  should be in the range ( 45 sec – 120 sec)

# Traffic signal timing design

## 6. Signal Setting

a) Effective green time,  $g_1$

$$g_1 = \frac{Y_i}{Y} (C_0 - L)$$

b) Actual green time,  $G$

$$G_1 = g_1 + l + R$$

c) Controller Setting Time,  $K$

$$K_1 = g_1 - a - R$$

@

$$K_1 = g_1 + l - a$$



# References

- Jabatan Kerja Raya Malaysia, A GUIDE TO THE DESIGN OF TRAFFIC SIGNALS, Arahan Teknik (Jalan) 13/87, 1987.
- Jabatan Kerja Raya Malaysia, A GUIDE TO THE DESIGN OF INTERCHANGES, Arahan Teknik (Jalan) 12/87, 1987.
- Jabatan Kerja Raya Malaysia, A GUIDE TO THE DESIGN OF AT GRADE INTERSECTIONS, Arahan Teknik (Jalan) 11/87, 1987.
- Roger P. Roess, Elena S. Prassas and William R. McShane, TRAFFIC ENGINEERING 3<sup>rd</sup> Edition, Pearson Education International, 2004.