UNIT - III

TRAFFIC ENGINEERING

Introduction:

To study about traffic systems and application of scientific principle for saftey and comfort to the passengers and good's

Scope of Traffic Engineering:

1. To study about traffic characteristics
2. To study about traffic studies and Analysis
3. To study about traffic Operation and control.
4. Planning and analysis
5. Geometric design.
6. Administration and Management

1. Traffic characteristics.

→ Road user characteristics
→ Vehicle characteristics

*Road user characteristics:

- Physical [vision, strength e.t.c.,]
- Psychological [Anger, fear, e.t.c.,]
- Mental [knowledge, Skill, experience, e.t.c.]
- Enviromental [Road side features, atmospheric Conditions e.t.c.,]

* Vehicale Characteristics

- Static
  [dimensions, weight of Vehicle, e.t.c.,]
- Dynamic
  [Speed, acceleration, breaking system e.t.c.,]

Traffic studies:

The objective of traffic studies are

1. To obtain knowledge of type and volume of traffic in present and in future.
2. To study the road facilities and improvements to be done
3. To design Geometric features and pavement thickness
4. To analyse road accidents.

* The traffic studies are classified into

→ Traffic Volume study
→ Speed studies
→ Origin and destination study
→ Traffic flow characteristics
→ Traffic capacity study
→ Parking study.
→ accident Studies

Traffic volume study:

It is expressed as the number of vehicles crossing a section of road per unit time is called Traffic volume study.

It is measured by manual methods and automatic counters (mechanical method)

Automatic counters:

1. Radar detector
2. Magnetic detector
3. Photo electric cell
4. Pneumatic method

* Traffic volume is expressed as vehicles/hour (or) vehicles/day (or) vehicles/month.

In view of variety of vehicles, a number is assigned to a vehicle based on its speed, space and characteristics it is termed as "passenger car unit (PCU)"

Type of Vehicle	PCU
Car	1
Truck/Bus	3
motor cycle (or) cycle	0.5
Rickshaw	0.5
Horse driven vehicle	4
Bullock cart	6 to 8

Presentation of traffic volume data.

As per IRC for Rural roads, Traffic count shall be taken over seven consecutive days and 24 hours during each day. Counters are taken atleast Twice each year.

One count been taken during the peak season of harvesting and marketing and other count during lean season

Average Annual Dialy Traffic (AADT)

The average 24 hours traffic volume at a given locator or location over full 365 days in a year i.e., the total number of vehicles per hour per whole year divided by 365.

$$AADT = \frac{\text{Total no. of Vehicle Per hr / whole year}}{365}$$

Average dialy Traffic (ADT)

An average 24 hours traffic volume at a given location for some period of time less than a year. It may be measured for 6 months, a season, a month, a week or a little as 2 days.

Volume flow diagram

This diagram is used for intersection design.

The no. of vehicles entering any intersection is equal to no. of vehicles going out.

~~No. of vehicles~~

** 30th highest hourly volume

The hourly volume that will be exceeded only 29 times in a year. and all the hourly volumes of the year will be less than this volume.

Travel time:

It is inversely proportional to speed i.e., if the speed increases, the travel time is decreases.

* Speed studies:

→ Spot speed:

The instataneous speed of a vehicle at a specified location is called spot speed.

→ Running speed:

It is defined as the average speed maintained over a given route while the vehicle is in motion.

→ Overall Speed: (or) Travel Speed: (or) Journey speed.

The effective speed with which a vehicle traverses a given route between two terminals.

Determination of spot speeds:

A) Manual method (By taking a fixed distance)

B) Artificial Methods (or) Mechanical methods.

→ Speed gun

→ Mirror box (Provide mirrors in 45°)

(or)

→ Enoscope method

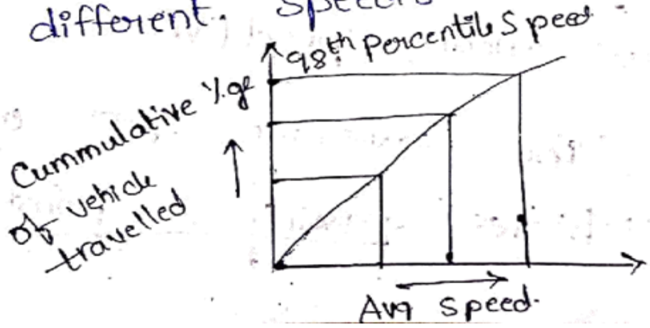
→ Electronic meter method.

→ photo electric meter

→ Pressure contact strip method.

*** Presentation of spot speed data.

A graph is plotted with the average value of each speed groupe on x-axis and the cummulative percentage of vehicles travelled at different speeds on y-axis.



98th percentile speed = Design speed

85th percentile speed = Max. speed

(The speed at (or) below which 85% of vehicles are passing a point on highway or only ~~15%~~ 15 percent of vehicles exceed a speed at that point)

Median speed = 50th percentile speed (or) Middle speed.

15th percentile speed = Minimum speed

model speed:

The speed at which greatest no. of vehicles travel is called model speed. (30th percentile speed).

Average speed:

The average of spot speed of all vehicles passing a given point on highway.

Spot speeds are divided into two type

1. Time mean speed (V_t)
2. Space mean speed (V_s)

Time mean speed (V_t)

The average sped of all the vehicles passing a point on a highway over some specified time period is called Time mean speed.

This is the average of spot speeds

i.e., $V_t = \frac{\sum_{i=1}^{n} V_i}{n}$

where V = speed in KmpH

n = No. of vehicles.

Space mean speed:

The average speed of all the vehicles occupying a given section of a highway over some specified time period. is called space mean speed.

It is hormonic mean of spot speeds.

i.e., $V_s = \frac{3.6\, dn}{\sum_{i=1}^{n} t_i}$

where n = no. of vehicles

d = Road length (fixed) in m

t = time for each vehicle to cross the distance d.

Note:

1. Space mean speed is slightly less than to the time mean speed.

i.e., $V_s < V_t$

2. When all the vehicles are moving with same speed

∴ Avg. Speed = TMS = SMS

1. The time for covering a stretch of length of 200mts by 10 vehicles are 12, 11, 13, 14.3, 15.5, 12.5, 12, 1.2, 14.1 and 13.6 sec. Calculate time mean speed and space mean speed.

$$V_s = \frac{n}{\sum_{i=1}^{n} \frac{1}{V_i}}$$

Given length $l = 200$mts

$n = 10$

$$\sum_{i=1}^{n} V_i = \sum_{i=1}^{10} V_i = V_1 + V_2 + V_3 + V_4 + V_5 + V_6 + V_7 + V_8 + V_9 + V_{10}$$

$$= [12 + 11 + 13 + 14.3 + 15.5 + 12.5 + 12 + 1.2 + 14.1 + 13.6]\, 200$$

$$= 23840$$

Time mean speed $V_t = \dfrac{\sum_{i=1}^{n} V_i}{n} = \dfrac{23840}{10}$

$= 2384$ m/sec.

$= 662.75$ kmph

$$V_s = \frac{n}{\sum_{i=1}^{n} \frac{1}{V_i}} = \frac{10}{\sum_{i=1}^{10} \frac{1}{V_i}}$$

$$= \frac{10}{1/23840}$$

$$= 238400$$

Space mean speed $V_s = \dfrac{3.6\, d n}{\sum_{i=1}^{n} t_i}$

$$= \frac{3.6 \times 200 \times 10}{119.2}$$

$V_s = 60.40$ m/sec

Traffic density :

the number of vehicles occupying a unit length of a lane of a road at a give instant is called Traffic density.

It is expressed as Vehicles / km or m

Relation between Traffic volume, Traffic density and Speed.

let ~~Length~~ q = Traffic volume or Traffic flow in vehicles/hour

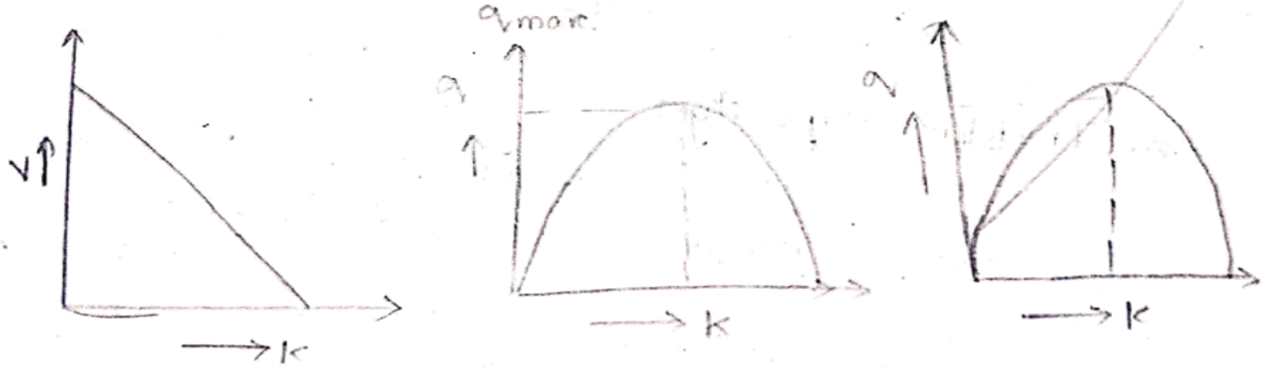
k = Traffic density in vehicle/m

V = Speed of the vehicle in km/hr

$$q = kV$$

$$\frac{\text{Vehicles}}{\text{hr}} = \frac{\text{Vehicles}}{\text{km}} \times \frac{\text{km}}{\text{hr}}$$

$$= \frac{\text{Vehicles}}{\text{hr}}.$$



Important definitions.

1. Time head way (H_t)

The time gap between two successive vehicles which are crossing a section on a road is called Time head way H_t

$$H_t = \frac{3600}{q}$$

where H_t = Time head way in sec

q = Traffic volume in vehicles/hr

2. Space head way (or) distance head way

The avg distance (or) space between two successive vehicles is called space head way (or) distance head way. (or)

inverse of density is called space head way.

$$S = \frac{1}{K}$$

where k = density of Traffic

3. Traffic capacity :

The ability of road way to accomodate traffic volume is called Traffic capacity.

i.e., the Traffic capacity is

The max. traffic volume (or) max. traffic flow

$$C = 1000 \frac{V}{S}$$

where V = speed in kmph
S = space head way (or) distance head way.

Types of Traffic capacity

1. Basic capacity (or) Theoritical capacity (or) ideal capacity
2. possible capacity
3. Practical capacity (or) design capacity

Basic Capacity:

The maximum number of vehicles that pass a given point on a road way during one hour under ideal road way and traffic conditions is called basic capacity.

Spacing head way $S = S_g + L$

where $S_g = Vt$
L = length of rigid wheel base
= 6.1m as per IRC
$t = 0.7$ sec = Reaction time of a driver.

Possible capacity:

The max. no. of vehicles that can pass through a given point on a road way during one hour ~~and~~ under prevailing rod way & traffic conditions

Practical capacity or design capacity:

The max. no. of vehicles that can pass through a given point on a road way during one hour without traffic density

So as to cause unreasonable delay, hazard or restriction to the driver freedom is called "design capacity"

Space head way $S = SSD + L$

where,

SSD = stopping sight distance

$= vt + \frac{v^2}{2gf}$

1) Calculate the theoritical capacity of traffic lane with one way traffic flow at speed of 50 kmph. Assume average space gap between vehicles to follow the relation $S_g = \cancel{vt}\ vt$ where v = speed in m/sec, t = reaction time = 0.7 sec.

Given

we know that

Traffic capacity $C = 1000 \frac{V}{S}$

where V = Speed in kmph = 50 kmph

S = Space head way (or) distance head way

$S = S_g + L$

$= vt + L$

~~S_g = 50 × 0.278~~

$S_g = 50 \times 0.273$

$= 13.89$ m/sec.

$S = S_g + L$

$= 0.7\,v + 6$

$= (0.7 \times 13.89) + 6$

$S = 15.72\,m.$

$\therefore$ Capacity $C = 1000\,\frac{V}{S}$

$= 1000 \times \frac{50}{15.72}$

$= 3180.66 \cong 3181$

$C \cong 3181$ vehicles / hr / lane.

Origin and Destination Studies.

These studies shows the amount of travel existing between certain destination. These studies gives an idea of number of vehicular traffic, their origin and destination in each zone of study.

These studies are most essential in improving the existing road system and planing the new highway facilities to the public

Applications of 'O' & 'D' studies:

1. To locate express ways or major routes along the designed lines
2. To locate intermediate stops for public transport
3. To locate terminals and to plan terminal facilities

4. To establish preferential routes for various categories of vehicles
5. To plan transportation system and mass transit facilities in cities including routes and schedule of operation.

Methods of collecting 'O' & 'D' studies Data.

1. Road side interveiw method
2. Home interveiw method
3. Return post card method
4. Telephone calling method
5. License plate method.
6. Tag on car method

Level Of Service Concept [LOS]

It is defined as a qualitative measure describing the operational condition with in a traffic stream and their perception by motorist ~~bikers~~ and passenger

Los Definitions

i. Los A – free flow, low traffic, and high speed
ii. Los B – stable flow, and noticable traffic
iii. Los C – Stable flow and Traffic interactions
iv Los D – unstable flow, high density and movement restrictions.

v. LOS E – unstable flow, lower speed, volume is nearly equal to capacity, little freedom.

vi. LOS F – unstable flow, No freedom, Traffic volume can drop to zero.

Parking studies:

- On street parking
  - Parallel parking
  - Angle parking
    - 30° angle parking
    - 45° angle parking
    - 60° angle parking
    - 90° angle parking
- Off street parking
  - Surface parking
  - under ground Parking

On street parking:

The vehicles are parked on the roads or beside the road is called "On street parking."

Angle parking:

The vehicles are parked on road with certain angle such as 30°, 45°, 60° and 90°

45° angle parking is most suitable for motorists or bikers

* Parking time

The time spent in parking space is called parking time

* Parking volume

The no. of vehicles parked in a particular area over a given period.

* Parking Turnover

The ratio of no. of vehicles parked in a duration to the no. of parking bays available.

* Parking Index (or) Parking occupancy (or) Parking efficiency.

It is defined as the ratio of no. of bays occupied in a particular duration to the total space available.

Effects of Parking:

→ Accidents
→ Enviromental pollution (noise & air pollution)

Accident studies

Accidents can't be prevented permanently but by applying some traffic operations and scientific principles we can reduce accident rate

Objective:

→ To study about the causes of accidents
→ To align evaluate existing design

→ Computations of financial loses due to accidents.
→ To carry out before and after studies after implementing changes.

Reasons for accidents :

1. Drivers – Over speed, unskilled, eye sight e.t.c.,
2. Vehicle conditions like brake efficiency, tyres, e.t.c.
3. Passengers – while getting into vehicles and moving infront of vehicles.
4. Geometric design of road – width of pavement, inadequate sight distance e.t.c.,
5. Climatic condition – heavy rainfall, snow fall, fog, humidity e.t.c.
6. Animals

Preventions :

By providing speed limit, speed brakers, sign boards, signals, markings, Islands

Collision diagrams :

The diagram represents pattern of accidents.

It also represents type of accidents and number of accidents.

This diagram useful for before studies and after studies.

Condition diagram:

The purpose of the condition diagram is to show the intersection and conditions with in the surrounding area.

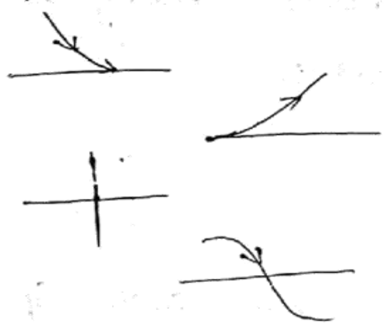
The diagram should include intersection alignment items such as buildings, trees, lighting poles, no. of lanes e.t.c.,

Conflict points:

These points are intersection points b/w traffic movement paths.

The group of conflict points are

Merging
Diverging
Crossing
weaving



Type of Traffic	No. of conflict points
Both the roads - two way	24
One is two lane and another one is one lane	11
Both the roads one - way	6

TRAFFIC CONTROLLING DEVICES:

The arrangements or the provision made to the road users to avoid accidents on the roads and for the free and effective traffic flow are known as traffic controlling devices.

Generally, following four devices are provided on road to control the traffic:

1. Road signs

2. Markings

3. Signals

4. Traffic islands

ROAD SIGNS:

Roads signs are provided to warn direct and guide the road users. They are in the form of symbols or inscription. They are mounted on fixed or portable supports and are placed on the side of roads.

Further road signs are classified in to three categories,

- Regulatory or mandatory signs.
- Warning or caution signs.
- Informatory or guiding signs.

Regulatory or mandatory signs:

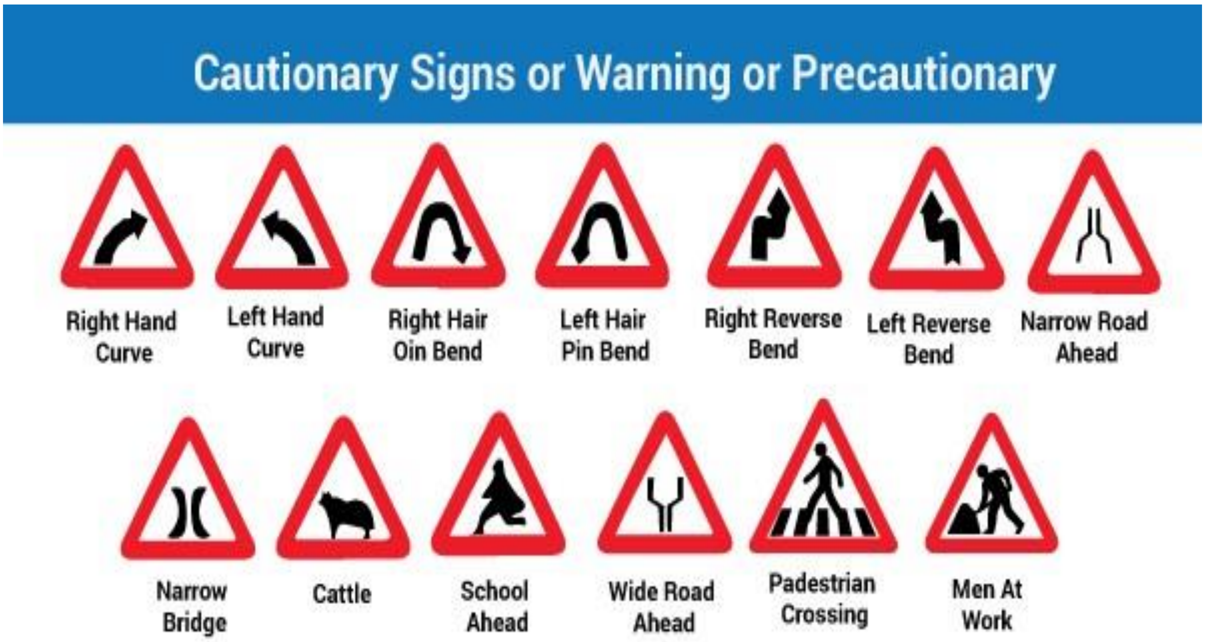
These signs are used to inform the road users, certain rules and regulations, which has to notice for safe and free, flow of traffic. (Displayed in circular disk of **600mm dia** with the **white color background**, **red border, black color numeral or symbols**)

Some of the regulatory signs are

- Give way and stop signs
- Prohibitory signs
- Speed limit and vehicle control
- No parking, no stopping signs

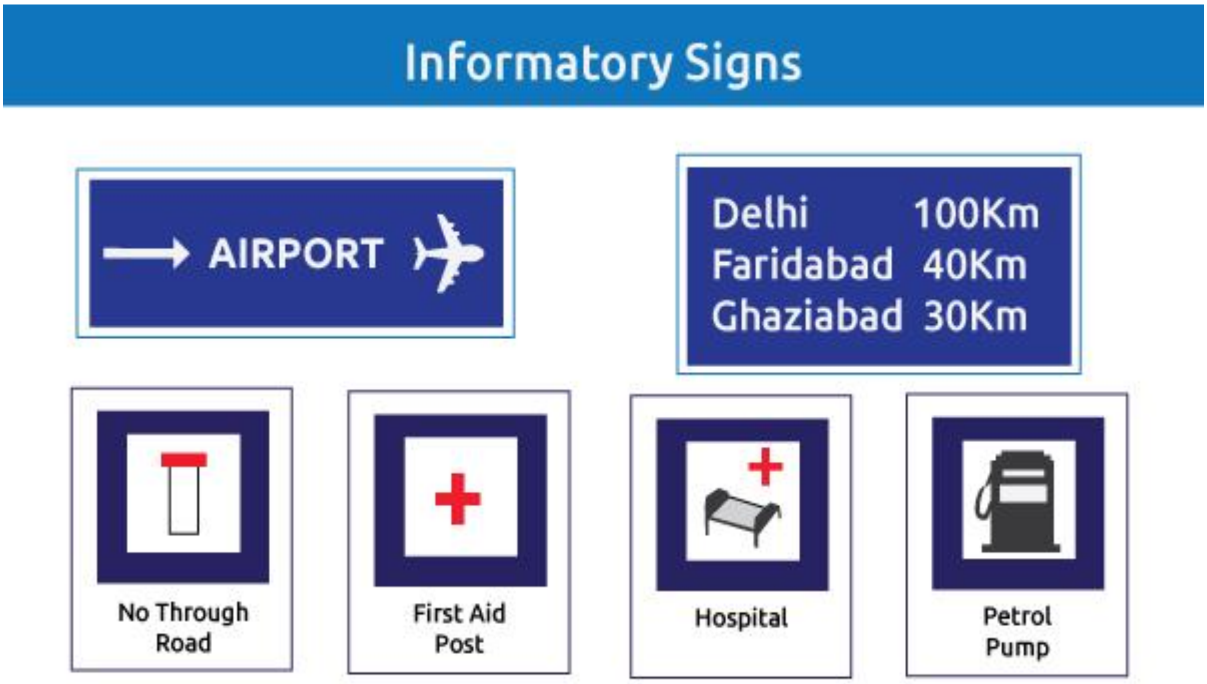
Warning or caution signs:

Used to make the road user aware of hazardous condition ahead. Generally, these Warning signs are of **Triangular shape** (400 mm on each side) with a **red strip on edges** and **markings with black color**.



Informatory or guiding signs:

- Informatory signs gives information about destination, distance and alternative routs. It also includes prominent locations like First Aid post, Public Toilets, Hospitals, Eating-place and Paring details etc.
- An informatory sign usually consist of a **rectangular board** of specified size.
- In case of facility **information signs**, the size of rectangle shall be 800mm x 600mm for **normal signs** and the size of square shall be 400mm and 300mm.



Functions of traffic signs

Knowledge of traffic signs for any driver is necessary as they perform certain functions, which are essential for road safety. The functions performed by traffic signs are:

- The distance left to cover to reach a specific destination.
- Alternative routes to the specific destination, if any.
- Locations on the cautionary traffic signs are also displayed such as schools, colleges, workplaces, clubs, public places and restaurants.

Importance of traffic signs in daily life

- As per statistics provided by the government, 400 accidents occur in India every day.
- Also, as per the data provided by WHO, traffic crashes cost about 3% of the total gross domestic product of a country on average.
- Therefore, the importance of knowing the traffic signs and rules is essential.
- Traffic signs prevent the undesirable risks posed on the road to drivers and the passengers in the vehicle.
- Traffic signs make sure that order has ensued on the road and if the signs are followed properly, the chances of accidents occurring are greatly minimised.
- Traffic signs also help in easy navigation of the routes.
- The importance of traffic signs and road rules cannot be ignored in one's life and it should be given paramount importance. Any driver who is driving a vehicle on the road should be aware of all the traffic signs and rules. The government has already made it mandatory for any person who wishes to obtain a driving licence in India for the different traffic signs and rules.

MARKINGS (Pavement markings)**:**

- Traffic markings are the lines, patterns, words, symbols or reflectors applied to the carriage way, kerbs, sides of islands or to fixed objects near the road way.
- The objects of the traffic marking is to warn, inform and guide the road users.
- They are made by using prints in contrast with colors and brightness on pavements or other background.
- Ordinary paints like oil paints are used for road markings.

The various types of markings may be classified as,

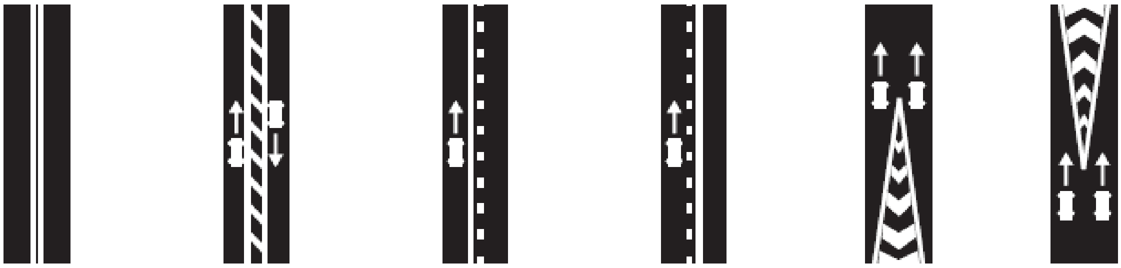
a. Pavement markings
b. Kerb markings
c. Object markings and
d. Reflector unit markings

PAVEMENT MARKINGS:

- Pavement markings are used to convey messages to roadway users.
- They indicate which part of the road to use, provide information about conditions ahead, and indicate where passing is allowed.
- Yellow lines separate traffic flowing in opposite directions.

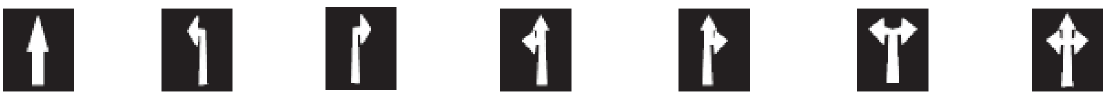
Purposes:

- Pavement markings are used to mark the centre line of the road in case of 2-lane highway.
- To make the pavement and shoulder distinct by means of shoulder lines drawn at the pavement edges.
- To make lane boundaries for multi-lane highway.
- To make crosswalks for pedestrians.
- To make stop lines at the road surface close to signals.
- Turning movement.
- These are used in parking places where parking is permitted.
- These are used in no passing zones. These are the areas where we do not over take i.e., on steep curve, on narrow bridge continuous line is drawn there.



Do not cross or straddle | Do not cross or enter hatched are | Do not cross or straddle | May cross to overtake | Merging | Diverging

No Stopping at any time | No Stopping at time shown on 'Time plate' | No parking at any time | Pedestrian crossing at Green man crossing or at traffic light junction | No stopping at markings showing pedestrian crossing



Ahead only in this lane | Turn left in this lane | Turn ringht in this lane | Ahead only or turn left in this lane | Ahead only or turn right in this lane | Turn left or right in this lane | Ahead, turn left or turn right in this lane

Zebra crossing markings showing pedestrian crossing, 'Give way' lines and zebra controlled area | Do not enter unless exit is clear | Do not enter unless exit is clear | No parking on hatched area

Width of paint line = 4 inches

Length of paint line = 10 feet dashes separated by 30 feet spaces.

Colour: Yellow for distinguish one surface to other, white for controlling.

White lines painted on the pavement indicate traffic traveling in your direction.

Broken White Line: you may change lanes if it is safe to do so.

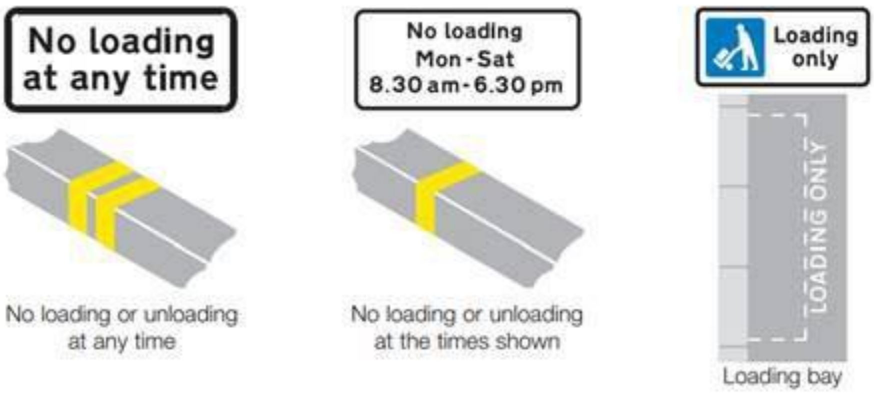
Solid White Line: requires you to stay within the lane and marks the shoulder of the roadway.

Yellow Lines mark the centre of a two-way road used for two-way traffic.

- You may pass on a two-way road if the yellow centreline is broken.
- When a solid and a broken yellow line are together, you must not pass if you are driving next to the solid line.
- Two solid yellow lines mean no passing. Never drive to the left of these lines.

KERB MARKINGS:

- Marking on the kerb **indicate certain regulations** like parking regulations.
- Marking on the kerb and edges of islands with alternative black and white line increase the visibility from a long distance.



OBJECT MARKINGS:

- Physical obstruction on or near the roadway are hazardous and hence should be properly marked.
- Typical obstructions are **signs** and **signals, traffic islands, narrow bridges, culvert**.

REFLECTOR MARKINGS:

- These are used as hazard markers and guide markers **for safe driving during night**.
- These markers should be visible from a long distance of about 150 m.

TRAFFIC SIGNALS:

- These are provided to control, warn and guide the traffic.
- These are provided at road intersections.
- These are control devices, which could alternatively direct the traffic to stop, proceed at intersections using red and green light signals automatically.
- The main requirement of traffic signals are to draw attention.

Advantages:

- Maintain orderly flow of traffic.
- Reduce certain types of accidents.
- Improves safety and efficiency of movement of vehicles.
- Pedestrians can cross the roads safety.
- More economical than manual control.
- Increase in speed along the major road traffic.

Disadvantages:

- The rear and end collision may increase.
- Improper design and location of signals may lead to violations the control systems.
- Failure of the signal due to electrical power failure or any other defects may cause confusion to the road users.

The normal sequence of traffic signals Red – Amber – Green, Amber – Red…etc.

- **Red** – Must Stop
- **Amber** – Clearance time for those who entered into intersection.
- **Green** – Go

OBJECTIVES:

- Amber period of 2 seconds.
- Lenses are normally of two sizes of 200 mm dia and 300 mm dia.
- Large size are used for 85 th percentile approach speed exceeds 65 KPH.
- The height of the signals shall be such that when erected ,the centre of amber shall be not less than 2.4 m nor more than 4.0 m above the carriageway level.
- Primary signal is installed at 0.9 m from the stop line and secondary signals is usually installed if there is a central island.
- A secondary signal is commonly installed opposite to first primary signal on the back of the primary signal intended for opposite traffic. (A minimum two signal faces to be provided)

Types of traffic signals:

The signals are classified into the following types

a. Traffic control signals
    i. Fixed time signal
    ii. Manual operated signals
    iii. Traffic actuated (automatic) signal
b. Pedestrian signals
c. Special traffic signals

Fixed time signals:

- These signals are set to repeat regularly a cycle of red, amber yellow and green lights.
- Depending upon the traffic intensities, the timings of each phase of the cycle is predetermined.
- Fixed time signals are the simplest type of automatic traffic signals, which are electrically operated.
- **Drawbacks of the signals**: The cycle of red, yellow and green goes on irrespective whether on any road, there is any traffic or not. Traffic in the heavy stream has to stop at end phase.

Manual operated signals:

- In these types of signals, the traffic police watches the traffic demand from a suitable point during the peak hours at the intersection and varies the timings of these phases and cycle accordingly.

Traffic Actuated (Automatic) Signals:

- In these signals, the timings of the phase and cycle are changed according to traffic demand.
- In **semi-actuated signals**, the normal green phase of a traffic stream may be extended up to a certain period for allowing the vehicles to clear off the intersection.
- In **fully actuated signals**, computers assign the right of way for the traffic movement on turn basis of traffic flow demand.

Pedestrian Signals:

- When the vehicular traffic remains stopped by red or stop signal on the traffic signals of the road intersection, these signals give the right of way of pedestrians to cross a road during the walk period.

Special Signals or Flashing Beacons:

- These signals are used to warn the traffic.
- When there is a red flashing signal, the drivers of vehicles must stop before entering the nearest cross walk at the intersection or at a stop line where marked.
- Flashing of yellow signals are used to direct the drivers of the vehicular traffic to proceed with caution.

Definitions:

Cycle: A signal cycle is one complete rotation through all of the indications provided.

Cycle length: Cycle length is the time in seconds that it takes a signal to complete one full cycle of indications. It indicates the time interval between the starting of green for one approach until the next time the green starts. It is denoted by **C**.

Total time by adding all these timings is called a “Cycle length”

Cycle length = Red light time + Yellow light time + Greenlight time + All red time (If provided)

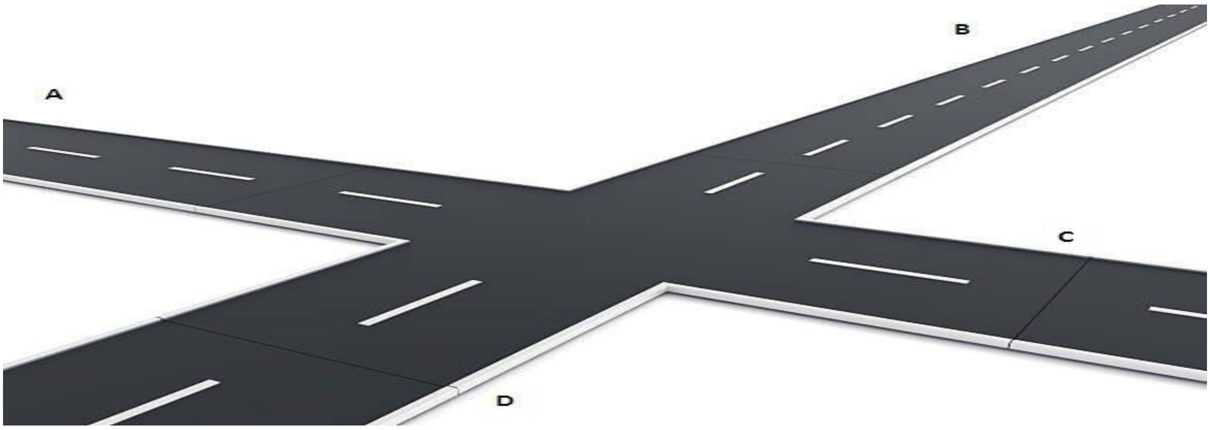
Interval: Thus, it indicates the change from one stage to another. There are two types of intervals - change interval and clearance interval. *Change interval* is also called the yellow time indicates the interval between the green and red signal indications for an approach. *Clearance interval* is also called *all red* is included after each yellow interval indicating a period during which all signal faces show red and is used for clearing off the vehicles in the intersection.

Green interval: It is the green indication for a particular movement or set of movements and is denoted by $\mathbf{G_i}$. This is the actual duration the green light of a traffic signal is turned on.

Red interval: It is the red indication for a particular movement or set of movements and is denoted by $\mathbf{R_i}$. This is the actual duration the red light of a traffic signal is turned on.

Phase: A phase is the green interval plus the change and clearance intervals that follow it. Thus, during green interval, non-conflicting movements are assigned into each phase. It allows a set of movements to flow and safely halt the flow before the phase of another set of movements start.

A Phase is that part of a cycle where one or more streams of traffic is (are) allowed to occupy the road simultaneously.

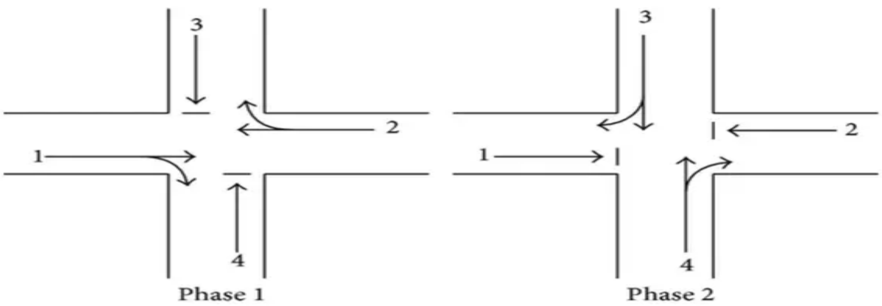


Consider above diagram. It shows intersection with four legs. Let me call each leg by a name A, B, C and D.

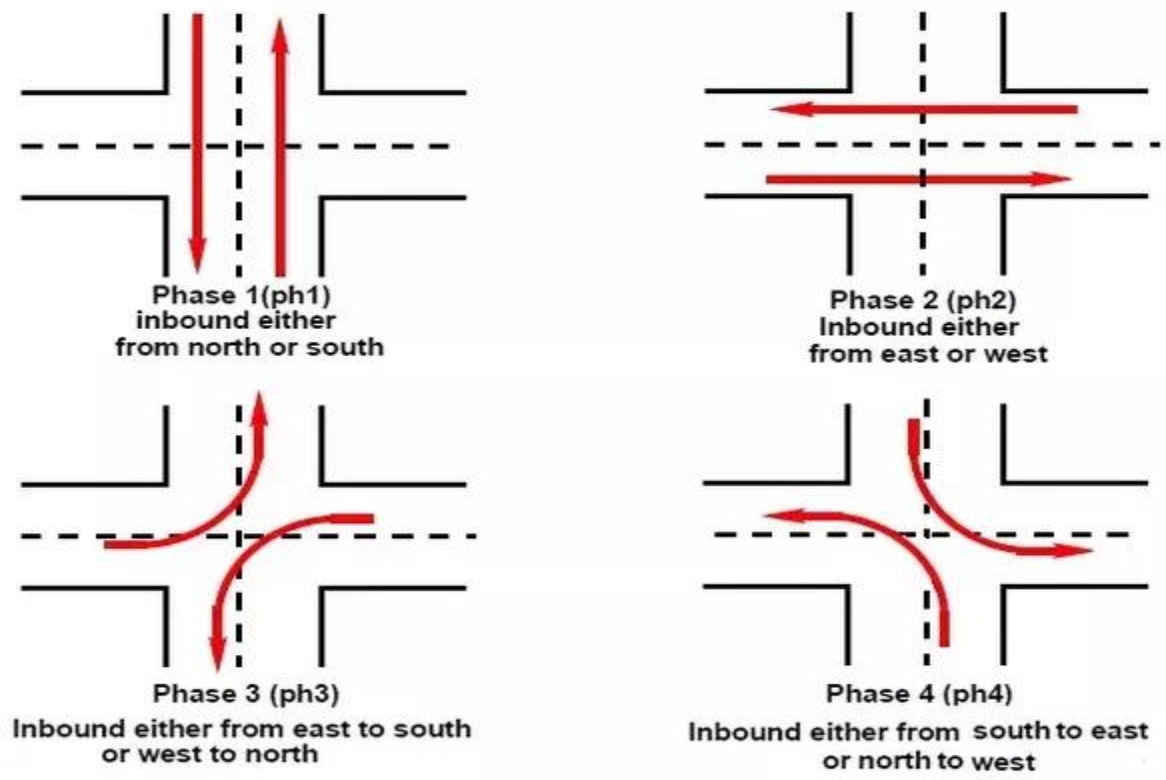
In a two-phase signal, there will be two phases. i.e.

1st phase: Traffic streams from A and C are allowed to cross intersection while traffic streams from B and D are stopped.

2nd phase: Traffic streams from B and D are allowed to cross intersection while traffic streams from A and C are stopped.



Similarly In a four-phase signal,



Lost time:

It indicates the time during which the intersection is not effectively utilized for any movement. For example, when the signal for an approach turns from red to green, the driver of the vehicle, which is in the front of the queue, will take some time to perceive the signal (usually called as reaction time) and some time will be lost here before he moves.

- **Starting lost time:** the time interval between the commencement of green and the commencement of effective green.
- **End lost time**: the time interval between the termination of effective green and the termination of the amber period.

Saturation Flow (S):

- This indicates the number of vehicles passing an intersection with minimum headway during the whole of a 'green' period.
- It is the **maximum flow**, expressed in pcu's, that can be discharged from a traffic lane when there is **a continuous green indication** and a continuous queue on the approach.
- The saturation flow is independent of traffic and control factors

For new signal installations, the RRL recommends the use of the following formula for determining saturation flow –

S = 525 w passenger car units (PCU) per hour

Where,

S = Saturation flow

w = Width of approach road in metros.

This works out to approximately 160 PCU for every 0.3 m width of the road and is applicable for w ranging from 5.50m to 18m. For smaller widths, reduced values of S are recommended.

Geometric factors affecting lane saturation flow are:

1. position of the lane (near side or non-near side)
2. width of the lane
3. gradient
4. radius of turning movements.

Effective green time:

- Effective green time is the time during which the signal is effectively green.
- The concept of effective green time was introduced as a means of determining the number of vehicles that could cross a stop line over the whole of the cycle.
- Maximum no. of vehicles crossing the stop line per hour,
  = (Saturation flow x effective green time) / Cycle time

In practice:

Lost time per phase = Starting lost time + End lost time $\approx$ 2 seconds

Amber time = 3 Secs

Actual green time + amber period = Effective green time + lost time

Effective green time = Actual green time + amber time - lost time

Effective green time = Actual green time + 3 s - 2s.

Problem:

The lost time due to starting delays and end of green time on a traffic signal approach = 2s. The actual green time = 25s. Find the effective green time.

Solution:

Effective green time = Actual green time + amber time - lost time

= 25 + 3 - 2 = 26 seconds

Design of Traffic Signals:

- The first two methods are 'approximate design procedures'.
- Webster's method of signal design is a rational approach with the objective to minimize the overall delay of all the vehicles entering the intersection.
- In addition the signal design method as per the guidelines of the IRC is also given.
- For the purpose of simplicity, two phase traffic signals with no turning movements are illustrated here;
- The methods may be suitably extended for multiphase operations also.

a) Trail Cycle Method

b) Approximate Method Based on Pedestrian Procedure

c) Webster Method of Traffic Signals

d) Design Method as Per IRC

a) Trial Cycle Method

- 15 min traffic count n1 and n2 on road 1 and 2 are noted during design peak hour.
- Trial cycle C1 seconds is assumed.
- Number of cycle in 15 min is found by

  = (15 x 60)/C1 = 900/C1
- Assuming the average head way is 2.5 seconds.
- The green period G1 and G2 of road 1 and road 2 is calculated by

  G1=(2.5n1 x C1)/900

  G2=(2.5n2 x C1)/900

  n1=traffic count on cross road 1 during peak hours

  n2=traffic count on cross road 2 during peak hours
- The amber period A1 and A2 are calculated or assumed as 3 or 4 seconds.
- The length C1'=(G1+G2+A1+A2).
- If the calculated length C1' is approximately equal to the assumed cycle length C1,the design cycle is accepted.
- Or the trail are repeated till the trial cycle length equal to the calculated value.

Problem:

The 15 min traffic count on cross road 1 and 2 during peak hours are observed as 178 and 142 vehicles per lane respectively in the direction of heavier traffic flow. If the amber times required are 3 and 2 sec for two loads based on approach speed, design the signal timing by trial cycle method. Assume an average time headway of 2.5 sec during green phase.

Solution:

n1 = 178 vehicles per lane

n2 = 142 vehicles per lane

Trail 1:

Assume a trial cycle C1 =50sec

Number of cycle in 15 min = 900/50=18

Average headway time =2.5 sec

Green time for road 1, G1=(2.5 x 178 x 50)/900 =24.7 sec

Green time for road 2, G2=(2.5 x 142 x 50)/900 =19.7sec

Amber time A1 and A2 = 3 and 2 sec

Total cycle length =24.7+19.7+3+2=49.4 sec

As this is **lower than** assumed cycle, try another cycle.

Trail 2:

Assume a trial cycle C1 =40sec

Number of cycle in 15 min = 900/40=22.5

Average headway time =2.5 sec

Green time foe road 1, G1=(2.5 x 178 x 40)/900 =19.8 sec

Green time foe road 2, G2=(2.5 x 142 x 40)/900 =15.8sec

Amber time A1 and A2 = 3 and 2 sec

Total cycle length =19.8+15.8+3+2=40.6 sec

As this is **higher than** assumed cycle, try another cycle

Trail 2:

Assume a trial cycle C1 =**45sec**

Number of cycle in 15 min = 900/45=20

Average headway time =2.5 sec

Green time foe road 1, G1=(2.5 x 178 x 45)/900 =22.25 sec

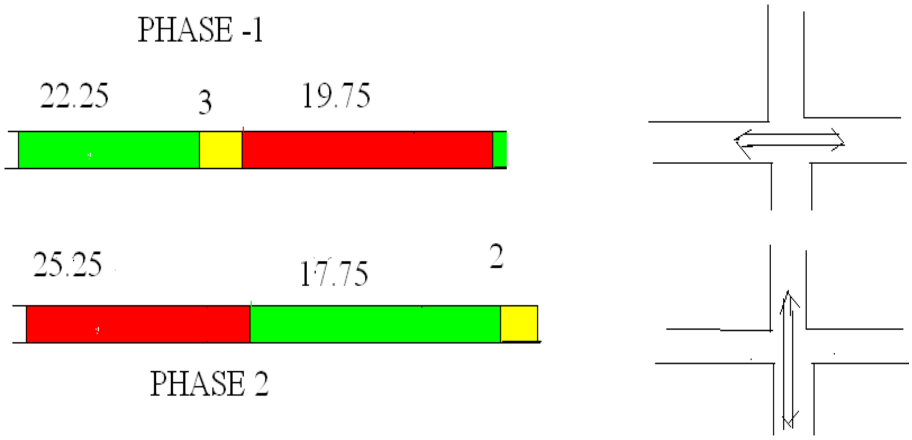
Green time foe road, G2=(2.5 x 142 x 45)/900 =17.75sec

Amber time A1 and A2 = 3 and 2 sec

Total cycle length =22.25+17.75+3+2=**45 sec**

Therefore, the trail cycle of 45 sec may be adopted.

Phase diagram



b) Design of pedestrian and traffic signals by approximate method

- Amber period 2, 3, 4 sec are taken.
- Pedestrian walking speed 1.2m per second.
- Minimum red time
  = pedestrian clearance time +initial interval for pedestrian to start crossing
- Minimum green time
  = pedestrian clearance time for cross road + initial interval to start by pedestrian - amber period
  Minimum green time= red time for crossing - amber time for cross road
- With pedestrian signal used, Walk period is not less than 7 sec.
- When no pedestrian signal is used, minimum period of 5 sec is used as initial interval.
- Actual green time is increased based on ratio.

Problem:

An isolated signal with pedestrian indications is to be installed on the right angled intersection with road A 18 m wide and road B 12 m wide. The heaviest volume per hour for each lane of road A and road B are 275 and 225 respectively. The approximate speed are 55 and 40 KMPH. Design the timing of traffic and pedestrian signals.

Solution:

Design of traffic signals:

- Based on the approach speed amber period are for road A with 55kmph Aa=4sec, For road B with 40kmph Ab=3sec
- Based on pedestrian walking speed of 1.2 m/sec pedestrian clearance time
  Road A = 18/1.2 =15 sec, Road B = 12/1.2 =10 sec
- Addition 7 sec for initial walk period.
- Minimum red time period for road A =15+7=22 sec.
- Minimum red time period for road B =10+7=17 sec.
- Minimum green time based on pedestrian criteria
  Road B =15+7-3 =19 sec
  Road A=10+7-4=13 sec
- Based on approach volume ,green time is increased for road A with higher traffic volume.
  Using relation
  (Ga/Gb)= (nA/nB)

  Ga and Gb are green time and nA and nB are approach volume per lane

Green time foe road A (Ga)= (nA/nB) xGb (Since, Gb is taken as 19 sec)

=(275/225) x 19 = 23.2 sec

- Total cycle = Ga + Aa + Ra = Ga + Aa + Gb + Ab (Since, Ra=Gb+Ab)

  =23.2+4+19+3=49.2 sec
- Hence, adopt 50sec.
- Addition period =50-49.2 =0.8 sec is distributed to green timings is proportion to approach traffic volume.

  GA =23.2+0.44=23.64 sec

  Gb=19+0.36=19.36 sec

  Ra=Gb+Ab=19.36+3=22.36 sec

  Rb=Ga+Aa=23.64+4=27.64 sec

Design of Pedestrian Signals:

Don't Walk (DW) period of pedestrian signal at road A (PSa) is red period of traffic signal at B.

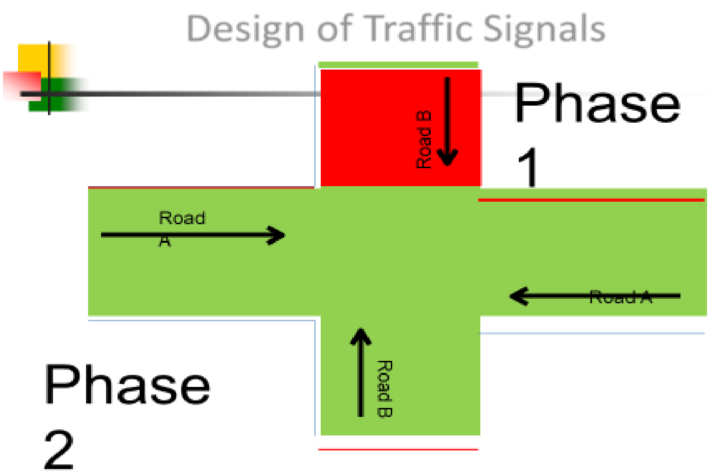
For PSa, DWa = Rb = 27.64 sec.

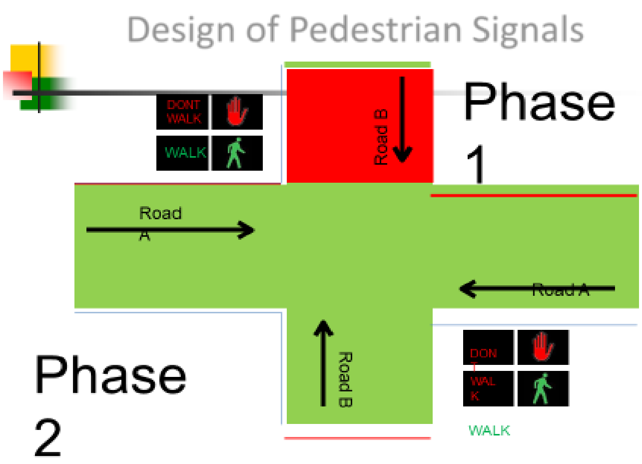
For PSb, DWb = Ra = 22.36 sec.

Pedestrian clearance intervals (CI) are of 15 and 10 secs respectively, for roads A and B for crossing from above. The walk time (W) is calculated from total cycle length.

For PSa, Wa = 50-(27.64+15)=7.36 sec.

For PSb, Wb= 50-(22.36+10) = 17.64 secs.





c) Webster Method

- This is a rational method.
- Optimum signal cycle time at intersection based on least delay at intersections is worked out.
- **Saturation flow (S)** and **Normal flow (q)** values per unit time on each road meeting at junctions are required for signal design.
- **OPTIMUM CYCLE LENGTH:**
  - Fixed time signals is to determine the cycle time.
  - Cycle time should be least delay caused to the traffic passing through the intersection.
  - If the cycle time is small, the proportional of time lost will be high resulting in insufficient signal operation.
  - If the cycle time is high, the proportional of time lost will be small resulting in more efficient signal operation.
- Optimum cycle time for intersection with respect to cycle time

  Co = (1.5 L + 5)/1-Y

  Co= optimum cycle time

  L= total lost time per cycle in sec = 2n+R

  n= Number of phases

  R= All red time (all-red time may also be provided for pedestrian crossing)

  Y=y1 +y2+…+yn= (q/s) i.e maximum of y values

  q= traffic flow

  S=saturation flow(maximum flow)
- Green times, $G_1 = \frac{y_1}{Y}(C_o - L)$, and $G_2 = \frac{y_2}{Y}(C_o - L)$
- Similar procedure is followed when there are more number of signal phases.

Problem:

The average normal flow of traffic on cross roads A and B during design period are 400 and 250 PCU per hour; the saturation flow values on these roads are estimated as 1250 and 1000 PCU per hour respectively. The all-red time required for pedestrian crossing is 12 sec. Design two-phase traffic signal with pedestrian crossing by Webster's method.

Solution:

Normal flow on road A and B,

qa = 400 PCU/hr

qb = 250 PCU/hr

Saturation flow ,

Sa = 1250 PCU/hr

Sb = 1000 PCU/hr

All – red time, R=12 sec

Number of phase, n = 2

$ya = qa/Sa = 400/1250 = 0.32$

$yb = 250/1000 = 0.25$

$Y= ya+yb = 0.32+0.25 = 0.57$

Total lost time = 2n+R = (2x2+12) = 16 sec

Optimum cycle time for intersection with respect to cycle time

$$\mathbf{Co = (1.5\,L + 5)/1\text{-}Y}$$

$= (1.5x16+5)/1\text{-}0.57 = 67.4$, Say 67.5

$Ga= Ya(Co\text{-}L)/Y = 0.32(67.5\text{-}16)/0.57 = 29$ secs

$Gb= Yb(Co\text{-}L)/Y = 0.25(67.5\text{-}16)/0.57 = 22.5$ secs

Provide an all-red time, R for pedestrian crossing = 12 sec

Providing Amber times of 2.0 sec each for clearance, total cycle time

= 29 + 22.5 + 12 + 2 + 2 = **67.5 sec.**

d) DESIGN METHOD AS PER IRC GUIDELINES

- The pedestrian green time required for the major roads are calculated based on walking speed of **1.2 m/sec** and initial walk time of **7.0 sec.**
  - These are the minimum green time required for the vehicular traffic on the minor and major roads respectively.
- The green time required for the vehicular traffic on the major road is increased in proportion to the traffic on the two approach roads.
- The cycle time is calculated after allowing amber time of **2.0 sec each**.
- The minimum green time required for clearing vehicles arriving during a cycle is determined for each lane of the approach road assuming that the first vehicle will take 6.0 sec and
  - The subsequent vehicles or the PCU of the queue will be cleared at a rate of 2.0 sec.
  - The minimum green time required for the vehicular traffic on any of the approaches is limited to 16 sec.
- The optimum signal cycle time is calculated using Webster's formula (explained in method, given above).
  - The saturation flow values may be assumed as 1850, 1890, 1950, 2250, 2550 and 2990 PCU per hour for the approach roadway widths (kerb to median or centre line) of 3.0, 4.0, 4.5, 5.0 and 5.5 m.
  - For widths above 5.5 m, the saturation flow may be assumed as **525 PCU per hour per meter width.**
  - The lost time is calculated from the amber time, inter-green time and the initial delay of **4.0 sec** for the first vehicle, on each leg.

- The signal cycle time and the phases may be revised keeping in view the green time required for clearing the vehicles and the optimum cycle length determined it steps iv and v above.

Problem:

At a right-angled intersection of two roads, Road 1 has four lanes with a total width of 12.0 m and Road 2 has two lanes with a total width of 6.6m. The volume of traffic approaching the intersection during design hour are 900 and 743 PCU/hour on the two approaches of Road-1 and 278 and 180 PCU/hour on the two approaches of Road-2. Design the signal timings as per IRC guidelines.

Solution:

Given:

Width of road – 1 = 12.0 m or total 4 lanes, with 2 lanes in each direction;

Width of road - 2 = 6.6 m or total 2 lanes, with one lane in each direction.

Approach volumes

on road – 1 = 900 & 743 PCU/hr

On road- 2 = 278 & 180 PCU/hr

Pedestrian walking speed = 1.2 m/sec.

Design traffic on road - 1 = higher of the two approach volume per lane

= 900/2 = 450 PCU/hr

Design traffic on road – 2 = 278 PCU/hr

Step – 1. Pedestrian crossing time

Pedestrian green time for road – 1 = (12/1.2) +7 = 17 sec

Pedestrian green time for road – 2 = (6.6/1.2)+7 = 12.5 sec

Step – 2, Minimum green time for traffic

Green time for vehicles on Road 2, G2 = 17 Secs.

Green time for vehicles on Road 1, G1 = (17x450)/278 = 27.5 secs.

Step – 3, revised green time for traffic signals

Adding 2.0 sec each towards clearance amber and 2.0 sec inter-green period for each phase,

total cycle time required = (2 + 17 + 2) + (2 + 27.5 + 2) = 52.5 sec.

Signal cycle time may be conveniently set in multiples of five sec and so the cycle time = 55 sec.

The extra time of 55.0 – 52.5 = 2.5 sec per cycle may be apportioned to the green times of Road – 1 and Road – 2, as 1.5 and 1.0 sec respectively.

Therefore adopt G1=27.5+1.5= 29 secs. And G2=17+10= 18 secs.

Step – 4, check for clearing the vehicles arrived during the green phase

Vehicle arrivals per lane per cycle on Road – 1 = 450/55=8.2 PCU/cycle

Minimum green time required per cycle to clear vehicles on Road 1 = 6 + (8.2 – 1.0)2 = 20.4 sec **(less than 29.0 sec and therefore accepted)**

Vehicle arrivals per lane per cycle on Road – 2 = 278/55 = 5.1 PCU/cycle

Minimum green time for clearing vehicles on Road 2 = 6 + (5.1 - 1.0) 2 = 14.2 sec **(less than 18.0 sec)**

As the green time already provided for the two roads by pedestrian crossing criteria in Step (2) above are higher than these values (29.0 and 18.0 sec), the above design values are alright.

Step – 5, check for optimum signal cycle by Webster's equation

Lost time per cycle = (amber time + inter – green time + time lost for initial delay of first vehicle) for two phases = (2 + 2 + 4) x 2 = 16 sec.

Saturation flow for Road – 1 of width 6 m = 525 x 6 = 3150 PCU/hr

Saturation flow for Road – 2 of width 3.3 m =1850 PCU for 3.0 m wide road + (40x3/5)= 1874 PCU/hr

$$Y1=900/3150=0.286$$

$$Y2=278/1874=0.148$$

$$Y=y1+y2= 0.286+0.148=0.434$$

Optimum signal cycle time,

$$Co = (1.5 L + 5)/1\text{-}Y = (1.5x15+5)/(1\text{-}0.434)= 51.2 \text{ secs.}$$

Therefore, the cycle time of 55 sec designed earlier is acceptable. The details of the signal timings are given below.

Road	Green phase, G sec	Amber time, sec	Red phase, R sec	Cycle time, C sec
Road 1	29	2	(22 + 2)	55
Road 2	18	2	(33 + 2)	55