TRAFFIC ENGINEERING

Traffic engineering is a branch of civil engineering that uses engineering techniques to achieve the safe and efficient movement of people and goods on roadways.

General:

Traffic engineering is the phase of engineering which deals with planning, geometric design, traffic operations of roads, streets and highways, their networks, terminals, abutting lands, relationship with other mode of transportation for the achievement of safe, efficient and convenient movement of persons and goods. This is achieved by systematic traffic studies, scientific analysis and engineering applications. Traffic studies are further divided into

1. Traffic characteristics
2. Traffic studies and analysis
3. Traffic control regulation

Traffic engineering pertains to the analysis of the behaviour of traffic and to design the facilities for a smooth, safe and economical operation of traffic. Traffic flow like the flow of water, has several parameters associate with it. The traffic stream parameters provide information regarding the nature of traffic flow, which helps the analyst in detecting any variation in flow characteristic. Understanding traffic behaviour requires a thorough knowledge of traffic stream parameters and their mutual relationships.

Objective of traffic engineering:

- Achieve efficient ‘free and rapid’ flow of traffic
- Reduce the no. of accidents.

Various phases of traffic engineering are: (3Es)

- Engineering (constructive i.e. geometric design of road)
- Enforcement (traffic laws, regulation and control)
- Education (publicity and through school and television)

Scope of traffic Engineering:

I. The basic object of the traffic is the achieve efficient free and rapid flow of traffic with least number of traffic accidents
II. The surface details sight distances requirements. Horizontal and vertical alignment. Intersections and parking facilities are to be suitably designed for better traffic performance.
III. The study of traffic of traffic engineering may be divide in to 6 major phases
    - Traffic characteristics

- Traffic studies and analysis
- Traffic operation control and regulation
- Planning and analysis
- Geometric design
- Administration and management

IV. The various phases of traffic engineering are implemented with help of 3E

- ✓ Engineering
- ✓ Enforcement
- ✓ Education

Engineering: deals with the improvement of road geometric, providing additional road facilities and installation of suitable design traffic control devices.

Enforcement: is usually made through traffic laws, regulations and control.

Education: may be possible by sufficient publicity and through schools and television.

Functions of Traffic Engineering:

The function of traffic engineering can be covered in the following categories:

- **Planning and travel forecasting:** To manage the future requirements of safe, comfort and economic travel.
- **Collection of the factual information:** Collection analysis and interpretation of factual data's the main function of traffic engineering. The data collected from different types of field's survey.
- **Research:** To develop more efficient methods and techniques research is essential. The various areas if importance under this are read design factors, safety, economic impact etc.
- Traffic accident recording: If proper data recording and analysis is done on a scientific basis then accidents can be avoided.
- Design and placement of control and regulatory measures. The main object of control device and regulation is to control the road user, direct him in a better way.

1. Traffic characteristics: -

(a) Vehicular limitations like weight, size, and power of the vehicle.

(b) Road user limitation

(i) Physical limitations like vision, hearing, fatigue etc.

(ii) Mental limitations like intelligence, skill, experience of drivers etc.

(iii) Emotional limitations like attentiveness, impatience etc.

•Traffic studies and analysis

•Traffic operation-control and regulation: - Which constitutes the traffic regulations, laws of speed limit, installation of traffic control device, traffic control devices like traffic signs, signals, marking etc.

• Traffic Planning and analysis like programme of construction, off street parking etc.

• Traffic Geometric design: - Involving Horizontal and vertical curve design, the design of expressways, streets, interchanges, intersections, and parking etc.

• Traffic Administration and management: - ‘3E’concept

Traffic characteristics:

In traffic characteristics study about road user characteristics and vehicular characteristics.

•**Road user characteristics**

Human element is involved in all the actions of road users i.e., motorist, pedestrian etc.

Factors affecting road user characteristics are:

- Physical
- Mental
- Psychological
- Environmental

(i) Physical: Vision, hearing, strength and general reaction to traffic situations.

(ii) Mental: Knowledge, skill, intelligence and experience etc.

(iii) Psychological: Attentiveness, fear, anger, superstition, impatience, general attitude towards traffic and regulations.

(iv) Environmental: Traffic stream characteristics, facilities to the traffic, atmospheric conditions and the locality.

NOTE: The temporary physical characteristics of the road users affecting their efficiency are fatigue, alcohol or drugs and illness.

Vehicular Characteristics

It is quite important to study the various characteristics of vehicle because a road can be designed for any vehicle but not for an indefinite vehicle. The various vehicular characteristics affecting the road design is classified as static and dynamic characteristics of the vehicle.

•Vehicular characteristics is two types (a) static (b) dynamic

Static characteristics of vehicle:

Static characteristics of vehicles affecting road design are the dimensions, weight and minimum turning radius.

Maximum dimensions of road vehicles:

(i) Maximum width of vehicle = 2.5 m

(ii) Maximum height: It affects the clearance of the overhead structures and visibility of driver

- (a) Single decked vehicle = 3.80 m
- (b) Double decked vehicle = 4.75 m

(iii) Maximum length: It affects the capacity, OSD and movability of vehicle

- (a) Single unit truck with two or more axles = 11.0 m
- (b) Single unit bus with two or more axles = 12.0 m
- (c) Semi trailor tractor combinations = 16.0 m
- (d) Tractor and trailor combinations = 18.0 m

Note: No vehicle is allowed to be of more than two units and no such combinations, laden or unladen is allowed to have an overall length exceeding 18 m.

Weight of vehicles:

(i) Maximum weight of loaded vehicle affects the design of pavement thickness and gradients.

(ii) No single axle load, as suggested by IRC, should exceed 102 kN (10.2 tonnes) and for tandom axle 180 kN (18 tonnes).

(iii) The gross load of any vehicle or combination of vehicles should not exceed the weight worked out by the following formula:

$W = 1525 (L + 7.3) – 14.7 L^2$

Where, W = The gross weight of the vehicle in kg

L = The distance in metre between the extreme axles measured parallel to the axis of the vehicle.

Power of Vehicle:

The power of the heaviest vehicles and their loaded weights govern the permissible and limiting values of gradient on road. Limiting gradients are governed by both the weight and power of the heavy vehicles. Stability of vehicle and its safe movement on horizontal curve depends upon the width of vehicle and height of centre of gravity.

Minimum turning radius:

(i) It depends upon the length of wheel base and the features of the steering system.

(ii) It affects the design of sharp curves for the movement of vehicles at slow speed.

Dynamic Characteristics of Vehicles:

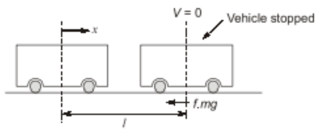
Speed, acceleration and braking characteristics are the dynamic characteristics of a vehicle. The speed and acceleration of a vehicle depends upon the power of the engine and the resistance to overcome. The deceleration and braking characteristics of vehicles depend on the design and type of braking system and its efficiency.

Braking test: This test is conducted to measure the skid resistance of a pavement surface. At least two of the following three measurements are needed during braking test to find skid resistance.

(i) Braking distance L (Length of skid mark on the road surface in m)

(ii) Initial speed, u (in m/sec)

(iii) Actual duration of brake application. T (in seconds)



Braking test

$$a = -\frac{fmg}{m} = -f.g$$

Following cases involved in the braking test are discussed below;

Case 1: When initial velocity and braking length is known

After the application of brake, work done by the frictional force to stop the vehicle will be equal to the kinetic energy of the vehicle.

$1/2mu^2 = fWL$

$\Rightarrow 1/2W/g\ u^2 = f\ WL$

$\Rightarrow f = u^2/2gL$

$$\frac{1}{2}mu^2 = f\text{WL} \Rightarrow \frac{1}{2}\frac{W}{g}u^2 = f\text{WL} \Rightarrow f = \frac{u^2}{2gL}$$

Where, f = Coefficient of friction

G = acceleration due to gravity (in m/s^2)

Case 2: When initial velocity and actual direction of brake application is measured

After application of brakes frictional force acting on the vehicle to stop it will be equal to the driving force of the vehicle.

$\therefore$ fmg = ma

$\Rightarrow f = a/g$

Where, a = Retardation of vehicle during skidding (in m/s^2)

Case 3: When braking length and actual direction of brake application is measured

On the application of brakes, the vehicle comes to rest with the retardation of a.

Using equation of motion, $v^2 = u^2 + 2as$

As we know that v = 0 and a is retardation

$\therefore\ 0 = u^2 – 2\,a\,L$ --------------------------------(i)

Now, $v = u + at \Rightarrow 0 = u – at$

$\therefore\ u = at$ -----------------------------(ii)

From equation (i) and (ii), we get

$a^2t^2 = 2aL$

$\therefore\ a = 2L/t^2$

As we know that, f = a/g

$\therefore\ f = 2L/gt^2$

Case-1: When braking length and initial velocity is known

$$V^2 = u^2 + 2as$$
$$0 = u^2 - 2(fg)l$$
$$\therefore \quad f = \frac{u^2}{2gl} \quad (V \text{ in m/sec})$$

Case-2 : When initial speed and actual direction of brake application known:

$$V = u + at$$
$$0 = u - fg \times t$$
$$f = \frac{u}{gt}$$

Case-3 : When braking length and actual duration of brake application is known:

$$S = ut + \frac{1}{2}at^2$$
$$\because \quad u = fgt$$
$$\therefore \quad l = \left(fgt^2\right) - \frac{fgt^2}{2} = \frac{fgt^2}{2}$$
$$f = \frac{2l}{gt^2}$$

If sometimes the maximum skid resistance of the pavement surface is already known than we can find the breaking efficiency also.

$$\eta = \text{Breaking efficiency} = \frac{f_{\text{obtained from braking test}}}{f_{\text{max. known}}}$$

TRAFFIC STUDIES AND ANALYSIS:

Traffic studies or surveys are carried out to analyze the traffic characteristics. A detailed knowledge of the operating characteristics of the traffic is essential to form a basis for the establishment of traffic control or for design of highways. These studies help in deciding the geometric design features traffic control for save and efficient traffic movement.

The results of data collected are used in

(i) Traffic planning

(ii) Traffic management

(iii) Economic studies

(iv) Traffic and environmental control

(v) Monitoring trends

Traffic studies are broadly classified into two categories

(i) Those concerned with the characteristics of traffic in transit

(a) Traffic volume study

(b) Speed studies

(c) Origin and destination study

(d) Traffic flow characteristics and studies

(e) Traffic capacity studies

(ii) Those related to land use movements

(a) Parking studies

(b) Accident studies

•The various traffic survey studies generally carried out are:

- Traffic volume study
- Speed study
- Spot speed study
- Speed and delay study
- Origin and destination study
- Traffic flow characteristics
- Traffic capacity study
- Parking study
- Accident studies

Fundamental parameters of traffic flow

Traffic stream parameters

The traffic stream includes a combination of driver and vehicle behaviour. The driver or human behaviour being non-uniform, traffic stream is also non-uniform in nature. It is influenced not only by the individual characteristics of both vehicle and human but also by the way a group of such units interacts with each other. Thus, a flow of traffic through a street of defined characteristics will vary both by location and time corresponding to the changes in the human behaviour.

The traffic engineer, but for the purpose of planning and design, assumes that these changes are within certain ranges which can be predicted. For example, if the maximum permissible speed of a highway is 60 kmph, the whole traffic stream can be assumed to move on an average speed of 40 kmph rather than 100 or 20 kmph. Thus, the traffic stream itself is having some parameters on which the characteristics can be predicted. The parameters can be mainly classified as: measurements of quantity, which includes density and flow of traffic and measurements of quality which includes speed. The traffic stream parameters can be macroscopic which characterizes the traffic as a whole or microscopic which studies the behaviour of individual vehicle in the stream with respect to each other.

As far as the macroscopic characteristics are concerned, they can be grouped as measurement of quantity or quality as described above, i.e., flow, density, and speed. While the microscopic characteristics include the measures of separation, i.e., the headway or separation between vehicles which can be either time or space headway. The fundamental stream characteristics are speed, flow, and density and are discussed below.

The traffic stream includes a combination of driver and vehicle behavior.

Traffic Volume Study

Volume of traffic is a very important variable and is essentially the quantity of movement per unit of time at a specified location. It is expressed as vehicles per day and vehicles per hour or PCU/hr. It can br determined by q

Traffic volume q = n x 3600/ T

$$q = \frac{n \times 3600}{T}$$

Where, n = The number of vehicles passing a point in the roadway in T seconds

q = Equivalent hourly flow

Note: Complete traffic volume study includes classified volume study (i.e., number of different of vehicle), directional study (distribution on different lanes)

Volume studies are basically useful to establish:

(i) The relative importance of any route
(ii) The fluctuations in flow
(iii) The distribution of traffic on the road system
(iv) The trends in the road use

Methods to measure traffic volume

Specific methods of the various traffic volume studies are given below:

1. Manual counting: In manual counts trained persons are posted at each lag of an intersection to count and record the number of trucks or buses, bullock carts, cars etc.

2. Automatic Counters: These are mainly of two types:

(i) Permanent counting recorders

(a) Magnetic detectors

(b) Pressure sensitive detectors

(c) Electronic detectors

(ii) Portable recorders which are smaller in size and actuated by air switches.

The main advantage of automatic counter is that it can work throughout the day and night for the desired period. Disadvantage associated with the automatic counter is that it is not possible to get traffic volumes of various classes of traffic in the stream and the details of turning movements.

Types of volume count

(i) Average Daily Traffic Volume (ADT: It is the average of 365 days. It can be used for the following purposes:

(a) Planning major street

(b) Improvement, construction or reconstruction of roads

(c) Computing accident rates

(d) Computing highway user revenue

(ii) Classified Volumes: It involves the composition of traffic i.e., trucks, cars, rickshaws, etc. These volumes can be used for geometric design of roads.

(iii) Hourly volume: This type of volume count is used for:

(a) Determining deficiency in capacities, geometric designs, etc.

(b) Determining number and width of lanes

(c) Parking demands

(d) Planning traffic control (traffic signs, signals, timing of signals etc.)

(e) Location of interchanges

(iv) Pedestrian Volumes: These are utilized in planning the crosswalks and signals for pedestrians.

(v) Turning Movements Counts: These are used in the design of intersections and interchanges, planning of signal timings and turn prohibitions, channelization etc.

Variations of Volume

The variation of volume with time, i.e., month to month, day to day, hour to hour and within a hour is also as important as volume calculation. Volume variations can also be observed from season to season. Volume will be above average in a pleasant motoring month of summer, but will be more pronounced in rural than in urban area. But this is the most consistent of all the variations and affects the traffic stream characteristics the least. Weekdays, Saturdays and Sundays will also face difference in pattern. But comparing day with day, patterns for routes of a similar nature often show a marked similarity, which is useful in enabling predictions to be made. The most significant variation is from hour to hour. The peak hour observed during mornings and evenings of weekdays, which is usually 8 to 10 per cent of total daily ow or 2 to 3 times the average hourly volume. These trips are mainly the work trips, which are relatively stable with time and more or less constant from day to day.

Types of volume measurements

Since there is considerable variation in the volume of traffic, several types of measurements of volume are commonly adopted which will average these variations into a single volume count to be used in many design purposes.

Types of volume measurements

I. Average Annual Daily Traffic (AADT)

II. Average Annual Weekday Traffic (AAWT)

III. Average Daily Traffic (ADT)

IV. Average Weekday Traffic (AWT)

1. Average Annual Daily Traffic (AADT): The average 24-hour traffic volume at a given location over a full 365-day year, i.e. the total number of vehicles passing the site in a year divided by 365.

$$AADT = \frac{No.ofvehicle \sin ayear}{365}$$

2. Average Annual Weekday Traffic (AAWT): The average 24-hour traffic volume occurring on weekdays over a full year. It is computed by dividing the total weekday traffic volume for the year by 260.

3. Average Daily Traffic (ADT): An average 24-hour traffic volume at a given location for some period of time less than a year. It may be measured for six months, a season, a month, a week, or as little as two days. An ADT is a valid number only for the period over which it was measured.

4. Average Weekday Traffic (AWT): An average 24-hour traffic volume occurring on weekdays for some period of time less than one year, such as for a month or a season.

Presentation Of Traffic Volume Data:

(i) Annual Average Daily Traffic (AADT): It is the average volume of traffic at a particular location over a full 365 days and it is given as:

AADT = Total yearly traffic/365

It helps in deciding the relative importance of a route and in phasing the road development program. If the flow is not measured for all the 365 days, but only for a few days then the average flow is known as average daily traffic (ADT). For this minimum of seven days count is done to include the daily variation like on Saturday and Sunday.

NOTE: (i) While calculating ADT seasonal variation of traffic is not accounted.

(ii) Design hourly volume = Approximately 7 to 8 % of AADT

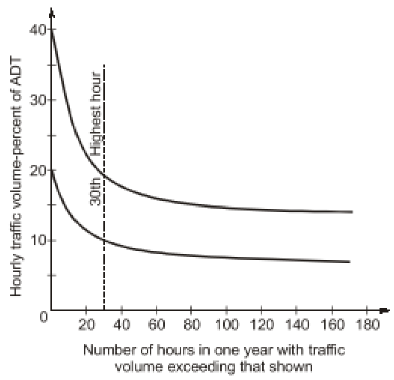
(ii) Trend Chart: They show the volume trends prepared over period of years. It helps in highway planning and design of pavement by the prediction of future loads. It helps in calculating the rate of growth of traffic which is used for calculation of design traffic volume for pavement design. According to IRC rate of growth of traffic is approximately 5-7.5 % per annum.

(iii) Variation Chart: Variation charts shows the hourly, daily, and seasonal variations. It helps in deciding the facilities and regulation needed during peak traffic hours.

(iv) Volume Flow Maps: Flow maps are prepared to show the distribution of volume by location. In volume flow maps, the width of the route is proportion to the volume for a specified period. At intersections, where the number of turning vehicles is important, flow maps may be prepared in a similar manner i.e., the width of band showing the volume.

(v) Thirtieth (30th) Highest Hourly Volume: It is that hourly volume which will be exceeded only 29 times in a year and all other hourly volume will be lesser than this is shown in figure. It is used to design the highway elements and also called as design hourly volume.

- It is taken as design hourly volume/design capacity.
- It is a plot between hourly volume and the number of hours in a year that the traffic volume is exceeded.
- For this all hourly volumes are arranged in decreasing order and order number is given to each of them. The data at order number 30 is the 30^{th} highest hourly volume.
- The 30^{th} highest hourly volume is the hourly volume that will be exceeded only 29 times in a year.



Hourly traffic volumes

Periodic Volume counts

Periodic Volume counts are used to calculate expansion factors needed to estimate the annual traffic volume.

$$\text{Hourly expansion factor} = \frac{\text{Total volume for 24 hours period}}{\text{Volume } \textit{for} \text{ particular hour}}$$

$$\text{Daily expansion factor} = \frac{\text{Weekly traffic volume}}{\text{Average 24 hour volume of that particular day}}$$

$$\text{Monthly expansion factor} = \frac{AADT}{ADT \text{ of particular month}}$$

Expansion factor value ≥ 1: It is equal to 1 only when traffic flows for a particular hour and there is no traffic flow during remaining hour. In this case total daily traffic is equal to hourly traffic.

Peak Hour Factor (PHF): It is defined as the ratio between the number of vehicles counted during the peak hour and four times the number of vehicles counted during the highest 15 consecutive minutes. Peak hour factor is a measure of the variation in demand during the peak hour.

$$PHF_{15} = \frac{\text{Hourly traffic volume}}{\left(\frac{60}{15}\right) \times V_{15}(\text{max})}$$

$$PHF_{5} = \frac{\text{Hourly traffic volume}}{\left(\frac{60}{5}\right) \times V_{5}(\text{max})}$$

Where, V_{15} = Maximum number of vehicles during any 15 consecutive minutes

V_5 = Maximum number of vehicles during any 5 consecutive minutes

NOTE: Value of peak hour factor varies between 0.25 and 1.0

Traffic Speed Studies:

Speed is the rate of travel expressed in kmph or in m/s. Over a particular route, the actual speed of vehicle may vary. Speed of a vehicle depends upon several factors such as geometric features, traffic conditions, time, place, environment and driver.

1. Speed

Speed is considered as a quality measurement of travel as the drivers and passengers will be concerned more about the speed of the journey than the design aspects of the traffic. It is denoted as the rate of motion in distance per unit of time. Mathematically speed or velocity v is given by,

$v = d/t$ (1)

where, v is the speed of the vehicle in m/s, d is distance travelled in m in time t seconds.

Speed of different vehicles will vary with respect to time and space. To represent these variation, several types of speed can be denoted. Important among them are spot speed, speed, journey speed, time mean speed and space mean speed. These are discussed below.

Travel time: It is the reciprocal of speed and it is a measure of efficiency of road.

Types of Speed

1. Spot Speed

Spot speed is the instantaneous speed of a vehicle at a specified location. Spot speed can be used to design the geometry of road like horizontal and vertical curves, super elevation etc. Location and size of signs, design of signals, safe speed, and speed zone determination, require the spot speed data. Accident analysis, road maintenance, and congestion are the modern field of traffic engineer, which uses spot speed data as the basic input. The spot speeds are affected by the physical features of road such as pavement width, curve, sight distance, gradient, pavement unevenness and road side developments. Spot speed can be measured using an enoscope, pressure contact tubes or direct timing procedure or radar speedometer or by time-lapse photographic methods. It can be determined by speeds extracted from video images by recording the distance traveling by all vehicles between a particular pair of frames.

Note: Travel time is the reciprocal of speed and it is a measure of efficiency of roads.

There are a number of methods to measure spot speed

(a) Enoscope method or Mirror box method
(b) Photographic method
(c) Electronic method
(d) Radar speed meter method

Most simplest method of finding spot speed is by using Enoscope.

Enoscope method: In this method an L shaped box shown in figure open at both ends, with mirrors set inside at 45^0 angle is used. An observer is stationed on one side of road and starts a stopwatch when a vehicle crosses that section. An enoscope is placed at a convenient distance of say 50 m in such a way that the image of vehicle is seen by the observer when the vehicle crosses the section where enoscope is fixed. The greatest disadvantage is that the progress is slow as it is difficult to spot out typical vehicles and the main advantage of enoscope method is that it is simple and cheap.

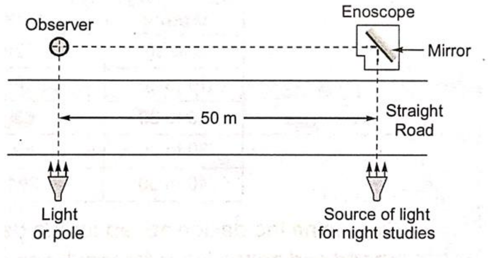


Figure- *Spot speed by enoscope*

Presentation of spot speed data

(a) Average Speed of vehicle: From the spot speed data of the selected sample frequency distribution tables are prepared by arranging the data in groups of various speed ranges. The arithmetic mean is taken as average speed.

(b) cumulative Speed of Vehicles:

A graph is plotted with the average value of each speed group on X-axis and the cumulative percent of vehicles travelled at or below the different speeds on Y-axis. From the graph (i.e., Cumulative frequency distribution curve) followings can be obtained.

- 98th percentile speed- Design speed
  Speed at or below which 98% of vehicles are moving and only 2 % crossing this limit.
- 85th percentile speed-Maximum speed
  Upper safe speed limit for regulation of traffic.
- 50th percentile speed-Median speed
- 15th percentile speed-Minimum speed
  Lower speed limit to avoid congestion.

A graph is plotted between the cumulative frequency and speed with speed group on x-axis and vehicles travelled at or below the different speeds on the y-axis as shown in figure. The 85th percentile speed is generally considered as the safe speed limit.

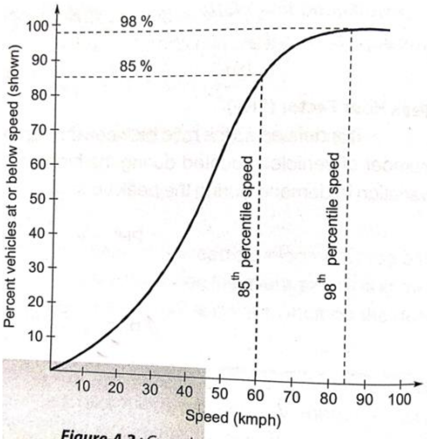
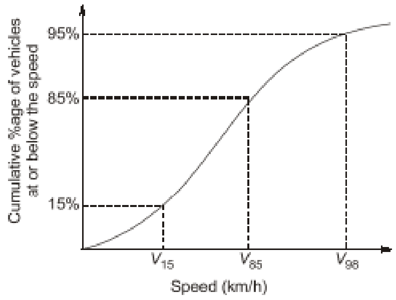


Figure-4.3 : *Cumulative speed distribution*



Cumulative speed distribution diagram

Note: 85^{th} percentile speed is that speed at or below 85 % of the vehicles are passing the point on the highway or only 15 % vehicles exceed the speed at that spot.

98^{th} percentile speed is taken for the purpose of highway geometric design. 15^{th} percentile speed is considered to be the lower safe speed limit to avoid congestion. 50^{th} percentile speed is known as median speed at which 50% vehicles are moving above and 50 % are moving below at that speed.

(c) Modal average speed (frequency distribution curve):

Speed at which maximum no. of vehicles are moving.

- A frequency curve of spot speed is plotted with average values of each speed group of vehicles on X-axis and the percentage of vehicle in that group on the Y-axis is known as speed distribution curve.
- The speed corresponding to peak value of curve is denoted as modal speed or speed at which maximum number of vehicles are moving is termed as modal speed.

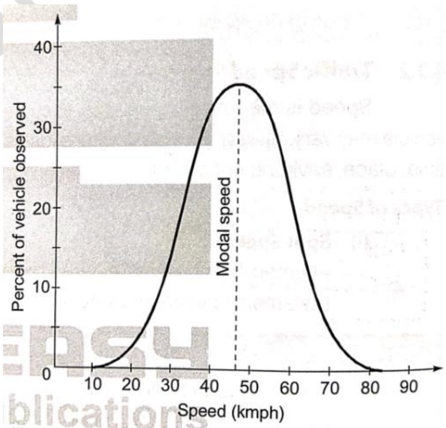
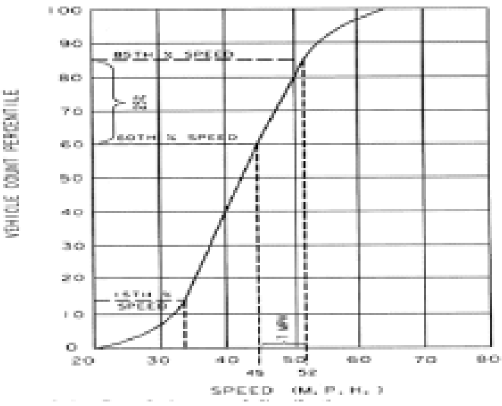


Figure-4.4 : *Frequency distribution curve of the spot speeds*



2. Average speed: It is the average of spot speed of all vehicles passing at given points on the highway or at a particular section or location. There are two types of average speed or mean speed.

(a) Time mean speed

Time mean speed is denoted as the average speed of all the vehicles passing a point on a highway over some specified time period or time interval.

Mean speed (arithmetic mean) of vehicle at a point in space over a period of time or it is the average of instantaneous speeds of observed vehicles at the spot.

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

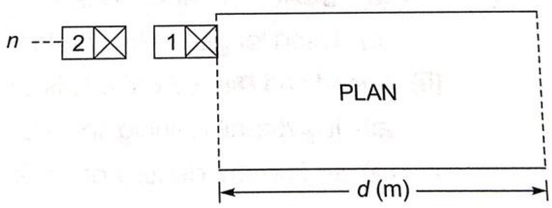
Where V_t = time mean speed

n = no. of vehicles

V = speed of the vehicle

(b) Space mean speed

Space mean speed is denoted as the average speed of all the vehicles occupying a given section of a highway over some specified time period. It is obtained from the observed travel time of the vehicles over a relatively long stretch of the road. Space mean speed is the harmonic mean of the speed of the vehicles passing a point on a highway during a particular interval of time.



Both mean speeds will always be different from each other except in the unlikely event that all vehicles are traveling at the same speed. Time mean speed is a point measurement while space mean speed is a measure relating to length of highway or lane, i.e., the mean speed of vehicles over a period of time at a point in space is time mean speed and the mean speed over a space at a given instant is the space mean speed.

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

Where V_s = space mean speed

n = no. of vehicles

V = speed of the vehicle

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

Space mean speed, $V_s = \frac{3.6\,dn}{\sum_{i=1}^{n} t_i} = 3.6\left[\frac{n}{\frac{t_1}{d_1} + \frac{t_2}{d_2} + \ldots \frac{t_n}{d_n}}\right] = 3.6\left[\frac{n}{\frac{1}{V_1} + \frac{1}{V_2} + \ldots \frac{1}{V_n}}\right]$

where, d = Length of road considered in m

n = Number of individual vehicle observations

t_i = Observed travel time (in sec) for i^{th} vehicle to travel distance d

Space mean speed is harmonic mean of all the speed.

3. Running speed

Running speed is the average speed maintained over a particular course while the vehicle is moving and is found by dividing the length of the course by the time duration the vehicle was in motion. i.e. this speed doesn't consider the time during which the vehicle is brought to a stop, or has to wait till it has a clear road ahead. The running speed will always be more than or equal to the journey speed, as delays are not considered in calculating the running speed.

$$Runnigspeed = \frac{Totaldis\tan cetravelledbyvehicle}{Runningtime}$$

4. Journey speed/overall speed/travel speed

Journey speed is the effective speed of the vehicle on a journey between two points and is the distance between the two points divided by the total time taken for the vehicle to complete the journey including any stopped time. If the journey speed is less than running speed, it indicates that the journey follows a stop-go condition with enforced acceleration and deceleration. The spot speed here may vary from zero to some maximum in excess of the running speed. A uniformity between journey and running speeds denotes comfortable travel conditions.

$$Overall speed = \frac{Total distance travelled}{Total time taken (including all stops \& delays)}$$

Interrelationship between space mean speed and time mean speed

$$V_t = V_s + \frac{\sigma_s^2}{V_s} \qquad V_s = V_t - \frac{\sigma_t^2}{V_t}$$

$V_t = V_s + \sigma_s^2/V_s$

And $V_s = V_t - \sigma_t^2/V_t$

Where, σ_s^2 and σ_t^2 are variance for space mean speed and time mean speed respectively.

Types of speed studies

Generally, there are two types of speed studies:

1. Spot speed study
2. Speed and delay study

(i) Spot speed study: Spot speed studies cannot be used to find density because measurements are done at one point only. Spot speed studies are conducted mainly for the following purposes:

(a) Design of traffic signals

(b) Analysis of high accident location

(c) Used for geometric design

(d) Determining the speed trends

Use of spot speed study

•To use in planning traffic control and in traffic regulation.

•To use in geometric design for redesigning the existing highway.

•To use in accident studies.

•To study the traffic capacity.

(ii) Speed and delay study: This study is made mainly for the following purposes

(a) The speed and delay studies give the running speeds, overall speeds, fluctuations in speeds and the delay between two stations of a road.

(b) To find the density of traffic.

(c) Economic studies utilize travel time and delay data.

(d) It also gives the information such as the amount, location, duration and cause of delay in the traffic stream.

Delay can be categorized into two types:

(a) Fixed delay: It is the delay to which traffic is subjected to regardless of the amount of traffic volumes and interferences present on the highway. This is not due to the characteristics of traffic streams. This includes traffic signals, stop signals, railroad crossings, etc. This delay can occur even with only one vehicle on the highway.

(b) Operational delay: This is also known as congestion delay. This is the delay caused by interference with other components of traffic. Operational delays are caused by the interference of traffic movement, such as turning vehicles, parking vehicles, pedestrians etc.

The difference between travel time over a route during an extremely low and during very high traffic volume indicates the amount of operational delay.

There are various methods of carrying out speed and delay study:

METHODS OF SPEED AND DELAY STUDY: There are various methods of carrying out speed and delay study.

This method is used to find travel time & to detect the spots of congestion.

a. Floating car or riding check method
b. License plate or vehicle number method
c. Interview technique method
d. Elevated observation
e. Photographic technique

a. Floating car or riding check method

•In the floating car method, a test vehicle is driven over a given course of travel at approximately the average speed of the stream, thus trying to float with the traffic stream. A number of test runs are made along the study stretch and a group of observers record the various details. One observeris seated in the floating car with two stop watches. One of the stopwatch is used to record the time at various control point like intersections, bridges or any other fixed points in each trip.

•The other stop watch is used to find the duration of the individual delays. The time, location and cause of these delays are recorded by the second observer.

•The number of vehicles overtaking the test vehicle and the overtaken by the test vehicle are noted in each trip by third observer.

•The no. of vehicles travelling in the opposite direction in each trip is noted by fourth observer.

•In this method the detailed information is obtained concerning all phases of speed and delay including location, duration and causes of delay. The average journey time, ($\bar{t}$) for all the vehicles in a traffic stream in the direction of flow is given as

$$\bar{t} = t_w - \frac{n_y}{q}$$

$$q = \frac{n_a + n_y}{t_a + t_w}$$

where, $\bar{t}$= average journey time in minute

q= Flow of vehicle (average volume) in one direction of the stream (vehicle/min)

$n_{a\ (against)}$ = average number of vehicles counted in the direction of the Stream when the test vehicle travels in the opposite directions

n_y= the average no. of vehicles overtaking the test vehicle minus the no. of vehicles overtaken when the test is in the direction of 'q'

t_w= average journey time, in minute when the test vehicle is travelling with the stream 'q'

t_a= average journey time, in minute when test vehicle is running against the stream 'q'

b. License plate or vehicle number method: In this method observers are stationed at the entrance and exit of a test section where information of travel time is required. This method does not give important details such as causes of delays and the duration and number of delays within the test stretch.

c. Interview technique method: In this method interview of road users on the spot is used to collect the details.

d. Elevated observation and Photographic technique: This method is useful for studying short test sections like intersections.

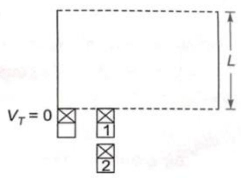
Moving Vehicle Estimation method

Case-I: When test vehicle is stopped and all other vehicles are moving.

Traffic flow, $q = \frac{n_0}{T}$

where T = Duration of study

n_0 = Number of Vehicle overtaking the test vehicle



Case-II: When test vehicle is moving and all other are stopped.

Traffic density, $K = \frac{n_s}{L}$

$\Rightarrow$ $n_s = KL = KV_TT$ $(\because L = V_TT)$

where n_s = number of vehicle stopped or overtaken by the test vehicle

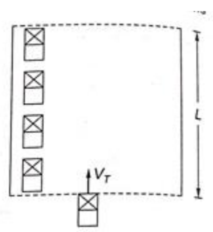
$n = n_0 - n_s = qT - KV_TT$

$$\frac{n}{T} = q - KV_T$$

when test vehicle moves in direction of stream (S – N)

$n = n_y$ and $T = T_w$

$$\Rightarrow \quad \frac{n_y}{T_w} = q - K\frac{L}{T_w} \quad \text{...(i)}$$



when test vehicle moves against the stream (N – S)

$$\Rightarrow \quad \frac{n_a}{T_a} = q + \frac{KL}{T_a} \qquad \text{...(ii)}$$

$$n = n_0 - n_s$$

$$n = n_a - n_s$$

$$n = n_a \qquad (\because n_s = 0)$$

From eq. (i)

$$n_y = qT_w - KL \qquad \text{...(iii)}$$

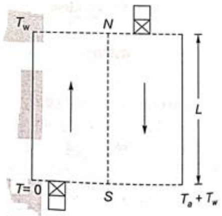
From eq. (ii)

$$n_a = qT_a + KL \qquad \text{...(iv)}$$

Adding eq. (iii) and (iv)

$$n_a + n_y = q(T_a + T_w)$$

$$q = \frac{n_a + n_y}{T_a + T_w}$$



From eq. (i)

$$\frac{n_y}{T_w} = q - \frac{KL}{T_w}$$

$$q_{(veh/hr)} = K_{(veh/km)} \times V_{(km/hr)}$$

$$\frac{n_y}{T_w} = q - \frac{q}{V} \times \frac{L}{T_w}$$

$$\frac{n_y}{T_w} = q - q \times \frac{\bar{t}}{T_w}$$

Origin And Destination Studies: This study is generally carried out to

(i) Plan the road network and other facilities for vehicular traffics.

(ii) Plan the schedule of different modes of transportation for the trip demand.

(iii) To judge the adequacy of existing routes and to use in planning new network to roads.

(iv) To locate expressway or major routes along the desire lines.

(v) To establish preferential routes for various categories to vehicle including by pass.

(vi) To locate intermediate stops of public transport.

(vii) It is also used for mass rapid transit system.

The object of this study is

- Plan the road network and other facilities for vehicular traffic
- Plan the schedule of different modes of transportation for the trip demand of commuters.

•It gives the information like the actual direction of travel, selection of routes and length of trip.

•Used in planning new highway facilities and in improving some of the existing system.

•To plan the transportation system and mass transit facilities in cities including route and schedules of operation

• To locate expressway or major routes along the desire lines.

• To locate terminals and to plan terminal facilities.

• To locate new bridge as per traffic demands.

•To locate intermediate stops of public transport.

Methods of 'O' and 'D' survey: There are number of methods for collecting the O and D data.

1. Road-side interview method
2. License plate method
3. Return post card method
4. Tag-on-car method
5. Home interview method
6. Work spot interview method

Note: O & D studies provides the basic data for determining the desire direction of flow or desire lines.

Desire line:

- It is a straight line connecting origin & destination
- Width of desire line is directly proportional to no. of trip in both directions.

(i) Road-side interview method:

The vehicles are stopped at previously decided interview stations by a group of persons and answer to prescribed questionnaire are collected on the spot. The information collected include the place and time of origin and destination, route, location of stoppages, the purpose of trip, type of vehicle and numbers of passenger in each vehicle.

In this method the data is collected quickly in short duration and the field organization is simple and the team can be trained quickly. The main drawback of this method is that vehicles stopped for interview, and there is delay to the vehicular movement.

(ii) License plate method:

This method is quite easy and quick as for as the fieldwork is concerned. The entire area under study is cordoned out and the observers are simultaneously stationed at all points of entry and exit on all the routes leading to out of the area.

Each party at the observation station is given synchronized time pieces and they note the license plate numbers (registration numbers) of the vehicles entering and leaving the cordoned area and the time.

Separate recording sheets are maintained for each direction of movement for a specified time interval. After collecting the field data major work remains of the office computations and analysis, by tracking each vehicle number and its time of entering and leaving the cordon area.

This method is quite easy and quick as far as the field work concerned. The field organization can also be trained quickly. However, this method is quite advantageous when the area under consideration is small, like a large intersection or a small business center.

(iii) Return post card method:

Pre-paid reply post cards with return address are distributed to the road users at some selected points along the route or the cards are mailed to the owners of vehicles. The questionnaire to be filled by road user is printed on the card, along with a request for co-operation and purpose of the study. The distributing stations for the cards may be selected where vehicles have to stop as in case of a toll booth.

The method is suitable where the traffic is heavy. The personnel need not be skilled or trained just distributing the cards. The only a draw back of this methos is part of the road users may return the cards promptly after filling in the desire details properly and correctly.

(iv) Tag-on-car method:

A precoded card is stuck on the vehicles as it enters the area under study. When the car leaves the study area then the other observations are recorded on the tag.

This method is useful where the traffic is heavy and moves continuously. But the method gives only information regarding the points of entry and exit and the time taken to traverse the area.

(v) Home interview method:

Random people are selected from the marked area and visited by an expert term who collect all the travel data from each member of the household. The problem of stopping vehicle and consequent difficulties are avoided altogether. Additional data including socioeconomic and other details may be collected so as to be useful for force casting traffic and transportation growth.

A random sample of 0.5 to 10 percent of the population it selected and the residences are visited by trained personal who collect the travel data from each member of the household. The data collected may be useful either for planning the road network and other facilities for the vehicular traffic or for planning the mass transportation requirement of passengers.

(vi) Work spot interview method:

The transportation needs of work trips can be planned by collecting the O & D data at work spots like offices, factories, educational institutions etc. by personal interviews.

Presentation of O and D Data

The O and D data are presented in the following form:

(i) O and D Table: These are prepared showing number of trips between different zones.

(ii) Desire lines: These are straight lines connecting origin points with destinations. Desire lines density map shows the actual desire of road user based on which necessity of new road link or bypass is decided. The width of desire line is proportional to the number of trips in both directions.

(iii) Pie Charts: Diameter of circles are proportional to number of trips.

(iv) Contour lines: The shape of the contours would indicate the general traffic need of the area

Traffic Flow Characteristics:

Traffic flow characteristics are divided under two categories:

1. Macroscopic Characteristics: Traffic flow theory assumes that there is a fundamental relationship among the three principle variables of traffic flow, speed, and density as follows:

q = k x U ---------------------------------------(1)

Where, q = Traffic volume (Vehicles/hour)

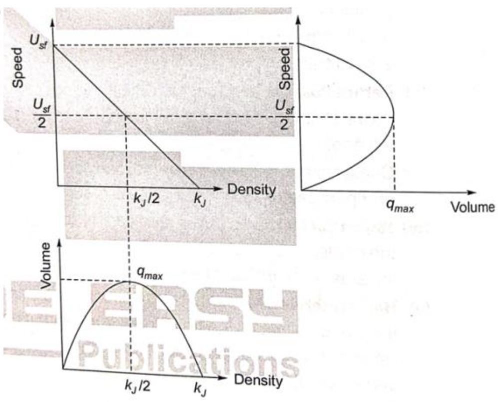
k = Traffic density (Vehicles/km)

U = Speed of vehicle (kmph) i.e., space mean speed

Equation (1) can be derived to get the relationship between any two variables in the three principal variables (e.g., speed-density), and the other two relationships (density-flow, speed-flow) will be got autonomically. Therefore, we choose the speed density k as a function of speed U, then the speed density function can be shown as k = k(U).

The first traffic flow model was proposed by Greenshields in 1935. He suggested a linear relationship between the density and speed.

$$U = U_{sf}\left(1 - \frac{k}{k_J}\right)$$



Where, k_J = jam density (Corresponding to zero speed, i.e., U =0); U_{sf} = free flow speed. And traffic volume,

$q = kU$

$\Rightarrow \quad = \quad U_{sf}\,(k - k^2/k_J)$

$$= U_{sf}\left(k - \frac{k^2}{k_J}\right)$$

For maximum volume, dq/dk = 0

$\Rightarrow \quad U_{sf}\,(1 - 2k/k_J) = 0$

$$k = \frac{k_J}{2}$$

when, $k = \frac{k_J}{2}$ and $U = \frac{U_{sf}}{2}$

$$\therefore \quad q_{max} = \frac{U_{sf}.k_J}{4}$$

A number of mathematical models between the traffic speed and density were proposed and calibrated by fitting curves to empirical traffic data.

Green berg model: $U = U_{sf} \ln \frac{k_J}{k}$

Underwood model (exponential distribution) : $U = U_{sf} e^{-k/k_J}$

2. Microscopic Characteristics:

Time headway: The time interval between the passage of successive vehicles moving in the same lane and measured from head to head as they pass appoint on the road is known as the time headway.

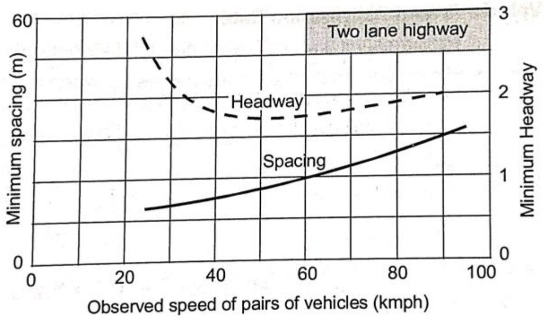


Figure- Variation of min. space and time headways with speed

Space headway: The distance between successive vehicles moving in the same lane measured from head at any instance is the space headway.

Space gap allowed by the driver of a followed vehicle depends on several factors such as:

(i) Speeds of leading and following vehicles.

(ii) Type and characteristics of the two vehicles.

(iii) Driver characteristics of the following vehicle.

(iv) Level of service

(v) Road geometrics

(vi) Environmental factors

Traffic stream generally has flow and counter flow along a common route. The basic traffic maneuvers are diverging, merging and crossing as shown in figure.

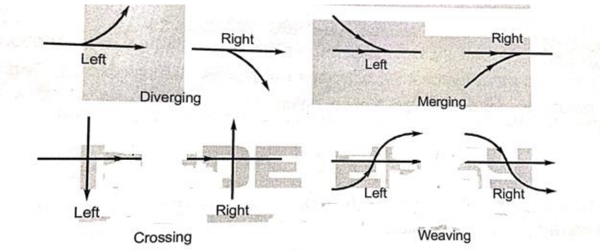


Figure-4.6 : *Traffic manoeuvres*

When a vehicle moves obliquely across the path of another vehicle moving in the same direction, as relatively small angle of crossing, the action is termed as weaving. The weaving manoevures may also consist of merging and diverging operations.

NOTE:

- The number of headways per unit time is dependent on the rate of traffic flow and is therefore a direct measure of traffic volume.
- With increase in speed of traffic stream, the minimum space headway increases whereas the minimum time headway first decreases and after reaching a minimum value at optimum speed on the stream increases.
- Maximum flow or capacity flow is attained at this speed when the time headway is minimum.

Vehicle Arrival Distribution Rate

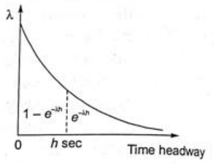
Probability $f(t) = \lambda e^{-\lambda t}$ (exponential distribution)

Probability that time headway lies between 0 and ∞.

$$P[0 \le t \le \infty] = \int_0^\infty \lambda e^{-\lambda t} dt = \lambda \left[\frac{e^{-\lambda t}}{-\lambda} \right]_0^\infty$$

$$= \lambda \left[0 - \frac{1}{-\lambda} \right] = 1$$

$$P[h \le t \le \infty] = \int_h^\infty \lambda e^{-\lambda t} dt = \lambda \left[\frac{e^{-\lambda t}}{-\lambda} \right]_h^\infty = e^{-\lambda h}$$



Poisson Distribution of Vehicle Arrivals

The distribution of vehicles in space or in time may assume various mathematical forms. In general, it is likely that the spacing between vehicles will be distributed in a random manner with gaps of various sizes. One of the statistical models to describe the distribution is the Poisson distribution.

As n becomes large, the binominal distribution approaches the Poisson distribution.

$$P(n) = \frac{(\lambda t)^n e^{-\lambda t}}{n!}$$

where, $P(n)$ = Probability of arrival of n vehicles in any internal of t sec

λ = average rate of arrival (vehicle per unit time)

t = time internal

e = base of natural logarithms

Density

Density is defined as the number of vehicles occupying a given length of highway or lane and is generally expressed as vehicles per km/mile**.**

One can photograph a length of road x, count the number of vehicles, n_x, in one lane of the road at that point of time and derive the density k as,

$$k = \frac{n_x}{x}$$

This is illustrated in figure given below. From the figure, the density is the number of vehicles between the point A and B divided by the distance between A and B. Density is also equally important as flow but from a different angle as it is the measure most directly related to traffic demand. Again it measures the proximity of vehicles in the stream which in turn affects the freedom to maneuver and comfortable driving.

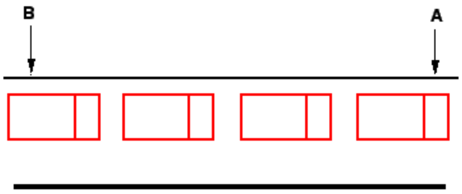


Figure: Illustration of density

Derived characteristics

From the fundamental traffic flow characteristics like flow, density, and speed, a few other parameters of traffic flow can be derived. Significant among them are the time headway, distance headway and travel time. They are discussed one by one below.

Time headway

The microscopic character related to volume is the time headway or simply headway. Time headway is denoted as the time difference between any two successive vehicles when they cross a given point. Practically, it involves the measurement of time between the passage of one rear bumper and the next past a given point. If all headways h in time period, t, over which flow has been measured are added then,

$$\sum_{1}^{n_t} h_i = t$$

But the flow is denoted n_t as the number of vehicles n_t measured in time interval t, that is,

$$q = \frac{n_t}{t} = \frac{n_t}{\sum_1^{n_t} h_i} = \frac{1}{h_{av}}$$

where, h_{av} is the average headway. Thus average headway is the inverse of flow. Time headway is often referred to as simply the headway.

Distance headway

Another related parameter is the distance headway. It is defined as the distance between corresponding points of two successive vehicles at any given time. It involves the measurement from a photograph, the distance from rear bumper of lead vehicle to rear bumper of following vehicle at a point of time. If all the space headways in distance x over which the density has been measured are added,

$$\sum_{1}^{n_x} s_i = x$$

But the density (k) is the number of vehicles n_x at a distance of x, that is

$$k = \frac{n_x}{x} = \frac{n_x}{\sum_1^{n_x} s_i} = \frac{1}{s_{av}}$$

Where, s_{av} is average distance headway. The average distance headway is the inverse of density and is sometimes called as spacing.

Travel time

Travel time is defined as the time taken to complete a journey. As the speed increases, travel time required to reach the destination also decreases and vice-versa. Thus, travel time is inversely proportional to the speed. However, in practice, the speed of a vehicle fluctuates over time and the travel time represents an average measure.

Time-space diagram

Time space diagram is a convenient tool in understanding the movement of vehicles. It shows the trajectory of vehicles in the form of a two dimensional plot. Time space diagram can be plotted for a single vehicle as well as multiple vehicles. They are discussed below.

Single vehicle

Taking one vehicle at a time, analysis can be carried out on the position of the vehicle with respect to time. This analysis will generate a graph which gives the relation of its position on a road stretch relative to time.

This plot thus will be between distance x and time t and x will be a functions the position of the vehicle for every t along the road stretch. This graphical representation of x(t) in a (t; x) plane is a curve which is called as a trajectory. The trajectory provide an intuitive, clear, and complete summary of vehicular motion in one dimension.

In figure, the the distance x goes on increasing with respect to the origin as time progresses. The vehicle is moving at a smooth condition along the road way. In figure 2(b), the vehicle at first moves with a smooth pace after reaching a position reverses its direction of movement. In figure 2(c), the vehicle in between becomes stationary and maintains the same position.

From the figure, steeply increasing section of x(t) denote a rapidly advancing vehicle and horizontal portions of x(t) denote a stopped vehicle while shallow sections show a slow-moving vehicle. A straight line denotes constant speed motion and curving sections denote accelerated motion; and if the curve is concave downwards it denotes acceleration. But a curve which is convex upwards denotes deceleration.

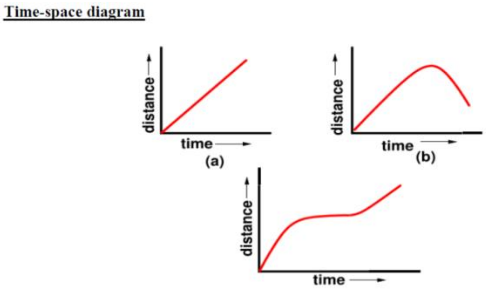


Figure: Single vehicle

Miultiple Vehicles

Time-space diagram can also be used to determine the fundamental parameters of traffic flow like speed, density and volume. It can also be used to find the derived characteristics like space headway and time headway. Figure below shows the time-space diagram for a set of vehicles traveling at constant speed. Density, by definition is the number of vehicles per unit length. From the figure, an observer looking into the stream can count 4 vehicles passing the stretch of road between x_1 and x_2 at time t. Hence, the density is given as

$$k = \frac{4\ vehicles}{x_2 - x_1}$$

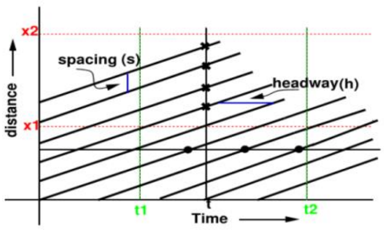


Figure: Many vehicle

We can also find volume from this time-space diagram. As per the definition, volume is the number of vehicles counted for a particular interval of time. From the figure above: we can see that 6 vehicles are present between the time t_1 and t_2. Therefore, the volume q is given as

$$q = \frac{3\ vehicles}{t_2 - t_1}$$

Again the averages taken at a specific location (i.e., time ranging over an interval) are called time means and those taken at an instant over a space interval are termed as space means.

Another related definition which can be given based on the time-space diagram is the headway. Space headway is denoted as the distance between corresponding points of two successive vehicles at any given time. Thus, the vertical gap between any two consecutive lines represents space headway. The reciprocal of density otherwise gives the space headway between vehicles at that time.
Similarly, time headway is denoted as the time difference between any two successive vehicles when they cross a given point. Thus, the horizontal gap between the vehicles represented by the lines gives the time headway. The reciprocal of flow gives the average time headway between vehicles at that point.

Relation between traffic volume, density & speed:

FUNDAMENTAL RELATION OF TRAFFIC PARAMETER:
Fundamental diagrams of traffic flow

The flow and density varies with time and location. The relation between the density and the corresponding flow on a given stretch of road is referred to as one of the fundamental diagrams of traffic flow. Some characteristics of an ideal flow-density relationship is listed below:

1. When the density is zero, flow will also be zero, since there is no vehicles on the road.
2. When the number of vehicles gradually increases the density as well as flow increases.
3. When more and more vehicles are added, it reaches a situation where vehicles can't move. This is referred to as the jam density or the maximum density. At jam density, flow will be zero because the vehicles are not moving.
4. There will be some density between zero density and jam density, when the flow is maximum.

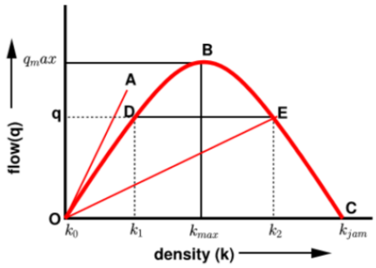


Figure: Flow density curve

Speed-density diagram

Similar to the flow-density relationship, speed will be maximum, referred to as the free flow speed, and when the density is maximum, the speed will be zero. The most simple assumption is that this variation of speed with density is linear

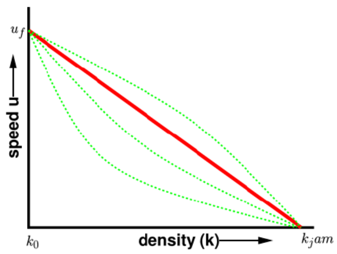


Figure: Speed-density diagram

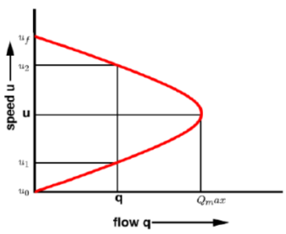


Figure: Speed-flow diagram

Traffic Capacity Studies

Capacity

Capacity is defined as the maximum number of vehicles, passengers, or the like, per unit time, which can be accommodated under given conditions with a reasonable expectation of occurrence.

(i) Traffic volume:

It is the number of vehicles moving in a specified direction on a given lane or roadway that pass a given point during specified unit of time. It is expressed as vehicles per hour or vehicles per day.

(ii) Traffic Density (k):

It is defined as the number of vehicles occupying a unit length of lane of roadway at a given instant. It is expressed in vehicles per kilometer.

(iii) Traffic capacity:

The ability of a roadway to accommodate traffic volume. It is expressed as the maximum number of vehicle in a lane or a road that can pass a given point in unit time, usually an hour. The capacity of roadway depends on a number of prevailing roadway and traffic conditions. Traffic capacity is always greater than or equal to traffic volume.

Volume represents an actual rate of flow whereas capacity indicates a maximum rate of flow with a certain level of service.

(iv) Basic capacity:

It is the maximum no. of passenger car that can be pass a given point on a roadway during one hour under the most nearly ideal roadway and traffic conditions. It is otherwise known as theoretical capacity.

(v) Possible capacity:

It is the maximum no. vehicle that can pass a given point on a roadway during one hour under prevailing roadway and traffic conditions. The value of possible capacity varies between zero to basic capacity.

(vi) Practical capacity:

It is the maximum no. of vehicle that can pass a given point on a roadway during one hour, without traffic density being so great as to cause unreasonable delay, hazard or restriction to the driver freedom to manoeuvre under the prevailing roadway and traffic conditions. This is also known as design capacity.

Highway capacity

Highway capacity is defined by the Highway Capacity Manual as the maximum hourly rate at which persons or vehicles can be reasonably expected to traverse a point or a uniform segment of a lane or roadway during a given time period under prevailing roadway, traffic and control conditions.

- Traffic conditions
- Road way characteristics
- Control conditions

For design purpose we neither use basic capacity nor possible capacity. Practical capacity is used as design capacity.

Determination Of Theoretical Maximum Capacity:

(i) Maximum theoretical capacity on the basis of space headway:

Theoretical maximum capacity of a lane,

C= 1000 V/S

Where,

C is the capacity of single lane in vehicle per hour per lane.

V = Speed of vehicle (kmph)

S = Average center to center spacing of vehicles in m = $S_g + L$ or

= $0.7V_B + L$ Where V_B in m/s

Sg = Minimum space gap = 0.278 Vt

L = Average length of vehicle

t = Reaction time = 0.7 sec

(ii) Maximum theoretical capacity on the basis of time headway:

Theoretical maximum capacity of a lane,

C= 3600 /H_t

Where, H_t = Minimum time headway in seconds

Relationship between speed and maximum capacity of a traffic lane

The peak value of the theoretical maximum capacity is reached at an optimum speed. As the further increase in speed will decreases the maximum capacity of the lane.

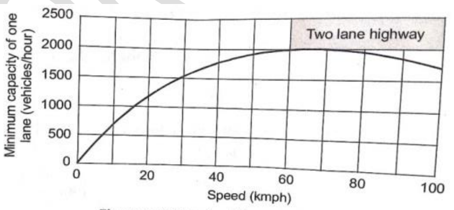


Figure-4.7 : *Speed and Capacity relation*

Factors affecting practical Capacity

There are various factors which affects the practical capacity are:

(i) Lane width: As the lane width decreases, the capacity also decreases.

(ii) Lateral clearance: Restricted lateral clearance affects driving comfort, increases accident rates and reduces capacity.

(iii) Width of shoulder: Narrow shoulder reduces the effective width of traffic lanes, thus reduce capacity of lane.

(iv) Commercial vehicle: Large commercial vehicles occupy more space, may travel at slow speeds and influence the traffic in the same lane as well as the adjoining lanes.

(v) Alignment: Restrictions to sight distance requirements cause reduction in capacity.

(vi) Presence of intersection at grade: Intersection restricts the free flow of traffic and thus adversely effect the capacity.

(vii) Other factors are stream speed one or two way movement of traffic, number of lanes and traffic volume.

The practical capacity values suggested by IRC for the purpose of design of different types of roads in rural areas and urban roads as shown in Table

Table: Capacity of different types of roads

Type of Road	Capacity (PCU per day in both direction)
Single lane roads having a 3.75 m wide carriageway with normal earthen shoulders.	1000
Single lane roads having a 3.75 m wide carriageway with adequately designed shoulders 1.0 m wide.	2500
Two lane roads having a 7 m wide carriageway with normal earthen shoulders.	10000
Roads of intermediate width i.e., having a carriageway of 5.5 m with normal earthen shoulders.	5000

Peak-Hour Factor

•It is basically represent the variation in traffic flow within an hour.

•Observations of traffic flow consistently indicate that the flow rates are found in the peak.

•A 15 minute period within an hour is not sustained throughout the entire period and that is why we need to use the peak-hour factor.

•Normally on freeways the peak-hour factor values range from 0.80 to 0.95.

Passenger Car Unit (PCU)

•The different vehicle classes have a wide range of statics characteristics and dynamic characteristics, apart from these the driver behavior of the different vehicle classes is also found to vary considerable. Therefore, mixed traffic flow characteristics are very much complex when compare to homogeneous traffic and it is difficult to estimate the traffic volume, capacity of roadway under the mixed traffic flow, unless the different vehicle classes are converted to one common standard vehicle unit.

Therefore, it is a common practice to consider the passenger car as the standard vehicle unit to convert the other vehicle classes and this unit is called passenger car unit.

PCU value depends upon the several factors, such as:

•Vehicle characteristics

•Transverse and longitudinal gaps or clearance between moving vehicles.

•Speed distribution of the mixed traffic stream, volume to capacity ratio.

•Roadway characteristics.

•Regulation and control of traffic.

•Environmental and climatic conditions.

- As per IRC:86-1983

S.L. No.	Vehicle class	Equivalency factor
1	Motor cycle, Scooter and Pedal cycle	0.5
2	Passenger car, Tempo, auto rickshaw, Agricultural tractor, Pick-up van	1.0
3	Cycle -rickshaw	1.5
4	Truck, Bus, Agricultural tractor-trailer	3.0
5	Horse-drawn vehicle	4.0
6	Small bullock-cart and Hand-cart	6.0
7	Large bullock-cart	8.0

The practical capacity values suggested by IRC for the purpose of design of different types of roads in rural areas and urban roads are shown in table:

Design Capacity and Level of service

A term closely related to capacity and often confused with it is service volume. When capacity gives a quantitative measure of traffic, level of service or LOS tries to give a qualitative measure.

When all the vehicles flow as a stream at a optimum speed with no opportunity of overtaking at that time flow is called as capacity flow. At this optimum speed, volume to capacity ratio approaches a maximum possible value of 1.0.

Level of service (LOS)

It is defined as a qualitative measure describing the operational condition within a traffic stream, and their perception by motorist and passengers. Or Rating of acceptable level of congestion.

Six level of services A,B,C,D,E and F are recommended by Highway Capacity Manual.

LOS definitions

- A: Free flow, low traffic, high speed
- B: Stable flow, noticeable traffic
- C: Stable flow, traffic interactions,
- D: Unstable flow, High density, movement restrictions
- E: Unstable flow, lower speed, volume is nearly equal to capacity, little freedom
- F: Unstable flow, no freedom, traffic volume can drop to zero, stop & go

(i) Level of service A exist when volume to capacity is so low that users has freedom to select desired speeds and manoeuvre within the traffic stream. Level of comfort and convenience to users is extreme.

LOS-A

- Free-flow operation
- no restriction in maneuvering.

(ii) With increase in the volume to capacity ratio, the operating speeds and overtaking opportunities reduces and level of service fall to decreasing values of B,C,D and E.

LOS-B

- Reasonably free flow
- Ability to maneuver is only slightly restricted
- Effects of minor incidents still easily absorbed

LOS-C

- Speeds at or near FFS
- Freedom to maneuver is noticeably restricted
- Queues may form behind any significant blockage.

LOS-D

- Speeds decline slightly with increasing flows
- Density increases more quickly
- Freedom to maneuver is more noticeably limited
- Minor incidents create queuing

LOS-E

- Operation near or at capacity
- No usable gaps in the traffic stream
- Operations extremely volatile
- Any disruption causes queuing

(iii) In the level of service F, flow and speed of vehicle reduces which leads to congestion. This is the lowest level of service.

LOS-F

- Breakdown in flow
- Queues form behind breakdown points
- Demand > capacity

  In India, as per IRC

  LOS-B: for design of rural road

  LOS-C: for the design of urban roads

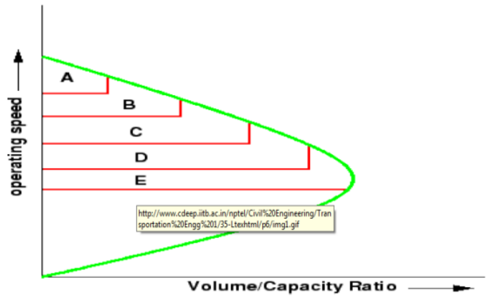


Figure: General concept of level of service

Factors affecting level of service

Level of service one can derive from a road under different operating characteristics and traffic volumes. The factors affecting level of service (LOS) can be listed as follows:

- Speed and travel time
- Traffic interruptions/restrictions
- Freedom to travel with desired speed
- Driver comfort and convenience
- Operating cost.

Parking studies:

Parking is one of the major problems that is created by the increasing road traffic, especially in metropolitan cities. The availability of less space in urban areas has increased the demand for parking space especially in areas like central business district.

Various aspects to be investigated during parking studies are as follows:

(i) Parking demand: Methods to measure parking demand is by making cordon counts recording accumulation of vehicles during the peak hours by subtracting the outgoing traffic from the traffic volume entering the cordoned area.

(ii) Parking Characteristics: The study is directed to note the present parking practices prevalent in the area under study and the problems in parking.

(iii) Parking Space Inventory: the area under study is fully surveyed and a map is prepared showing all places where kerb parking and off-street parking facilities can be provided to meet the parking demands.

Parking Statistics

(i) Parking Accumulation: It is defined as the number of vehicles parked at a given instant of time. Normally this is expressed by accumulation curve. Accumulation curves is the graph obtained by plotting the number of bays occupied with respect to time.

(ii)Parking Volume: Parking volume is the total number of vehicles parked at a given duration of time. This does not account for repetition of vehicles.

(iii) Parking load: Parking load gives the area under the accumulation curve. It can also be obtained by simply multiplying the number of vehicles occupying the parking area at each time interval with the time interval. It is expressed as vehicle hours.

(iv) Average Parking Duration: It is the ratio of total vehicle hours to the number of vehicles parked.

(v) Parking Turnover: It is the ratio of number of vehicles parked in a duration to the number of parking bays available.

This can be expressed as number of vehicles per day per time duration.

(vi) Parking Index: It is also called occupancy or efficiency. It is defined as the ratio of number of bays occupied in a time duration to the space available. Parkin index can be found out as follows.

Kerb Parking/On street parking:

In this type of parking vehicles are parked on the kerb which is designed for parking. Angle parking accommodates more vehicle per unit length but maximum vehicles can be parked with an angle of 900.

As per IRC the standard dimensions of a car is taken as 5x2.5 m and that for a truck is 3.75x7.5 m.

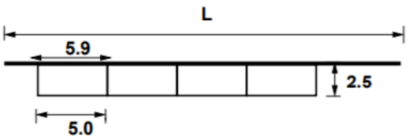


Figure 38:2: Illustration of parallel parking

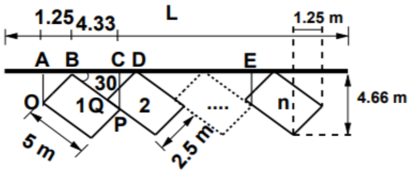


Figure 38:3: Illustration of 30° parking

For parallel parking

The vehicles are parked along the length of the road. Here there is no backward movement involved while parking or unparking the vehicle. Hence, it is the most safest parking from the accident perspective. However, it consumes the maximum curb length and therefore only a minimum number of vehicles can be parked for a given kerb length. This method of parking produces least obstruction to the on-going traffic on the road since least road width is used. Parallel parking of cars is shown in figure 38:2. The length available to park N number of vehicles, L = N/5.9

30◦ parking: In thirty degree parking, the vehicles are parked at 30◦ with respect to the road alignment. In this case, more vehicles can be parked compared to parallel parking. Also there is better maneuverability. Delay caused to the traffic is also minimum in this type of parking. An example is shown in figure 38:3. From the Figure

$$\begin{aligned} AB &= OB\sin 30^\circ = & 1.25, \\ BC &= OP\cos 30^\circ = & 4.33, \\ BD &= DQ\cos 60^\circ = & 5, \\ CD &= BD - BC = 5 - 4.33 = & 0.67, \\ AB + BC &= 1.25 + 4.33 = & 5.58 \end{aligned}$$

For N vehicles, L = AC + (N-1)CE =5.58+(N-1)5 =0.58+5N

45◦ parking: As the angle of parking increases, more number of vehicles can be parked. Hence compared to parallel parking and thirty degree parking, more number of vehicles can be accommodated in this type of parking. From figure 38:4, length of parking space available for parking N number of vehicles in a given kerb is L = 3.54 N+1.77

60◦ parking: The vehicles are parked at 60◦ to the direction of road. More number of vehicles can be accommodated in this parking type. From the figure 38:5, length available for parking N vehicles =2.89N+2.16.

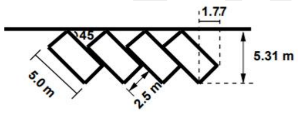


Figure 38:4: Illustration of 45° parking

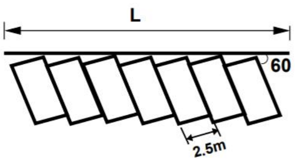


Figure 38:5: Illustration of 60° parking

Right angle parking: In right angle parking or 90◦ parking, the vehicles are parked perpendicular to the direction of the road. Although it consumes maximum width kerb length required is very little. In this type of parking, the vehicles need complex maneuvering and this may cause severe accidents. This arrangement causes obstruction to the road traffic particularly if the road width is less. However, it can accommodate maximum number of vehicles for a given kerb length. An example is shown in figure 38:6. Length available for parking N number of vehicles is L = 2.5N.

Off street parking:

In many urban centres, some areas are exclusively allotted for parking which will be at some distance away from the main stream of traffic. Such a parking is referred to as off-street parking. They may be operated by either public agencies or private firms. A typical layout of an off-street parking is shown in figure 38:7.

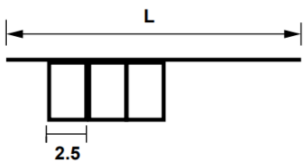


Figure 38:6: Illustration of 90° parking

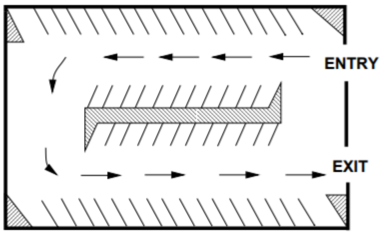


Figure 38:7: Illustration of off-street parking

ACCIDENT STUDIES:

The traffic accidents may involve property damages, personal injuries or even causalities. One of the main objectives of traffic engineering is to provide safe traffic movements Road accident cannot be totally prevented, but suitable traffic engineering and management measures, the accident rate can be considerably decreases. Therefore, the traffic engineer has to carryout systematic accident studies to investigate the causes of accidents and to take preventive measures in terms of design and control.

Objectives of the Accident studies:

The objective of the accident studies may be listed below:

(i) To study the causes of accidents and to suggest corrective treatment at potential location

(ii) To support the proposed designs

(iii) To make computations of financial losses

(iv) To carry out the before and after studies and to demonstrate the improvement in the problem

(v) To give economic justification for the suggested improvements

There are four basic elements in a traffic accident:

- The road users
- The vehicles
- The roads and its condition and
- Environmental factor – traffic, weather etc.

Types of accident:

- A moving vehicle hits a parked vehicle
- Two vehicles moving towards crossing collide at intersection
- A moving vehicle collides with an object

- Head on collision

Causes of accidents:

Basically four factors are involved in road accidents

(i) The vehicle

(ii) The road and its condition

(iii) The road user

(iv) The environment

Road users: excessive speed and rash driving, careless, violation of rules and regulations, failure to see or understand the traffic situations, signs or signal, temporary effect du eto fatigue, sleep or alcohol.

Vehicles defects: Failure of brakes, steering system, and lighting system etc.

Road condition: Skidding road surface, pot holes, ruts and other damaged conditions of the road surfaces.

Road design: Defective geometric design like inadequate sight distance, inadequate width of shoulders, improper curve design, improper lighting and improper control devices.

Environmental factor:

Unfavorable weather condition like mist, fog, snow, dust, smoke and heavy rainfall which restrict the normal visibility and render driving unsafe.

TYPES OF ACCIDENTS:

- Fatal accident
- Grievous injury accidents
- Slightly injured accidents
- Minor injury accidents
- Non-injury accidents

Fatal accidents: An accident in which one or more persons were killed.

Grievous injury accident: Accidents in which persons were grievously injured. For example permanent disfigurement of head or face.

Slightly injured accidents: Persons who have sustained only minor injuries or bruises or sprains.

Minor injury accidents: Accidents in which persons received only minor injuries.

Non-injury accidents: Accidents in which no one was killed or injured.

COLLISION DIAGRAM:

A collision diagram is the schematic representation of all accidents occurring at a particular location.

Nature of collision:

Different types of collision are,

- Head on collision
- Rear end collision
- Side swipe collision
- Right angle collision
- Right turn collision
- Fixed object collision
- Out of control collision

Mathematical Analysis of Accident studies:

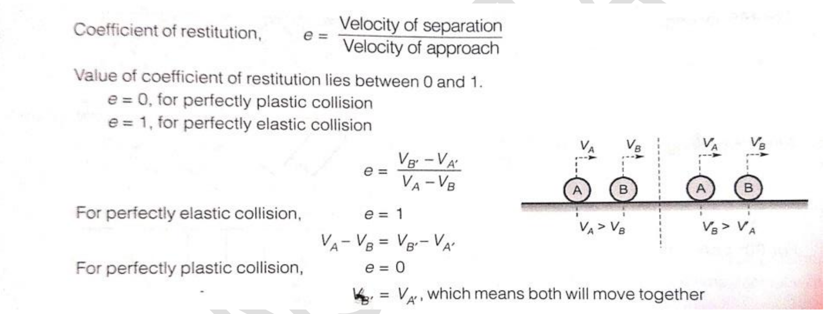
The following assumptions involved in the analysis of accidents are:

(i) If skid marks the present, then it is assumed that 100 % skid occurs

(ii) If skid marks are not present then free collision is assumed means no brakes are applied.

According to Newton's law of collision,

Coefficient of restitution, e = Velocity of separation/velocity of approach



Coefficient of restitution, $e = \frac{\text{Velocity of separation}}{\text{Velocity of approach}}$

Value of coefficient of restitution lies between 0 and 1.

$e = 0$, for perfectly plastic collision

$e = 1$, for perfectly elastic collision

$$e = \frac{V_{B'} - V_{A'}}{V_A - V_B}$$

For perfectly elastic collision, $e = 1$

$$V_A - V_B = V_{B'} - V_{A'}$$

For perfectly plastic collision, $e = 0$

$V_{B'} = V_{A'}$, which means both will move together

Different cases of accidents

Case -1 When moving vehicle hits the parked vehicle

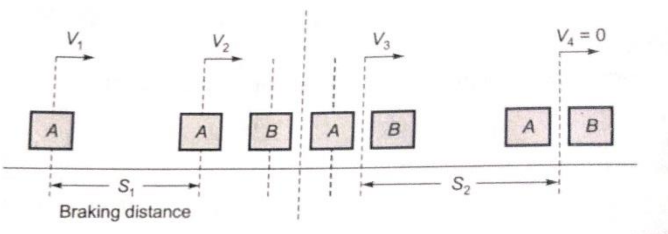


Figure-4.10 : *Moving vehicle A hits parked vehicle B*

Let s_1 = skid mark length between v_1 and v_2

s_2 = skid mark length after collision to stop condition

f = coefficient of friction

(i) Energy Conversation equation just before collision

$1/2mv_1^2 - 1/2mv_2^2 = fws_1 = fmgs_1$

$v_1^2 - v_2^2 = 2gfs_1$

(ii) Conservation of momentum just before and after collision

$m_Av_2 + m_B \text{ x } 0 = (m_A + m_B)\ v_3$

$m_Av_2 = (m_A + m_B)\ v_3$

(iii) Conservation of energy equation after the collision

$1/2mv_3^2 - 1/2m(0)^2 = fmgs_2$

Where, m_A and m_B are masses of vehicle A and B

Case-2 When two vehicles moving towards crossing collides at intersection

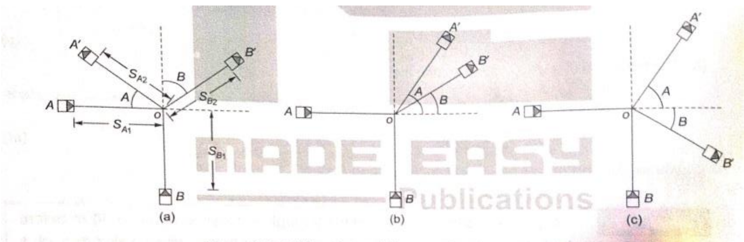


Figure-4.11 : Collision of two vehicle approaching from right angles

(i) Energy conservation before collision:

$$\frac{1}{2}mv_{A_1}^2 - \frac{1}{2}mv_{A_2}^2 = fmgs_{A1}$$

$$v_{A_1}^2 - v_{A_2}^2 = 2g\,fs_{A1}$$

Similarly, $$v_{B_1}^2 - v_{B_2}^2 = 2\,g\,fs_{B1}$$

(ii) Conservation of momentum at the time of collision:

Along W – E: $$m_A v_{A_2} + m_B \times 0 = m_A v_{A_3}\cos\theta_A + m_B v_{B_3}\sin\theta_B$$

Along S – N: $$m_A \times 0 + m_B v_{B_2} = m_A v_{A_3}\sin\theta_A + m_B v_{B_3}\cos\theta_B$$

(iii) Energy conservation after collision:

$$\frac{1}{2}mv_{A3}^2 - 0 = fmgs_{A2}$$

$$v_{A3}^2 = 2g\,fs_{A2}$$

Similarly, $$v_{B3}^2 = 2g\,fs_{B2}$$

TRAFFIC CONTROL DEVICES

Traffic control device is the medium used for communicating between traffic engineer and road users. Unlike other modes of transportation, there is no control on the drivers using the road. Here traffic control devices come to the help of the traffic engineer.

The various aids and devices used to control, regulate and guide traffic may be called traffic control devices. The general requirements of traffic control devices are: attention, meaning, time for response and respect of road users.

Requirements of traffic control devices

- The control device should fulfill a need
- It should command attention from the road users
- It should convey a clear, simple meaning
- Road users must respect the signs
- The control device should provide adequate time for proper response from the road users.

The generally requirements of traffic control devices

(i) The control device should fulfill a need: Each device must have a specific purpose for the safe and efficient operation of traffic flow.

(ii) It should command attention from the road users: This affects the design of signs. For commanding attention, proper visibility should be there. Also, the sign should be distinctive and clear.

(iii) It should convey a clear and simple meaning: Clarity and simplicity of message is essential for the driver to properly understand the meaning in short time. The use of color, shape and legend as codes becomes important in this regard.

(iv) Road users must respect the signs: Respect is commanded only when the drivers are conditioned to expect that all devices carry meaningful and important messages.

(v) The control device should provide adequate time for proper response from the road users: This is again related to the design aspect of traffic control devices. The sign boards should be placed at a distance such that the driver could set it and gets sufficient time to respond to the situation.

A number of mechanisms are used by the traffic engineer to communicate with the road users. These mechanisms recognize certain human limitations, particularly eyesight. Messages are conveyed through the following elements.

(i) Colour

(ii) Shape

(iii) Pattern

(iv) Legend

The most common control devices are:

(i) Traffic signs

(ii) Traffic Signals

(iii) Road markings

(iv) Islands/ Parking control.

In addition, road lights are useful in guiding traffic during night.

Communication tools

A number of mechanisms are used by the traffic engineer to communicate with the road user. These mechanisms recognize certain human limitations, particularly eyesight. Messages are conveyed through the following elements.

1. Color: It is the first and most easily noticed characteristics of a device. Usage of different colors for different signs are important. The most commonly used colors are red, green, yellow, black, blue, and brown. These are used to code certain devices and to reinforce specific messages. Consistent use of colors helps the drivers to identify the presence of sign board ahead.

2. Shape: It is the second element discerned by the driver next to the color of the device. The categories of shapes normally used are circular, triangular, rectangular, and diamond shape. Two exceptional shapes used in traffic signs are octagonal shape for STOP sign and use of inverted triangle for GIVE WAY (YIELD) sign. Diamond shape signs are not generally used in India.

3. Legend: This is the last element of a device that the drive comprehends. This is an important aspect in the case of traffic signs. For the easy understanding by the driver, the legend should be short, simple and specific so that it does not divert the attention of the driver. Symbols are normally used as legends so that even a person unable to read the language will be able to understand that. There is no need of it in the case of traffic signals and road markings.

4. Pattern: It is normally used in the application of road markings, complementing traffic signs. Generally solid, double solid and dotted lines are used. Each pattern conveys different type of meaning. The frequent and consistent use of pattern to convey information is recommended so that the drivers get accustomed to the different types of markings and can instantly recognize them.

Traffic Signs:

A traffic sign is a device mounted on a fixed or portable support whereby a specific message is conveyed by means of words or symbols. Traffic signs should be placed such that they could be seen and recognized by the road users easily and in time.

On the kerb roads, the edge of the sign adjacent to the road should not be less than 0.6 m away from the edge of the kerb. On roads without kerbs, the nearest edge may be 2.0 to 3.0 m from the edge of the carriageway.

Traffic signs should be mounted on sign posts painted alternately with 25 cm black and white bands. The reverse side of all the sign plates should be painted gray.

Traffic signs have been divided in to three categories according to Indian motor vehicles act.

1) Regulatory signs
    a. Prohibitory signs
    b. Mandatory signs
2) Warning or danger signs
3) Informatory signs
    a. Indication signs
    b. Advance direction signs
    c. Place and route identification signs

Regulatory signs

These signs are also called mandatory signs because it is mandatory that the drivers must obey these signs. Regulatory or mandatory signs are meant to inform the road users of certain laws, regulations and prohibitions to provide safety and free flow to traffic. The violation of these signs is a legal offence. Regulatory signs are further subdivided into two types:

i) Prohibitory signs

These signs are part of the regulatory signs, which are intended to inform the highway users of traffic laws or regulation.

They may be of following types:

(a) Movement prohibition (such as prohibition of right turns, prohibition of overtaking, prohibition of entry, one-way streets, exclusion of certain types of vehicles)
(b) Waiting restriction signs,
(c) Speed limit and vehicle control signs
(d) No parking and no stopping signs
(e) Compulsory direction signs

Prohibitory signs are meant to prohibit certain traffic movements, use of horns or entry of certain vehicles class. These signs are circular traffic movements, use of horns or entry of certain vehicle class.

According to the IRC standards, the prohibitory signs are circular in shape and white in color with a red border and a diameter of 600 mm. The common prohibitory signs are, straight prohibited, no entry, one prohibited, bullock cart and hand cart prohibited, Tonga prohibited, hand cart prohibited, cycle prohibited, pedestrian prohibited, right/left turn prohibited, U turn prohibited, overtaking prohibited and horn prohibited.

If the driver fails to obey them, the control agency has the right to take legal action against the driver. The regulatory signs can be further classified into:

1. Right of way series
2. Speed series
3. Movement series
4. Parking series
5. Pedestrian series
6. Miscellaneous

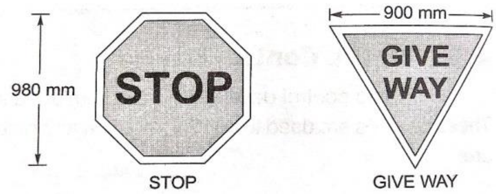

Fig.1 No Entry fig.2 One way fig.3 Right turn prohibited

1. Right of way series:

(a) It includes two unique signs i.e., stop and giveway that assign the right of way to the selected approaches of an intersection.

(b) Stop sign is intended to stop the vehicles on a roadway. It is octahedral in shape and red in colour with a white border.

(c) Give way sign is used to control the vehicles on a road so as to assign right of way to traffic on other roadways. This sign is in triangular shape with apex downwards and white in colour with a red border.

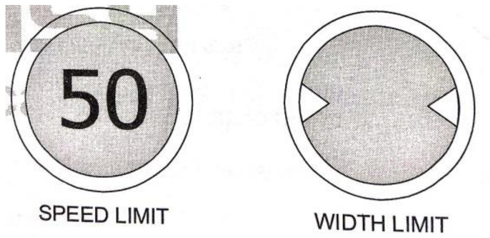


2. Speed series:

(a) Speed limit signs are meant to restrict the speed of all or certain classes of vehicles on a particular stretch of a road.

(b) These signs are circular in shape and have white back ground, red border and black numerals indicating the speed limit.

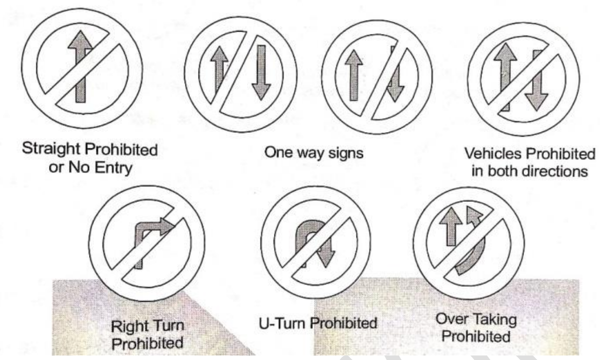
(c) The vehicle control signs are circular in shape, red border and black symbols instead of numerals.



3. Movement series:

(a) These are meant to prohibit certain traffic movements.

(b) They are circular in shape and white in colour with a red border.

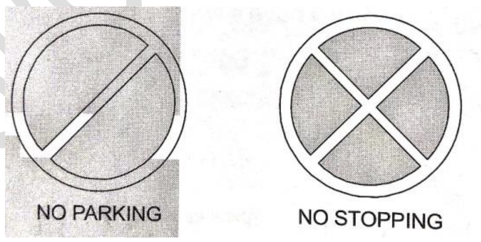


4. Parking series:

(a) They are meant to prohibit parking and stopping of vehicles at that place, the definition plate may indicate the parking restriction with respect to days, distance etc.

(b) These are circular in shape with a blue background and a red border.

(c) In no parking sign an oblique red bar at an angle of 45^0. While in no stopping sign two oblique red bars at 45^0 and right angles to each other.



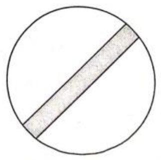
5. Pedestrian series: They include both legend and symbol signs. These signs are meant for the safety of pedestrians and include signs indicating pedestrian only roads, pedestrian crossing sites etc.

6. Miscellaneous: Wide variety of signs that are included in this category are: a "KEEP OF MEDIAN" sign, signs indicating road closures, signs restricting vehicles carrying hazardous cargo or substances, signs indicating vehicle weight limitations etc.

Restriction Ends Sign:

(a) Restricted ends sign indicates the point at which all prohibitions notified by prohibitory signs for moving vehicles binding to apply. Compulsory direction control signs indicate by arrows, the appropriate directions in which the vehicles are oblique to proceed, or the only directions in which they are permitted to proceed.

(b) They are circular in shape with white back ground and a broad diagonal black band at 45^0.



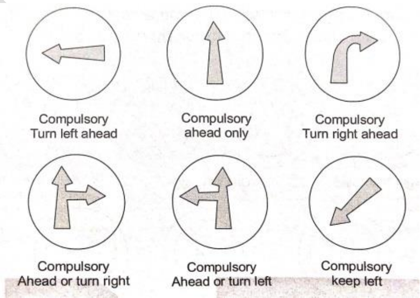
No stopping/standing sign is meant to prohibit stopping of vehicles at the place; the scope of the scope of the prohibition may be indicated on a definition plate. The No stopping/standing sign is circular in shape with blue black ground, red border and two oblique red bars at 45 degree and right angle to each other.

Fig.4 No parking Fig.5 No standing

Compulsory direction control signs:

(a) They are indicated by arrows, the appropriate directions in which the vehicles are bound to proceed.

(b) They are circular in shape with a blue back ground and white direction arrows.



Some of the Compulsory direction controls are compulsory turn left, ahead only, ahead or turn left/right and keep left. Other compulsory signs are compulsory cycle track and compulsory sound horn; these are indicated by white symbols instead of white direction arrows of compulsory direction signs.

ii) Mandatory signs

Mandatory signs are part of regulatory signs and are intended to convey definite positive instructions when it is desires that motorist take some positive actions. The two most important mandatory signs are the (i) STOP sign and (ii) GIVE WAY sign.

Fig.7 Stop sign fig.8 Giveway sign

The stop sign requires all vehicles to come to a halt before stop line. According to IRC stop sign is octagonal in shape and red in color with a white border, the side of the octagon being 900 mm for the standard sized sign.

It is generally used at an intersection where the following conditiond exit:

i. Street entering a through highway or street
ii. Un signalized intersection in a signalized area

The stop sign should not be used:

i. On the through expressways
ii. For speed control
iii. At signalized intersections

The GIVE WAY sign is used to control the vehicles on a road so as to assign right of way to traffic on other roadways. According to the I.R.C. the shape of GIVE WAY sign is downward pointing equilateral triangle having a red border band with white back ground. It is used under the following conditions:

i. On a minor road at a entrance to an intersection where it is necessary to assign right of way to the major road.
ii. On the entrance ramp to an express way when acceleration lane is not provided.

The **GIVE WAY or YIELD** sign should not be used:

i. On the express ways
ii. To control the major flow of traffic at an intersection
iii. On the approach more than one of the intersection streets

Some examples of the regulatory signs are shown in figure. They include a stop sign, give way sign, signs for no entry, sign indicating prohibition for right turn, vehicle width limit sign, speed limit sign etc.

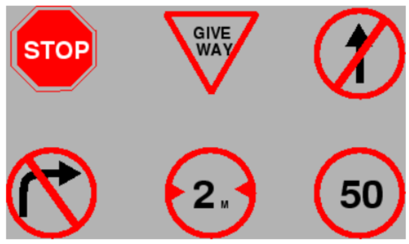
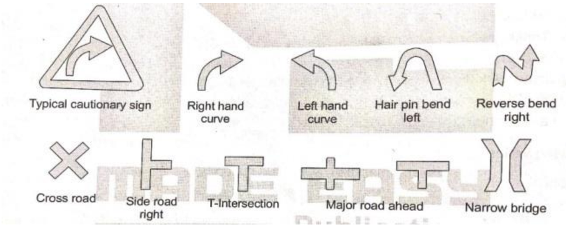


Figure : Examples of regulatory signs (stop sign, give way sign, signs for no entry, sign indicating prohibition for right turn, vehicle width limit sign, speed limit sign)

Warning signs:

Warning or cautionary signs are used to warn the road users of certain hazardous conditions that exist on or adjacent to the roadway. The warning signs are in the shape of equilateral triangle with its apex pointing upwards. According to I.R.C. warning signs are white back ground, red border and black symbols. The side of triangle is 900 mm.

The commonly used warning signs are, right hand/left hand curve, right/left hair pin bend, right/left reverse bend, steep ascent/descent, narrow bridge/road ahead, gap in median, slippery, cycle crossing, pedestrain crossing, school zone, men at work, ferry, cross road, side road, T-intersection, Y-intersection, major road ahead, round about, dangerous dip, hump or rough road, barrier ahead, unguarded railway crossing, graduated railway crossing and falling rock.



Informatory signs:

Informative signs also called guide signs, are provided to assist the drivers to reach their desired destinations. These are predominantly meant for the drivers who are unfamiliar to the place. The guide signs are redundant for the users who are accustomed to the location.

These signs are used to guide the road users along routes, inform them of destination and distance and provide with information to make travel easier, safe and pleasant. The information signs are

- Direction and place identification signs
- Facility information signs
- Other useful information signs
- Parking signs
- Flood gauge

The direction and place identification signs are rectangular with white background, black border and black arrows and letters. The signs of this group include destination signs, direction signs, Re-assurance signs, Route marker and place identifcation signs.

The facility information signs are rectangular signs are rectangular with blue background and white/black letters/symbols. Some of these signs indicate public telephone, petrol pump, hospital, First aid post, eating place and resting place. Other useful information signs include No through road, No through side road, etc.

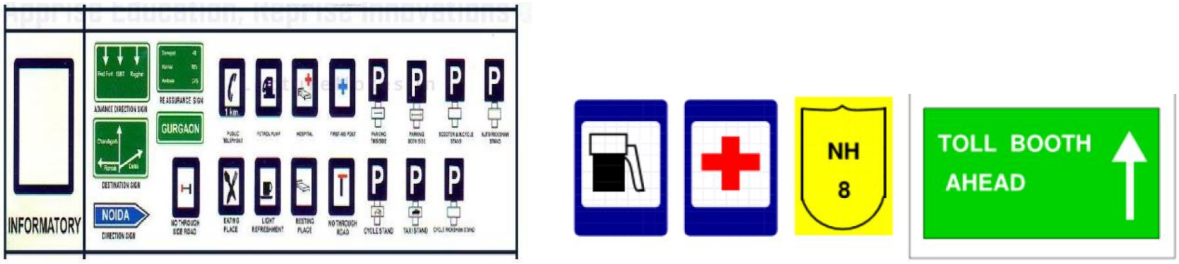


Figure: Examples of informative signs

The information signs are of following types

(i) **Direction and place identification signs:** These are rectangular in shape with white background, black border, black arrows and black letters. They include destination signs, direction signs, route marker and place identification signs.

(ii) The facility information signs: They are rectangular in shape with blue background and white/black letters/symbols. Information signs include public telephone, petrol pump, Hospital, First Aid Post etc.

(iii) Parking signs: They are set up parallel to the road using square sign board with blue background and white coloured letter ‘P’.

(iv) Flood gauge sign: It is installed at all cause ways.

Design of Traffic signs:

The effectiveness of sign depends upon:

(i) Uniformity of design, application and installation.

(ii) Attention or target value depends upon the size shape, colour, colour contrast, and level of illumination.

(iii) Priority value, i.e., the characteristics which determine the order in which the signs are reads. It will depend primarily on the placement and size of message compared with all others in a group.

(iv) Legibility which may be either pure legibility or glance legibility depending upon the conditions. Pure legibility is the distance at which the sign can be read in unlimited time. Glance legibility is the distance at which sign can be read under normal traffic conditions and speed. Both are dependent upon the letter size, shapes, level of illumination, etc. and familiarity of the motorist with the particular design.

IRC Recommendations for the design of traffic signs:

(i) Use large signs on high -speed roads.

(ii) Wider spacing between letters, with optically equal spacing, depending upon the type of adjacent strokes, increases the legibility.

(iii) Use a maximum of three words.

(iv) Reflectize of illuminate the signs to be read at night.

(v) Location of the signs will depend on the speed of vehicles and the size of letters on the sign.

(vi) Keep uniformity in (a) design i.e., shape, colour (b) size of sign (c) symbols (d) word messages (e) illumination (f) lettering

(vii) Distraction or advertisement signs and other unnecessary signs should be eliminated whenever possible.

(viii) It is recommended that two signs for different purposes should not be placed on the same sign post but should be separated by at least 30 m if possible.

(ix) Location of the signs with respect to the carriageway.

TRAFFIC SIGNALS

A traffic signal is defined as any power operated traffic control device or a sign by which traffic is warned or directed to take some specific action. Traffic signals are control devices which could alternately direct the traffic to stop and proceed at intersections using red and green traffic light signals automatically. The main requirements of traffic signals are to draw attention, provide meaning and time to respond and to have minimum waste of time.

Advantages of traffic signals:

Properly designed traffic signals have the following uses:

- They provide orderly movement of traffic and increase the traffic handling capacity of most of the intersections at grade.
- They reduce certain types of accidents, notably the right -angled collisions.
- Pedestrians can cross the roads safely at the signalized intersection.
- The signals allow crossing of the heavy traffic flow with safely.
- Signals provide a chance to crossing traffic of minor road to cross the path of continuous flow of traffic stream at reasonable intervals of time.
- Automatic traffic signal may work out to be economical when compared to manual control.

Disadvantages of traffic signals:

- The rear end collisions may increase.
- Improper design and location of signals may lead to violations of the control system.

- Failure of the signal due to electric power failure or any other defect may cause confusion to the road users.

Type of traffic signals:

The signals are classified into the following types:

1. Traffic control signals:

Traffic control signals have three coloured light glows facing each direction of traffic flow. The RED light is meant for STOP, the GREEN light is meant for GO and the AMBER or YELLOW light allows the CLEARABCE TIME for the vehicles which enter the intersection area by the end of green time, to clear off. Traffic control signs are of three types:

a. Fixed –time signal
b. Manually operated signal
c. Traffic actuated (Automatic) signal

FIXED –TIME SIGNALS or pre-timed signals are set to repeat regularly a cycle of red, amber and green lights. The timing of each phase of the cycle is predetermined based on the traffic studies and they are the simplest types of automatic traffic signals which are electrically operated. The main drawback of the signal is that sometimes the traffic flow on one road may be almost nil and traffic on the cross road may be quite heavy.

TRAFFIC ACTUATED SIGNALS are those in which the timings of the phase and cycle are changed according to traffic demand.

1. **Vehicle actuated signal**

   In fully actuated traffic signals the detectors and a computer assigns the right of way for traffic movements on the basis of demand and pre-determined programming. But these are very costly to be installed at all intersections

2. **Semi-vehicle actuated signal**

In semi actuated traffic signals the normal green phase of an approach may be extended up to a certain period of time for allowing a few more vehicles approaching closely, to clear off the intersection with the help of detectors installed at the approaches.

MANUALLY OPERATED SIGNAL:

This type of signal operated manually. Normally traffic police can operate this type signal

Pedestrian signal

Pedestrian signals are meant to give the right of way to pedestrians to cross a road during the "walk period" when the vehicular traffic shall be stopped by red or stop signal on the traffic signal of the road.

2. Pedestrian signal: It is used to give the right of way to pedestrians to cross a road when the vehicular traffic shall be stopped by stop signal.

3. Special traffic signal: Special traffic signal such as “FLASHING BEACONS” are meant to warn the traffic. When signal is flashing red then the vehicles shall stop before entering the nearest crosswalk at an intersection.

While flashing yellow signals are caution signals meant to signify that drivers may proceed with caution.

TRAFFIC SIGNAL CO-ORDINATION

When there are series of signals on a city road at each intersection with crossroad, the signal system may be operated with only one controller. But it is desirable that a vehicle moving along a main road at normal speed should not have to stop at a very signalized intersection till getting the Go signal. Hence there should be proper co-ordination of the signal system to provide a through band.

Need for co-ordinated control

i. To pass maximum amount of traffic without enforced halts.
ii. To have minimum overall delay to traffic streams, both in main and side roads.
iii. To prevent the queue of vehicles at one intersection from extending and reaching the next intersection.

Types of traffic signal system:

There are four general types of co-ordination of signals for road network, as listed below

- Simultaneous system
- Alternate system
- Simple progressive system, and
- Flexible progressive system

SIMULTANEOUS SYSTEM:

In this system all the signals along a given road always show the same indication (green, red etc.) at the same time. As the division of cycle is also the same at all intersections, this system does not work satisfactorily.

The disadvantages of a simultaneous systems are:

i. The overall speed often reduced
ii. It encourages speeding of drivers between stops.
iii. It is not conductive to give continuous movements of all vehicles.

ALTERNATE SYSTEM:

In this system, alternate signals or groups of signals show opposite indications in a route at the same time. This system is also operated by a single controller, but by reversing the red and green indicator connections at successive signal systems. This system generally is considered to be more satisfactory than the simultaneous system.

The disadvantages of this system are:

i. The green time for the main and side streets have to be substantially equal, resulting inefficiency at most of the intersections.
ii. Adjustments are difficult for changing traffic conditions.

SIMPLE PROGRESSIVE SYSTEM:

A time schedule is made to permit, as nearly as possible, a continuous operation of groups of vehicles along the main at a reasonable speed. The signal phases controlling "GO" indications along this road is scheduled to work at the predetermined time schedule. The phases and intervals at each signal installation may be different; but signal unit works as fixed time signal, with equal signal cycle length.

FLEXIBLE PROGRESSIVE SYSTEM

This system is an improvement over the simple progressive system with the following provisions:

i. It is possible to introduce flashing or shut down during off-peak hours.
ii. It is possible to vary the cycle time and division at each signal depending upon the traffic.

Elements used in the design of traffic signals:

(i) Cycle Length (Co): It indicates the time interval between starting of signal such as green to the next time green starts.

(ii) Interval: It indicates the change from one stage to another. There are two types of interval:

(a) Change interval: It is also called yellow time and it indicates the interval between green and red signal.

(b) Clearance interval: It is also known as all red time and is included after each yellow interval indicating a period during which all signal phases shows red and it is used for clearing of vehicles at the intersections.

Total cycle length = Green interval + Red interval + Change interval

NOTE: Green interval is the actual duration for which green light of traffic is turned on.

(iii) Phase: A phase is taken as the sum of green interval and clearance interval. During green interval, non- conflicting movement are assigned into each phase. It allows a set of movement to flow and safely halt the flow before phase of another set of movement starts.

Two phases of 2 phase system are shown in Figure:

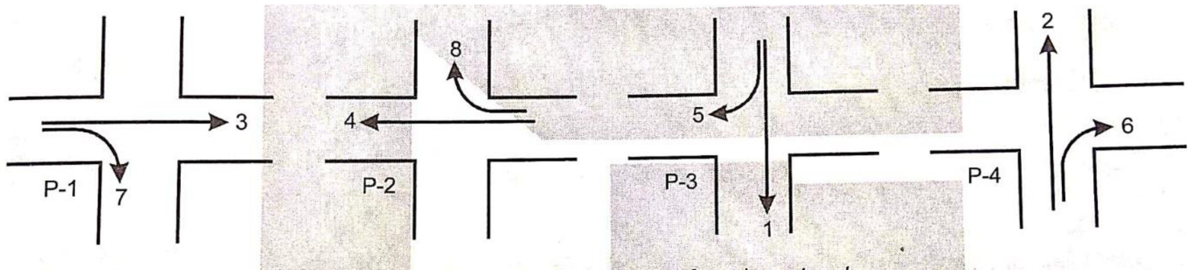
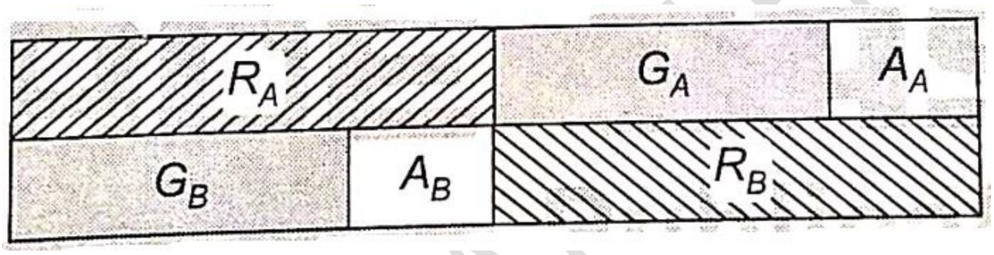


Figure-4.12 : One way of providing four phase signals

Representation of intervals for 2-phases system is shown below:



NOTE: When straight moving traffic and turning traffic are comparable then 4-phase signal is adopted.

(iv) Lost time: It represents the time during which the intersection is not effectively utilized for any movement.

Example: When the signal for an approach turns red to queue will take some time to perceive the signal and same time is lost before they moves. Let, there is a group of 'N' vehicles at an intersection. The 1st headway is the time interval between the initiation of the green signal and the instant vehicle crossing the kerb line.

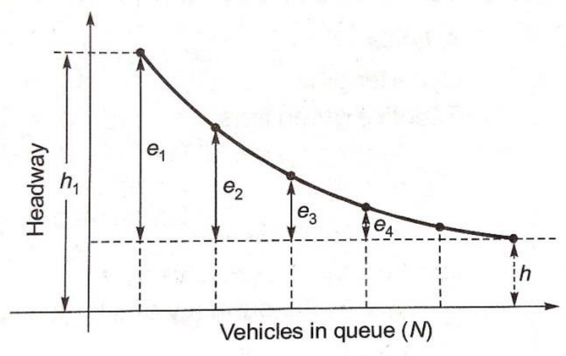


Figure-4.13 : Headways of vehicles at intersection

e_i = Difference between actual and saturation headway for i^{th} vehicle.

h_i = Actual time headway of i^{th} vehicle

h = Saturation headway

2^{nd} headway will be comparatively lower, because the second vehicle crossing the kerb line. The 1^{st} headway is relatively longer since it includes the reaction time of the driver and the time necessary to accelerate.

Total time lost in a cycle length is given as

Lost time (l) = $\sum_{i=1}^{n} ei$

Green time = l + Nh

Where, N is the number of vehicles

Total time lost in a cycle length is the sum of time lost in starting delay for single phase and clearance time lost for single phase.

(v) effective Green Time (g_i): Effective green time is the actual time available for vehicle to cross the intersection.

$g_i = G_i + A_i – t_L$

where, G_i = Actual green time

A_i = Amber time

t_L = Lost time

(v) Lane Capacity: If every vehicle requires 'h' seconds time headway to cross the kerb line and assume the signal is always green then saturation capacity is given as

Saturation capacity, S = (3600/h)veh/hr/lane

And traffic capacity of a lane = S x g_i/C_0 veh/hr

Where, g_i/C_0 = green ratio

C_0 = Cycle length

g_i = Effective green time

NOTE: When $g_i = C_0$, green ratio will become equal to 1 and traffic capacity of lane will be maximum.

Design Principle of Signals

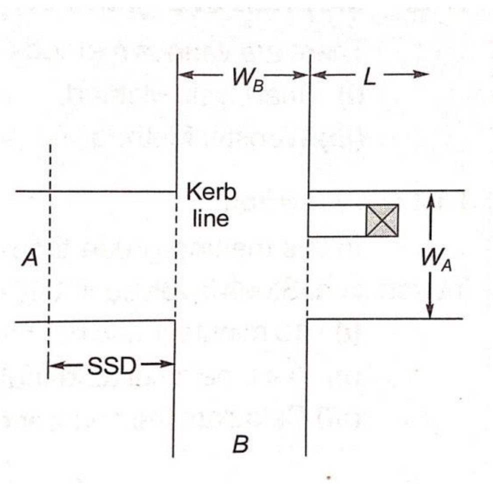
Suppose we have to design a 2 phase signal without any turning movements.

Red time of road A can be written as $R_A = G_B + A_B$

Similarly for road B, $R_B = G_A + A_A$

Where, G_A/G_B = Green time of road A/B

Green time is calculated on the basis of number of vehicles at any road.



Amber time of a road is taken as the maximum calculated on the basis of different cases given below:

(i) When vehicles are within SSD from intersection

$$Amber\ time = \frac{SSD + Width\ of\ another\ road + Length\ of\ vehicle}{Speed\ of\ vehicle}$$

(ii) When vehicles are beyond SSD from intersection

Amber time of road = Reaction time + Braking time = t_R + u/a

Where, u = Speed of vehicle and a Retardation

Road Sign:

The essential purpose of road markings is to guide and control traffic on a highway. They supplement the function of traffic signs. The markings serve as a psychological barrier and signify the delineation of traffic path and its lateral clearance from traffic hazards for the safe movement of traffic. Hence, they are very important to ensure the safe, smooth and harmonious flow of traffic.

Classification of road markings

The road markings are defined as lines, patterns, words or other devices, except signs, set into applied or attached to the carriageway or kerbs or to objects within or adjacent to the carriageway, for controlling, warning, guiding and informing the users. The road markings are classified as

- Longitudinal markings
- Transverse markings
- Object markings
- Word messages
- Marking for parking
- Marking at hazardous locations

Longitudinal markings

Longitudinal markings are placed along the direction of traffic on the roadway surface, for the purpose of indicating to the driver, his proper position on the roadway.

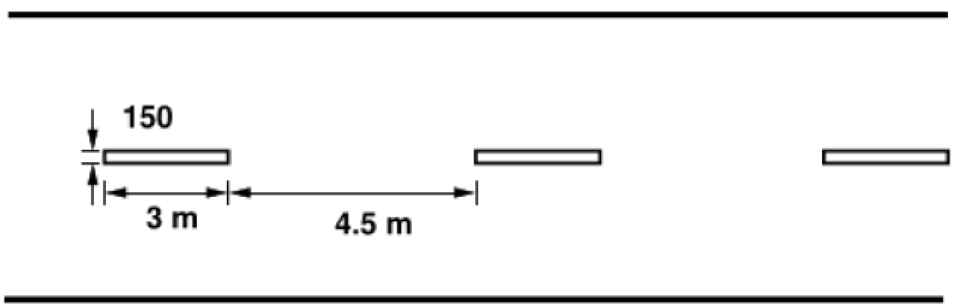


Figure Centre line marking for a two lane road

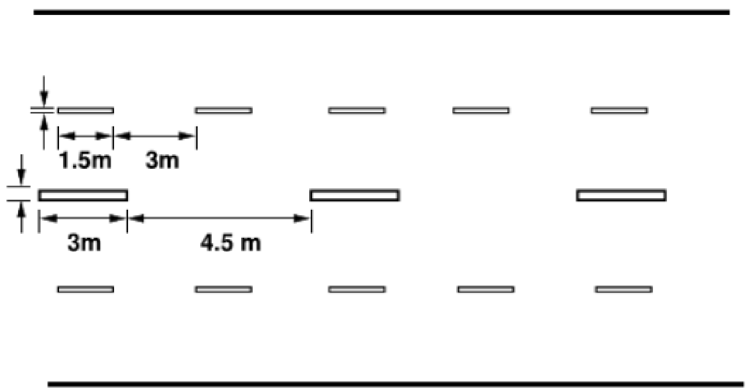


Figure Centre line and lane marking for a four lane road

Centre line

Centre line separates the opposing streams of traffic and facilitates their movements. Usually no centre line is provided for roads having width less than 5 m and for roads having more than four lanes. The centre line may be marked with either single broken line, single solid line, double broken line, or double solid line depending upon the road and traffic requirements.

Traffic lane lines

The subdivision of wide carriageways into separate lanes on either side of the carriage way helps the driver to go straight and also curbs the meandering tendency of the driver.

No passing zones

No passing zones are established on summit curves, horizontal curves, and on two lane and three lane highways where overtaking maneuvers are prohibited because of low sight distance. It may be marked by a solid yellow line along the centre or a double yellow line.

Traffic Signal Design

The conflicts arising from movements of traffic in different directions is solved by time sharing of the principle. The advantages of traffic signal includes an orderly movement of traffic, an increased capacity of the intersection and requires only simple geometric design. However, the disadvantages of the signalized intersection are it affects larger stopped delays, and the design requires complex considerations.

Definitions and notations

- Cycle
- Cycle length
- Interval
- Green interval
- Red interval
- Phase
- Lost time

Phase design

The signal design procedure involves six major steps.

They include the

1. phase design
2. determination of amber time and clearance time
3. determination of cycle length
4. apportioning of green time
5. pedestrian crossing requirements,
6. the performance evaluation

Two phase signals

Two phase system is usually adopted if through traffic is significant compared to the turning movements.

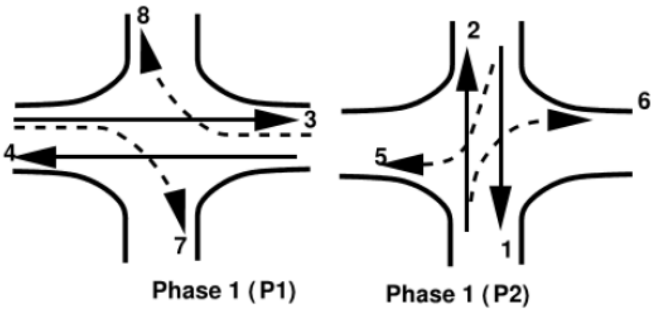


Figure Two phase signal

Four phase signals

There are at least three possible phasing options.

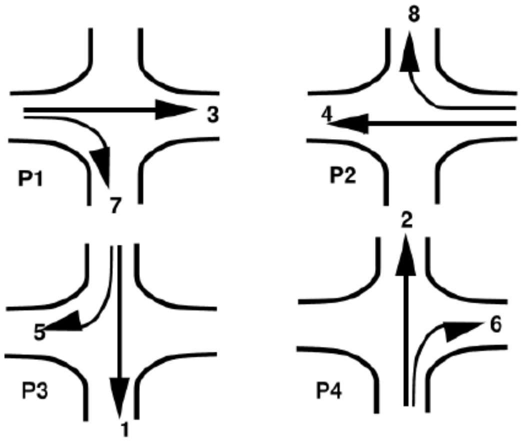


Figure One way of providing four phase signals

Cycle time

Cycle time is the time taken by a signal to complete one full cycle of iterations. i.e. one complete rotation through all signal indications. It is denoted by C.

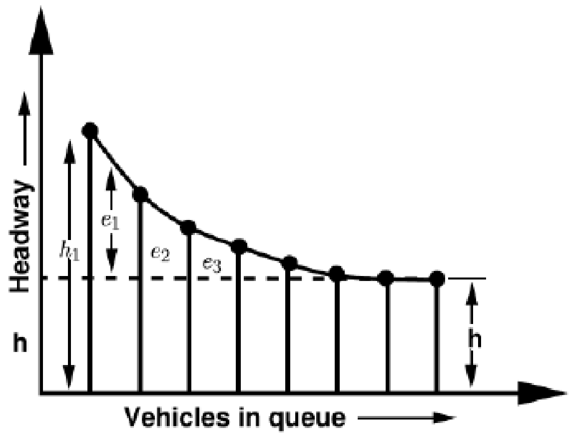


Figure Headways departing signal

GEOMETRIC DESIGN OF INTERSECTIONS

Intersection:

Intersection is the area where two or more roads meet. At intersection there are through, turning and crossing traffic and their movements may be controlled in different ways depending on the type of intersection and its design. Its main function is to guide vehicles to their respective directions.

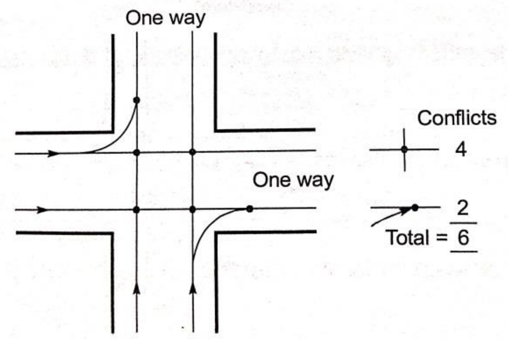


Figure-4.15 : *Vehicular conflicts with one-way regulation on both roads*

Due to movement of traffic at intersection various types of conflicts occur like crossing, merging and diverging conflict. Generally, merging from right and diverging to right creates conflict. Consider a typical four legged intersection as shown below.

Conflict points for crossing movements are 4, for diverging movement are 4, for merging movement are 4 and for weaving movements are 12. Hence, there are total 24 types of vehicular conflict points.

In a typical four legged intersection there are 8 pedestrian conflict points also. Hence total 32 different types of conflict points are formed in a four legged intersection.

Table-4.3 : Conflicts points

Number of lanes		Number of potential conflicts		
Road A	Road B	Both roads Two way	A-One way B-Two way	Both roads One way
2	2	24	11	6
2	3	24	11	8
2	4	32	17	10
3	3	24	13	11
4	4	44	25	18

Crossing conflicts are the major conflicts and merging and diverging conflicts are minor conflicts. To reduce the conflicts at intersection we have to control it effectively various types of intersection controls are discussed below.

(i) Passive control: It is used when volume of traffic is less and road sign and road marking are used to control the traffic on minor road to slow down and allow that an major road to proceed. In this control system road users are required to follow traffic rules.

(ii) Semi control: This control system guides the driver gently to avoid conflict. Channelization and rotary are two example of this.

(iii) Active control: In this the road users are forced to follow the path suggested by traffic control agencies. Traffic signals and grade separated intersection come under this classification.

Types of Intersection

(i) Intersection at grade: All road intersections which meet at the same level allowing traffic movements like merging, diverging, crossing and weaving are called intersection at grade. These intersection are further classified as unchannelized, channelized and rotary intersections.

Basic requirements of intersection at grade are:

(a) At the intersection the area of conflict should be same as small as possible.

(b) The relative speed and particularly the angle of approach of vehicle should be small.

(c) Adequate visibility should be available for vehicles approaching the intersection.

(d) Sudden change of path should be avoided.

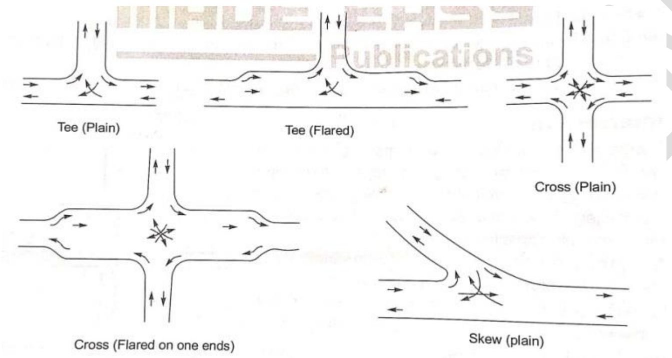


Figure-4.16 : *Unchannelized intersection*

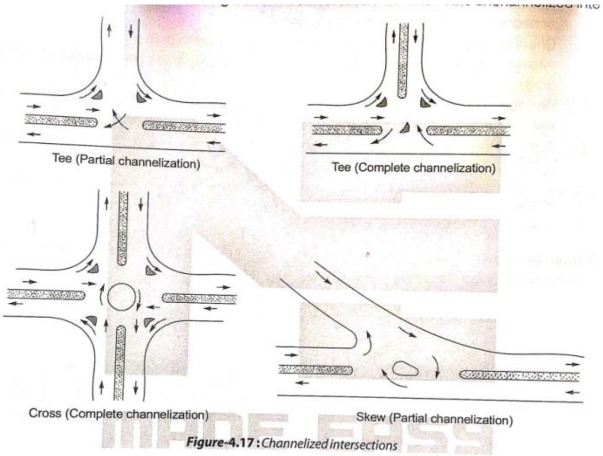
CHANNELIZATION:

The direction of traffic flow at intersections to definite path, by means of traffic markings, islands or other means is known as channelization.

Unchannelized intersection: In this type of intersection area is paved and there is absolutely no restriction to vehicles to use any part of intersection area. When no additional pavement width for turning movement is provided, it is called plain intersection. When the pavement is widened at the intersection area, by a traffic lane or more, it is known as flared intersection.

The conflict area is quite large as path of turning vehicles are not restricted or controlled then one of the crossing vehicle will have to stop while the other proceeds.

Channelized intersection: A channelized intersection is one which traffic is directed into definite paths by islands and markings. Channelized intersection is achieved by introducing islands into the intersection area, thus reducing the total conflict area available in the unchannelized intersection.

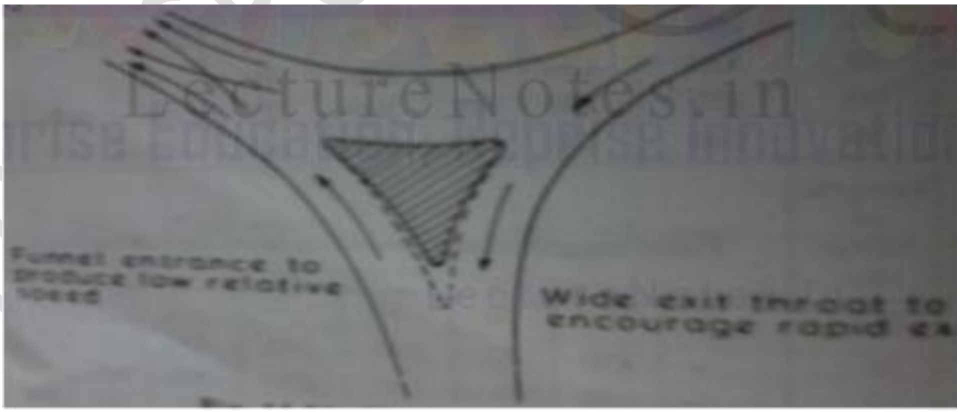


It is very useful as traffic control devices for intersection at grade and when the direction of the flow is to be changed.

Rotary Intersection: It is an enlarged road intersection where all converging vehicles are forced to move round a large central island in clockwise direction before they can weave out of traffic flow into their respective directions.

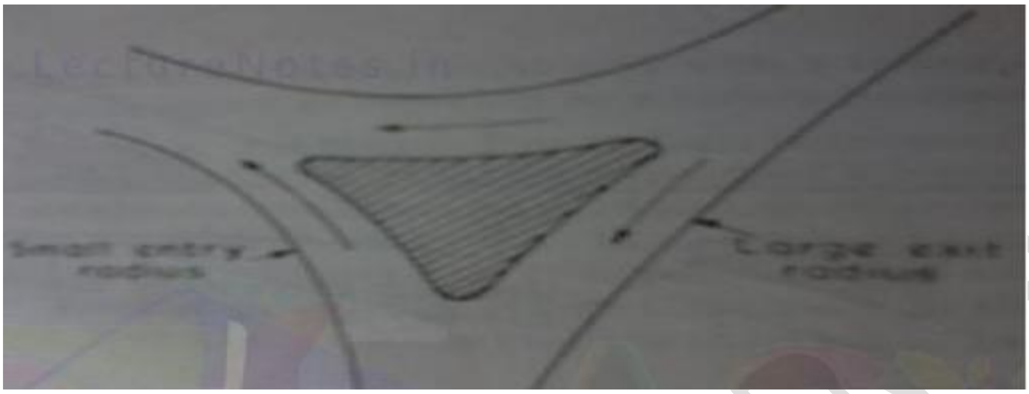
An unchannelised intersection, on the other hand, is one without islands for directing traffic into definite paths. An unchannelised intersection is the most dangerous and inefficient.

1. Seperation of conflicts:
   To diminish the number of possible vehicle conflicts, to reduce the possible area of conflicts in the carriage way and to present drivers with only one decision at a time.

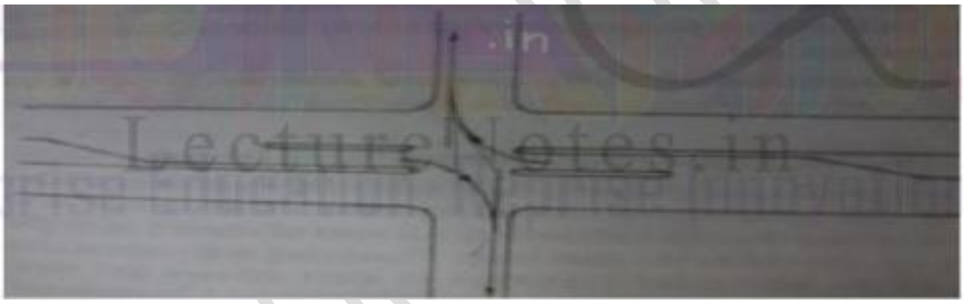


2. **Control of angle of conflicts:**
   Small angles of crossing cause severe accidents if they occur. Severity is reduced if the angle of conflict is controlled.
3. **Control of speed:**

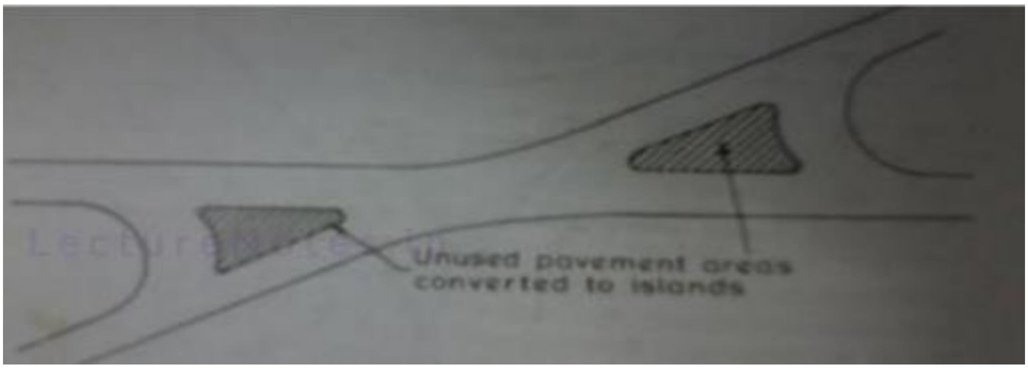
To reduce the speed of traffic entering the intersection and increase the speed of traffic leaving the intersection, bending or funneling by suitable channelization techniques is resorted to, vide figs.



4. **Protection of traffic for leaving/crossing the main traffic stream**
   This is exemplified by the separate storage pockets for right turning traffic at an intersection and the adjacent island, vide fig.



5. **Protection of pedestrians:**
   To provide a haven or refuge for pedestrians b/w traffic flows. A channelizing island such as in fig serves as a refuge and makes the crossing much safer.
6. **Elimination of excessive intersectional areas:**
   Intersections with large corner radii & those at oblique angles have large paved areas, which permit & encourage hazardous uncontrolled vehicle movements. If these unused paved areas are converted into channelizing islands, orderly movement results and hazards are reduced vide fig.



7. **Blockage of prohibited movements:**

   To support regulations by making improper movements or encroachments impossible or inconvenient.

8. **Location of traffic control devices:**

   To provide space for traffic control devices such as direction indicators, reflectors, signs, etc.

(ii) Grade separated intersection: Grade separation structures that permit the cross flow of traffic at different levels without interruptions.

Advantages of grade separation are:

(a) There is increased safely for turning traffic and by indirect interchange ramp even right turn movement is quite easy and safe.

(b) There is overall increase in comfort and convenience to the road users.

(c) Stage constructions of additional ramps are possible after the grade separation structure between main roads are constructed.

Disadvantages of grade separation are:

(a) It is very costly to provide complete grade separation and interchange facilities.

(b) Construction of grade separation is difficult and undesirable in the area where there is limited right of way.

(c) In flat or plain terrain, grade separation may introduce undesirable sags in the vertical alignment.

(iii) Traffic Islands: Traffic Islands are constructed within the roadway to establish physical channels through which the vehicular traffic may be guided. Classification of traffic islands on the basis of there function are:

(a) Divisional Islands: Pedestrian loading islands are provided as regular bus stops and similar places for the protection of passengers. A pedestrian islands at or near a cross walk to aid and protect pedestrian crossing the carriageway.

(b) Channelizing Islands: Channelizing islands are used to guide the traffic into proper channel through the intersection area. These are very useful as traffic control devices for intersection at grade.

(c) Pedestrian Loading Islands: Divisional islands are supposed to separate opposing flow of traffic on a highway with four or more lanes. By thus head on collisions are eliminated.

(d) Rotary: Rotary island is the large central island of a rotary intersection. The crossing movement is converted to weaving by providing sufficient weaving length.

NOTE: The area adjacent to the kerb which is kept reserved for use by stopped bus may be called as bus kerb loading zone.

(iv) Interchange: An interchange is a grade separated intersection with the facilities of ramp for turning traffic between approaching highway.

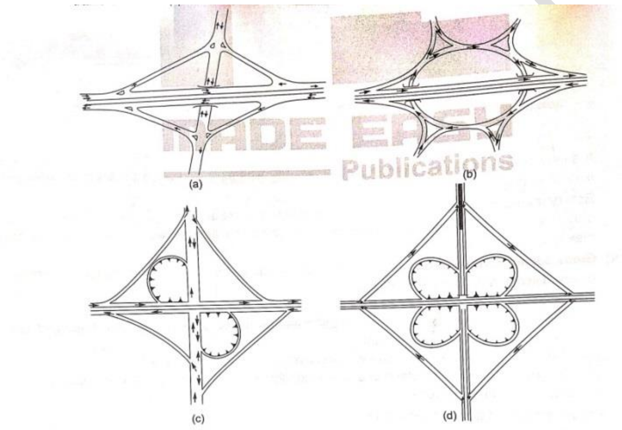


Figure-4.18 : Types of Interchanges (a) Diamond (b) Rotary interchanges (c) Partial clover leaf and (d) Full clover leaf

TRAFFIC ROTARIES:

Rotary Intersections are special form of intersection at grade laid out for the movement of traffic in one direction around a central traffic island. The vehicles entering the rotary are gently forced to move in a clockwise direction in orderly fashion. They then weave out of the rotary to the desired direction.

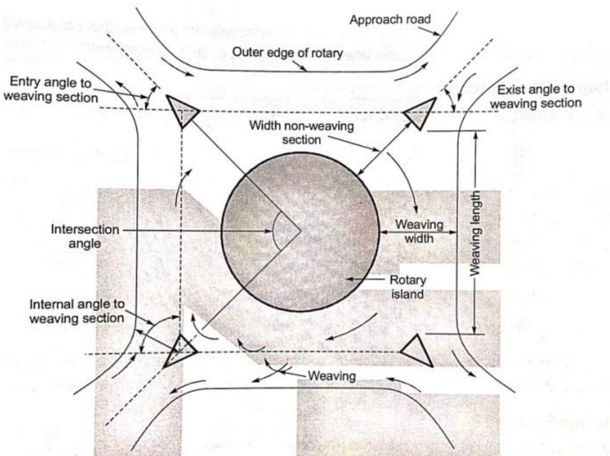
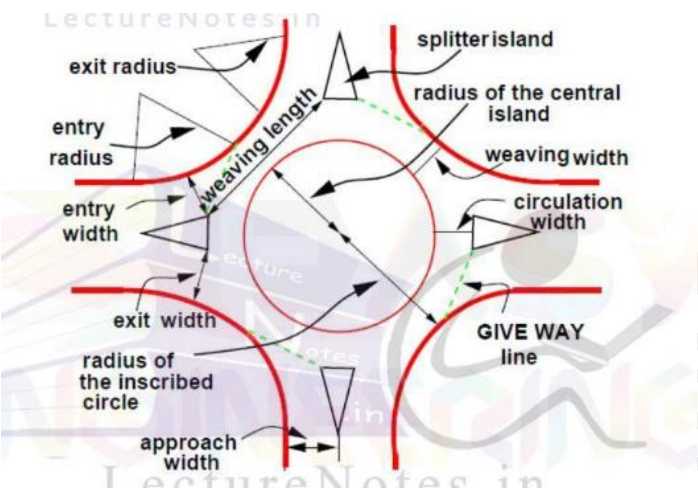


Figure-4.19 : Rotary elements

ROTARY INTERSECTION (ROUND ABOUT):

A rotary intersection is an enlarged road intersection where all converging vehicles are forced to move round a large central island in one direction (clockwise direction).



General Guidelines for the selection of rotaries are:

(i) Rotaries are suitable when the traffic entering from all the four approaches are relatively equal.

(ii) A total volume of about 3000 vehicles per hour can be considered as the upper limiting case and a volume of 500 vehicles per hour is lower limit.

(iii) A rotary is very beneficial when the proportion of the right turn traffic is very high, typically if it is more than 30 percent.

(iv) Rotaries are suitable when there are more than four approaches or if there is no separate lanes available for right turn traffic. Rotaries are ideally suited if the intersection geometry is complex.

ADVANTAGES OF ROTARY INTERSECTIONS

- The main objective of providing a rotary are eliminate the necessity of stopping even for cross streams of vehicles and to reduce the area of conflict.
- An orderly and regimented traffic flow is provided by rotary one way movement.
- Normally, all traffic proceeds simultaneously & continuously at fairly uniform, though low speed. Frequent stopping & starting are avoided.
- All turns can be made with ease, although little extra travel distance is required for all movements except left turns.
- A rotary is especially suited for intersections legs, and/or where there are right-turning movements.

- For moderate traffic, rotaries are self-governing & need no control by police or traffic signals.

DISADVANTAGES OF ROTARY INTERSECTIONS

- A rotary requires more land & may not be feasible in many built up locations.
- Where pedestrian traffic is large, a rotary by itself is not sufficient to control traffic & has to be supplemented by traffic police.
- When used on high speed roads, rotaries require extremely large size.
- Traffic turning right has to travel a little extra distance.
- A rotary requires many warning & directional signs for safety. The central island & entrances & exists must be well lighted at night. These tend to make it costly.

Guidelines for selecting a rotary Type of intersection

- A total volume of 3000 vehicles per hour entering from all the intersection legs appears to be maximum practical capacity of high type rotaries.
- A rotary design is most appropriate when the proportion of turning traffic is very high.
- A rotary is a good choice when there are more than four approaches to the junction.
- Rotaries are not generally warranted for intersections carrying very light traffic. Normally, the lowest traffic volume for which a rotary design should be considered is about 500 vehicles per hour.

Shape of Rotary Island:

There are many different shapes of rotary required on the basis of volume of traffic approaching.

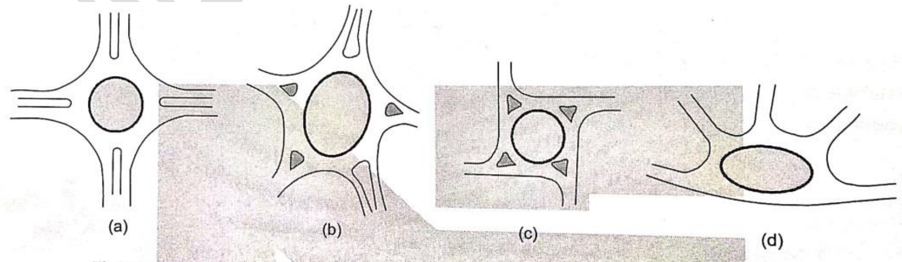


Figure-4.20 : *Shapes of rotary islands (a) Circular (b) Elliptical (c) Turbine and (d) Tangent*

Circular shape of rotary is preferred when traffic in both the roads are comparable and tangential shape of rotary is preferred when traffic in one direction is significant compared to traffic in other direction.

Design speed of Rotary:

At rotary all the vehicles are required to slow down their speed. So the design speed of rotary is generally, much lower than approaching roads. As per IRC the design speed for rural road is taken as 40 kmph and 30 kmph for the urban roads.

Radius of curve at entry: Radius at entry depends on various factors like design speed, super elevation, and coefficient of lateral friction. The entry to rotary is not straight but small curvature is introduced which force the driver to reduce the speed.

Rotary design speed (kmph)	Suggested values of radius at entry (m)
40	20 - 35
30	15 - 25

Radius of curve at exit: Exit radius should be higher than entry radius of rotary island so that vehicle discharge from the rotary at a higher rate

$R_{exit} = (1.5 – 2) R_{entry}$

Radius of central Traffic Island:

Theoretically the radius of central island should be equal be equal to the radius at entry but in practice it is normally kept slightly greater than radius at entry. Radius of central island is taken to be 1.33 times the radius at entry

$R_{C.I.} = 1.33 \times R_{entry}$

Width of weaving section (w):

Entry and exit width of the roadway is governed by the traffic entering and leaving the intersection and the width of approaching road. The width of carriageway at entry and exit will be lower than width of carriageway at the approaches to enable reduction of speed.

$W = (e_1+e_2)/2 + 3.5$

Where, e_1 = Entry width and e_2 = Exit width

Approach road width (m)	7.0	10.5	14
Entry width, e (m)	6.5	7.0	8.0

NOTE: Take width at exit as entry if nothing is given about the exit width.

Weaving Length (L):

Weaving length determines how smoothly the traffic can merge and diverge. Very large weaving length is also dangerous as it may encourage over speeding. Length of weaving section is kept at least 4 times the width of the weaving section.

To discourage over speeding in the weaving section s, the maximum weaving length should not exceed the above given values.

Design speed (kmph)	Minimum weaving length (m)
40	45
30	30

Entry and exit angles:

Entry angle should be larger than exit angle and desirable entry angle is 60^0. Exit angles should be small and 30^0 is desired exit angles.

Capacity of the Rotary:

Capacity of a rotary is determined by the capacity of each weaving section. Capacity of individual weaving sections depends upon

(i) Width of weaving section (w)

(ii) Average width of entry into rotary (e)

(iii) Weaving length (l)

(iv) Proportioning ratio (p)

Practical capacity of rotary in PCU per hour is given by

$$Q = \frac{280w\left(1+\frac{e}{w}\right)\left(1-\frac{p}{3}\right)}{1+\frac{w}{l}} \quad \text{...(i)}$$

Calculation for proportioning ratio (p),

$$p = \frac{\text{Crossing/ Weaving Traffic}}{\text{Total Traffic}}$$

$$p = \frac{b+c}{a+b+c+d}$$ (proportioning ratio always lies between 0.4 and 1)

Where,
- a = Left turning traffic moving along left extreme lane
- b = Crossing / Weaving traffic turning towards right while entering to the rotary
- c = Crossing / Weaving traffic turning towards left while leaving rotary
- d = Right turning traffic moving along right extreme lane

Conditions to apply the above formula of capacity of rotary are:

(*i*) 6 m $\leq$ width of weaving section (w) $\leq$ 18 m

(*ii*) $\frac{e}{w} = (0.4 - 1)$

(*iii*) $\frac{w}{L} = 0.12 - 0.4$

(*iv*) $p = (0.4 - 1)$

(*v*) $l = 18 - 90$ m

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