UNIT-3

TRAFFIC VOLUME STUDIES

Traffic volume is the number of vehicles in a specified direction on a given lane or road way that costs a given point or cross section during specified unit of time and this is used as a quantitative measure of flow and it is usually expressed in the units of vehicle per hour (or) vehicles per day.

OBJECTIVES OF TRAFFIC VOLUME COUNT

• Traffic volume is generally expressed as a true measure of the relative importance of roads and in deciding priority for improvement and expansion.

• Traffic volume study is used in planning traffic operation and control of existing facilities and also for planning and designing the new facilities.

• Traffic volume study is used in analysis of traffic patterns and trends.

• Classified volume study is used in useful in structural design of pavements in geometric design and in computing road way design.

• Volume distribution study is used in planning one-way streets and other regulatory measures.

• Pedestrian traffic volume study is used for planning side walk, cross walks subways and pedestrian signals.

• Turning movement study is used in the design of intersections, in planning signal timings, canalization and other control devices.

A true picture is to be obtained, the hourly traffic volume should be known along with the patterns of hourly, daily and seasonal variation. In classified traffic volume study, the traffic is classified and the volume of each class of traffic viz., buses, truck, passenger-cars, other light vehicles, rickshaws, Tonga's, bullock carts, cycles and pedestrians is found separately. The direction of each class of traffic flow is also noted. At intersections the traffic flow in each direction of flow including turning movements are recorded.

COUNTING OF TRAFFIC VOLUME

Traffic volume counts may be done by mechanical counters or manually.

MECHANICAL COUNTERS

These may be either fixed (permanent) type or portable type. The mechanical counter can automatically record the total number of vehicles crossing a section of the road in a desired period. Traffic count is recorded by electrically operated counters and recorder capable of recording the impulses. The impulses caused by vehicles of light weight may not be enough in some cases to actuate the counter. Also it is not possible to easily record pedestrian traffic by this method. Other methods of working the mechanical detectors are by photo-electric cells, magnetic detector and radar detectors. The main drawback of the mechanical counter is that it is not possible to get the traffic volumes of various classes of traffic in the stream and the details of turning movement.

MANUAL COUNTS

This method employs a field team to record traffic volume in the prescribed record sheets. By this method it is possible to obtain data which cannot be collected by mechanical counters, such as vehicle classification, turning movements and counts where the loading conditions or number of occupants are required. However it is not practicable to have manual count for all the 24 hours of the day and on all days round the year. Then by statistical analysis the peak hourly traffic volumes as well as the average daily traffic volumes are calculated. This method is very commonly adopted due to the specific advantages over other methods.

PRESENTATION OF TRAFFIC VOLUME DATA

The data collected during the traffic volume studies are sorted out and are presented in any of the following forms depending upon the requirements.

• Annual average daily traffic (AADT or ADT) of the total as well as classified traffic are calculated. This helps in deciding the relative importance of a route and in phasing the road development programme. In order to conversion factors known as passenger Car Units (PCU) are used.

• Trend charts showing volume trends over period of year are also prepared. These data are useful for planning future expansion, design and regulation.

• Variation charts showing hourly, daily and seasonal variations are also prepared. These helps in deciding the facilities and regulation needed in peak traffic periods.

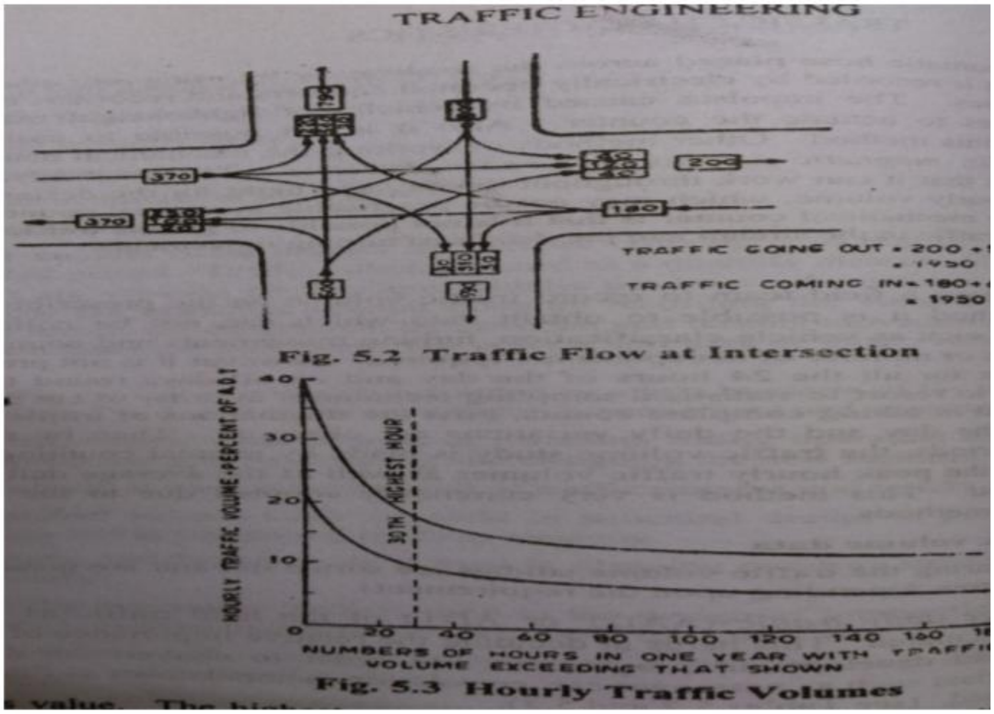


Fig. 5.2 Traffic Flow at Intersection

Fig. 5.3 Hourly Traffic Volumes

SPEED STUDIES

The actual speed of vehicle over a particular route may fluctuate widely depending on several factors such as geometric features, traffic conditions, time, place; environment and driver.

Travel time is the reciprocal of speed and is a simple measure of how all well a road network is operating.

Spot speed is the instantaneous speed of a vehicle at a specified section or location. Average speed is the average of a series of spot speed measurements via; space-mean speed and time-mean speed. Space-mean speed represents the average speed of vehicles in a certain road. Space-mean speed is calculated from:

$$Vs = \frac{3.6dn}{\sum_{i=1}^{n} tl}$$

Where Vs = space-mean speed, kmph

d = Length of road, considered, m

n = Number of individual vehicle observations

tl = Observed travel time (sec) for it vehicle to travel distance d, m

The average travel time of all the vehicles is obtained of vehicles at a point on the roadway and it is the average of instantaneous speeds of observed vehicles at the spot. Time-mean speed is calculated from:

$$Vt = \frac{\sum_{i=1}^{n} Vi}{n}$$

Where Vt = time-mean speed, kmph

Vi = Observed instantaneous speed of it vehicles, Kmph

n = Number of vehicles observed

The space-mean speed is slightly lower than time-mean speed under typical speed conditions on rural highways.

Running speed is the average maintained by a vehicle traverses a particular stretch of road, while the vehicle is in motion; this is obtained by dividing the distance covered by the time during which the vehicle is actually in motion.

Overall speed or travel speed is the effective speed with which a vehicle traverses a particular route between two terminals; this is obtained by dividing the total distance travelled by the total time taken including all delays and stoppages reroute.

Speed studies carried out occasionally give the general trend in speeds. There are two types of speed studies carried out,

• Spot speed study

• Speed and delay study

SPOT SPEED STUDY

Spot speed study may be useful in any of the following aspects of traffic engineering:

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

• To use in geometric design-for redesigning highways or for deciding design speed for new facilities.

• To use in accident studies.

• To study the traffic capacity.

• To decide the speed trends.

• To compare diverse types of drivers and vehicles under specified conditions.

The spot speeds are affected by physical features of the road like pavement width, curve, sight distance, gradient, pavement unevenness intersections and road side developments. Other factors affecting spot speeds are environmental conditions (like weather, visibility), enforcement, traffic conditions, driver, vehicle and motive of travel. There are a number of methods to measure spot speed.

One of the simplest methods of finding spot speed is by using enoscope which is just a mirror box supported on a tripod stand. In its simplest principle, the observer is stationed on one side of the road and starts a stopwatch when a vehicle crosses that section. An enoscope is placed at a convenient distance of say 30 m in such a way that the image of the vehicle is seen by the observer when the vehicle crosses the section where the enoscope is fixed and at this instant the stop watch is stopped. Thus the time required for the vehicle to cross the know length is found and is converted to the speed in kmph. The main advantage of this method is that it is simple and cheap equipment and is easy to use. The greatest disadvantage is that the progress is as slow as it is difficult to spot out typical vehicles and the number of samples observed will be less. There is also a possibility of human error.

Other equipment used for spot speed measurements are graphic recorder, electronic metre, photo electric meter, radar, speed meter and by photographic methods. Of all these methods, the radar speed meter method seems to be the most efficient one as it is capable of measuring the spot speeds instantaneously and also record them automatically. But this equipment is costly.

PRESENTATION OF SPOT SPEED DATA

• **Average speed of vehicles:** From the spot speed data of the selected samples, frequency distribution table are prepared by arranging the data in group covering various speed ranges and the number of vehicles in such range. The arithmetic mean is taken as the average speed. The table gives the general information of the speeds maintained on the section, and also regarding the speed distribution pattern.

• **Cumulative speed of vehicles:** A graph is plotted with the average values of each speed group on the X-axis and the cumulative per cent of vehicles travelled at or below the different speeds on the Y-axis. From this graph, the 85th percentile speed is found out which gives that speed at or below 85 per cent of the vehicle are passing the point on the highway or only 15 per cent of the vehicles exceed the speed at that spot. The drivers exceeding 85th percentile speeds are usually considered to drive faster than the safe speed under existing condition and hence this speed is adopted for the safe speed limit at this zone. However for the purpose of highway geometric design, the 98th percentile speed is taken.

The 15th percentile speed represents the lower speed limit of it is desired to prohibit slow moving vehicles to decrease delay and congestion, as 85 per cent of the vehicles to the stream travel at speeds higher than this value and therefore need overtaking opportunities.

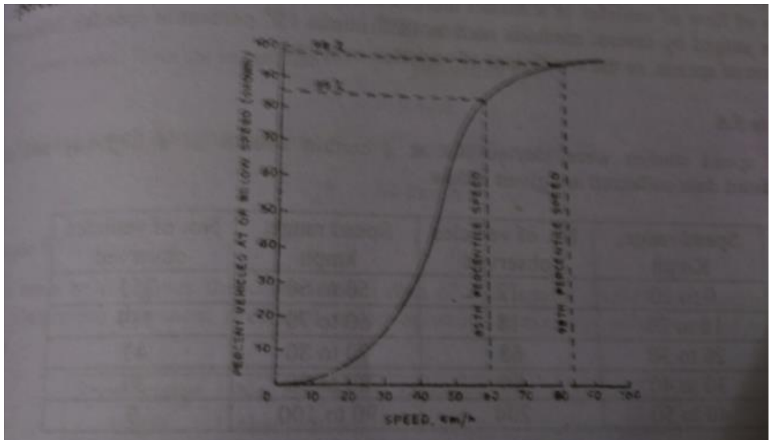


Fig. 5.5 Cumulative Speed Distribution

• **Modal average:** a frequency distribution curve of spot speeds is plotted with speed of vehicles or average values of each speed group of vehicles on the X-axis and the percentage of vehicles in that group on the Y-axis. This graph is called the speed distribution curve. This curve will have a definite peak value of travel speed across the section and this speed is denoted as model speed. The speed distribution curve is helpful in determining the speed at which the greatest proportions of vehicles move, given by the model speed.

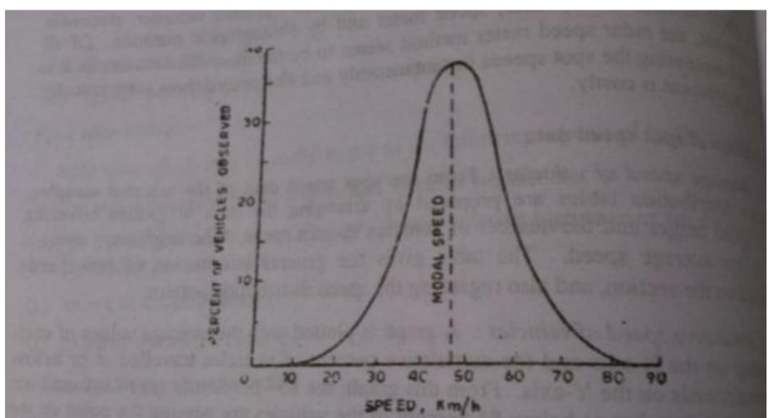


Fig. 5.6 Frequency Distribution Curve of the Spot Speeds

- All vehicles do not travel at the same speed at a location along a road. The amount of speed dispersion or the spread from the average speed affects both capacity and safety. For free flow of vehicles, the speed distribution follows a normal distribution curve. The quality of flow of vehicles in a stream therefore depends on the speed dispersion. This may be judged by several methods such as (85th minus 15th percentile speeds); Standard deviation of speeds, or the coefficient of variation in speed.

SPEED AND DELAY STUDY

The speed and delay studies give the running speeds, overall speeds, fluctuations in speeds and the delay between two stations of a road spaced far apart. They also give the information such as the amount, location, duration frequency and cause of the delay in the traffic stream. The results of the speed and delay studies are useful in detecting the spots of congestion, the causes and in arriving at a suitable remedial measure. The studies are also utilised in finding the travel time and in benefit-cost analysis. In general the efficiency of the roadway be judged from the travel time.

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

• Floating car or riding check method

• License plate or vehicle number method

• Interview technique • Elevation observation

• Photographic technique

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 study stretch and a group of observers record the various details. One observer seated in a floating car with two stop watches. One of the stop watches used to record the time at various control points like intersections, bridges or any other fixed points in each trip. The other stop watch is used to find the duration of individual delays. The time, location and cause of these delays are recorded by the second observer either on suitable tabular forms or by voice recording equipment. The no of vehicles over taking the test vehicle and that overtaken by the test vehicles are noted in each trip by a third observer. The number of vehicles travelling in opposite direction in each trip is noted by fourth observer. However in mixed traffic flow, more no if observers will be required to count the vehicles of different classes. 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 $\bar{t}$ (min) for all the vehicles in a traffic stream in the direction of flow is given by

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

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

Where

q = Flow of vehicles (volume per min) in one direction of the stream

n_a = Average no of vehicles counted in direction of stream and the test vehicle travelling in opposite direction

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

t_w =Average journey time, in minute when test vehicle is travelling with stream q.

t_a =Average journey time, in minute when test vehicle is running against stream q.

In the licence plate or vehicle number method, synchronized stop watches or voice recording equipment are used. Observers are stationed at the entrance and exit of a test section where information of travel time is required. The timing and vehicle numbers are noted by observers of the selected sample. From the office computations travel time if each vehicle could be found. But the method does not give important details such as causes of delays and duration and no of delays within the test section.

In the interview technique, the work can be completed in short time by interviewing and collecting details from the road users on the spot. However the data collected may not provide with all the details correctly.

Elevated observation and photographic technique are useful for studying short test sections like intersections etc.

Intersection delays studies need special attention as this poses a major problem to the traffic engineer. Such studies at each intersection will help in evaluating the efficiency and effectiveness of the controlled device like signal system, the remedial measures for accidents etc.

CONCEPT OF PCU (passenger car unit):

“PCU value is defined as the capacity of the roadway when there are passenger cars only to the capacity of the same roadway when there are vehicles of that class only”.

In a road way there will be different types of vehicle like buses, cars, carts, scooters etc. there will be different traffic characteristics for different vehicles and different drivers behaves in a different way.

Hence it is very difficult to compute the traffic capacity and volume in a mixed traffic condition but we can easily compute in homogeneous traffic condition. In order to achieve this the different types of vehicles are converted into a standard passenger car and the unit is passenger car unit ie., PCU.

With the help of PCU we can easily calculate the traffic capacity and volume.

For different types of vehicles there will be different PCU's. The following factors influence the value of PCU:

• Vehicle characteristics like speed, acceleration, dimensions of the vehicle.

• Transverse and longitudinal gaps or clearances between the vehicles which are moving on the road and driver characteristics.

• Traffic stream characteristics like the speed distribution of mixed traffic and volume to capacity ratio.

• Roadway characteristics like geometrics such as curves, intersections, gradients etc.

• Regulation characteristics like speed limits, one way traffic and traffic control devices.

• Climatic and environmental characteristics.

The value of PCU for different types of vehicles depends on:

i) The speed of vehicle
ii) Length and width of vehicle
iii) Transverse and longitudinal clearance between the vehicles which are moving on the road.

HIGHWAY CAPACITY

CAPACITY:

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

BASIC CAPACITY:

The maximum number of passenger cars that can pass a point on a lane or a roadway during one hour under the most nearly ideal roadway and traffic conditions which can possibly be attained.

POSSIBLE CAPACITY:

The maximum number of vehicles that can pass a given point on a lane or a roadway during one hour under prevailing roadway (or) traffic conditions is called possible capacity.

PRACTICAL CAPACITY:

The maximum number of vehicles that can pass a given point on a lane or roadway during one hour without traffic density being so great as to cause unreasonable delay, hazard or restriction to the drivers freedom.

IMPORTANCE OF CAPACITY:

The design of a highway facility is possible only where capacity is related to the projected requirements of traffic. The design features governed by capacity are the highway type, number of lanes, width of lanes, intersections and weaving sections. By comparing the present traffic volume with the capacity of existing highway networks, their adequacy or deficiency can be assessed.

Improvement and changes in the geometric features, junction features, traffic control devices and traffic management measures can be planned effectively if capacity studies are considered.

Theoretical formula to determine capacity is given by the formula:

$$C=1000V/S$$

$$S=L+0.278Vt+ (V2/254f)$$

Where,

C=capacity in vehicles per hour per lane

V=speed in K.P.H

S=average spacing in meters of moving vehicles

L=length of vehicles in meters

t=perception reaction time in seconds

f=friction factor

g=acceleration due to gravity in m/sec2

FACTORS AFECTING CAPACITY:

Some of the important factors the affects the capacities of traffic lane are listed below:

1. Lane width: as the lane width decreases the capacity also decreases. The practical capacity of 3m wide lane in two lane lane rural road may decreases to 76% of the capacity of a 3.5m lane.

2. Lateral clearance: vertical obstructions such as retaining walls or parked vehicles near the traffic lane reduce the effective width of lane and thus result in reduction in capacity of lane. Further, restricted lateral

clearance effects driving comfort and increases rates. A minimum clearance of 1.85m from the pavement edge to the obstruction is considered desirable so that capacity is not affected adversely. When the distance from pavement edge to an obstruction decreases to 0.75m on one side only, the capacity decreases to 96% and when this obstruction is on both sides, the percentage further decreases to 80% of the standard design capacity.

3. Width of Shoulders: Narrow shoulders reduce the effective width of traffic lanes as the vehicle travel towards the centre of the pavement. When vehicle in emergency (like that of a tyre puncture or other breakdown) has to park on the shoulder of insufficient width, there is reduction in effective lane width resulting in a great reduction in capacity of the lane.

4. Commercial Vehicles: Large commercial vehicles like truck and buses occupy greater space and influence the other traffic in the same lane as well as the vehicle along the adjoining lanes. Also these commercial vehicles may travel at lower speeds especially on grades.

5. Alignment: If the alignment and geometrics are not upto the desired standards, the capacity will decrease. Particularly, restrictions to sight distance requirement cause reduction capacity. Steep and long grades affect the capacity. When 60% of the road length has substandard OSD the capacity decreases to 65% of the standard capacity.

6. Presence of Intersection At Grade: Intersections restrict free flow of traffic and thus adversely affect the capacity. The capacity of an intersection of two road crossing at grade will be slightly less than the road with the lower capacity of the two.

7. Other Factors which affect the capacity are the stream speed, one or two way traffic movement, number of traffic lanes, vehicular and driver characteristics, composition of traffic and traffic volume.

CONCEPT OF LEVEL OF SERVICE:

For a given road or facility, capacity could be constant. But actual flow will be different for different days and different times in a day itself. The intention of LOS is to relate the traffic service quality to a given flow rate of traffic. It is a term that designates a range of operating conditions on a particular type of facility. Highway capacity manual (HCM) developed by the transportation research board of USA provides some procedure to determine level of service. It divides the quality of traffic into six levels ranging from level A to level F. Level A represents the best quality of traffic where the driver has the freedom to drive with free own speed and level F represents the worst quality of traffic. Level of service is defined based on the measure of effectiveness (MOE). Typically three parameters are used under this and they are speed and travel time, density, and delay.

TYPES OF LEVEL OF SERVICES

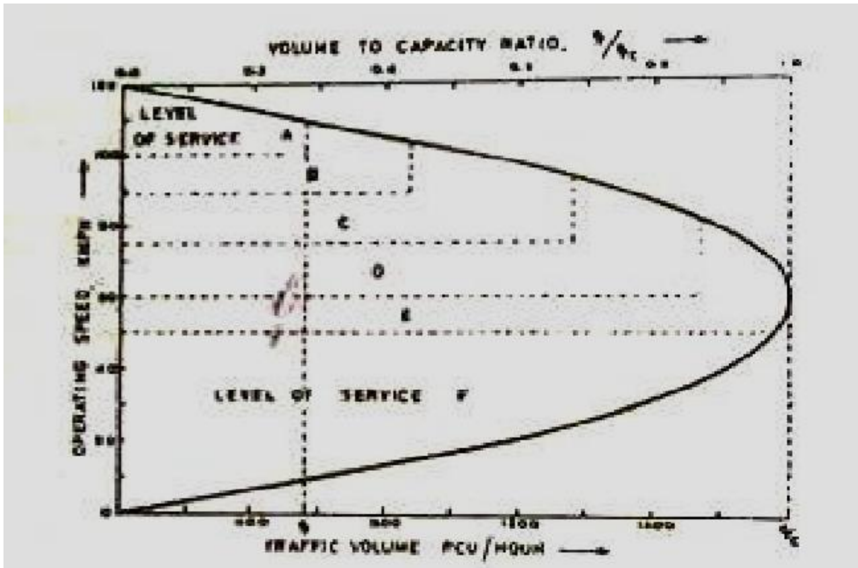


Fig. 5.11 General concept of level of service

LEVEL OF SERVICE A:

Free flow with low volumes and high speeds traffic density is low with speeds controlled by drivers, desired speed limits and physical roadway conditions. Little or no restriction in manoeuvrability due to presence of other vehicles and drivers can maintain their desired speeds with little or no delay.

LEVEL OF SERVICE B:

Zone of stable flow with operating speeds beginning to be restricted somewhat by traffic conditions. Drivers still have reasonable freedom to select their speed and lane of operation. This level of service has been used in the design of rural highways.

LEVEL OF SERVICE C:

Zone of stable flow, but speeds and manoeuvrability are more closely controlled by higher volumes. Most of the drivers restricted in the freedom to select their own speed lane changing or overtaking manoeuvres. A relatively satisfactory operating speed is still obtained and may suitable for urban design practice.

LEVEL OF SERVICE D:

Zone of unstable flow, with tolerable operating speeds being maintained though considerably affected by changes in operating conditions. Fluctuations in volume and temporary restrictions to flow may cause substantial drops in operating speeds. Drivers have little freedom to manoeuvre. Comfort and convenience are low, but conditions can be tolerated for Short periods of time.

LEVEL OF SERVICE E:

Cannot be described by speed alone, but represents operations at even lower operating speeds than in level D, with volumes at or near the capacity of highway. At capacity, speeds are typically but not always around 50 K.P.H flow is unstable, and there may be stoppages of momentary duration.

LEVEL OF SERVICE F:

Forced flow operations at low speeds, where volumes are below capacity. Conditions result from queues of vehicles backing up. Speeds are reduced substantially and stoppages may occur for short or long periods of time. In the extreme, both speed and volume can drop to zero.

SERVICE VOLUME:

The HCM terms the traffic volumes that can be served at each level of service as “SERVICE VOLUME”. After having selected a particular level of service for design purposes, the corresponding service volume then logically becomes the design capacity, which signifies that if the traffic volume using the road exceeds that value, the operating conditions will fall below the level of service selected for design.

PEAK HOUR FACTOR

Peak hour factor is a measure of variation in demand during the peak hour and is defined as the ratio between the number of vehicles counted during the peak hour and four times the number counted during the highest 15 consecutive minutes. The peak hour can range from 0.25 to 1.0, the former value representing the extreme parking condition and the latter representing a uniform flow during a peak hour.

PARKING STUDIES

The demand by automobiles users of parking space is one of the major problems of highway transportation, especially in metropolitan cities. In industrial, commercial and residential places with multi-storied buildings, parking demand is particularly high. Parking studies are useful to evaluate the facilities available.

Various aspects to be investigated during parking studies are:

(i) Parking demand: The parking demand may be evaluate by different methods. One of the methods is by making cordon counts of the selected area and recording accumulation of vehicles during the peak hours by subtracting the outgoing traffic from the traffic volume entering the cordoned area. One other method is by counting the number of vehicles parked in the area under study during different periods of the day; this method is useful when the parking demand is less than the space available for parking. By noting the registration number of each parked vehicle at any desired time interval (such as 30 minute, one hour, etc.) it is possible to estimate the duration of parking of each vehicle at the parking area.

(ii) Parking characteristics: The study is directed to note the present parking practices prevalent in the area under consideration and the general problems in parking. In case of kerb parking, it is also necessary to study the parking pattern, interference to smooth flow of traffic and the accidents involved during parking and unparking operations.

(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. Types of parking facilities:

1. On-street Parking

2. Off-street Parking

Common methods of On-street parking:

i) Parallel parking

ii) 30 degree angle parking

iii) 45 degree angle parking

iv) 60 degree angle parking

v) Right angle parking

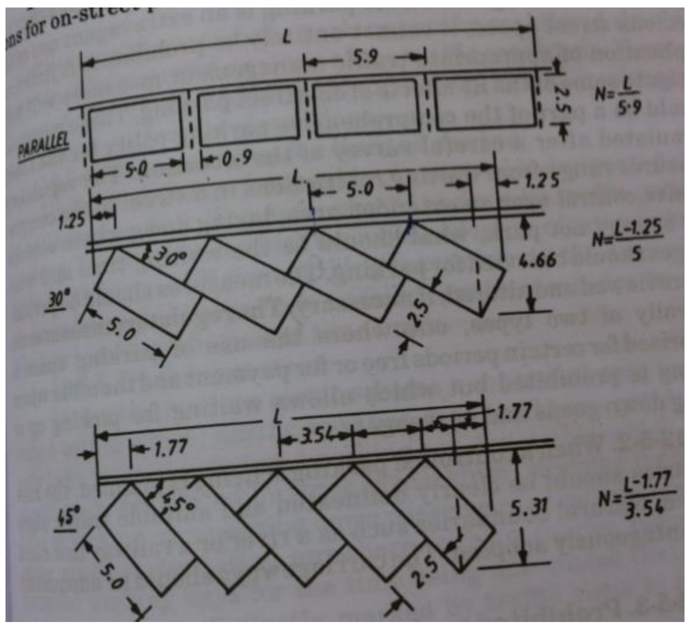
Parallel parking consumes the maximum curb length width decreases as the angle of parking increases.The minimum curb length is consumed by right angle parking, which accommodates nearly 2 times the number of vehicles as parallel parking.

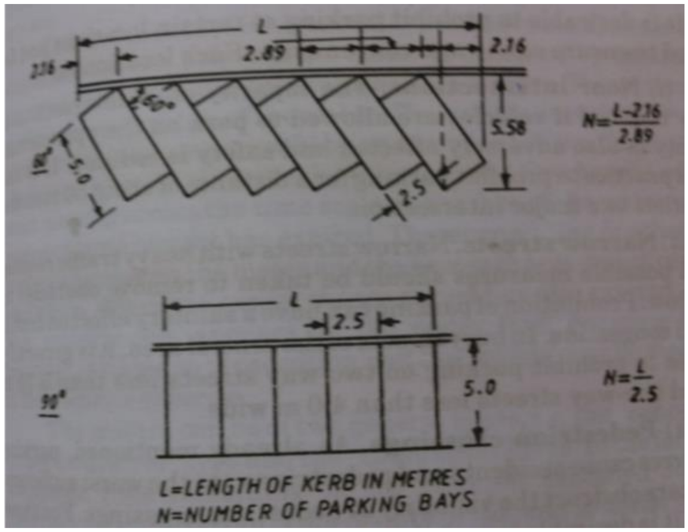
On the other hand, parallel parking makes the least use of the width of the street, and this is an important consideration in narrow streets. As the angle parking increases the width of street used also increases.

From the point of view of maneuverability, angle parking seems to be better than parallel parking which usually involves a backing motion. Delay of traffic is minimum with angle parking.

As regards safety, it has been noticed that angle parking is more hazardous than parallel parking.

Considering the above, it is recommended that in general parallel parking should be favored on streets .On exceptionally wide (wider than 20m) and low volume streets, consideration might be given for angle parking.





ACCIDENT STUDIES

The problem of accident is very acute in highway transportation due to complex flow pattern of vehicular traffic presence of mixed traffic and pedestrians. Traffic accidents may involve property damages, personal injuries or even casualties. One of the main objectives of traffic engineering is to provide safe traffic movements. Road accident cannot be totally prevented, but by suitable traffic engineering and management measures, the accident rate can be decreased considerably. Therefore the traffic engineer has to carry out systematic accident studies to investigate the causes of accidents and to take preventive measures in terms of design and control. It is essential to analyse every individual accidents carried out periodically at critical locations or road stretches or zones will help to arrive at suitable measures to effectively decrease the accident rates.

The various objectives of the accident studies may be listed as :

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

(ii) to evaluate existing designs,

(iii) to support proposed designs,

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

(v) to make computations of financial loss, and

(vi) to give economic justification for the improvements suggested by the traffic engineer. Causes of accidents

There are four basic elements in a traffic accident:

(i) the road users (ii) the vehicles (iii) the road and its condition, and (iv) Environmental factors-traffic, weather etc.

The road user responsible for the accident may be the driver of one or more vehicles involved, pedestrians or the passengers. Vehicles involved in the accident may also be defective. The condition of the road surface or other existing geometric features or any of the environmental conditions of the road may not be upto the expectation causing an accident.

Various causes of accidents may hence be listed as given below:

(a) Drivers : Excessive speed and rash driving, carelessness, violation of rules and regulations, failure to see or understand the traffic situation, sign or signal, temporary effects due to fatigue, sleep or alcohol. (b) Pedestrians: Violating regulations, carelessness in using the carriageway meant for vehicular traffic. (c) Passengers: Alighting from or getting into moving vehicles.

(d) Vehicle defects: Failure of brakes, steering system, or lighting system, tyre burst and any other defect in the vehicle.

(e) Road condition: Slippery or skidding road surface, pot holes, ruts and other damaged conditions of the road surface.

(f) Road design: defective geometric design like inadequate sight distance, inadequate width of shoulders, improper curve design, improper lighting and improper traffic control devices.

(g) Weather: Unfavourable weather condition like mist, fog, snow, dust, smoke or heavy rainfalls which restrict normal visibility and render driving unsafe.

(h) Animals: Stray animals on the road

(i) Other causes: Incorrect signs or signals, gate of level crossing not closed when required, ribbon development, badly located advertisement boards or service station etc.

Accident studies and records

The various steps involved in traffic accident student studies are collection of accident data, preparation of reports, location file and diagrams, and application of the above records for suggesting preventive measures.

(i) Collection of accident data:

The collection of accident data is the first step in the accident study. Standard forms for collecting the data are prepared, as suggested by the IRC (see Ref. 25).

The details to be collected are briefly mentioned here.

(a) General: Date, time, persons involved in the accident and their particulars, classification of accident like fatal, serious, minor etc.

(b) Location: Description and details of the location of accident.

(c) Details of vehicles involved: Registration number make and description of the vehicle, loading details, vehicular defects.

(d) Nature of accident: Condition of road geometrics, details of collision, and pedestrians or objects involved, damages, injuries causality etc.

(e) Road and traffic conditions: Details of road geometrics, whether the road is straight or curved, surface characteristics such as dry, wet or slippery etc. Traffic condition – type of traffic, traffic density, etc.

(f) Primary causes of accident: Various possible causes and the primary cause of the accident.

(g) Accident costs: The total cost of the accident computed in terms of rupees, of the various involvements like property damages, personal injuries and casualties.

(ii) Accident report:

The accident should be reported to police authorities who would take legal actions especially in more serious accidents involving injuries, casualties or severe damage to property. Accident report of the individuals involved may be separately taken. The accident data should be collected as given above and the accident report is prepared with all facts which might be useful in subsequent analysis, claims for compensation, etc.

(iii) Accident records:

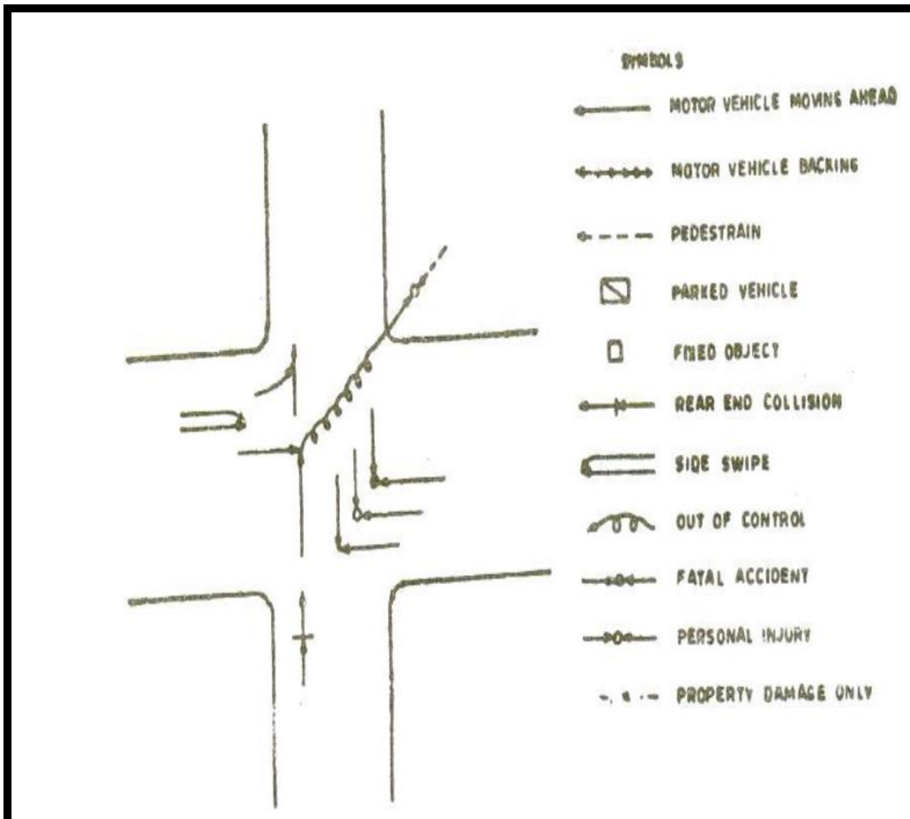
The accident records are maintained giving all particulars of the accidents, location other details. The records may be maintained by means of location files, spot maps. Collision diagrams and condition diagrams.

(a) Location files: These are useful to keep a check on the location of accident and to identify points of high accident incidence. Location fields should be maintained by each police station for the respective jurisdiction.

(b) Spot maps: accident location spot maps show accidents by spots, pins or symbols on the map. A map of suitable scale say, 1 cm = 40 to 60 metre, may be used for spotting urban accidents. The common legend used for spot maps, are given in Fig. 5.12.

(c) Condition diagram: A condition diagram is a drawing to scale showing all important physical conditions of an accident location to be studied. The important features generally to be shown in this diagram with suitable dimensions marked there in an roadway limits, curves, kerb lines, bridges, culverts trees and all details of roadway conditions, obstruction to vision, property lines, signs, signals etc. there are standard symbols used in showing various details. The condition and collision diagrams may be combined together in a single sketch, if necessary.

(d) Collision diagram: these are diagrams showing the approximate path of vehicles and pedestrians involved in the accidents. Collision diagrams are most useful to compare the accident pattern before and after the remedial measures have been taken.



Collision Diagram and Symbols

TRAFFIC CONTROL DEVICES

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. The most common among these are (a) Signs (b) Signals (c) Markings and (d) Islands. In addition, road lights are useful in guiding traffic during night.

Traffic signs

The traffic signs should be backed by law in order to make them useful and effective. Traffic signs have been divided into three categories according to Indian Motor Vehicles Act. These are

(i) Regulatory signs

(ii) Warning signs and

(iii) Informatory signs.

Regulatory signs

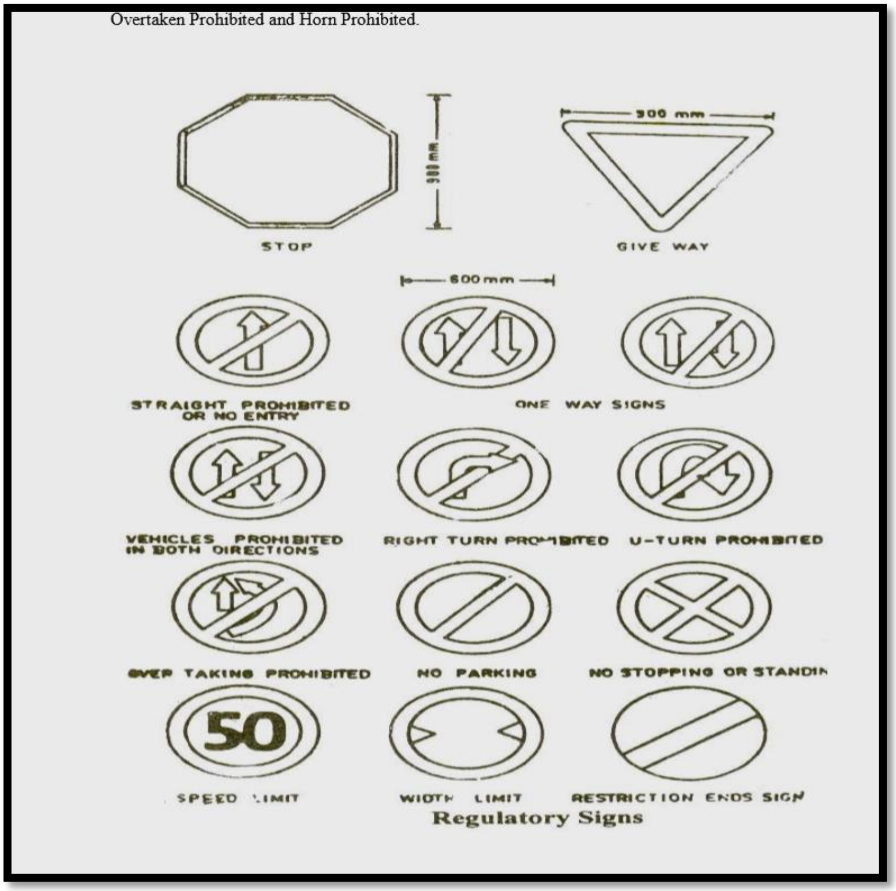
Regulatory or mandatory signs are meant to inform the road users of certain laws, regulations and prohibitions; the violation of these signs is a legal offence. The regulatory signs are classified under the following sub-heads:

(i) Stop and Give-way signs
(ii) Prohibitory signs
(iii) No parking and No Stopping signs
(iv) Restriction Ends sign
(v) Compulsory Direction Control and other signs

The stop sign is intended to stop the vehicles on a roadway; it is octagonal in shape and red in colour with a white border. This sign may be used in combination with a rectangular definition plate with the word 'STOP' written in English and other languages as necessary. 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. This sign is triangular in shape with the apex downwards and white in colour with a red border; this sign may also be used in combination with a definition plate. These signs are shown in Fig. 5.24.

Prohibitory signs are meant to prohibit certain traffic movements, use of hours or entry of certain vehicle class. These signs are circular in shape and white in colour with a red border. The common prohibitory signs are, Straight Prohibited, No Entry, One – way, Vehicles Prohibited in Both Directions, all Motor

Vehicles Prohibited, Trunk Prohibited, Bullock Cart and Hand Cart Prohibited, Bullock Cart Prohibited, Tonga Prohibited, Hand Cart Prohibited, Cycle Prohibited, Pedestrian Prohibited, Right/Left Turn Prohibited, U-Turn Prohibited, Overtaken Prohibited and Horn Prohibited.



Regulatory Signs

No Parking sign is meant to prohibit parking of vehicles at that place, the definition plate may indicate the parking restriction with respect to days, distance, etc. the No parking sign is circular in shape with a blue back ground, a red border and an oblique red bar at an angle of 45 degrees. No Stopping/ Standing sign is meant to prohibit stopping of vehicles at that place; the scope of the prohibition may be indicated on a definition plate. The No Stopping/Standing sign is circular in shape with blue back ground, red border and two oblique red bars at 45 degrees and right angle to each other. The sketches of the Prohibitory Signs, No Parking and No Stopping signs are shown in Fig. 5.24.

Speed Limit signs are meant to restrict the speed of all or certain classes of vehicles on a particular stretch of a road. These signs are circular in shape and have white back ground, red border and black indicating the speed limit. The Vehicle Control sings are also similar to Speed Limit signs with black symbols instead of the numerals. The common controls are Width Limit, Height Limit, Length Limit, Load Limit and Axle

Load Limit. The definition plate may be used in combination to give more details, symbolically or by words.

Restriction End sign indicates the point at which all prohibitions notified by prohibitory signs for moving vehicles case to apply. These signs are also circular with a white back ground and a broad diagonal black band at 45 degrees.

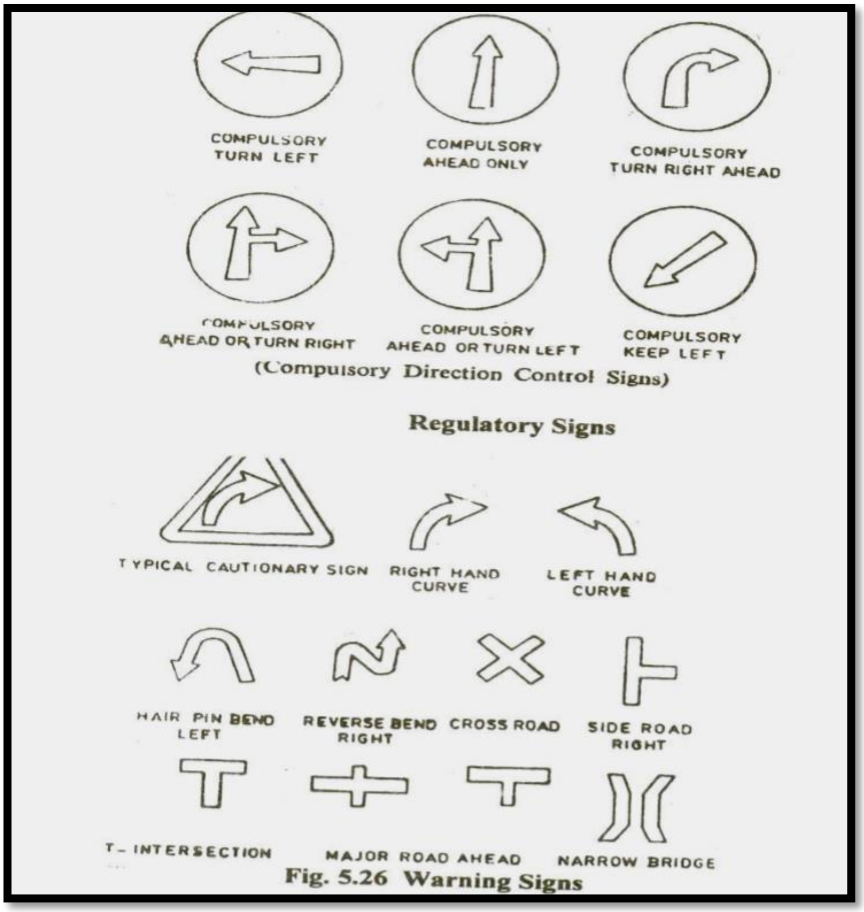
Compulsory Direction Control signs indicate by arrows, the appropriate directions in which the vehicles are obliged to proceed, or the only directions in which they are permitted to proceed. These signs are circular in shape with a blue back ground and white direction arrows. Some of the Compulsory Direction Controls are Compulsory Turn Left, Ahead Only, Ahead or Turn Left/Right and keep Left. (See Fig. 5. 25.). other Compulsory sign are Compulsory Cycle Track and Compulsory Sound Horn; these are indicated by white symbols instead of white direction arrows of the Compulsory Direction Signs.

The dimensions shown in fig. 5.25 are for normal size signs; however smaller size signs may be permitted on minor roads

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. They have a white back ground, red border and black symbols. The warning signs are to be located at sufficient distance in advance of the hazard warned against; these distances are 120, 90, 60 and 40 metre respectively on National/State Highways, Major District Roads, Other District Roads and Village Roads; on urban roads this distance is 50 metre.

The commonly used are 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 Road, Cycle Crossing, Pedestrian Crossing, School Zone, Men at Work, Ferry, Cross Road, Side Road, T-Intersection, Major Road Ahead, Round About, DangerousDip, Hump or Rough Road, Barrier Ahead, Unguarded Railway Crossing, Guarded Railway Crossing and Falling Rock. Some of these Warning Signs are shown in Fig. 5.25.



(Compulsory Direction Control Signs)

Regulatory Signs

Fig. 5.26 Warning Signs

Informatory signs

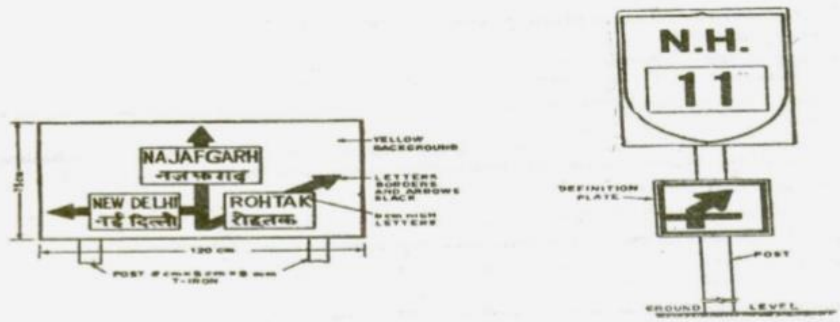
These signs are used to guide the road users along routes, inform them of destination and distance and provide with information to make travel easier, safe and pleasant. The information signs are grouped under the following sub-heads:

(i) Direction and Information signs
(ii) Facility Information signs
(iii) Other useful information signs
(iv) Parking signs
(v) Flood Gauge

The Direction and Place Identification signs are rectangular with back ground, black border and black arrows and letters. The inscriptions should be in English and other languages as necessary. The signs of this group include Destination signs, Direction signs, Re-assurance signs, Route Marker and place Identification signs. Figure 5.27 shows some of the Informatory signs.

The Facility Information signs are rectangular with blue back ground 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. parking signs are set up parallel to the road using square sign board with blue black ground and white coloured letter ‘p’ Additional definition plate may be used to indicate category of vehicle for which parking space is reserved, direction of parking space etc.

Flood Gauge sign should be installed at all cause way and submersible bridges or culverts to indicate to the road users the height of the flood above road level.



(a) Road Junction Approach

(b) Route Marker Sign

Informatory Signs

TRAFFIC SIGNALS

At intersection where there are a large number of crossing and right-turn traffic, there is possibility of several accidents as there cannot be orderly movements. The earlier practice has been to control the traffic by means of traffic police by showing stop signs alternately at the cross roads so that one of the traffic streams may be allowed to move while the cross traffic is stopped. Thus the crossing streams of traffic flow are separated by time, segregation. 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 signal 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:

(i) They provide orderly movement of traffic and increase the traffic handling capacity of most of the intersections at grade.

(ii) They reduce certain types of accidents, notably the right angled collisions

(iii) Pedestrians can cross the roads safely at the signalized intersection.

(iv) The signals allow crossing of the heavy traffic flow with safety.

(v) When the signal system is properly co-ordinated, there is a reasonable speed along the major road traffic.

(vi) 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.

(vi) Automatic traffic signal may work out to be economical when compared to manual control.

(vii) The quality of traffic flow is improved by forming compact platoons of vehicles, provided all the vehicles move at approximately the same speed.

Disadvantages of traffic signals

(i) The rear-end collisions may increase.

(ii) Improper design and location of signals may lead to violations of the control system.

(iii) 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:

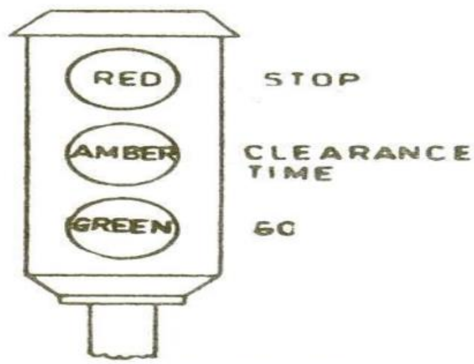
(i) Traffic control signals

- (a) Fixed-time signal
- (b) Manually operated signal
- (c) Traffic actuated (automatic) signal

(ii) Pedestrian signal

(iv) Special traffic signal

The traffic control signals have three coloured light glows facing each direction of traffic flow. The red light is meant for stop, the green light indicates Go and the amber or yellow light allows the clearance time for the vehicle which enter the intersection area by the end of green time, to clear off.



Traffic Signal

Fixed-time signal 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 type 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 in 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. 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. In fully actuated traffic signals the detectors and a computer assigns the right of way for various traffic movements on the basis of demand and predetermined programming. But these are very costly to be installed at all intersections.

In some cities in India the traffic police are assigned the duty to watch the traffic demand from suitable observation point during the peak hours on various approaches and to vary the timings of the phases and cycle according to the actual traffic demand.

WEBSTER'S METHOD

In this method, the optimum signal cycle Co corresponding to least total delay to the vehicles at the signalized intersection has been worked out. This is a rational approach. The field work consists of finding (i) the saturation flow S per unit time on each approach of the water section and (ii) the normal flow q on each approach during the design hour. Based on the higher value of normal flow, the ratio $y1 = q1/S1$ and $y2 = q2/S2$ are determined on the approach roads 1 and 2. in the case of mixed traffic, it is necessary to convert all the normal flow and saturation flow values in terms of suitable PCU values which should be determined separately.

The saturation flow is to be obtained from careful field studies by noting the number of vehicles in the stream of compact flow during the green phases and the corresponding time intervals precisely. In the absence of data the approximate value of saturation flow is estimated assuming 160 pcu per 0.3 metre width of the approach. the normal flow of the traffic is also determined on the approach roads from the field studies for the design period (during the peak or off-peak hours as the case may be).

The optimum signal cycle is given by:

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

Where L = total lost time per cycle, secs. = 2n + R (n is the number of phase and R is all red- time)

$$\mathbf{Y} = \mathbf{y1 + y2}$$

Then, $$\mathbf{G1} = \frac{y1}{Y}\ \mathbf{(Co - L)\ and\ G2} = \frac{y2}{Y}\ \mathbf{(Co = L)}$$

Similar procedure is followed when there are more number of signal phases.

DESIGN METHOD AS PER IRC GUIDELINE

(i) The pedestrian green time required for the major and minor roads are calculated based on walking speed of 1.2 m/sec. and initial walking time of 7.0 secs. These are the minimum green time required for the vehicular traffic on the minor and major roads respectively.

(ii) The green time required for the vehicular traffic on the major road is increased in proportion to the traffic on the two approach roads.

(iii) The cycle time is calculated after allowing amber time of 2.0 secs.

(iv) The minimum green time required for clearing vehicles arriving during a cycle is determined for each lane of the approach road assuming that the first vehicle will take 6.0 secs. And the subsequent vehicles (PCU) of the queue will be cleared at a rate of 2.0 secs. The minimum green time required for the vehicular traffic on any of the approaches is limited to 16 secs.

(v) The optimum signal cycle time is calculated using Webster's formula (explained in method 3). The saturation flow values may be assumed as 1850, 1890,1950,2250.2550 and 2990 PCU per hour for the approach roadway widths (kerb to median or centre line) of 3.0, 3.5, 4.0, 5.0 and 5.5 m; for width above 5.5 m, the saturation flow may be assumed as 525 PCU per hour per metre width. The lost time is calculated from the amber time, inter-green time and the initial delay of 4.0 secs. For the first vehicle, on each leg.

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

Road Marking

Road or traffic marking are made of lines, patterns, words, symbols or reflectors on the pavement, kerb, sides of islands or on the fixed objects within or near the roadway. Traffic markings may be called special signs intended to control, warn, guide or regulate the traffic. The markings are made using paints in contrast with colour and brightness of the pavement or other back ground.

The various types of markings may be classified as,

(a) Pavement markings

(b) Kerb markings

(c) Object marking and

(d) Reflector unit markings

Pavement Markings

Pavement or carriageway markings may generally be of white paint. Yellow colour markings are used to indicate parking restrictions and for the continuous centre lines and barrier line markings. Longitudinal solid lines are used as guiding or regulating lines and are not meant to be crossed by the driver. Transverse solid lines indicate the position of stop lines for vehicular traffic.

Some of the common types of pavement markings are given below:

(a) Centre Lines: These are meant to separate the opposing streams of traffic on undivided two-way roads. On rural highway with two or three lanes, single broken lines of width 0.1 m and length 4.5 segments and

7.5 m gaps may be painted on straight stretches of NH and SH, these may be decreased to 3.0 and 6.0 m at horizontal curves and approaches to intersection. On urban roads with less than four traffic lanes the centre line consists of white broken lines of width 0.10 to 0.15 m, length of segment 3.0 m and length of gaps 4.5 m to be reduced to 3.0 m at curves and approaches to intersections.

(b) Lane Line: lines are drawn to designate traffic lanes. These are used to guide the traffic and to properly utilize the carriageway.

(c) No passing Zone Markings: These are marked to indicate that overtaking is not permitted.

(d) Turn Markings: these are useful near intersection to designate proper lateral placement of vehicles before turning to the different directions.

(e) Stop Lines: these are meant for vehicles to stop near the pedestrian crossing, signalized intersection etc. where the vehicles have to stop and proceed.

(f) Cross Walk Lines : The particular places where pedestrian are to cross the pavement are properly marked by the pavement markings. The width of pedestrian crossing may be between 2.0 and 4.0 m depending on local requirements.

(g) Approach to Obstructions: These may be indicated by appropriate pavement markings.

(h) Parking Space limits: For proper utilization of parking facility, markings are made.

(i) Border or edge lines indicate carriageway edges of rural which have no kerb stones along the edges.

(j) Route direction arrows are marked by one or more arrows to guide effectively the traffic into correct lanes.

(k) Parking space limits on urban roads are marked to promote efficient use of parking spaces in a systematic manner.

(l) Bus Stops: The length of kerb which is reserved for buses to stop are marked by continue yellow line on the kerb indicating ‘parking prohibited’. The pavement space meant for bus stop is also marked by the word ‘BUS’.

Kerb Markings

These may indicate certain regulations like parking regulations. Also the markings on the kerb and edges of islands with alternate black and white line increase the visibility from a long distance.

Object Markings

Physical obstruction on or near the roadway are hazardous and hence should be properly marked. Typical obstructions are supports for bridge, signs and signals, level crossing grates, traffic islands, narrow bridges, culver head walls etc.

Reflector Unit Markings

Reflector markers are used as hazard markers and guide markers for safe driving during night. Hazard markers reflecting yellow light should be visible from a long distance of about 150 m.

Road Delineators

Road delineators are devices or treatment to outline the roadway or a portion there-of to provide visual assistance to drivers about the alignment of a road ahead, especially at night.

Hazard Markers and Object Markers.

Hazard markers are approximately 1.2 m high plates on posts, either with three red reflectors or markers with black and yellow strips at 45o towards the side of obstruction, meant to define obstructions or objects close to road.

DESIGN OF INTERSECTION

General

At the intersections there are through, turning and crossing traffic and these traffic movements may be handled in different ways depending on the type of intersection and its design. Intersections may be classified into two broad groups:

(i) Intersection at grade: These include all roads which meet at more or less the same level. The traffic manoeuvres like merging, diverging and crossing are involved in the intersections at grade.

(ii) Grade separated intersection: The intersecting roads are separated by difference in and manoeuvre areas.

Intersection at Grade

All road intersections which meet at about the same level allowing traffic manoeuvres like merging, diverging, crossing, and weaving are called intersections at grade. These intersections may be further classified as unchannelized, channelized and rotary intersections.

The basic requirements of intersection at grade are:

(i) At the intersection the area of conflict should be as possible.
(ii) The relative speed and particularly the angle of approach of vehicle should be small.
(iii) Adequate visibility should be available for vehicles approaching the intersection.
(iv) Sudden change of path should be avoided.
(v) Geometric features like turning radius and width of pavement should be adequately provided.
(vi) Proper signs should be provided on the road approaching intersection to warn the drivers.
(vii) Good lighting at night is desirable.
(viii) If the number of pedestrians and cyclists are large, separate provision should be made for their safe passage in intersections with high volume of fast moving traffic.

Unchannelized intersections

The intersection area is paved and there is absolutely no restriction to vehicles to use any part of intersection area. Hence the unchannelized (all-paved) intersections are the lowest class of intersection, easiest in the design, easiest in the design; but most complex in traffic operations resulting in maximum conflict area and more number of accidents, unless controlled by traffic signals or police. When no additional pavement width for turning movement is provided, it is called plain intersection. But when the pavement is widened at the intersection area, by a traffic lane or more, it is known as flared intersection.

Channelized intersections

Channelized intersection is achieved by introducing islands into the intersectional area, thus reducing the total conflict area available in the unchannelized intersection. The radius of the entrance and exit curves and the area are suitably designed to accommodate the Channelling islands of proper size and shape. These islands help to channelized turning traffic, to control their speed and angle of approach and to decrease the conflict area at the intersection.

The advantages of channelized intersections may be summed up as follows:

(i) By channelization vehicles can be confined to definite paths.
(ii) Angle of merging streams can be forced to be at flat angles so as to cause minimum disruption.
(iii) Both the major and minor conflict areas within the intersection can considerably be decreased, as shown in Fig. 5.32.
(iv) Angle between intersecting streams of traffic may be kept as desired in a favourable way.
(v) Speed control can be established over vehicles entering the intersection.

(vi) Refuse islands can be provided for pedestrians within the intersection area.

(vii) Points of conflicts can be separated.

(viii) The channelizing islands provide proper place for installation of signs and other traffic control devices.

ROTARY INTERSECTION

A rotary intersection or traffic rotary is an enlarged road intersection where all converging vehicles are forced to move round a large central island in one direction (clock wise direction) before they can weave out of traffic flow into their respective directions radiating from the central island, the main objects of providing a rotary are to eliminate the necessity of stopping even for crossing streams of vehicles and to reduce the area of conflict.

Design factors of Rotary

Various design factors to be considered in a traffic rotary are speed, shape of central island, radius of rotary roadway, weaving angle, weaving distance, width of rotary roadway, radius of entrance and exit curves, channelizing islands, camber and super elevation, grade, lighting and signs.

These are briefly explained here.

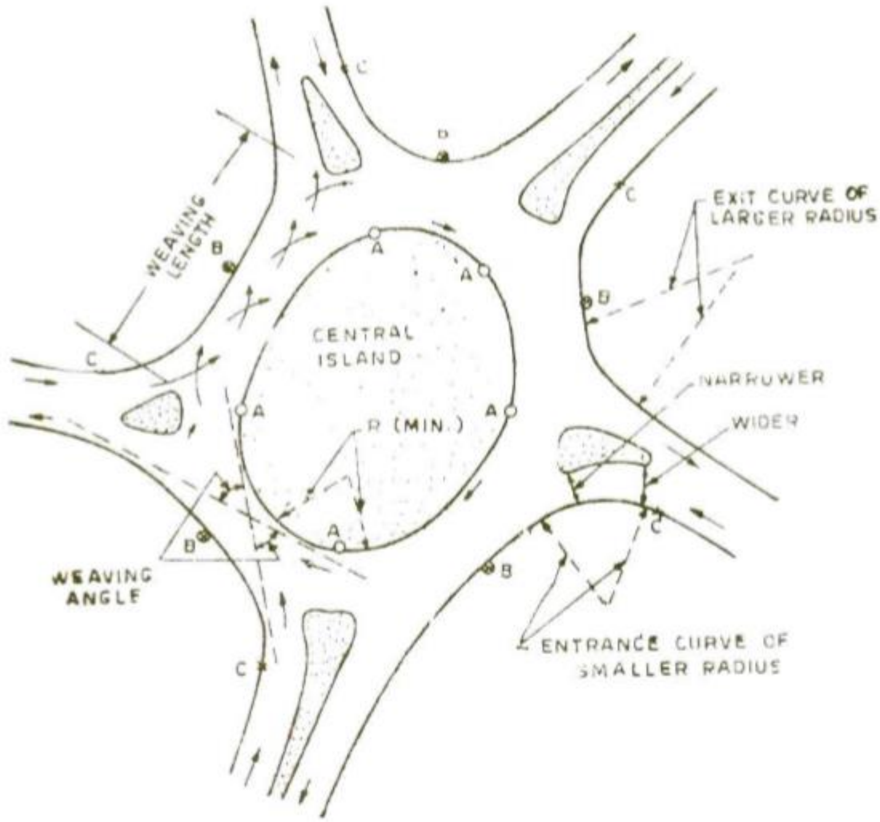
(i) **Design speed:** Vehicle approaching as intersection at grade have to considerably slow down their speed when compared to the design speed standard of the highway under consideration. Though there is no need for vehicles in a traffic rotary to come to a dead stop before allowing cross traffic to cross, still there has to be considerable reduction in speed.

(ii) **Shape of Central Island:** The various shapes considered to suit different conditions are circular, elliptical, turbine and tangent shapes, each having its own advantages and limitations. when two equally important roads cross at roughly right angles i.e., all the four radiating roads placed symmetrically, a circular shape is suitable. The island may be often elongated to accommodate in the layout four or more intersection roads; and to allow for the greater traffic flow along the direction of elongation.

(iii) **Radius of rotary roadway:** The one-way rotary road round the central island has different radii at different points depending on the shape of the central island.

$$\mathbf{R} = \frac{V^2}{127f}$$

The value of the design coefficient of friction ‘f’ are taken as 0.43 and 0.47 for the speeds 40 and 30 kmph respectively, after allowing a factor of safety of 1.5. the IRC has suggested the radius of entry curve to be 20 to 30 m and 15 to 25 m for rotary design speeds of 40 and 30 kmph. The recommended minimum radii of Central Island are 1.33 times the radius of entry curves.



Rotary Intersection

(iv) **Weaving angle and weaving distance:** The angle between the path of a vehicle entering the rotary and that of another vehicle leaving the rotary at adjacent road, thus crossing the path of the former is termed as the weaving angle. The weaving operation including merging and diverging can take place between the two channelizing islands of the adjacent intersection legs, and this length of the rotary is known as weaving length.

For smooth flow traffic the weaving angle should be small but not less than 15^{o} as the diameter of Central Island required will be too large. For any design speed the freedom of movement on a rotary depends on the size of the weaving section. The recommended values of weaving length are 45 to 90 m for 40 kmph and 30 to 60 m for 30 kmph design speeds.

(v) Width of carriageway at entry and exit: The carriageway width at the entrance and exit of a rotary is governed by the amount of traffic entering the rotary from the road or that leaving the rotary to the entry width e1 may be increased to 6.5, 7.0 and 8.0 m when the carriageway width of approach road is 7.0, 10.5 and 14.0 m respectively and the radius at entry is 25 to 35 m.

(vi) Width of carriageway at entry and exit : All the traffic entering the traffic rotary have to go round the one-way rotary roadway for at least a short distance. As the outer kerb lines follow the entrance and exit-sides of roads, the actual width of the rotary roadway varies from section to section. The width of non-weaving section e2 of the rotary should be equal to the widest single entry to the rotary and should generally be less than the width of weaving section. The width of weaving section W of the rotary should be one traffic lane wider than the mean width of the entry and non-weaving section i.e.;

$$\mathbf{W} = \left[\frac{e_1 + e_2}{2} + 3.5\right] m$$

(vii) Entrance and exit curves : The curve traced by the inner rear wheel of vehicles determines the radius and shapes to which the kerb line is to be set. A vehicle entering a rotary has to slow down to the design speed of the rotary and therefore the radius of the central island. For the design speed of 40 kmph the suggested radius at entry curves is 20 to 35 m and for 30 kmph, 15 to 25 m. it has been seen that the buses and trucks can take right angled curves may be provided instead of simple circular curve.

Vehicles leaving the rotary would accelerate to the speed of the radiating roads and hence the exit curves should be of a larger radius than entry curves; one and a half to two times radius of entry is considered reasonable.

The normal pavement width at entrance and exit should be equivalent to two lanes in order to prevent clustering of mixed traffic at the approaches. Extra widening has to be provided at the entrance and exit curve.

The pavement width at entrance curve will be higher than at exit curve as the radius of the former is less than the latter.

(viii) Capacity of the rotary: The practical capacity of the rotary is dependent on the minimum capacity of the individual weaving section. The capacity is calculated from the formula:

$$\mathbf{Qp} = \frac{280W(1+e/W)(1-p/3)}{(1+W/L)}$$

Where Qp = practical capacity of the weaving section of a rotary in pcu per hour.

W = width of weaving section(6 to 18 m)

E = average width of entry e1 and width of non-weaving section e2 for the range e/W = 0.4 to 1.0

L = length of weaving section between the ends of channelizing islands in metre for the range of W/L = 0.12 to 0.4

p = proportion of weaving traffic given by

$$p = \frac{b+c}{a+b+c+d} \text{ in the range 0.4 to 1.0}$$

a = left turning traffic moving along left extreme lane

d = right turning traffic moving along right extreme lane

b = crossing/weaving traffic turning towards right while entering the rotary

c = crossing/weaving traffic turning towards left while leaving the rotary.

Grade Separated Intersections

Grade separated intersection design is the highest form of intersection treatment. This type of intersection causes least delay and hazard to the crossing traffic and in general is much superior to intersections at grade from the point of view of traffic safety and efficient operation.

A highway grade separation is achieved by means of vertical level. Separation of intersection roads by means of a bridge thus eliminating all crossing conflicts at the intersection. The grade separation may be either by an over bridge or under pass Transform of route at the grade separation is provided by interchange facilities consisting of ramps

The grade separated intersections have the following advantages and limitations.

Advantages of Grade Separation

(i) Maximum facility is given to the crossing traffic. As the roads are separate, this avoids necessity of stopping and avoids accidents while crossing.

(ii) There is increased safety for turning traffic and by indirect interchange ramp even right turn movement is made quite easy and safe by converting into diverging to left and merging from left.

(iii) There is overall increase in comfort and convenience to the motorists and saving in travel time and vehicle operation cost.

(iv) The capacity of the grade operated intersection can practically approach that of the two cross roads.

(v) Grade separation is an essential part of controlled access highway like expressway and freeway.

(vi) It is possible to adopt grade separation for all likely angles and layout of intersecting roads.

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

Disadvantages of Grade Separation

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

(ii) Where there is limited right of way like built up or urban area or where the topography is not favourable, construction of grade separation is costly, difficult and undesirable.

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