1.1 ROAD CHARACTERISTICS

The various road characteristics may be classified into six types.

a. Road surface
b. Lighting
c. Roughness
d. Pavement color
e. Night visibility
f. Geometric aspects

1. Road surface

The type of pavement is determined by the volume and composition of traffic, the availability of materials, and available funds. Some of the factors relating to road surface like **road roughness, tire wear, tractive resistance, noise, light reflection**, electrostatic properties etc. should be given **special attention in the design, construction and maintenance of highways** for their safe and economical operation.

Unfortunately, it is impossible to build road surface which will provide the best possible performance for all these conditions.

For heavy traffic volumes, a **smooth riding surface with good all-weather antiskid properties is desirable.** The surface should be chosen to retain these qualities so that maintenance cost and interference to traffic operations are kept to a minimum.

2. Lighting

Illumination is used to **illuminate the physical features of the road way** and to aid in the driving task.

Highway lighting is particularly more **important at intersections, bridge site, level crossing** and in places where there is restriction of traffic to movements.

On urban roads where the density of population is also high, road lighting has other advantages like feeling of security and protection.

3. **Roughness**

This is one of the main factors that an engineer should give importance during the design, construction, and maintenance of a highway system.

Drivers tend to seek smoother surface when given a choice. On four-lane highways where the texture of the surface of the inner-lane is rougher than that of the outside lane, passing vehicles tend to return to the outside lane after execution of the passing maneuver.

Shoulders or even speed change lanes may be deliberately roughened as a means of delineation.

4. **Pavement colors**

When the pavements are light colored(for example, cement concrete pavements) there is better visibility during day time whereas during night dark colored pavements like bituminous pavements provide more visibility.

Contrasting pavements may be used to indicate preferential use of traffic lanes. A driver tends to follow the same pavement color having driven some distance on a light or dark surface, he expects to remain on a surface of that same color until he arrives a major junction point.

5. **Night visibility**

The main reason for increased accident rate during night time may be attributed to poor night visibility.

An important factor is the amount of light which is reflected by the road surface to the drivers eyes.

Glare caused by the reflection of oncoming vehicles is negligible on a dry pavement but is an important factor when the pavement is wet.

6. **Geometric aspects**

The roadway elements such **as pavement slope, gradient, right of way etc affect transportation in various ways.**

Central portion of the pavement is slightly raised and is sloped to either sides so as to prevent the ponding of water on the road surface. This will deteriorate the riding quality since the pavement will be subjected to many failures like potholes etc.

Minimum lane width should be provided to reduce the chances of accidents. Also the speed of the vehicles will be reduced and time consumed to reach the destination will also be more.

Right of way width should be properly provided. If the right of way width becomes less, future expansion will become difficult and the development of that area will be adversely affected.

One important other road element is the **gradient**. It reduces the **tractive effort of large vehicles.** Again the fuel consumption of the vehicles climbing a gradient is more.

The other **road element that cannot be avoided are curves**. Near curves, chances of accidents are more.

1.2 ROAD USER CHARACTERISTICS

HUMAN FACTORS AFFECTING TRANSPORTATION

Road users can be defined as drivers, passengers, pedestrians etc. who use the streets and highways. The physical, mental and emotional characteristics of human beings affect their ability to operate motor vehicle safely or to service as a pedestrian.

The various factors which affect road user characteristics may broadly beclassified into four heads:

1. Physical
2. Mental
3. Psychological and
4. Environmental

1.Physical characteristics

The physical characteristics of the road users may be either permanent or temporary. The physical characteristics are the vision, hearing, strength and the general reaction to traffic situations.

Vision: The perception-reaction time depends greatly on the effectiveness of drivers vision in perceiving the objects and traffic control measures. The PIEV time will be decreased if the vision is clear and accurate. Visual acuity relates to the field of clearest vision. The most **acute vision (visual acuity or cone of vision)** is within a cone of **3 to 5** degrees, **fairly clear vision within 10 to 12 degrees** and the **peripheral vision will be within 120 to 180** degrees. This is important when **traffic signs and signals are placed**, but other factors like dynamic visual acuity, depth perception etc. should also be considered for accurate design. Glare vision and color vision are also equally important. **Glare vision** is greatly affected by age. Glare recovery time is the time required to recover from the effect of glare after the light. source is passed, and will be higher for elderly persons. **Color vision** is important as itcan come into picture in case of sign and signal recognition.

Hearing: Hearing is required for **detecting sounds,** but lack of hearing acuity can be compensated by usage of hearing aids. Lot of experiments were carried out to test the drive vigilance which is the ability of a drive to discern environmental signs over a prolonged period. The results showed that the drivers who did not undergo any type of fatiguing conditions performed significantly better than those who were subjected to fatiguing conditions. But the mental fatigue is more dangerous than skill fatigue. The variability of attitude of drivers with respect to age, sex, knowledge and skill in driving etc. are also important.

The temporary physical characteristics of the road users affecting their efficiency are fatigue, alcohol or drugs and illness. All these reduce alertness and increase the reaction and also affect the quality of judgement in some situations.

2.Mental characteristics

Knowledge, skill, intelligence experience and literacy can affect the road user characteristics. knowledge of vehicle characteristics, traffic behavior, driving practice, rules of road and psychology of road users will be quite useful for safe traffic operation.

Understanding the traffic regulations and special instruction and timely action depends on intelligence and literacy.

Reactions to certain traffic situations become more spontaneous with experience.

1. Psychological Characteristics

These affect reaction to traffic situations of road users to a great extent. The emotional factors such as attentiveness, fear anger, superstition impatience, general attitude towards traffic and regulations and maturity also come under this.

1.2.1 PIEV THEORY

According to this theory total reaction time of the driver is split into four parts,viz.,time taken by the driver for:

Perception: it is the time required for the sensations received by the eyes or ears to be transmitted to the brain through the nervous system and spinal chord. In other words it is the time required to perceive an object or situation.

Intellection: It is the time required for understanding the situation. It is also time required for comparing the different thoughts, regrouping and registering new sensations.

Emotion: This stage involves the judgment of the appropriate response to be made on the stimuli like to stop, pass, move laterally etc.

Volition: Volition is the time taken for the final action.

2. Environmental Factors

The environmental factors like weather, visibility and other atmospheric conditions. The various environmental conditions affecting the behavior of road user are traffic stream characteristics, facilities to the traffic, atmospheric conditions andthe locality.

COMPONENTS OF TRAFFIC ENGINEERING

The components of traffic engineering classified into three types.

1. Road users including drivers, cyclists and pedestrians
2. Vehicle
3. Roads and Highways
4. Control devices
5. Land use characteristics

1.3 VECHICLE CHARACTERISTICS

The various vehicular characteristics affecting road the road design may be classified into two types.

1. Static characteristics
2. Dynamic characteristics

- **Static characteristics**

Static characteristics of vehicle includes the vehicle dimensions, weight, axle configuration, turning radius and turning path.

- **Vehicle Dimensions**

The vehicular dimensions which can affect the road and traffic design are mainly: **width, height, length, rear overhang, and ground clearance**. The width of vehicle affects the **width of lanes, shoulders and parking facility**.

The capacity of the road will also decrease if the width exceeds the design values. The **height of the vehicle affects** the clearance height of structures like over- bridges, under-bridges and electric and other service lines and also placing of signsand signals.

Another important factor is the **length of the vehicle** which **affects** the extra width of pavement, minimum turning radius, safe overtaking distance, capacity andthe parking facility.

The **rear overhang** control is mainly important when the vehicle takes aright/left turn from a stationary point.

The ground clearance of vehicle comes into picture while designing ramps and property access and as bottoming out on a crest can stop a vehicle from moving under its own pulling power.

1. Weight, axle configuration etc.

The weight of the vehicle is a **major consideration during the design of pavements both flexible and rigid.**

The **weight of the vehicle** is transferred to the **pavement** through the axles andso the **design** parameters are fixed on the basis of the number of axles.

The power to weight ratio is a measure of the ease with which a vehicle can move. It determines the operating efficiency of vehicles on the road.

The ratio is more important for heavy vehicles. The power to weight ratio is the major criteria which determines the length to which a positive gradient can be permitted taking into consideration the case of heavy vehicles.

2. Turning radius and turning path

The minimum turning radius is dependent on the design and class of the vehicle. The effective width of the vehicle is increased on a turning. This also important at an intersection, roundabout, terminals, and parking areas. acceleration and braking characteristics, Power Performance and some aspects ofvehicle body design.

1. Speed

The vehicle speed affects, **(i)** sight distances **(ii)** super elevation, length of transition curve and limiting radius on horizontal curves **(iii)** length of transition curves on vertical valley curves and humps **(iv)** width of pavement shoulders on straight and on horizontal curves **(v)** design gradient **(vi)** capacity of traffic lane **(vii)** design and control measures on intersections.

2. Acceleration Characteristics

The acceleration capacity of vehicle is dependent on its mass, the resistance to motion and available power. In general, the acceleration rates are highest at low speeds, decreases as speed increases.

Heavier vehicles have lower rates of acceleration than passenger cars. The difference in acceleration rates becomes significant in mixed traffic streams. Forexample, heavy vehicles like trucks will delay all passengers at an intersection.

Again, the gaps formed can be occupied by other smaller vehicles only if they are given the opportunity to pass. The presence of upgrades make the problem more severe.

3. Braking performance

As far as highway safety is concerned, the braking performance and deceleration characteristics of vehicles are of prime importance. The time and distance taken to stop the vehicle is very important as far as the design of various traffic facilities are concerned.

Trucks are forced to decelerate on grades because their power is not sufficient to maintain their desired speed. As trucks slow down on grades, long gaps will be formed in the traffic stream which cannot be efficiently killed by normal passing maneuvers.

The factors on which the braking distance **depends are the type of the road and its condition, the type and condition of tire and type of the braking system.**

The main characteristics of a traffic system influenced by braking and 4deceleration performance are: (i) sight distance (ii) clearance and change in interval (iii) sign placement

Safe stopping sight distance: The minimum stopping sight distance includes both the reaction time and the distance covered in stopping. Thus, the driver shouldsee the obstruction in time to react to the situation and stop the vehicle.

Clearance and change interval: The Clearance and change intervals are again related to safe stopping distance. All vehicles at a distance further away than one stopping sight distance from the signal when the Yellow is flashed is assumed to be able to stop safely.

Sign placement: The placement of signs again depends upon the stopping sight distance and reaction time of drivers. The driver should see the sign board from a distance at least equal to or greater than the stopping sight distance.

3. Power performance of vehicles

Knowledge of the power performance of a vehicle is necessary to determine the vehicle running costs and the geometric design elements like grades.

The power developed by the engineer (P_p) should be sufficient to overcome all resistance to motion at the desired speed and to acceleration at any desired rate to the desired speed. The forces have to be overcome for this purpose:

1. Rolling resistance(P_f)
2. Air resistance(P_a)
3. Grade resistance(Pi)

4. Inertia forces during acceleration and deceleration(P_j)

5. Transmission losses

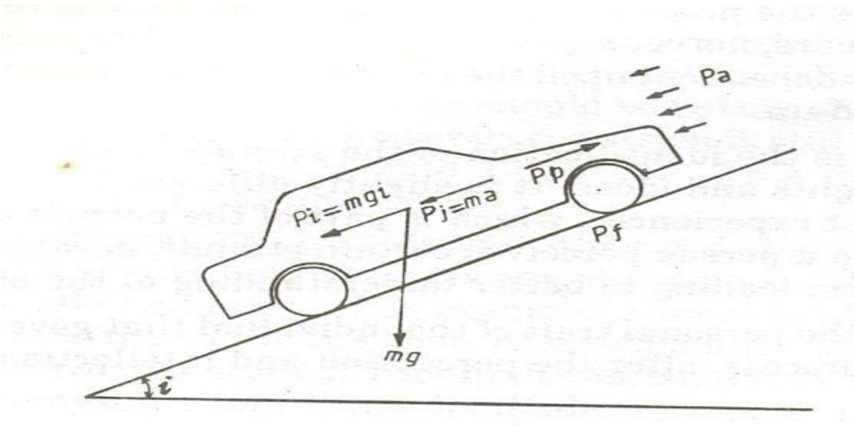


Fig. 2·1. Forces acting on a vehicle.

1.3.1 TRAFFIC CHARACTERISTICS

Traffic engineering covers a broad range of engineering applications with a focus on the safety of the public, the efficient use of transportation resources, and the mobility of people and goods.

Traffic engineering involves a variety of engineering and management skills, including design, operation, and system optimization. In order to address the above requirement, the traffic engineer must first understand the traffic flow behaviour and characteristics by extensive collection of traffic flow data and analysis. Based on this analysis, traffic flow is controlled so that the transport infrastructure is used optimally as well as with good service quality.

❖ In short, the role of traffic engineer is to protect the environment while providing mobility, to preserve scarce resources while assuring economic activity, and to assure safety and security to people and vehicles, through both acceptable practices and high-tech communications is difficult to categorize them into separate well defined disciplines because of the significant overlap, it may be worth the effort to highlight the importance given by the transportation community.

They can be enumerated as below:

1. **Public transportation**: Public transportation or mass transportation deals with study of the transportation system that meets the travel need of several people by sharing a vehicle. Generally this focuses on the urban travel by bus and rail transit. The major topics include characteristics of various modes; planning, management and operations; and policies for promoting public transportation.

2. **Financial and economic analysis:** Transportation facilities require large capital investments. Therefore it is imperative that whoever invests money should get the returns. When government invests in transportation, its objective is not often monetary returns; but social benefits. The economic analysis of transportation project tries to quantify the economic benefit which includes saving in travel time, fuel consumption, etc. This will help the planner in evaluating various projects and to optimally allocate funds. On the contrary, private sector investments require monetary projects from the projects. Financial evaluation tries to quantify the return from a project.

Environmental impact assessment: The depletion of fossil fuels and the degradation of the environment has been a severe concern of the planners in the past few decades. Transportation; in spite of its benefits to the society is a major contributor to the above concern. The environmental impact assessment attempts in quantifying the environmental impacts and tries to evolve strategies for the mitigation and reduction of the impact due to both construction and operation. The primary impacts are fuel consumption, air pollution, and noise pollution.

4. **Accident analysis and reduction:** One of the silent killers of humanity is transportation. Several statistics evaluates that more people are killed due to transportation than great wars and natural disasters. This discipline of transportation looks at the causes of accidents, from the perspective of human, road, and vehicle and formulate plans for the reduction.

5. **Intelligent transport system:** With advent to computers, communication, and vehicle technology, it is possible in these days to operate transportation system much effectively with significant reduction in the adverse impacts of transportation. Intelligent transportation system orders better mobility, efficiency, and safety with the help of the state-of-the-art-technology.

The study of traffic engineering may be divided into six major sections:

1. Traffic characteristics
2. Traffic surveys and analysis
3. Traffic operation control and regulations
4. Planning and analysis
5. Geometric design
6. Traffic management

5E'S OF TRAFFIC ENGINNERING:

1. Engineering
2. Enforcement
3. Education
4. Economics
5. Environmental

1.4 ORIGIN AND DESTINATION SURVEY

The origin and destination survey carried out mainly due to

(i) plan the road network facilities for vehicular traffic, and

(ii) plan the schedule of different modes of transportation for the trip demand ofcommuters

(iii) to locate the intermediate stops

(iv) to establish the design standards for the road, bridges and culverts along theroute

(v) to locate the terminals and plan the terminal facilities

(vi) to plan the transportation system and mass transit facilities in cities including routes and schedules of operation to judge adequacy of existing routes and to use in planning new networks of roads.

There are a number of methods for collecting the O-D data. Some of the methods are commonly adopted are:

1. **Roadside 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**

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.

License plate method

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.

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 method is part of the road users may return the cards promptly after filling in the desire details properly and correctly.

Tag on car method

In this method a pre-coded card stuck on the vehicles as its enters the area under study. When the car leaves cordon area 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.

Home interview method

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.

Work spot interview method

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

1.5 ACCIDENT STUDIES

The traffic accidents may involve property damages, personal injuries or even casualties. One of the main objective 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.

The objective of the accident studies may be listed below:

To study the causes of accidents and to suggest corrective treatment at location,

- To evaluate the existing design
- To support the proposed designs
- To carryout the before and after studies and to demonstrate the improvement inthe problem
- To make computations of financial loss

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.

Causes of accidents

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 due to 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 drivingunsafe.

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. Forexample 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 aparticular 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

2.1 TRAFFIC FLOW CHARACTERISTICS

Traffic surveys are carried out to analyses the traffic characteristics. These studies help in deciding the geometric design feature and traffic control for safe and efficient traffic movements. Traffic surveys for collecting traffic data are also called traffic census.

The various traffic surveys generally carried out are:

1. Traffic volume count survey
2. Speed studies
   a. Spot speed studies
   b. Speed and delay studies
3. Origin and destination survey
4. Parking survey
5. Accident studies
6. Traffic flow characteristics
7. Traffic capacity studies

2.1.1 TRAFFIC VOLUME COUNT SURVEY

Methods of Measurements:

a. Measurement at a point of road
b. Measurement over short section of road
c. Measurement over long section of road
d. Moving observer method

Traffic volume is the number of vehicles crossing a section of road per unit time at any selected period. The **uses of traffic volume survey are given below:**

1. Traffic volume survey is used in planning, traffic operation and control of existing facilities and also for planning and designing the new facilities.
2. This survey is used in the analysis of traffic patterns and trends.
3. Volume distribution study is used in planning one-way streets and other regulatory measures.
4. It is used for design of intersections, in planning signal timings, channelization and

other control devices.

5. Classified volume count survey is useful in structural design of pavements, in geometric design and in computing roadway capacity.
6. Pedestrian volume study is used for planning sidewalks, cross walks, subways and pedestrian signals.
7. To determine the traffic flow or traffic in the peak hour.

Methods Available For Traffic Counts

The available for traffic volume counts are listed below:

1. Manual count
2. Mechanical count
3. Combination of manual and mechanical methods
4. Automatic devices(pneumatic tube, photo electric cells, magnetic detectors and radar detectors)
5. Photographic methods

Number of lanes in the highway on which the count is to be taken and the type of information desired. However it is not practicable to have counts for all the 24 hoursof the day and on all days round the year.

Equipment needed:

The following equipment is needed for manual counts,

1. A watch
2. Pencils or pen
3. Supply of blank field data sheet with clip board

The **advantages** of manual methods and situations where these are to be preferred are:

1. Data accumulated by manual methods are easy to analyse.
2. Manual methods are suitable for short-term and non-continuous counts.
3. Details such as vehicle classification and number of occupants can be easilyobtained.
4. Specific vehicular movements such as left turns, right turns, straight aheadetc.at a junction can be noted and recorded.
5. Even if automatic devices are used, it is often necessary to check the

accuracyof these devices periodically and manual methods are serving this purpose.

Disadvantages of manual methods:

It is not practicable to have counts for all the 24 hours of the day and on all days round the year.

Mechanical counts:

The method employs a field team to record traffic volume on the prescribed record sheets. By this method it is possible to obtain data which can not be collected by mechanical counters, such as **vehicle classification, turning movements and counts where loading conditions or numbers of occupants are required**.

However it is not practicable to have counts for all the 24 hours of the day and on all days round the year.

Hence it is necessary to resort to statistical sampling techniques in order to cut down the manual hours involved in taking complete counts complete counts, first the fluctuations of traffic volume during the hours of the day and the daily variations are observed. Then by **statistical analysis** the peak hourly traffic volume as well as average daily traffic volumes are calculated.

Combination of Manual and Mechanical Method:

An example of a combination of manual and mechanical method is the multiple pen recorder. A chart moves continuously at the speed of a clock. Different pens record the occurrence of different events on the chart.

The main advantage of this method is

(i) A permanent record is kept arrival of each class of vehicle. The classification and vehicle count performed simultaneously.

(ii) Additional information such as time headways between successivevehicles and the arrival per unit time become available.

Automatic devices:

- Photo electric cells
- Magnetic detector and
- Radar detectors
- Pneumatic tube

- Electric contact
- Co axial cable

Photographic method:

In this method, the video camera stationed on the top of an elevated building select vehicles at random and follow their course along the road, noting the number of vehicles entering the test section. This method useful for studying short test sections like intersection etc.

Presentation of traffic volume data:

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.

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 onweekdays for some period of time less than one year, such as for a month or a season. **PCU(passenger car unit): It is common practice to consider the passenger car asthe standard vehicle unit to convert the other vehicle classes and this unit iscalled passenger car unit or PCU**

2.2 SPEED STUDIES

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

SPOT SPEED

Spot speed is the **instantaneous speed of a vehicle** at a specified location.

Uses:

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

1. 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.**

2. **Accident analysis**, road maintenance, and congestion are the modern fields of traffic engineer, which uses spot speed data as the basic input.

3. To use in planning **traffic control** and in **traffic regulations**.

Spot speed can be measured using an **enoscope,** pressure contact tubes or direct timing procedure or radar speedometer or by time-lapse photographic methods.

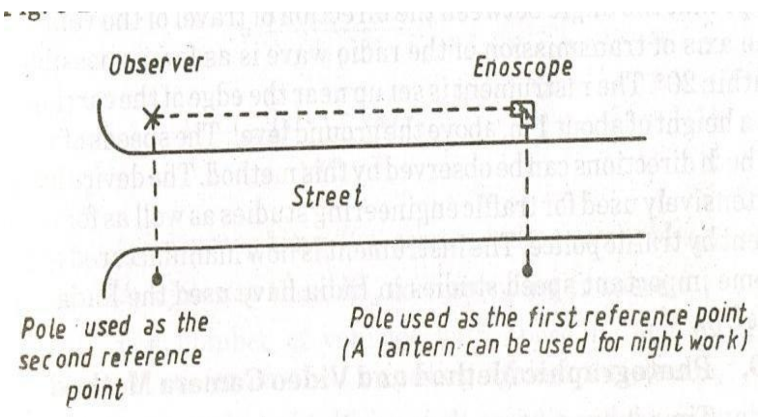
Spot speed by enoscope method:

It is one of the simplest methods of finding spot speed is by using enoscope which 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 30m 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.

The main advantage of this method is that it is a simple and cheap equipment and is easy to use. The greatest disadvantage is that the progress is so flow as it is difficult to spot out typical vehicles and the number of samples observed willbe les. There is also a possibility of human error.



Spot Speed by Enoscope

Other equipment used:

Graphic recorder

Photo electric meter

Speed meter

Photographic method

radar

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.(EXCLUIDING DELAY)

Journey 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 forthe vehicle to complete the journey including any stopped time.(INCLUDING DELAY)

Time mean speed:

Time mean speed is defined as the average speed of all the vehicles passing apoint on a highway over some specified time period.

Space mean speed:

Space mean speed is defined as the average speed of all the vehicles occupyinga given section of a highway over some specified time period.

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

Average speed:

It is the average of the spot speeds of all vehicles passing a given point on the highway.

2.3 CAPACITY AND LEVEL OF SERVICE

Overview

Capacity and Level of service are two related terms. Capacity analysis tries to give a clear understanding of how much flow much traffic a given transportation facility can accommodate. Level of service tries to answer how much flow good is the present traffic situation on a given facility. Thus it gives a qualitative measure of traffic, whereas capacity analysis gives a quantitative measure of a facility. Capacity and level of service varies with the type of facility, prevailing traffic and road conditions etc. These concepts are discussed in this chapter.

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.

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. The highway capacity depends on certain conditions as listed below;

1. **Traffic conditions:** It refers to the traffic composition in the road such as the mix of cars, trucks, buses etc in the stream. It also include peaking characteristics, proportions of turning movements at intersections etc.
2. **Road way characteristics:** This points out to the geometric characteristics of the road. These include lane width, shoulder width, lane configuration, horizontal alignment and vertical alignment.
3. **Control conditions:** This primarily applies to surface facilities and often refer tothe signals at intersections etc.

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. A service volume is the maximum number of vehicles, passengers, or the like, which can be accommodated by a given facility or system under given conditions at a given 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 form level A to level F. Level A represents the best quality of traffic where the driver has the freedom to drive with free flow speed and level F represents the worst quality of traffic. Level of service is defined based on the measure of effectiveness or (MOE).

Typically three parameters are used under this and they are speed and travel time, density, and delay. One of the important measures of service quality is the amount of time spent in travel. Therefore, speed and travel time are considered to be more effective in defining LOS of a facility. Density gives the proximity of other vehicles in the stream.

Since it affects the ability of the driver to maneuver in the traffic stream, it is also used to describe LOS. Delay is a term that describes excess or unexpected time spent in travel. Many specific delay measures are defined and used as MOE's in the highway capacity manual.

Factors affecting level of service

Level of service was introduced in Highway capacity manual(HCM) to denote the 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

1. Speed and travel time

2. Traffic interruptions/restrictions
3. Freedom to travel with desired speed
4. Driver comfort and convenience
5. Operating cost

2.4 PASSENGER CAR UNIT

Passenger Car Unit (PCU) is a vehicle unit or car unit used to measure the rate of traffic flow on highway. In other words, PCU is a measure of number of vehicles moving on a highway at a given point of time. In some instances, PCU is referred to as Passenger Car Equivalent (PCE).

Traffic flow is a measure of flow of vehicles on a road from one point to another point at a given point of time. The flow of traffic on highway consists of different classes of vehicles that are classed as follows:

Cars

Buses

Heavy Commercial Vehicles

Light Commercial Vehicles

Auto-Rickshaws

Two-wheeler automobiles etc..

The movement of different class of vehicles of highway is termed as mixed traffic flow. In developing countries like India, the traffic stream consists of mixed traffic flow.

PASSENGER CAR

To describe the entire traffic flow on a highway per unit time, the flow of various vehicle classes must be converted into a single standard vehicle type, such as Passenger Car. As a result, Equivalency factor known as passenger car unit (PCU) is allotted to each vehicle type.

Unless the various vehicle classes are converted to a single common standard vehicle unit, estimating the traffic volume of roadway facilities under mixed traffic flows is difficult.

The different vehicle classes have a wide range of static and dynamic properties, such as length, width, and so on. Apart from that, the driver behavior of various vehicle types is found to differ significantly. As a result, mixed traffic flow characteristics are far more complex than homogeneous traffic consisting solely of passenger cars.

PCU VALUES FOR DIFFERNT CONDITIONS

PCU per hour per lane width or PCU per hour for the full roadway are used to describe the capacity of various types of roadway facilities with mixed traffic flow, such as highways in rural areas and roads in urban areas.

For different types of fast and slow moving vehicles on rural roads, The Indian Road Congress (IRC) has proposed a range of PCU values in India for different types of vehicles on roads in rural areas.

Sl. No.	Vehicle Class	Equivalency Factor
Fast Vehicles		
1	Motor cycles and scooter	0.5
2	Passenger car, Pick-up van and auto-rickshaw	1.0
3	Agricultural tractor and light commercial vehicles	1.5
4	Single unit Truck and Bus	3.0
5	Truck-trailer and agriculture tractor - trailer	4.5
Slow Vehicles		
6	Pedal Cycle	0.5
7	Cycle Rickshaw	2.0
8	Hand Cart	3.0
9	Horse drawn vehicle	4.0
10	Bullock cart	8.0

PCU Values recommended by the IRC 064: 1990 for different types of vehicles on roads in rural areas

Rural

PCU Values recommended by the IRC 064: 1990 for different types of vehicles on roads in rural areas

Equivalency factors will differ depending on the terrain, such as rolling/hilly sections. Since the influence of terrain in the design of service volumes for traffic in various terrains has been accounted for in a consolidated way. Therefore, IRC has proposed a range of PCU values in India for different types of vehicles on urban roads.

Urban

PCU Values recommended by the IRC 106: 1990 for different types of vehicles on roads in urban areas

Sl. No.	Vehicle Class	Equivalency Factor	
		Percentage composition of vehicle type in traffic stream	
Fast Vehicles		**5%**	**10% & Above**
1	Two wheelers - motor cycle, scooter, etc.	0.5	0.8
2	Passenger car, Pick-up van	1.0	1.0
3	Auto-rickshaw	1.2	2.0
4	Light Commercial vehicle	1.4	2.0
5	Truck or Bus	2.2	3.7
6	Agricultural Tractor - trailor	4.0	5.0
Slow Vehicles			
7	Pedal cycle	0.4	0.5
8	Cycle rickshaw	1.5	2.0
9	Tonga (Horse drawn vehicle)	1.5	2.0
10	Hand cart	2.0	3.0

PCU Values recommended by the IRC 106: 1990 for different types of vehicles on roads in urban areas

METHODS OF ESTIMATING PCU

The different types of methods mostly used to determine the different vehicle classes of PCU values are:

Homogenous Coefficient Method

Headway method

Multiple Linear Regression Method

Walker's Method

Simulation Technique

Simultaneous Equations Method

Huber Method

Speed Based Method

FACTORS AFFECTING PCU VALUES

Several factors influence the PCU values of different vehicle types. Such as

Dimensions of vehicle i.e. Length and width

Dynamic characteristics of the vehicle – speed, acceleration, etc.

Environmental and Climatic conditions

Traffic regulation and control

Roadway characteristics such as gradient, curves, intersections, geometrics, etc.

Characteristics of traffic stream

There should be enough space between the moving vehicles.

The PCU value of a specific vehicle may not be as consistent as commonly believed. The PCU value of a vehicle class is found to fluctuate based on a number of factors. As a result, the PCU of a certain vehicle class is a dynamic changeable value that rarely remains constant.

3.1 TRAFFIC MANAGEMENT SYSTEMS (TMS)

Traffic Management Systems (TMS) use a variety of technologies to manage traffic flows and the effects of congestion on the roading network. Traffic Management Systems do this by addressing the traffic management effects of accidents and slow moving or queuing vehicles, planned events and extreme weather. TMS include, ramp signaling, dynamic lane management, variable speed limits, incident detection, vehicle activated signs and adaptive traffic signal control.

Many of the systems are usually integrated to gain maximum benefit. Managing the allocation of road space is an important concept that is becoming increasingly relevant as it is not feasible or cost-effective to continue to accommodate the growth of urban traffic by constructing additional roads.

Tools for Traffic Management Systems

Incident detection tools are designed to reduce the time taken in identifying and reacting to incidents on the network. If combined with other TMS and Traveler Information Services (TIS) it can improve network efficiency by minimizing congestion. It can also contribute to reduced response times for emergency vehicles and also minimise the chances of secondary accidents occurring.

Automatic Incident Detection

(AID) is usually implemented through the use of sensors or detectors and aims to detect traffic incidents along major roadways. Sensors are usually divided into two categories; intrusive (buried within the road) and non-intrusive (not buried within the road). Ramp signals are essentially traffic lights at motorway on-ramps that manage the flow of traffic onto the motorway during peak periods. When lights are red, vehicles stop and wait for the green signal. When lights turn green, two cars (one from each lane) are able to drive down the ramp to merge easily with motorway traffic. Ramp signals run on a quick cycle, only a few seconds between green lights.

Ramp signals do not have to operate all the time and can be switched on when necessary, especially during morning and afternoon peaks and other busy times. Ramp metering can be a cost effective tool in improving the throughput of a motorway and overall road network. It is most effective when applied system wide along a corridor that balances the needs of maximizing motorway throughput in addition to effective queue management.

Variable message signs

(VMS) can be used to alert drivers to traffic incidents ahead, congestion, events, parkingavailability and weather conditions.

There are three broad categories of information that can be displayed via VMSs:

• control (e.g. lane control, prescribing control)

• warning (e.g. weather conditions, incidents, congestion, road works, road closures)

• information (e.g. useful traffic/weather information, network messages, safety messages)The benefits of providing real time travel information include:

• a reduction in driver frustration

• allowing drivers to choose to use alternative routes

• a reduction in congestion

• improved safety

Variable Speed
Limits

(VSL) and advisory speeds are designed to 'smooth traffic flow' by introducing a temporary speed limit based on traffic volumes and hence delay the start of

conditions. Other outcomes include enhanced safety and reduced vehicle emissions. VSL systems primarily aim to reduce incidents by managing the posted speed limits for congested or hazardous situations.

The benefits of variable speed signs are that they:

• improve journey times

• smooth traffic flow by minimising vehicles stopping and starting

• reduce accidents

• produce environmental benefits through fewer emissions

Adaptive Traffic signal

Adaptive traffic signals can improve network efficiency by optimising signal timings and balancing traffic flows. This is achieved through automatic updating of cycle times that highlight changes in traffic distribution and volumes. Adaptive Traffic signal control enable traffic signal controlled

junctions to interact with each other. Such tools include Sydney Coordinated Adaptive Traffic System (SCATS). Adaptive traffic signal control systems seek to optimise traffic flow by considering traffic flow at multiple sites rather than a single junction's performance. This area wide approach can bring significant traffic management benefits including reduced congestion and faster more reliable journey times.

3.2 TRAFFIC MANAGEMENT MEASURES

The fundamental approach in traffic management measures is to restrain as much as possible existing pattern of streets but to alter the pattern of traffic movement on these, so that the most efficient use is made of the system.

Some of the well-known traffic management measures are

Regulatory Techniques:

i. Restrictions on turning movements

ii. One-way streets

iii. Tidal-flow operations

iv. Exclusive Bus-lanes

v. Closing side-streets

1.RESTRICTIONS OF TURNING MOVEMENTS

a. The problem posed by turning traffic

At a junction, the turning traffic includes left-turners and right-turners. Left –turning traffic dose not usually obstruct traffic flows through the junctions, but right-turning traffic can cause serious loss of capacity.

At times, right-turning traffic can lock the flow and bring the entire flow to a halt. One way of dealing with heavy right-turning traffic is to incorporate a separate right-turning phase in the signal scheme, or to introduce an early cut-off or late start arrangement. These schemes have their limitations and result in a long signal cycle. Another solution is to ban the turning movement altogether.

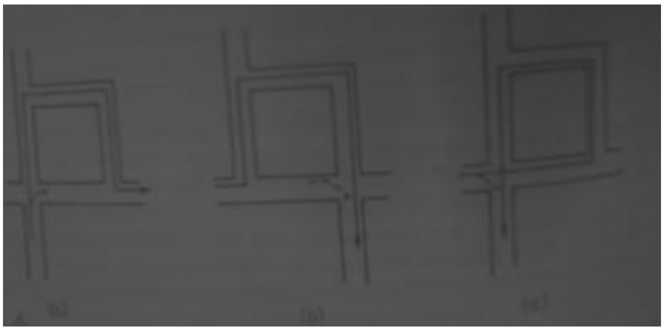
b.Prohibited right- turning movement

Prohibition of right-turning movement can be established only if the existing street system is capable of accommodating an alternative routing. Depending upon the existing layout of the street system, three methods are available:

i. Diversion of the right-turning traffic to an alternative intersection further along the road where there is more capacity for dealing with a right-turn. This scheme is known as a T turn.(fig a)

ii. Diversion of the right-turning traffic to the left before the junction. This scheme is known as a G turn.(fig b)

iii. Diversion of the right-turning traffic beyond the junction. This scheme is known as a Q turn.(fig c)



2. ONE-WAY STREETS

One-way streets are those where traffic movement is permitted in only one direction**.** As a traffic management measure intended to improve traffic flow, increase the capacity and reduce the delays, one-way streets are known to yield beneficial results.

Advantages of one-way streets

i. **A reduction in the points of conflict.** Traffic movements at junctions involve a number of points of conflict. These generate delay, congestion and accident hazards. Any scheme where the points of conflict are reduced in number is thus conductive to better safety and less delay.

ii. **Increased capacity.** The removal of opposing traffic and the reduction of intersection points of conflict results in a marked increase in the capacity of a one-way street.

iii. **Increased speed.** Since the opposing traffic is eliminated, drivers can operate at higher speeds. This is further facilitated by the more efficient operation of the traffic signal system that is possible under one-way street operation.

Disadvantages

i. Although the journey times and delays are reduced, the actual distances to be covered by drivers increase.

ii. Where buses operate on the streets, the stop will have to be relocated and in many instances the passengers will have to be relocated and in many instances the passengers will have to walk extra distances.

iii. The excessive speeds that follow as a result of one-way operation may be a hazard to residential areas. Thus, while the number of accidents may decrease, the severity will increase with one-way operation.

3. TIDAL FLOW OPERATION

One of the familiar characteristics of traffic flow on any street leading to the city center is the imbalance in directional distribution of traffic during peak hours. One of the methods of dealing with this problem is to allot more than half the lane for one direction during peak hours. This system is known as “tidal flow operation” or reverse flow operation.

Methods

The principle of tidal flow operation can be translated into practice in two ways:

(i) The first is to apportion a great number of lanes in a multi-lane street to the in-bound traffic during morning peak and similarly a great number of lanes to the out-bound traffic during the evening peak.

(ii) The second requires the existence of two separate streets parallel to each other and close to each other, so that the wider of the two can be set apart for the heavier traffic both during morning peak and evening peak. In this case, the two streets will operate as one-way streets.

4. CLOSING SIDE-STREETS

Method

A main street may have a number of side-streets where the traffic may be very light. In such situations, it may be possible to close some of these side-streets without affecting adversely the traffic, and yet read a number of benefits.

Advantages

i. Since interference from the traffic from side streets is eliminated, the speed increases and journey time reduces.

ii. For the same reason as above, the accident gets reduced.

iii. If the side streets are too many and at close intervals, it is difficult to formulate a scheme for the progressive system of signals.

Disadvantages

i. Closure of a number of cross-streets may increase the flow to and fro the remaining cross-streets. This may necessitate signal control and other measures at these junctions.

ii. When a number of side-streets are closed, the immediate effect is an increase in the parking of vehicles on the main street itself.

5.EXCLUSIVE BUS LANES

Exclusive bus lanes running against heavy one-way flow are also very common. One experience suggests that such an arrangement nearly halves the journey time. A good measure of enforcement is needed if serious accidents have to be avoided in this system.

Bus priority measures are a cheap and easy way to provide some aid to bus services. The journey time can be considerably reduced and bus journey time can be made more attractive.

3.3 TRAVEL DEMAND MANAGEMENT

This user service develop and implement strategies to reduce the number of single occupancy vehicles while encouraging the use of high occupancy vehicles and the use of more efficient travel mode. The strategies adopted are:

1. Congestion pricing
2. Parking management and control
3. Mode change support
4. Telecommuting and alternate work schedule.Emissions Testing and Mitigation

The main objective of this service is to monitor and implement strategies to divert traffic away from sensitive air quality areas, or control access to such areas using advanced sensors. This also used to identify vehicles emitting pollutants exceeding the standard values and to inform drivers to enable them to take corrective action. This helps in facilitating implementation and evaluation of various pollution control strategies by authorities.

Highway Rail Intersection

This service is to provide improved control of highway and train traffic to avoid or decrease the severity of collisions between trains and vehicles at highway-rail intersections. This also monitors the condition of various HRI equipments.

TDM techniques are aimed at reducing traffic flows, especially during the peak hour. Some of thecommonly adopted are:

1. Car pooling and other ride-sharing programs
2. Peripheral parking schemes
3. Chartered buses (Institutional buses) to serve areas of trip origins to common work place
4. Staggering of office hours and flexible time of work
5. Internal shuttle service in the CBD
6. Parking restraint
7. Road Pricing
8. Entry fee

9. Priority for buses in traffic

10. Restrictions on entry of trucks during day timeTraffic calming

Traffic calming consists of physical design and other measures for the intention of reducing the motor vehicle speed as well as to improve the safety of pedestrians and cyclists. Traffic calming includes the engineering measures such as:

a) Narrowing traffic lanes

b)Speed humps

c)Speed cushions

d)Speed tables

Tidal Flow Operation

The morning peak results in a heavy attraction of flow towards the city centre, whereas the evening peak brings in heavier flow away from the city centre. In either case, the street space provided for the opposing traffic will be found to be in excess. This phenomenon is called as 'Tidal flow'. One method of dealing with the problem of tidal flow is to allot more than half the lanes for one direction during peak hours. This system is known as 'Tidal flow operation', or 'Reverse flow operation'.

3.4 TRAFFIC SIGNALS

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 ofthe intersections at grade.
- They reduce certain types of accidents, notably the right-angled collisions.
- Pedestrians can cross the road 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 oftraffic 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 theroad users.

Type of traffic signal

The signals are classified into the following types:

1. Traffic control signals

a. Fixed-time signals

b. Manually operated signals

c. Traffic actuated (automatic) signal

2. Pedestrian signal

3. Special traffic signal

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.

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 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 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.*Vechicle Acuated 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.*Semivehicle Acuated 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 withthe help of detectors installed at the approaches.

manually operated signals

This type of signal operated by manually. normally traffic police can operate this type signals.

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 signals of the road.

3.5 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:

Traffic Control Devices

1) Signs
2) Markings
3) Signals and
4) Islands.

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

Traffic signs have been divided into three categories according to Indian motor vehicles act. 1)

Regulatory signs

i) Prohibitory signs

ii) Mandatory signs

2) Warning or danger signs

3) Informatory signs.

i) Indication signs

ii) Advance direction signs

iii) Place and route identification signs.

1. 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. Regulatory signs are further sub-divided intotwo 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 the following types:

a) Movement prohibition (such as prohibition of right turns, prohibition of overtaking, prohibition ofentry, 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 movement s, use of horns or entry of certain vehicles class.

According to the I.R.C. standards, the prohibitory signs are circular in shape and white in color with a red border and a diameter of 600mm. 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 andhorn prohibited.

Fig.1 No Entry

fig.2 One way

fig.3 Right turn prohibited

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-black 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 the place; 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

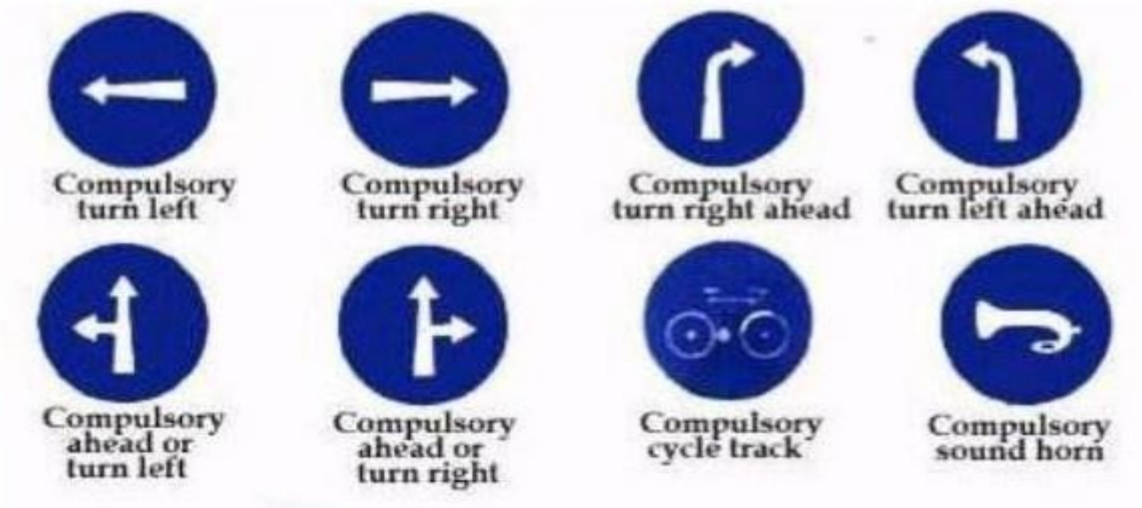
Fig.5 No standing

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 numerals indicating the speed limit.

Fig.6 speed limit

Restricted ends sign indicates the point at which all prohibitions notified by prohibitory signs for moving vehicles case 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.

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 arethe (i) STOP sign and (ii) GIVE WAY sign.

Fig.7 Stop sign fig.8 Giveway sign

Fig.7 Stop sign fig.8 Give way sign

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

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

(i) Street entering a through highway or street

(ii) Unsignalized 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 equilateraltriangle having a red border band with white back round. 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 themajor road.

(ii) On the entrance ramp to an express way when acceleration lane is not provided. The GIVEWAY or YIELD sign should not be used:

(i) On the expressways

(ii) To control the major flow of traffic at an intersection

(iii) On the approach more than one of the intersection streets

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 900mm.

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, pedestrian crossing, school zone, men at work, ferry, cross road, side road, T-intersection, Y- intersection, major road ahead, roundabout, dangerous dip, hump or rough road, barrier ahead, unguarded railway crossing, graduated railway crossing and falling rock.

Fig.2 Warning signs

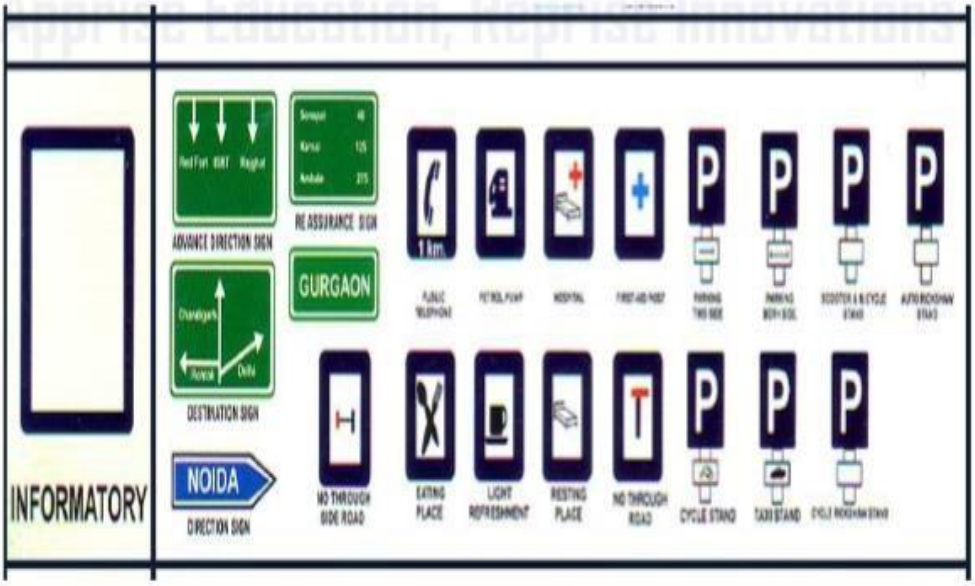
Informatory signs:

These signs are used to guide the road users along routes, inform them of destination and distance andprovide 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

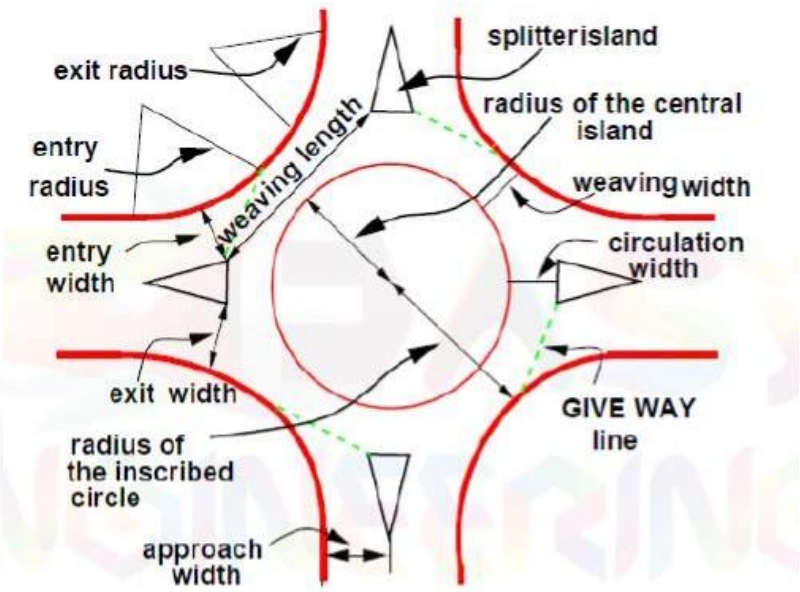
The direction and Place Identification signs are rectangular with white background, black border and black arrows and letters. The signs of this group include Destination signs, Direction signs, Re- assurance signs, Route Marker and Place Identification signs.

The facility Information 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.



4.1 ROTARY INTERSECTION

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



ADVANTAGES OF ROTARY INTERSECTIONS

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

4.2 CHANNELIZED INTERSECTION

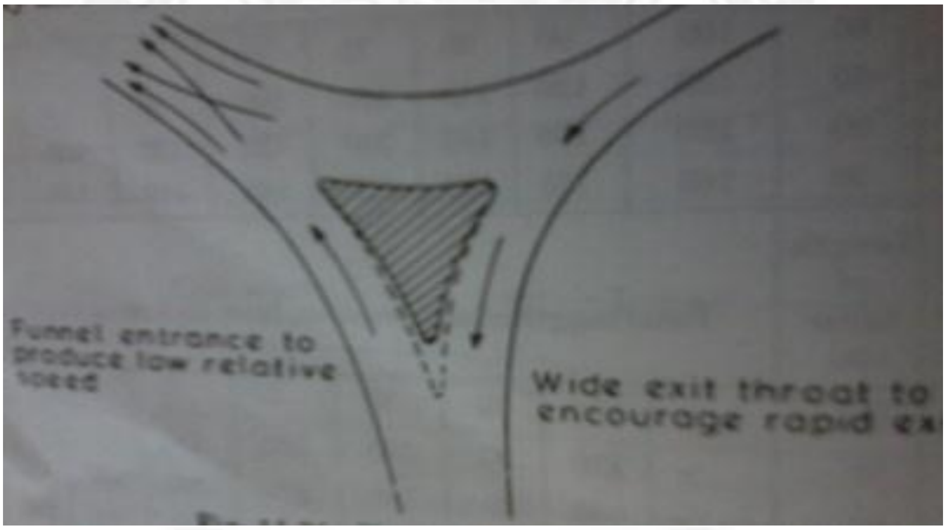
The direction of traffic flow at intersections to definite path, by means of traffic markings, islands orother means is known as channelization.

A channelized intersection is one which traffic is directed into definite paths by islands and markings. 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.

Channelization serves the following Purposes:

1. Separation of conflicts

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

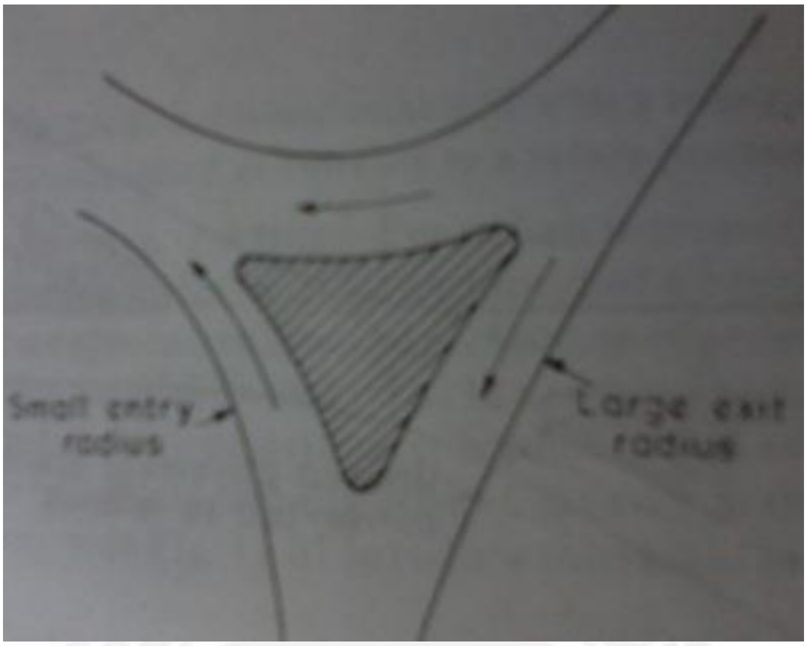


2. Control of angle of conflicts

Small angles of crossing cause severe accidents if they occur. Severity is reduced if the angle of conflictis controlled.

3. Control of speed

To reduce the speed of traffic entering the intersection & 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

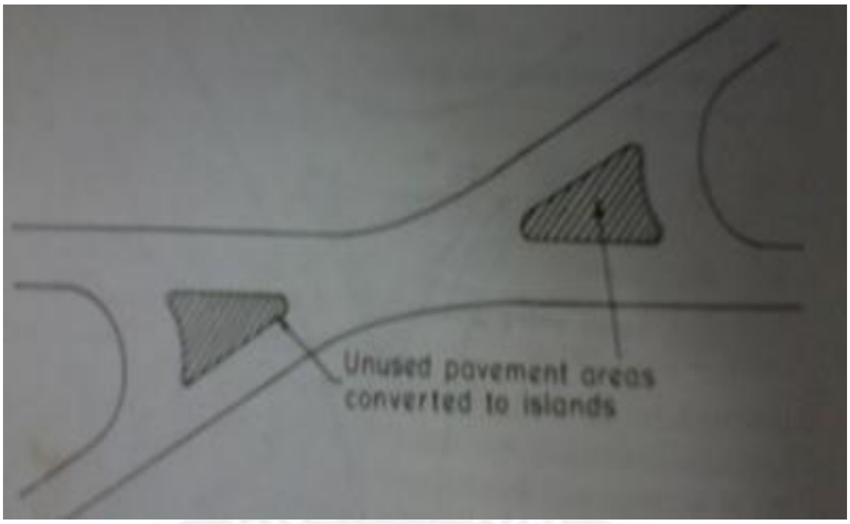
This is exemplified by the separate storage pockets for right turning traffic at an intersection & the adjacent island, vide fig.

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 & 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& 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.

4.3 ROTARY INTERSECTION DESIGN ELEMENTS

a. Design speed

The design speed of a rotary governs the various elements such as radii and weaving length.

Current Indian practice is to design rotaries in rural areas for a speed of 40 K.P.H and those in urban areas to a speed of 30 K.P.H.

b. Radius at Entry

The radius at entry is determined by the design speed, super elevation and coefficient or friction.

A range of 20-35 m is found to be suitable for rural design and a range of 15-20 m is suitable for urban design.

c. Radius at exit

The exit radius should be higher than the radius of rotary island so that it favours a higher speed by drivers. The general practice is to keep the radius of exit curves 11/2 to 2 times the radius of the entry curves.

d. Radius of the central island

The radius of the central island is governed by the rotary design speed and theoretically it should be equal to the radius at entry. In practice the radius of the central island may be kept slightly larger than that of the curve at entry. The value of 1.33 times the radius of entry curve is probably adequate for this purpose.

e. Weaving lengths

The weaving length determines the ease with which the traffic can merge and diverge.

Minimum Length of Weaving Section

Design speed(K.P.H)	Minimum weaving length(m)
40	45
30	30

f. Width of Carriageway at Entry and Exit

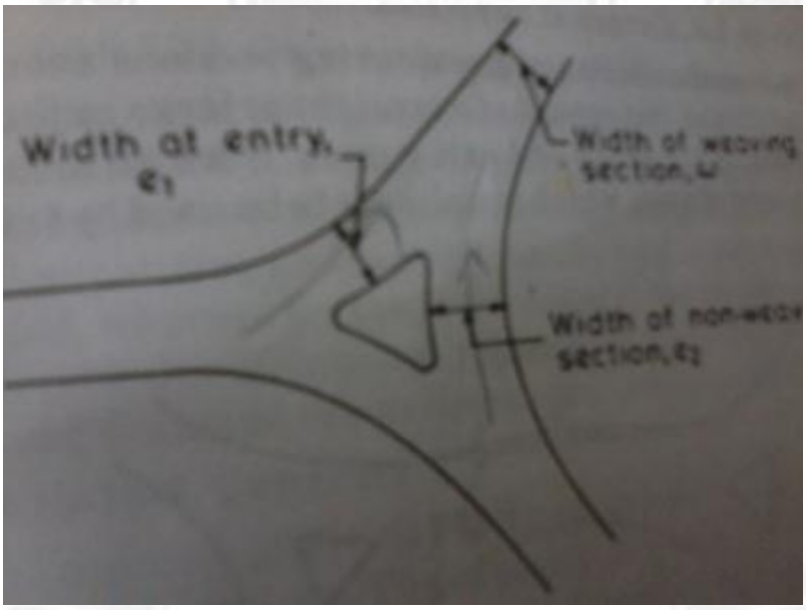
The carriageway width of the intersection legs is governed by the design year traffic entering and leaving the intersection. As per I.R.C minimum width of carriage way of 10m both entry and exit.

g. Width of Rotary Carriageway

The width of the non-weaving section should be equal to be widest single entry into the rotary andshould generally be less than the width of the weaving section.

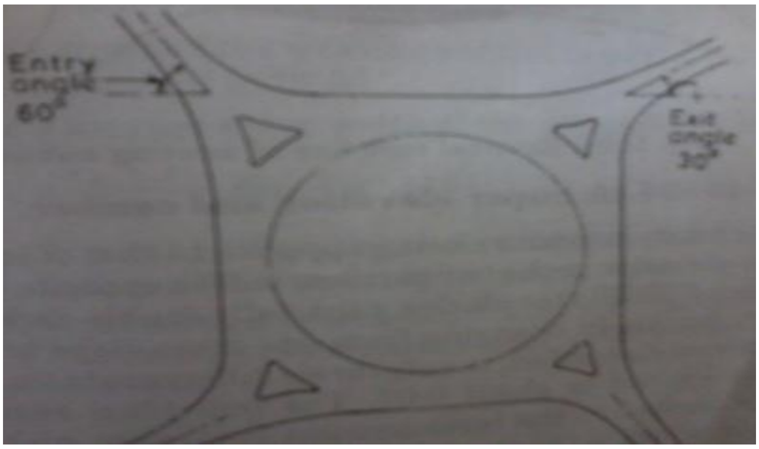
W= (e1 + e2)/2 + 3.5

The entry angles should be larger than exit angles and it is desirable that the entry angles should be about 60 degree, if possible, the exit angles should be small, even tangential.



h. Entry and Exit Angles

Entry angles should be larger than exit angles and it is desirable that the entry angles should be about60◦ and exit angle 30◦ is shown in fig.



i. Capacity

The capacity of a rotary is directly determined by the capacity of each weaving section. Qp = (280 w (1+(e/w)) (1-(p/3))/ 1 + (w/l)

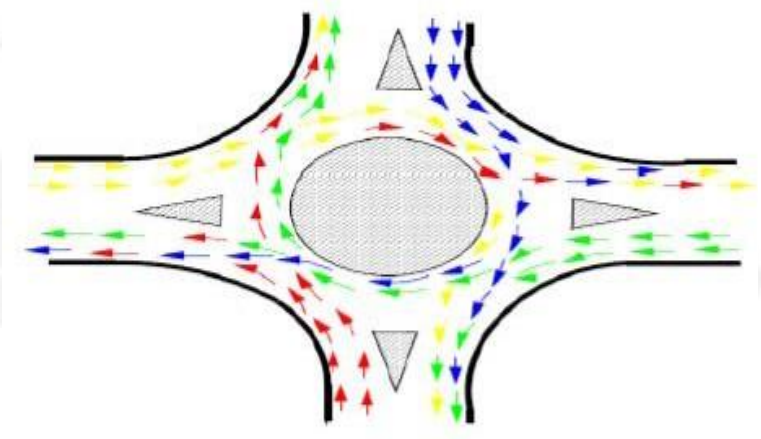
Where,

Qp = practical capacity of the weaving section of the rotary in passenger car units. W= width of the weaving section in meters (within the range of 6-18m)

E = avg entry width of the rotary in meters = (e1+e2)/2

L= length of the weaving section between the ends of the channelization islands in meters.

P = proportion of weaving traffic, i.e ratio of sum of crossing streams to the total traffic on the weavingsection. = (b+c)/(a+b+c+d)



Traffic operation of rotary

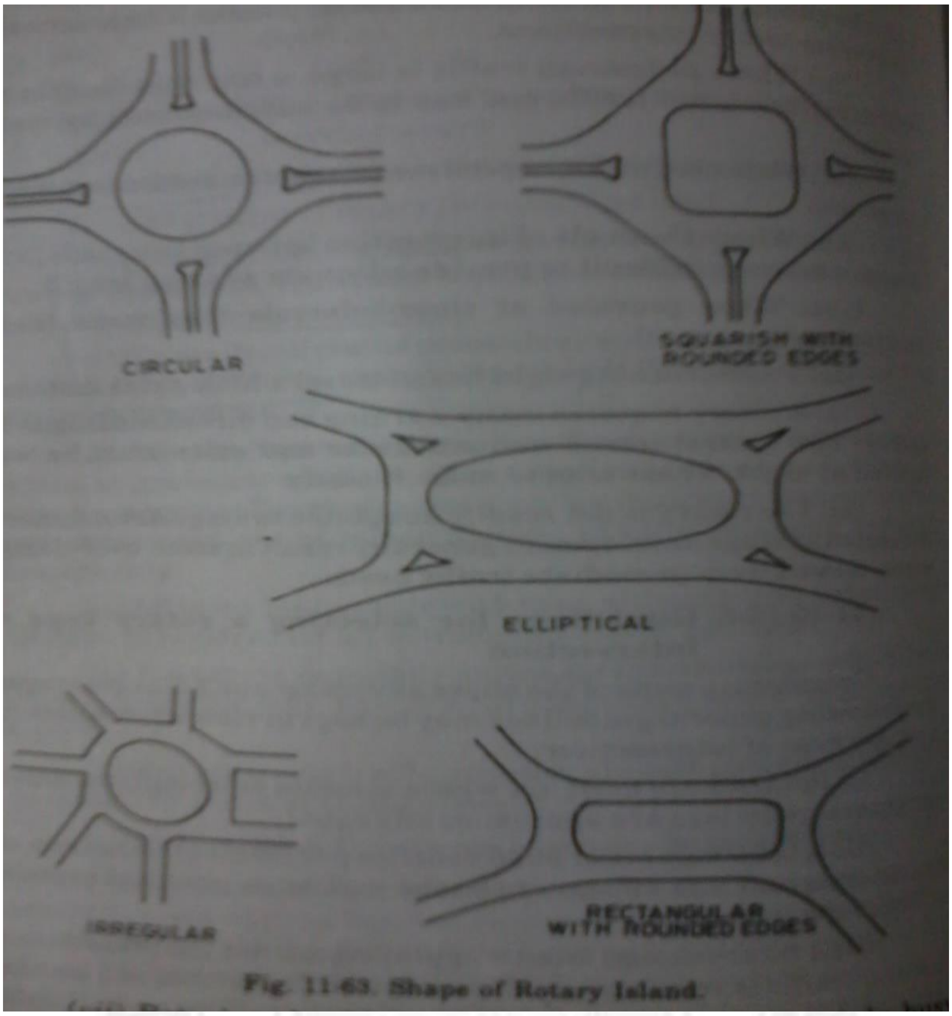


Fig. 11·63. Shape of Rotary Island.

Shape of rotary Island

Types of Grade – Separated Intersection Basically, two types are met with:

1. Grade – separated intersections without interchange.

2. Grade – separated intersections with interchange.

Interchange is a system whereby facility is provided for movement of traffic between two or more roadways at different levels in the grade separated junction. A structure without interchange is an over bridge or underpass or flyover, whereby the traffic at different levels moves separately without a provision for an interchange between them.

The different forms of a grade-separated junction can be considered under the number of legs the intersection serves. Thus, the interchanges can be classified as three-leg & multi leg, & these in turn can be sub-divided into various types as below:

Three - leg interchange.

1. T interchange
2. Y interchange
3. A partial rotary interchange

Four leg interchange

1. Diamond interchange
2. Half clover leaf interchange
3. Clover leaf interchange
4. Directional interchange
5. Rotary interchange.

Multi – leg interchange

1. Rotary interchange.

4.4 SIGNALIZED INTERSECTION

Traffic Signal Design

Definitions and notations

A number of definitions and notations need to be understood in signal design. They are discussed below:

- Cycle: A signal cycle is one complete rotation through all of the indications provided.
- Cycle length: Cycle length is the time in seconds that it takes a signal to complete one full cycle of indications. It indicates the time interval between the starting of of green for one approach till the next time the green starts. It is denoted by .
- Interval: Thus it indicates the change from one stage to another. There are two types of intervals - change interval and clearance interval. Change interval is also called the yellow time indicates the interval between the green and red signal indications for an approach. Clearance interval is also called all red is included after each yellow interval indicating a period during which all signal faces show red and is used for clearing off the vehicles in the intersection.
- Green interval: It is the green indication for a particular movement or set of movements and is denoted by . This is the actual duration the green light of a traffic signal is turned on.
- Red interval: It is the red indication for a particular movement or set of movements and is denoted by . This is the actual duration the red light of a traffic signal is turned on.
- Phase: A phase is the green interval plus the change and clearance intervals that follow it. Thus, during green interval, non conflicting movements are assigned into each phase. It allows a set of movements to flow and safely halt the flow before the phase of another set of movements start.
- Lost time: It indicates the time during which the intersection is not effectively utilized for any movement. For example, when the signal for an approach turns from red to green, the driver of the vehicle which is in the front of the queue, will take some time to perceive the signal (usually called as reaction time) and some time will be lost here before he moves.

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, and (6) the performance evaluation of the above design. The objective of phase design is to separate the conflicting movements in an intersection into various phases, so that movements in a phase should have no conflicts. If all the movements are to be separated with no conflicts, then a large number of phases are required. In such a situation, the objective is to design phases with minimum conflicts or with less severe conflicts.

There is no precise methodology for the design of phases. This is often guided by the geometry of the intersection, flow pattern especially the turning movements, the relative magnitudes of flow. Therefore, a trial and error procedure is often adopted. However, phase design is very important because it affects the further design steps. Further, it is easier to change the cycle time and green time when flow pattern changes, where as a drastic change in the flow pattern may cause considerable confusion to the drivers. To illustrate various phase plan options, consider a four legged intersection with through traffic and right turns. Left turn is ignored. See figure 1.

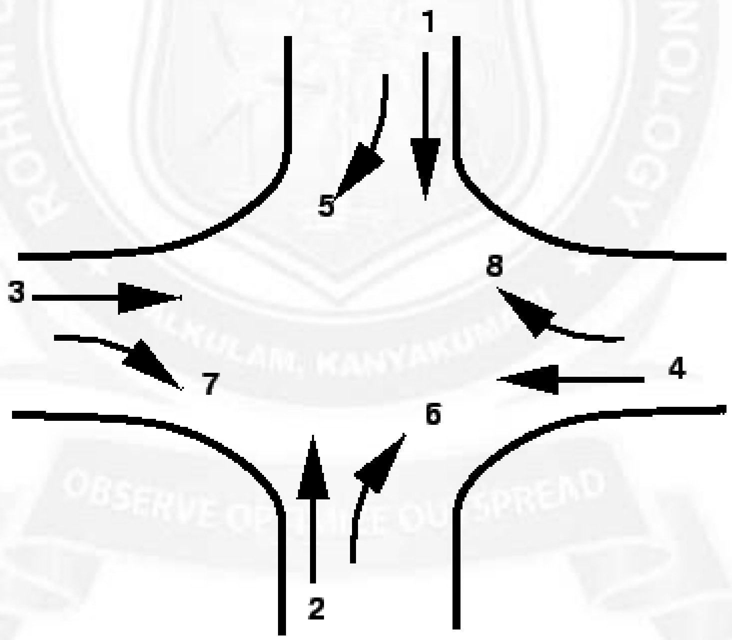


Figure 1: Four legged intersection

The first issue is to decide how many phases are required. It is possible to have two, three, four or even more number of phases.

Two phase signals

Two phase system is usually adopted if through traffic is significant compared to the turning movements. For example in figure 2, non-conflicting through traffic 3 and 4 are grouped in a single phase and non-conflicting through traffic 1 and 2 are grouped in the second phase.

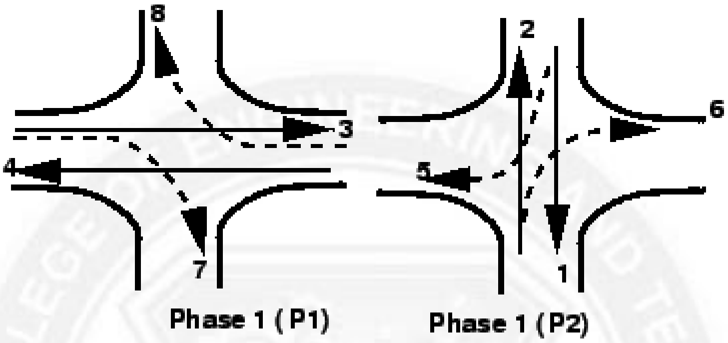


Figure 2: Two phase signal

However, in the first phase flow 7 and 8 offer some conflicts and are called permitted right turns. Needless to say that such phasing is possible only if the turning movements are relatively low. On the other hand, if the turning movements are significant ,then a four phase system is usually adopted.

Four phase signals

There are at least three possible phasing options. For example, figure 3 shows the most simple and trivial phase plan.

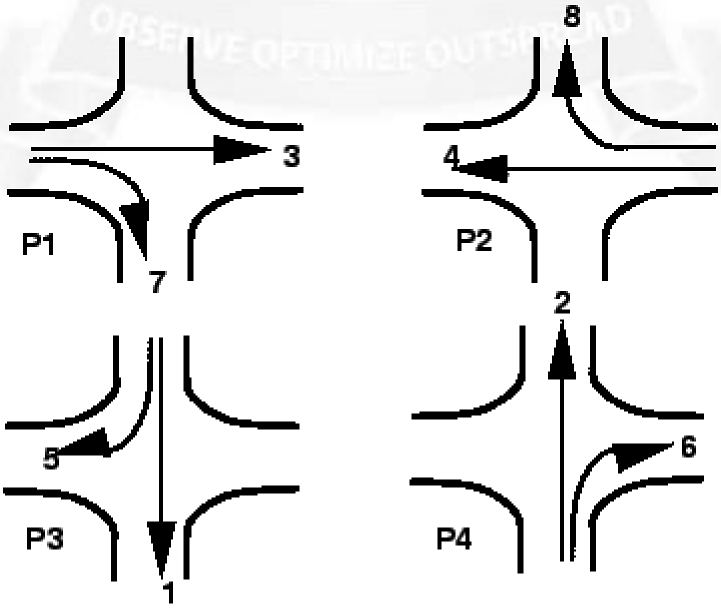


Figure 3: One way of providing four phase signals

where, flow from each approach is put into a single phase avoiding all conflicts. This type of phase plan is ideally suited in urban areas where the turning movements are comparable with through movements and when through traffic and turning traffic need to share same lane. This phase plan could be very inefficient when turning movements are relatively low.

Figure 4 shows a second possible phase plan option where opposing through traffic are put into same phase.

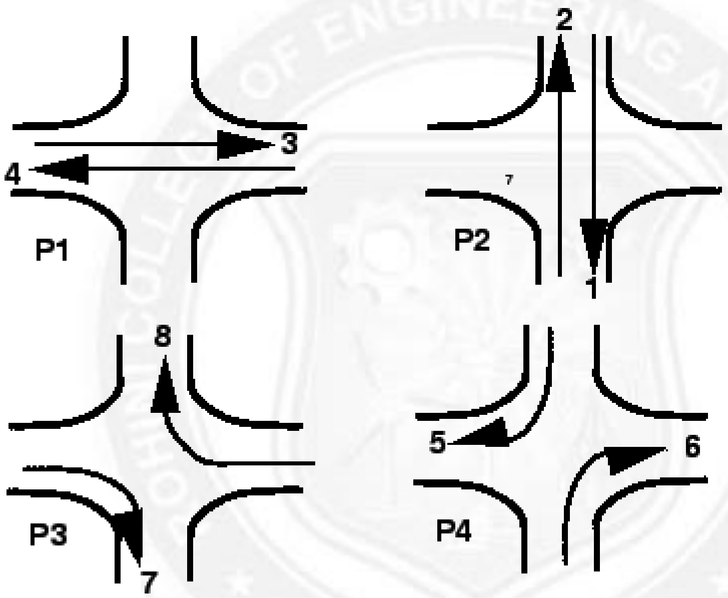


Figure 4: Second possible way of providing a four phase signal

The non-conflicting right turn flows 7 and 8 are grouped into a third phase. Similarly flows 5 and 6 are grouped into fourth phase. This type of phasing is very efficient when the intersection geometry permits to have at least one lane for each movement, and the through traffic volume is significantly high. Figure 5 shows yet another phase plan. However, this is rarely used in practice.

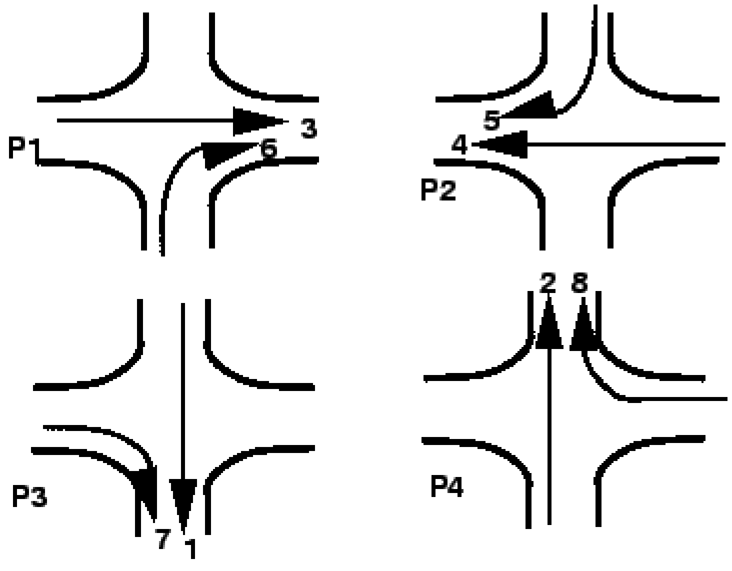


Figure 5: Third possible way of providing a four-phase signal

There are five phase signals, six phase signals etc. They are normally provided if the intersection control is adaptive, that is, the signal phases and timing adapt to the real time traffic conditions.

Interval design

There are two intervals, namely the change interval and clearance interval, normally provided in a traffic signal. The change interval or yellow time is provided after green time for movement. The purpose is to warn a driver approaching the intersection during the end of a green time about the coming of a red signal. They normally have a value of 3 to 6 seconds.

The design consideration is that a driver approaching the intersection with design speed should be able to stop at the stop line of the intersection before the start of red time. Institute of transportation engineers (ITE) has recommended a methodology for computing the appropriate length of change interval which is as follows:

$$y = t + \frac{v_{85}}{2a + 19.6g} \quad (1)$$

where y is the length of yellow interval in seconds, t is the reaction time of the driver, v_{85} is the 85 th percentile speed of approaching vehicles in m/s, a is the deceleration rate of vehicles in m/s^2, g is the grade of approach expressed as a decimal. Change interval can also be approximately computed as $y = \frac{SSD}{v}$, where SSD is the stopping sight distance and v is the speed of the vehicle. The clearance interval is provided after yellow interval and as mentioned earlier, it is used to clear off the vehicles in the intersection. Clearance interval is optional in a signal design. It depends on the geometry of the intersection. If the intersection is small, then there is no need of clearance interval whereas for very large intersections, it may be provided.

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. The way in which the vehicles depart from an intersection when the green signal is initiated will be discussed now. Figure 6 illustrates a group of N vehicles at a signalized intersection, waiting for the green signal.

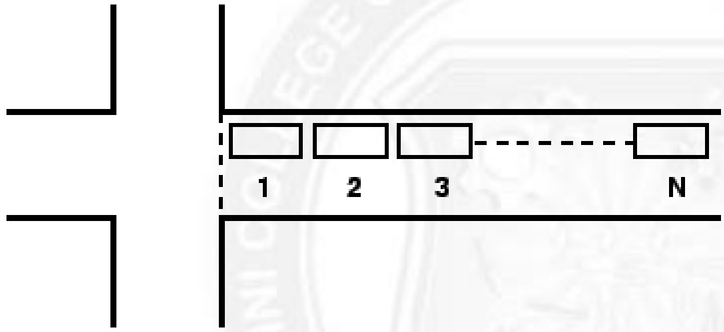


Figure 6: Group of vehicles at a signalized intersection waiting for green signal

As the signal is initiated, the time interval between two vehicles, referred as headway, crossing the curb line is noted. The first headway is the time interval between the initiation of the green signal and the instant vehicle crossing the curb line. The second headway is the time interval between the first and the second vehicle crossing the curb line. Successive headways are then plotted as in figure 7.

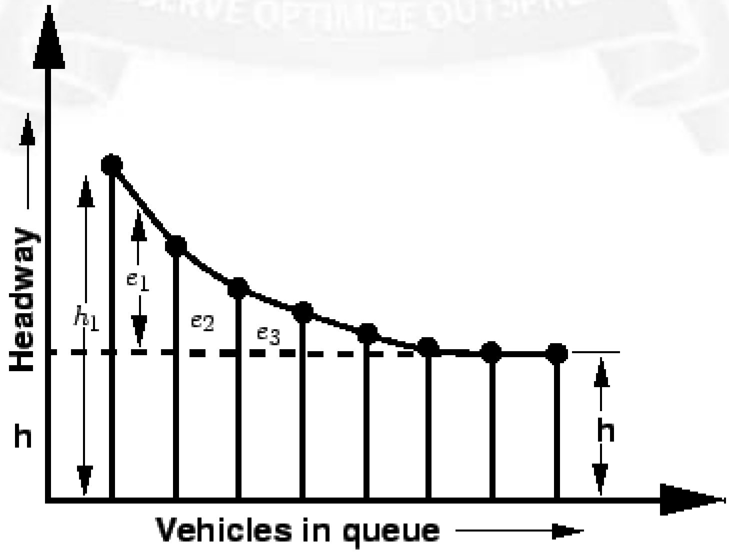


Figure 7: Headways departing signal

The first headway will be relatively longer since it includes the reaction time of the driver and the time necessary to accelerate. The second headway will be comparatively lower because the second driver can overlap his/her reaction time with that of the first driver's. After few vehicles, the headway will become constant. This constant headway which characterizes all headways beginning with the fourth or fifth vehicle, is defined as the saturation headway, and is denoted as h. This is the headway that can be achieved by a stable moving platoon of vehicles passing through a green indication. If every vehicles require h seconds of green time, and if the signal were always green, then s vehicles/per hour would pass the intersection. Therefore,

$$s = \frac{3600}{h} \tag{2}$$

where s is the saturation flow rate in vehicles per hour of green time per lane, h is the saturation headway in seconds. vehicles per hour of green time per lane. As noted earlier, the headway will be more than h particularly for the first few vehicles. The difference between the actual headway and h for the i^{th} vehicle and is denoted as e_i shown in figure 7. These differences for the first few vehicles can be added to get start up lost time, l_1 which is given by,

$$l_1 = \sum_{i=1}^{n} e_i \tag{3}$$

The green time required to clear N vehicles can be found out as,

$$T = l_1 + h.N \tag{4}$$

where T is the time required to clear N vehicles through signal, l_1 is the start-up lost time, and h is the saturation headway in seconds.

Effective green time

Effective green time is the actual time available for the vehicles to cross the intersection. It is the sum of actual green time (G_i) plus the yellow minus the applicable lost times. This lost time is the sum of start-up lost time (l_1) and clearance lost time (l_2) denoted as t_L. Thus effective green time can be written as,

$$g_i = G_i + Y_i - t_L \tag{5}$$

Lane capacity

The ratio of effective green time to the cycle length ($\frac{g_i}{C}$)is defined as green ratio. We know that saturation flow rate is the number of vehicles that can be moved in one lane in one hour assuming the signal to be green always. Then the capacity of a lane can be computed as,

$$c_i = s_i \frac{g_i}{C} \tag{6}$$

where c_i is the capacity of lane in vehicle per hour, s_i is the saturation flow rate in vehicle per hour per lane, C is the cycle time in seconds.

5.1 PARKING STUDIES

There are three major types of parking surveys. They are

1. **In-out survey:** In this survey, the occupancy count in the selected parking lot is taken at the beginning. Then the number of vehicles that enter the parking lot for a particular time interval is counted. The number of vehicles that leave the parking lot is also taken. The final occupancy in the parking lot is also taken. Here the labour required is very less. Only one person may be enough. But we won"t get any data regarding the time duration for which a particular vehicle used that parking lot. Parking duration and turnover is not obtained. Hence we cannot estimate the parking fare from this survey.

2. **Fixed period sampling:** This is almost similar to in-out survey. All vehicles are counted at the beginning of the survey. Then after a fixed time interval that may vary between 15 minutes to 1 hour, the count is again taken. Here there are chances of missing the number of vehicles that were parked for a short duration.

3. **License plate method of survey**: This results in the most accurate and realistic data. In this case of survey, every parking stall is monitored at a continuous interval of 15 minutes or so and the license plate number is noted down. This will give the data regarding the duration for which a particular vehicle was using the parking bay. This will help in calculating the fare because fare is estimated based on the duration for which the vehicle was parked. If the time interval is shorter, then there are less chances of missing short-term parkers. But this method is very labour intensive.

PROHIBITED PARKINGS

- **Near intersections**
- **Narrow streets**
- **Pedestrian crossings**
- **Entrance driveways**
- **Structures such as bridges, tunnel and underpasses**

DESIGN OF PARKING FACILITY

The parking facilities may be broadly classified into two types:

- On street parking
- Off street parking

On street parking

On street parking means the vehicles are parked on the sides of the street itself. This will be usually controlled by government agencies itself. Common types of on-street parking are as listed below. This classification is based on the angle in which the vehicles are parked with respect to the road alignment. As per **IRC** the standard dimensions of a car is taken as 5.0mx 2.5m and that for a truck is 3.75m x 7.5m .

1. 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. But it consumes the maximum curb length and therefore only a minimum number of vehicles can be parked for a given kerb length. Since it consumes least width of the road it produces least obstruction to the on-going traffic on the road.

2. 30°parking: Here more vehicles can be parked compared to parallel parking. Alsothere is better maneuverability. It causes minimum delay to traffic.

3. **45°parking**: As the angle of parking increases, more number of vehicles can be parked. Hence compared to parallel and thirty degree parking, more number ofvehicles can be accommodated in this type of parking.
4. **60° parking**: Here also more number of vehicles can be accommodated.
5. **Right angle parking:** Here the vehicles are parked perpendicular to the direction ofthe road. Hence it consumes maximum width. Curb length required is very little. Hence there are chances of severe accidents. Also it causes obstruction to the road traffic. But it can accommodate maximum number of vehicles.

Advantages of on street parking:

1. Angle parking is more convenient for the motorists than the parallel parking.
2. From the point of view of maneuverability, angle parking seems to be betterthan parallel parking which usually involves backing motion.
3. Delay to traffic is minimum with angle parking
4. Parallel parking makes the least use of the width of the street, and this is an important consideration in narrow streets.

Disadvantages of on street parking:

- **Congestion:** By parking, there will be loss in the street space which leads to the lowering of the road capacity. Hence speed will be reduced, journey time and delay will also subsequently increase. The operational cost of the vehicle increases leading to great economical loss to the community.
- **Accidents:** Careless maneuvering of parking and un parking leads to accidents which are referred to as parking accidents. Common type of parking accidents occur while driving out a car from the parking area, careless opening of the doors of parked cars, and while bringing in the vehicle to the parking lot for parking.
- **Obstruction to firefighting operations:** Parked vehicles may obstruct the movement of fire fighting vehicles. Sometimes they block access to hydrants and access to buildings.
- **Environmental pollution:** They also cause pollution to the environment because stopping and starting of vehicles while parking and un parking results in noise and fumes. They also affect the aesthetic beauty of the buildings because cars parked at every available space creates a feeling that building rises from a plinth of cars.

Off street parking

When the parking facility is provided at a separate place away from the kerb, it is known as off street parking. There will be some area 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.

The different types of off-street parking facilities commonly considered are:

- Surface car parks
- Paring lots
- Multi-storey car parks
- Under ground car parks
- Roof parks
- Mechanical parks

Advantages of off street parking:

- The main advantage of this method is that there is no undue congestion, accidents, environmental pollution and delay on the road as in on street parking.
- It gives good safety for the parking vehicles.

Disadvantages of off street parking:

- Main drawback of this method is, the owners will have to walk greater distance after parking the vehicle.
- It is also not possible to provide the off street parking facility at very close intervals especially in business centers of a city.

Parking statistics:

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 curve is the graph obtained by plotting the number of bays occupied with respect to time.

Parking volume: Parking volume is the total number of vehicles parked at a given duration of time.

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

Average parking duration: It is the ratio of total vehicle hours to the number of vehicles parked.

Parking turnover: It is the ratio of number of vehicles parked in a duration to the number of parking bays available.

Parking index: Parking index is also called occupancy or efficiency. It is defined as the ratio of number of bays occupied in a time duration to the total space available. It gives an aggregate measure of how effectively the parking space is utilized. Parking index can be found out as follows:

Parking Index = parking load /parking capacity x100

5.2 PEDESTRIAN STUDIES

People walk for many reasons: to go to a neighbor's house, to run errands, for school, or to get to a business meeting. People also walk for recreation and health benefits or for the enjoyment of being outside. Some pedestrians must walk to transit or other destinations if they wish to travel independently. It is a public responsibility to provide a safe, secure, and comfortable system for all people who walk. In this lecture we will discuss about the pedestrian problems, pedestrian survey (data collection), characteristics, different level of services, and design principles of pedestrian facilities. There are many problems related to safety security of pedestrians.

Pedestrian Problems

Accidents Circumstances - Pedestrian accidents occurs in a variety of ways; the most common type involves pedestrian crossing or entering the street at or between intersections.

1. Darting: It is used to indicate the sudden appearance of a pedestrian from behind a vehicle or other sight obstruction.
2. Dashing: It refers to the running pedestrians.

Special Problems

1. Age: Children under 15 years of age from the largest group of pedestrian victims and have the highest injury rate per population in their age group, the elderly have the highest fatality rate because of the lower probability of their recovery from injuries.
2. Intoxication and Drug effects: Alcohol and drugs impair the behavior of pedestrians to the extent that they may be a primary cause of accident.

3. Dusk and Darkness: Special pedestrian safety problems arise during the hours of dusk and darkness, when it is most difficult for motorists to see pedestrians.

Definition of a Pedestrian

Any person afoot is the definition of Uniform Vehicle Code of pedestrian. However expand this definition to explicitly include people with disabilities, such as who use wheelchairs or other mobility devices. At the beginning and end of every motorist's trip, he or she is pedestrian. The driver and/or passenger walks to the vehicle, which is parked, drives to a destination, parks the vehicle again, and walks to the final destination. In urban centers, pedestrian flows can be significant, and they must be accommodated in planning and design of traffic facilities and controls. Pedestrian safety is also a major issue, as the pedestrian is at a visible disadvantage where potential pedestrian-vehicle conflict exist, such as at the intersections.

It is important to recognize the forces influencing the demand for provision of more and better pedestrian facilities. Undoubtedly one important factor has been the increased awareness of the environmental problems created by the rapid national and worldwide growth in vehicle travel, but of equal important has been the recognition by many people of need for physical fitness and the role that play in achieving this.

Factors affecting pedestrian demand

The demand for pedestrian facilities is influenced by a number of factors of which some of the most important are

1. **The nature of the local community-** Walking is more likely to occur in a community that has a high proportion of young people.
2. **Car ownership -**The availability of the private car reduces the amount of walking, even for short journey.
3. **Local land use activities-** Walking is primarily used for short distance trips. Consequently the distance between local origins and destinations (e.g. homes and school, homes and shops) is an important factor influencing the level of demand, particularly for the young and elderly.
4. **Quality of provision-** If good quality pedestrian facilities are provided, then demand will tend to increase.
5. **Safety and security-** It is important that pedestrians perceive the facilities to be safe and secure. For pedestrians this means freedom from conflict with motor vehicle, as well as a minimal threat from personal attack and the risk of tripping on uneven surfaces.

Terminology

1. Pedestrian speed is the average pedestrian walking speed, generally expressed in units of meters per second.
2. Pedestrian flow rate is the number of pedestrians passing a point per unit of time, expressed as pedestrians per 15 min or pedestrians per minute. Point refers to a line of sight across the width of a walkway perpendicular to the pedestrian path.
3. Pedestrian flow per unit of width is the average flow of pedestrians per unit of effective walkway width, expressed as pedestrians per minute per meter (p/min/m). Pedestrian density is the average number of pedestrians per unit of area within a walkway or queuing area, expressed as pedestrians per square meter (p/m2).

4. Pedestrian space is the average area provided for each pedestrian in a walkway or queuing area, expressed in terms of square meters per pedestrian. This is the inverse of density, and is often a more practical unit for analyzing pedestrian facilities.
5. Platoon refers to a number of pedestrians walking together in a group, usually involuntarily, as a result of signal control and other factors.

Data collection

Before deciding on the appropriate extent and standard of pedestrian facilities, it is important to assess the potential demand. The possible methods of obtaining such estimates are manual count, video survey, and attitude survey described as follows.

Manual counts

Count the flow of pedestrian through a junction, across a road, or along a road section/footway manually using *manual clicker and tally marking sheet*. Manual counts need to satisfy the following conditions.

1. The time period(s) in the day over which the counts are undertaken must coincide with the peak times of the activity of study.
2. The day(s) of the week and month(s) of the year when observations are made must be representative of the demand. School holidays, early closing, and special events should be avoided since they can result in non-typical conditions.
3. The survey locations need to be carefully selected in order to ensure that the total existing demand is observed.

Advantages of this manual counting are that these are simple to set up and carry out, and flexible to response observed changes in demand on site and disadvantages are that these are labour intensive also simple information can be achieved and not detailed information.

Video survey

Cameras are setup at the selected sites and video recording taken of the pedestrians during the selected observation periods. A suitable vantage point for the camera is important. Such survey produces a permanent record of pedestrian movement and their interaction with vehicles. In it the record of behavior pattern is also obtained which helps in analyzing the crossing difficulties.

Attitude survey

Detailed questionnaire requires enabling complete information about pedestrian's origins and destination points, also can gather information on what new facilities, or improvements to existing facilities, need to be provided to divert trips to walking, or increase the current pedestrian activities.

Pedestrian Flow characteristic

In many ways pedestrian flow are similar to those used for vehicular flow because it can be described in terms of familiar variables such as speed, volume, rate of flow and density. Other measures related specifically to pedestrian flow include the ability to cross a pedestrian traffic stream, to walk in the reverse direction of a major pedestrian flow, to manoeuvre generally without conflicts and changes in walking speed, and the delay experienced by pedestrians at signalized and unsignalized intersections. It is dissimilar to the vehicular flow in that pedestrian flow may be unidirectional, bidirectional, or multi-directional. Pedestrian do not always travel in clear ”lanes” although they may do sometimes under heavy flow.

Pedestrian Speed-Density Relationships

The fundamental relationship between speed, density, and volume for pedestrian flow is analogous to vehicular flow. As volume and density increase, pedestrian speed declines. As density increases and pedestrian space decreases, the degree of mobility afforded to the individual pedestrian declines, as does the average speed of the pedestrian stream, it is shown in Fig. 1.

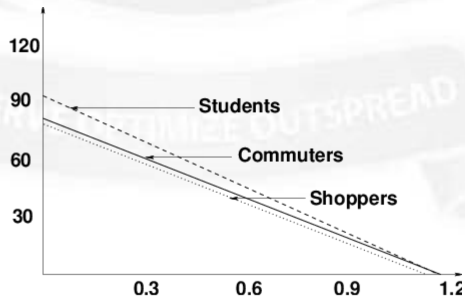


Figure 1: Relationship between pedestrian speed and density

Flow-Density Relationships

The relationship among density, speed, and flow for pedestrians is similar to that for vehicular traffic streams, and is expressed in equation.

$$Q_{ped} = S_{ped} * D_{ped} \quad (1)$$

where, Q_{ped}= unit flow rate (p/min/m), S_{ped}= pedestrian speed (m/min), and D_{ped}= pedestrian density (p/m^2). Pedestrian density is an awkward variable in that it has fractional values in pedestrian per square meter. This relationship often expressed in terms of Space module(M) which is the inverse of pedestrian density. The inverse of density is more practical unit for analyzing pedestrian facilities ,so expression becomes

$$Q_{ed} = \frac{S_{ped}}{M} \quad (2)$$

where M in(m^2/*ped*). The basic relationship between flow and space, recorded by several researchers, is illustrated in the Fig. 2.

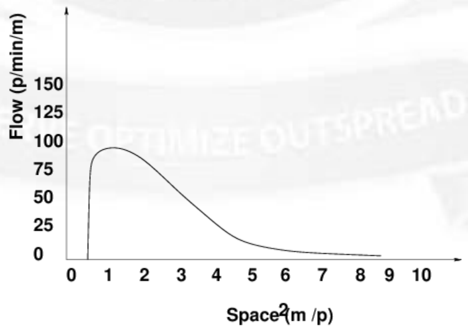


Figure 2: Relationship between pedestrian space & flow

The conditions at maximum flow represent the capacity of the walkway facility. From Fig. 2, it is apparent that all observations of maximum unit flow fall within a narrow range of density, with the average space per pedestrian varying between 0.4 and 0.9 m^2/p. Even the outer range of these observations indicates that maximum flow occurs at this density, although the actual flow in this study is considerably higher than in the others. As space is reduced to less than 0.4 m^2/p, the flow rate declines precipitously. All movement effectively stops at the minimum space allocation of 0.2 to 0.3 m^2/p.

Speed-Flow Relationships

The following Fig. 3 illustrates the relationship between pedestrian speed and flow. These curves, similar to vehicle flow curves, show that when there are few pedestrians on a walkway (i.e., low flow levels), there is space available to choose higher walking speeds. As flow increases, speeds decline because of closer interactions among pedestrians. When a critical level of crowding occurs, movement becomes more difficult, and both flow and speed decline.

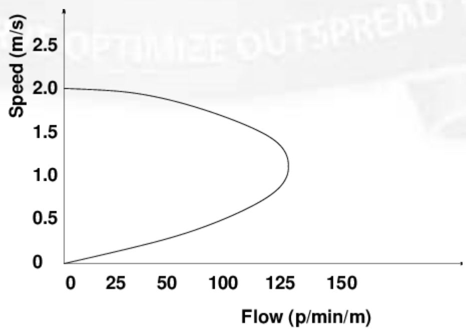


Figure 3: Relationships between Pedestrian Speed and Flow

The Fig. 4 confirms the relationships of walking speed and available space, and suggests some points of demarcation for developing LOS criteria. The outer range of observations indicates that at an average space of less than 1.5 m_2/p, even the slowest pedestrians cannot achieve their desired walking speeds. Faster pedestrians, who walk at speeds of up to 1.8 m/s, are not able to achieve that speed unless average space is 4.0 m_2/p or more.

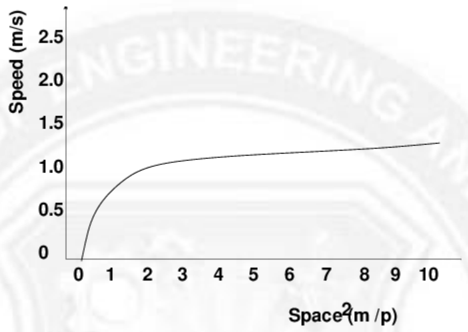


Figure 4: Relationships between Pedestrian Speed and Space

Pedestrian Space Requirements

Pedestrian facility designers use body depth and shoulder breadth for minimum space standards, at least implicitly. A simplified body ellipse of 0.50 m * 0.60 m, with total area of 0.30 m_2 is used as the basic space for a single pedestrian, as shown in Fig. 5 this represents the practical minimum for standing pedestrians. In evaluating a pedestrian facility, an area of 0.75 m_2 is used as the buffer zone for each pedestrian. A walking pedestrian requires a certain amount of forward space. This forward space is a critical dimension, since it determines the speed of the trip and the number of pedestrians that are able to pass a point in a given time period. The forward space in the Fig 6 is categorized into a pacing zone and a sensory zone.

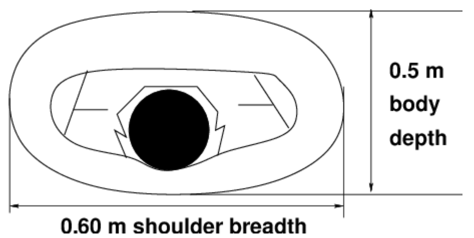


Figure 5: Pedestrian body ellipse

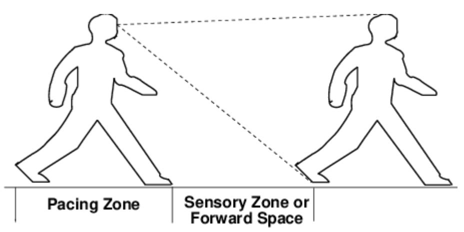


Figure 6: Pedestrian walking space requirement

Pedestrian Walking Speed

Pedestrian walking speed is highly dependent on the proportion of elderly pedestrians (65 years old or more) in the walking population. If 0 to 20 per cent of pedestrians are elderly, the average walking speed is 1.2 m/s on walkways. If elderly people constitute more than 20 per cent of the total pedestrians, the average walking speed decreases to 1.0 m/s. In addition, a walkway upgrade of 10 per cent or more reduces walking speed by 0.1 m/s. On sidewalks, the free-flow speed of pedestrians is approximately 1.5 m/s. There are several other conditions that could reduce average pedestrian speed, such as a high percentage of slow-walking children in the pedestrian flow.

Pedestrian Start-Up Time and Capacity

A pedestrian start-up time of 3 s is a reasonable midrange value for evaluating crosswalks at traffic signals. A capacity of 75p/min/m or 4,500p/h/m is a reasonable value for a pedestrian facility if local data are not available. At capacity, a walking speed of 0.8 m/s is considered a reasonable value.

5.3 PEDESTRIAN WALKWAY LEVEL OF SERVICE

Provision of adequate space for both moving and queuing pedestrian flow is necessary to ensure a good LOS. Alternatively LOS considered as pedestrian comfort, convenience, perception of safety and security. Alternative LOS measurements consider specific constraints to pedestrian flow such as stairway and wait time to cross roadways. We are going to discuss LOS of walkways, LOS of queuing and LOS at signalized intersection below.

LOS A

Pedestrian Space > 5.6 m^2/p *Flow Rate* ≤ 16 *p/min/m*. At a walkway LOS A, pedestrians move in desired paths without altering their movements in response to other pedestrians. Walking speeds are freely selected, and conflicts between pedestrians are unlikely. It is shown in Fig.

Figure: LOS A

LOS B

Pedestrian Space > 3.7 - 5.6 m^2/p *Flow Rate* > 16 - 23 *p/min/m*. At LOS B, there is sufficient area for pedestrians to select walking speeds freely, to bypass other pedestrians, and to avoid crossing conflicts. At this level, pedestrians begin to be aware of other pedestrians, and to respond to their presence when selecting a walking path. It is shown in Fig.

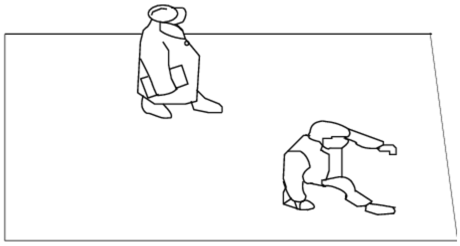


Figure: LOS B

LOS C

Pedestrian Space > 2.2 - 3.7 m^2/p *Flow Rate* > 23 - 33 *p/min/m*. At LOS C, space is sufficient for normal walking speeds, and for bypassing other pedestrians in primarily unidirectional streams. Reverse-direction or crossing movements can cause minor conflicts, and speeds and flow rate are somewhat lower. It is shown in Fig.

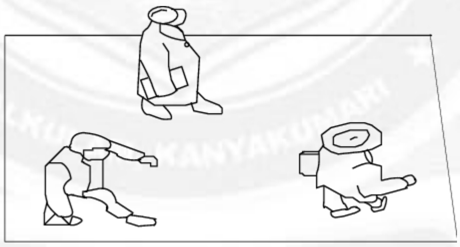


Figure: LOS C

LOS D

Pedestrian Space > 1.4 - 2.2 m^2/p *Flow Rate* > 33 - 49 *p/min/m*. At LOS D, freedom to select individual walking speed and to bypass other pedestrians is restricted. Crossing or reverse flow movements face a high probability of conflict, requiring frequent changes in speed and position. The LOS provides reasonably fluid flow, but friction and interaction between pedestrians is likely. It is shown in Fig.

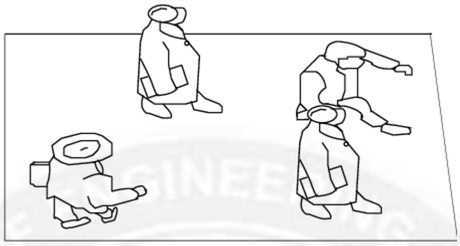


Figure: LOS D

LOS E

Pedestrian Space > 0.75 - 1.4 m^2/p *Flow Rate* > 49 - 75 *p/min/m*. At LOS E, virtually all pedestrians restrict their normal walking speed, frequently adjusting their gait. At the lower range, forward movement is possible only by shuffling. Space is not sufficient for passing slower pedestrians. Cross- or reverse-flow movements are possible only with extreme difficulties. Design volumes approach the limit of walkway capacity, with stoppages and interruptions to flow.

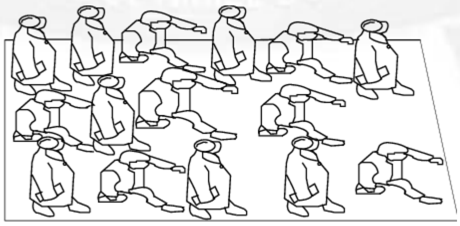


Figure: LOS E

LOS F

Pedestrian Space ≤ 0.75 m^2/p *Flow Rate varies p/min/m*. At LOS F, all walking speeds are severely restricted, and forward progress is made only by shuffling. There is frequent, unavoidable contact with other pedestrians. Cross- and reverse-flow movements are virtually impossible. Flow is sporadic and unstable. Space is more characteristic of queued pedestrians than of moving pedestrian streams. It is shown in Fig.

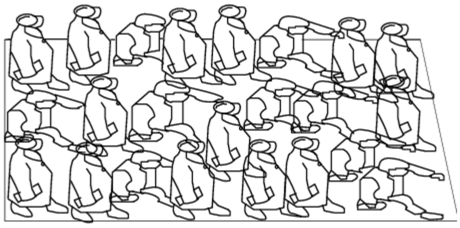


Figure: LOS F

Pedestrian Queuing LOS

LOS A

Average Pedestrian Space > 1.2 m^2/p. Standing and free circulation through the queuing area is possible without disturbing others within the queue.

LOS B

Average Pedestrian Space > 0.9 - 1.2 m^2/ p. Standing and partially restricted circulation to avoid disturbing others in the queue is possible.

LOS C

Average Pedestrian Space > 0.6 - 0.9 m^2/p. Standing and restricted circulation through the queuing area by disturbing others in the queue is possible; this density is within the range of personal comfort.

LOS D

Average Pedestrian Space > 0.3 - 0.6 m^2/p. Standing without touching is possible; circulation is severely restricted within the queue and forward movement is only possible as a group; long-term waiting at this density is uncomfortable.

LOS E

Average Pedestrian Space > 0.2 - 0.3 m^2/p. Standing in physical contact with others is unavoidable; circulation in the queue is not possible; queuing can only be sustained for a short period without serious discomfort.

LOS F

Average Pedestrian Space ≤ 0.2 m^2/p. Virtually all persons within the queue are standing in direct physical contact with others; this density is extremely uncomfortable; no movement is possible in the queue; there is potential for panic in large crowds at this density.

LOS at signalized intersection

The signalized intersection crossing is more complicated to analyze than a mid-block crossing, because it involves intersecting sidewalk flows, pedestrians crossing the street, and others queued waiting for the signal to change. The service measure is the average delay experienced by a pedestrian. Research indicates that the average delay of pedestrians at signalized intersection crossings is not constrained by capacity, even when pedestrian flow rates reach 5,000 p/h. The average delay per pedestrian for a crosswalk is given by Equation:

$$d_p = \frac{0.5(C-g)^2}{C} \quad (3)$$

Where, d_p= average pedestrian delay (s), g = effective green time (for pedestrians) (s), and C= cycle length (s).

Table 1: LOS Criteria For Pedestrians At Signalized Intersections

LOS	Pedestrian Delay(s/p)	Likelihood of Noncompliance
A	< 10	Low
B	≥ 10 - 20	
C	> 20 - 30	Moderate
D	> 30 - 40	
E	> 40 - 60	High
F	> 60	Very high

Numerical example

Calculate time delay of pedestrian crossing at a signalized intersection operating on a two phase, 80.0-s cycle length, with 4.0-s change interval, and no pedestrian signals. Major street: Phase green time, Gd = 44.0 s; Crosswalk length, Ld = 14.0 m; Minor street: Crosswalk length, Lc = 8.5 m; Phase green time, Gc = 28.0 s;

Solution dp $=(c\text{-}g)^2/2c$, dp (major) = (80.0 - 28.0)* (80.0 - 28.0)/2(80), = 16.9 s (i.e. LOS B using above table), dp (minor) = (80.0 - 44.0)* (80.0 - 44.0)/2(80) = 8.1 s (i.e. LOS A using above table).

5.4 DESIGN PRINCIPLE OF PEDESTRIAN FACILITIES

In the design facilities we will discuss the design criteria of sidewalk, street corner, crosswalk, traffic island, overpass and underpass and other facilities like as pedestrian signals and signage.

Side walk

Sidewalks are *pedestrian lanes* that provide people with space to travel within the public right-of-way that is separated from roadway vehicles. They also provide places for children to walk, run, skate, ride bikes, and play. Sidewalks are associated with significant reductions in pedestrian collisions with motor vehicles.

1. **Width:** The minimum clear width of a pedestrian access route shall be 1220 mm exclusive of the width of curb. It varies according to pedestrian flow rate and different LOS. It is shown in following Table.

Table 2: Minimum pedestrian clear area (excluding sidewalk obstructions)

Pedestrian Flow rate (pedestrian/hour)	LOS A	LOS B	LOS C	LOS D	LOS E
< 600	1.5 m	1.2 m	1.2 m	1.2 m	1.2 m
600-1200	3.1 m	1.2 m	1.2 m	1.2 m	1.2 m
1200-2400	6.1m	1.8 m	1.5 m	1.2 m	1.2 m
2400-3600		2.8 m	1.8 m	1.5 m	1.2 m
3600-4800		3.7 m	2.5 m	1.8 m	1.2 m
4800-6000		4.6 m	3.1 m	2.1 m	1.2 m

6000-7200	Not recommended	5.5 m	3.7 m	2.5 m	1.5 m
7200-8400		6.1 m	4.3 m	3.1 m	1.8 m
8400-9600		7.1 m	4.9 m	3.4 m	2.1 m
9600-10800		8.1 m	5.5 m	3.7 m	2.5 m
10800-12000		8.9 m	6.1 m	4.3 m	2.5 m

2. **Cross slope:** The cross slope of the pedestrian access route shall be maximum 1:48.
3. **Surfaces:** Surface should be firm, stable, slip resistance and prohibit openings & avoid service elements i.e. manholes etc.

A buffer zone of 1.2 to 1.8 m (4 to 6 ft) is desirable and should be provided to separate pedestrians from the street. The buffer zone will vary according to the street type. In downtown or commercial districts, a street furniture zone is usually appropriate.

Cross Walk

Marked crosswalks indicate optimal or preferred locations for pedestrians to cross and help designate right-of-way for motorists to yield to pedestrians. Crosswalks are often installed at signalized intersections and other selected locations.

1. It should be located at all open legs of signalized intersection.
2. It should be perpendicular to roadway.
3. The parallel line should be 0.2-0.6 m in width and min. length 1.8 m (standard 3m).

4. Marking may be of different type to increase visibility like as solid, standard, continental, dashed, zebra, ladder. It is shown in Fig. 13.

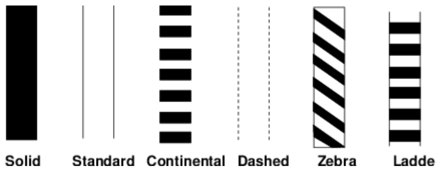


Figure: Cross walk marking pattern

Figure: Ladder pattern at intersection

Traffic Islands

Traffic islands to reduce the length of the crossing should be considered for the safety of all road users. It is used to permit safe crossing when insufficient gap in two directions traffic & helps elderly, children and disabled.

1. It works best when refuse area median is greater than cross walk width or 3.6 m, have a surface area of at least 4.6 sq.m, are free of obstructions, have adequate drainage, and provide a flat, street level surface to provide accessibility to people with disabilities.

2. The Refuge area width should be at least 1.2 m wide and depend upon traffic speed. It should be 1.5m wide on streets with speeds between 40-48 kmph, 1.8 m wide(48-56 kmph), and 2.4 m (56-72 kmph).

Pedestrian Overpass and Underpass

Pedestrian facilities at-grade and as directly as possible are always preferred. However, where grade separation is indicated, paths that are attractive, convenient and direct can become well-used and highly valued parts of a city's pedestrian infrastructure.

1. These are expensive method but eliminate all or most conflicts. These may be warranted for critical locations such as schools factory gates, sports arenas, and major downtown intersections (specially in conjunction with transit stations).
2. Overpasses are less expensive than underpass. However , vertical rise and fall to be negotiated by pedestrians is usually greater for an overpass, and it may be aesthetically inferior.
3. Minimum width is required 1.22 m, although 1.83 is preferred.
4. Ramps slopes not greater than 1:12 (8.33%) are preferable to flights of stairs to accommodate wheelchair, strollers, and bicycles and to comply with ADA.

Street Corner

Available Time-Space: The total time-space available for circulation and queuing in the intersection corner during an analysis period is the product of the net corner area and the length of the analysis period. For street corners, the analysis period is one signal cycle and therefore is equal to the cycle length. The following equation is used to compute time-space available at an intersection corner. Intersection Corner Geometry is shown in Fig.

$$TS = C(W_a * W_b - 0.215R^2) \quad (4)$$

where, TS =available time-space (m_2-s), W_a = effective width of Sidewalk a (m), W_b = effective width of Sidewalk b (m), R = radius of corner curb (m), and C = cycle length (s).

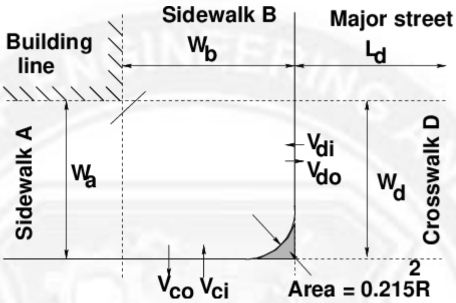


Figure: Intersection Corner Geometry

Pedestrian signals

Pedestrian signals are designed basically considering minimum time gap required for crossing the pedestrians. This minimum time gap can be calculated by using following gap equation.

$$Gs = \frac{W}{S_{ped}} + tc(N - 1) + ts \quad (5)$$

where, Gs=min time gap in sec, W= width of crossing section, ts= startup time, tc=consecutive time between two pedestrian, N=no of rows, and S_{ped} =pedestrian speed.

Numerical example

Calculate time gap for a platoon of 27 school children 5 in a row, consecutive time 2 sec width of crossing section is 7.5 m and walking speed of children .9 m/s start up time 3 sec. **Solution** Given w=7.5m; tc= 3 sec S_{ped}= 0.9m/s Find out N N=27/5 i.e. 6 row (5 containing 5 & 6th containing 2) Time gap

$$\begin{aligned} Gs &= \frac{W}{S_{ped}} + tc(N-1) + ts \\ &= [(7.5/0.9) + 2(6-1) + 3] \\ &= 21.33 sec \end{aligned}$$

Traffic signage

There are many signage used for pedestrian facilities like as in-pavement flashers, overhead signs, animated pedestrian indications and school zone symbol. These are shown below.

1. In-Pavement Flashers

Figure: In-Pavement Raised Markers with Amber LED Strobe Lighting and LED Signs

2. Overhead Signs

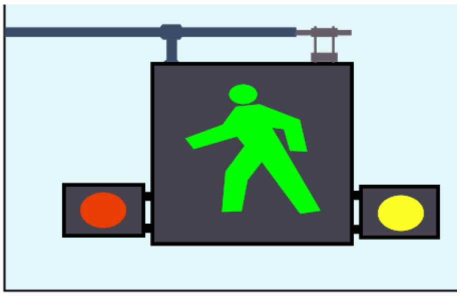


Figure: Overhead Pedestrian Signs

3. Animated Pedestrian Indications

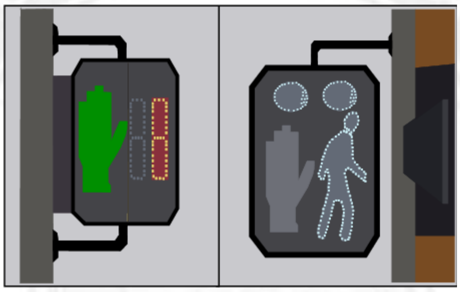


Figure: Animated Pedestrian Signals

4. School Zone Symbol

Figure: School Zone Symbol

5.5 CYCLE TRACKS

Bicycles are the low cost and easiest form of transport mode that is used to reduce environmental pollution and to use as eco friendly. For the low income countries, especially like India the developing country, bicycles offers a good option to use when it becomes difficult to use motorized vehicles.

Cycling is amongst the most sustainable modes of mobility, which has zero dependence on fossil fuels and zero emissions unlike the motorized modes of transport, which have huge negative externalities, namely- accidents, congestion, fossil energy use, and environmental degradation.

Cycling, in fact, is associated with positive externalities like health improvements, congestion reduction, lessening of air pollution and greenhouse gas (GHG) emissions, and minimizing energy use. In addition to these positive impacts, in the context of a developing country like India, cycling presents the most affordable and efficient means of travel for low-income households who find it difficult to afford most motorized transport options.

Proper design of cycle track enables to reduce conflicts between other motorists and it also ensures the safety of cyclists. It has more beneficiary advantages like health, reduction in traffic jams, saving fuel costs, eco mobility transport, environmental friendly etc.

The properly designed cycle track provides the travel pattern of motorized as well as non motorized vehicles without causing disturbance to large and high speed moving vehicles and also helps in encouraging the bicycle users

Methodology

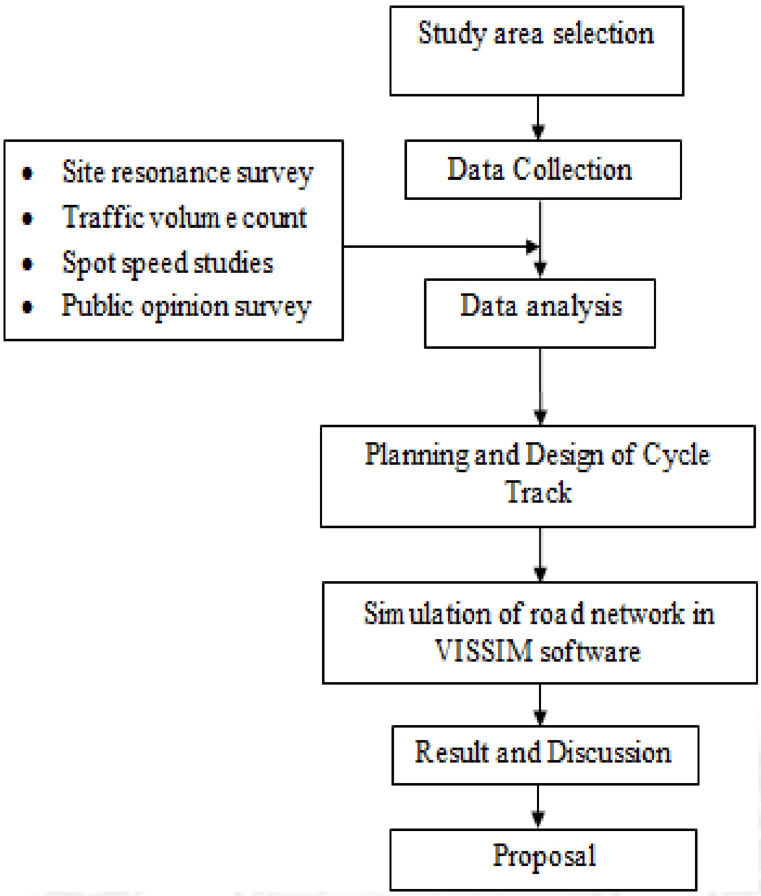


Fig.1. Methodology adopted for the study.

The methodology for the present study consists of selection of study area. Main criteria adopted for selection of study area was, more number of cycle traffic. In cities more of cycle users are students. Based on the data analysis results planning and design of the work to be made. Required input for the VISSIM software for simulation can be generated. Precise output can be drawn from the software after calibration.