TRAFFIC FLOW MODELLING

COURSE MATERIAL

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INTRODUCTION ON TRAFFIC ENGINEERING

1. SCOPE AND SIGNIFICANCE

- 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.

1.1 Other important disciplines

In addition to the four major disciplines of transportation, there are several other important disciplines that are being evolved in the past few decades. Although it 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.

3. 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

2. 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 signs and signals.

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

The **rear overhang** control is mainly important when the vehicle takes a right/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 and so 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.

2.2Dynamic Characteristics

Dynamic characteristics of vehicles affecting road design are speed, acceleration and braking characteristics, Power Performance and some aspects of vehicle 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. For example, 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.

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.

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.

- Braking distance

$$d_b = \frac{v_i^2 - v_f^2}{254(f \pm G)} = \frac{v_i^2}{254(f \pm G)} \Rightarrow \text{stopping distance}$$

  - Where,
    - db = breaking distance (m)
    - vi = initial vehicle speed (km/h)
    - vf = final vehicle speed (km/h)
    - f = coefficient of forward friction between tires and roadway = usually 0.35
    - G = grade expressed as a decimal
    - 254 = units conversion factor (used 30 if speed in mph)

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 should see 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

A 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 engine(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

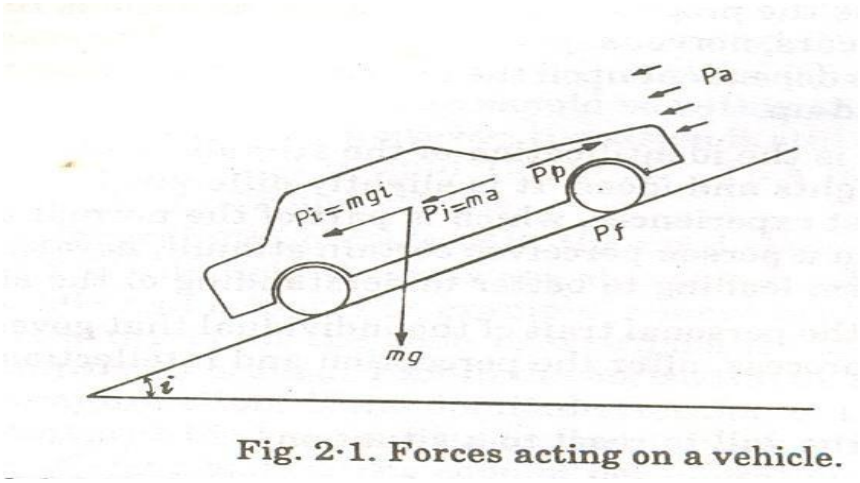


Fig. 2·1. Forces acting on a vehicle.

Road user characteristics (or) 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 be classified 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 it can come into picture in case of sign and signal recognition.

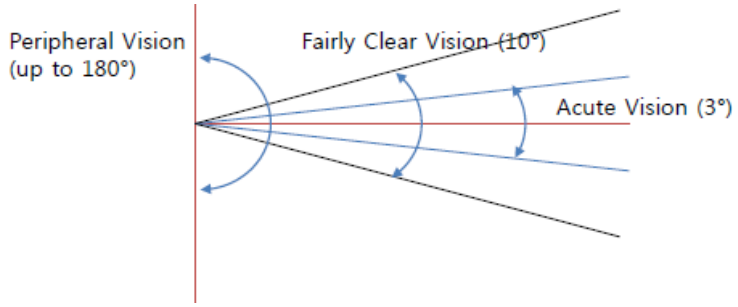


Fig.1 Visual acuity

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.

3.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.

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.

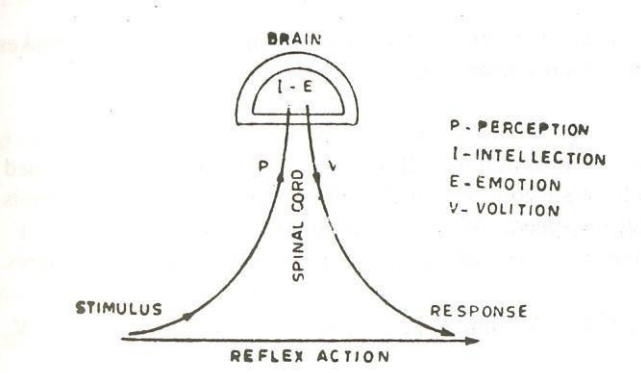


Fig. 4.12 Reaction Time and PIEV Process

4. 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 and the 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.ROAD USER CHARACTERISTICS

Sames as above mentioned road user characteristics

2.VEHICLE

Same as above mentioned vehicle characteristics

3.ROAD CHARACTERISTICS

The various road characteristics may be classified into six types.

1. Road surface
2. Lighting
3. Roughness
4. Pavement color
5. Night visibility
6. 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.

4. CONTROL DEVICES

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

Here traffic control devices comes to the help of the traffic engineer. The major types of traffic control devices used are **traffic signs, road markings , traffic signals and parking control.**

Traffic signs: Used to regulate, guide or warn the traffic.

Fig.3 Traffic signs

The three different types of signs are,

1. **Regulatory signs**: These signs require the driver to obey the signs for the safety of other road users.

2. **Warning signs**: the warning signs are in the shape of equilateral triangle with apex upwards.These signs are for the safety of on self who is driving and advice the drivers to obey these signs.

3. **Informative signs**: These signs provide information to the driver about the facilities available ahead,and the route and distance to reach the specific destinations.

Traffic markings:

The essential purpose of road markings is to guide and control traffic on a highway. The road markings are classified as longitudinal markings, transverse markings, object markings, word messages, marking for parkings, marking at hazardous locations etc.

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 requirement of traffic signal are draw the attention, provide meaning and time to respond and to have minimum waste of time.

Parking control:

Parking is one of the major problems that is created by the increasing road traffic. It is an impact of transport development. The availability of less space in urban areas has increased the demand for parking space especially in areas like Central

business district. This affects the mode choice also. This has a great economical impact.

LAND USECHARACTERISTICS

The amount of traffic depends on how the land is used. for example shopping centers, residential buildings and complexes. land uses characteristics depends on

1. Number of household
2. Population of the area
3. Road pattern
4. Mode of travel
5. Socio economic characteristics

TRAFFIC SURVEYS AND ANALYSIS

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.

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

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

1. TRAFFIC VOLUME COUNT SURVEY

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

1.Manual counts

This method employs a field team to record traffic volume on the prescribed record sheets. The number of observers needed to count the vehicles depends upon the 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 hours of 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 easily obtained.
4. Specific vehicular movements such as left turns, right turns, straight ahead etc.at a junction can be noted and recorded.
5. Even if automatic devices are used, it is often necessary to check the accuracy of 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.

The data‟s are not fully accurate due to some manual errors.

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 successive vehicles 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 on weekdays 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 as the standard vehicle unit to convert the other vehicle classes and this unit is called passenger car unit or PCU

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 will be les. There is also a possibility of human error.

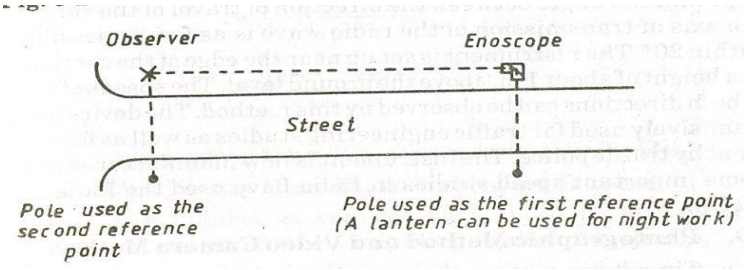


Fig.1 Spot Speed by Enoscope

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 for the 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 a point on a highway over some specified time period.

Space mean speed:

Space mean speed is defined as the average speed of all the vehicles occupying a 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.**(GATE qus)**

Average speed:

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

Example 1

If the spot speeds are 50, 40, 60,54 and 45, then find the time mean speed and space mean speed.

Solution Time mean speed v_t is the average of spot speed. Therefore, from 31.1,

$v_t = \frac{\Sigma v_i}{n} = \frac{50+40+60+54+45}{5} = \frac{249}{5} = 49.8$ Space mean speed is the harmonic mean of spot speed.Therefore,

$v_s = \frac{n}{\Sigma \frac{1}{v_i}} = \frac{5}{\frac{1}{50}+\frac{1}{40}+\frac{1}{60}+\frac{1}{54}+\frac{1}{45}} = \frac{5}{0.12} = 48.82$

SPEED AND DELAY STUDY

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

The delay or the time lost by traffic during the travel time period may be either due to **fixed delays and operational delays**. Fixed delay occurs primarily at intersections due to traffic signals and at level crossings. Operational delays are caused by interference of traffic movements, such as turning vehicles, parking and imparking vehicles, pedestrians etc., and by internal friction in the traffic stream due to high traffic volume, insufficient capacity and by accidents.

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

1. **Moving observer method or Floating car method**
2. **License plate or vehicle number method**
3. **Interview method**
4. **Elevated observations, and**
5. **Photographic technique**

Moving observer method

In the floating car methods a test vehicle is driven over a given course of travel at approximately the average speed of the stream, thus trying to float the traffic stream. A number of test runs are made along the study stretch and a group of observers record the various details.

One observer is seated in the floating or moving car with two stop watches. One of the stop watches is used to record the time at various control points like intersections, bridges or any other fixed points in each trip.

The other stop watch is used to find the duration of individual delays.

The time, location and causes of these delays are recorded by using suitable tabular forms or by voice recording equipment.

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

The number of vehicles travelling in the opposite direction in each trip is noted by the a fourth observer. However in mixed traffic flow, more number of observers will be required to count the vehicles of different classes.

The average journey time t(minute) for all the vehicles in a traffic stream in the direction of flow q is given by:

$$t = t_w - n_y/q$$

$$q = (n_a+n_y)/(t_a+t_w)$$

where,

q= flow of vehicles (volume per minute),in one direction of the stream

n_a = avg number of vehicles counted in the direction of the stream when the test vehicle in the opposite direction

n_y = avg number of vehicles overtaking the test vehicle minus the number of vehicles overtaken when the test vehicle in the direction of q

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

t_a= avg journey time, in minute when the test vehicle is running against the stream.

License Plate Method

In license plate method, synchronized **stop watches** or voice recording equipment are used. Observers are stationed at the **entrance and exit of a test section** where information of travel time is required. The timings and the vehicle numbers are noted by the observers of the selected samples. From the office computations travel time of each vehicles could be found. But the method **does not give** important details such as **causes of delays** and the duration and number of delays within the test section.

Interview method

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

Elevated Observation and Photographic Technique

In this method, the observers stationed on the top of an elevated building select vehicles at random and follow their course along the road, noting the time of entering the test section, duration and nature of delays suffered and time of leaving. This method useful for studying short test sections like intersection etc.

PARKING SURVEYS:

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. Also there 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 of vehicles 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 of the 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 better than 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.

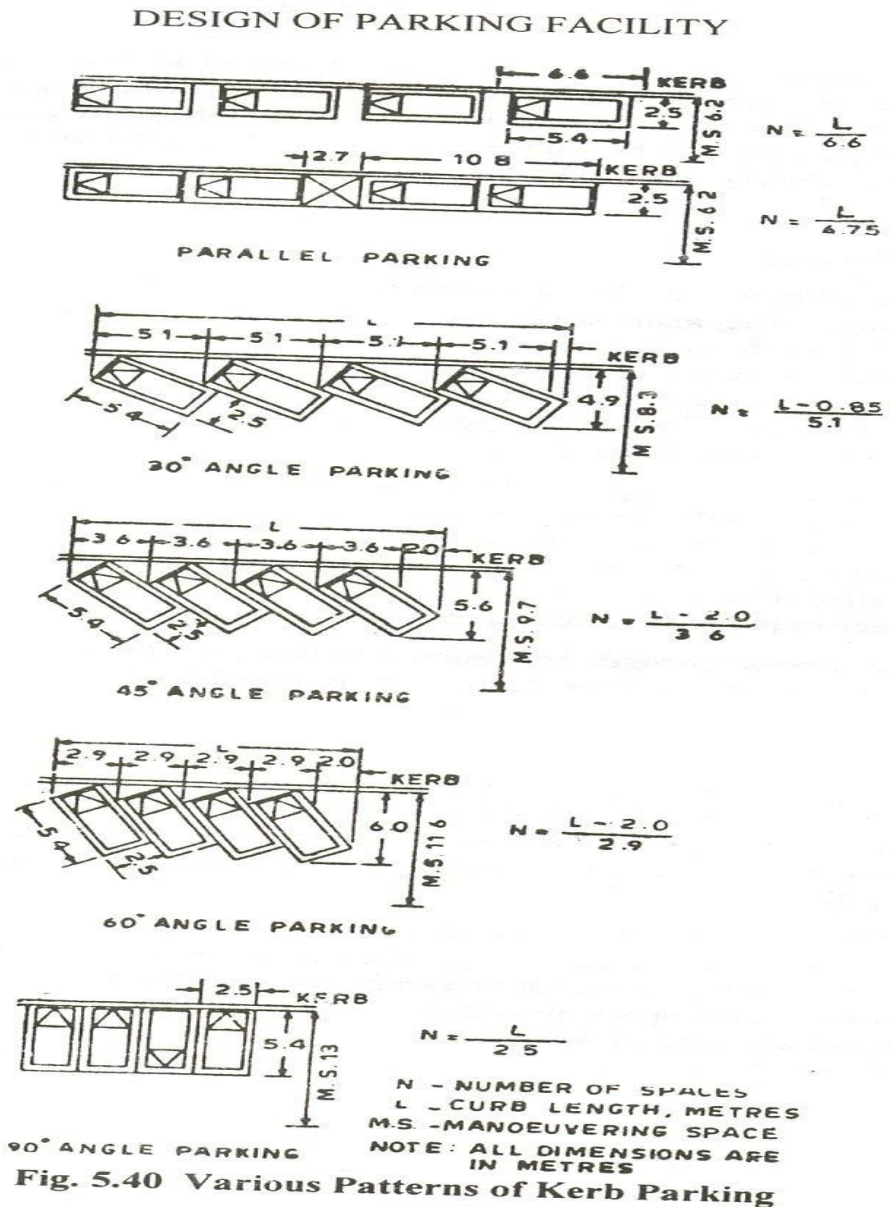


Fig. 5.40 Various Patterns of Kerb Parking

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

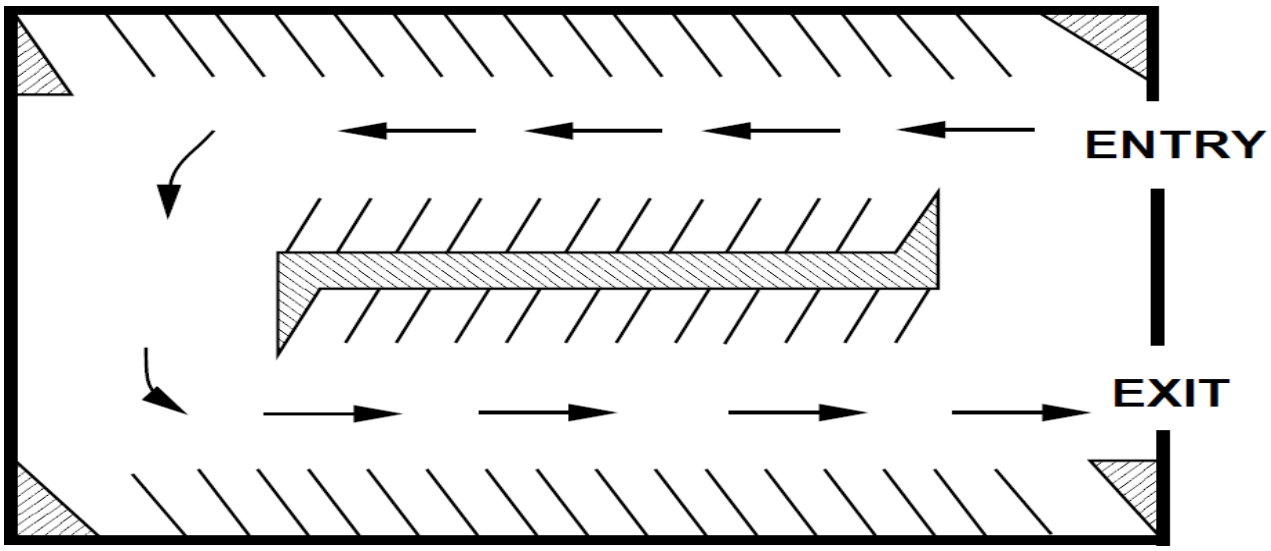


Fig.1 OFF STREET PARKING

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

TRAFFIC FLOW CHARACTERISTICS

Speed

It is defined as the rate of motion in distance per unit of time.

Density

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

Flow

The flow or volume, which is defined as the number of vehicles that pass a point on a highway or a given lane or direction of a highway during a specific time interval.

FLOW-DENSITY CURVE

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

1. When the density is zero, flow will also be zero, since there is no vehicles on the road.

2. When the number of vehicles gradually increases the density as well as flow increases.

3. When more and more vehicles are added, it reaches a situation where vehicles can't move. This is referred to as the jam density or the maximum density. At jam density, flow will be zero because the vehicles are not moving.

4. There will be some density between zero density and jam density, when the flow is maximum. The relationship is normally represented by a parabolic curve as shown in figure.

The point O refers to the case with zero density and zero flow. The point B refers to the maximum flow and the corresponding density is kmax. The point C refers to the maximum density kjam and the corresponding flow is zero. OA is the tangent drawn to the parabola at O, and the slope of the line OA gives the mean free flow.

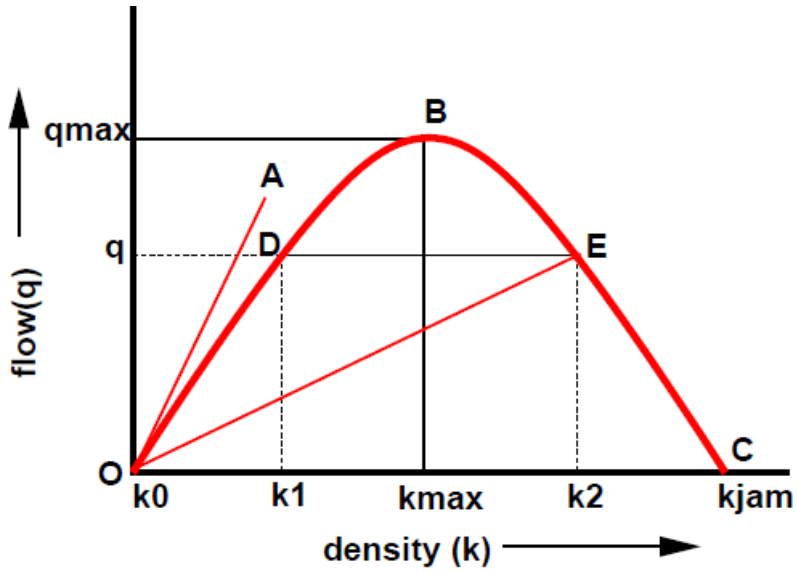


Figure 31:3: Flow density curve

SPEED-DENSITY DIAGRAM

Similar to the flow-density relationship, speed will be maximum, referred to as the free flow speed, and when the density is maximum, the speed will be zero. The most simple assumption is that this variation of speed with density is linear as shown by the solid line in figure. Corresponding to the zero density, vehicles will be flowing with their desire speed, or free flow speed. When the density is jam density, the speed

of the vehicles becomes zero. It is also possible to have non-linear relationships as shown by the dotted lines. These will be discussed later.

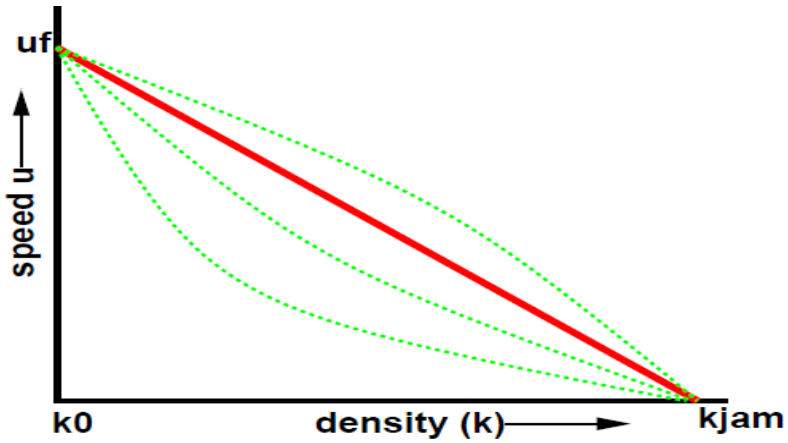


Figure 31:4: Speed-density diagram

Where,

u- speed,k- density,kjam- jam density,uf- free flow speed

SPEED FLOW RELATION

The relationship between the speed and flow can be postulated as follows. The flow is zero either because there is no vehicles or there are too many vehicles so that they cannot move. At maximum flow, the speed will be in between zero and free flow speed. This relationship is shown in figure. The maximum flow qmax occurs at speed u. It is possible to have two different speeds for a given below.

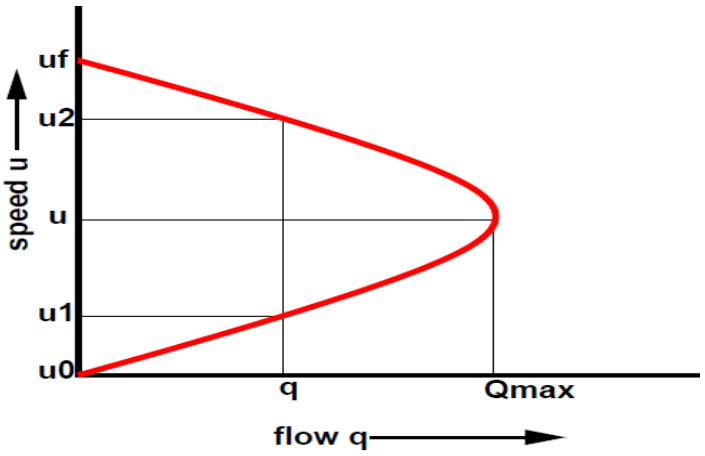


Figure 31:5: Speed-flow diagram

Origin and destination studies

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 of commuters

(iii) to locate the intermediate stops

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

(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

(vii) to judge adequacy of existing routes and to use in planning new networks of roads.

There are a number of method 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.

ACCIDENT STUDIES

The traffic accidents may involve property damages, personal injuries or even casualities. 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 potential location,
- To evaluate the existing design
- To support the proposed designs
- To carryout the before and after studies and to demonstrate the improvement in the 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 driving unsafe.

TYPES OF ACCIDENTS:

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

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

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

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

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

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

COLLISION DIAGRAM:

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

Nature of collision:

Different types of collision are,

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

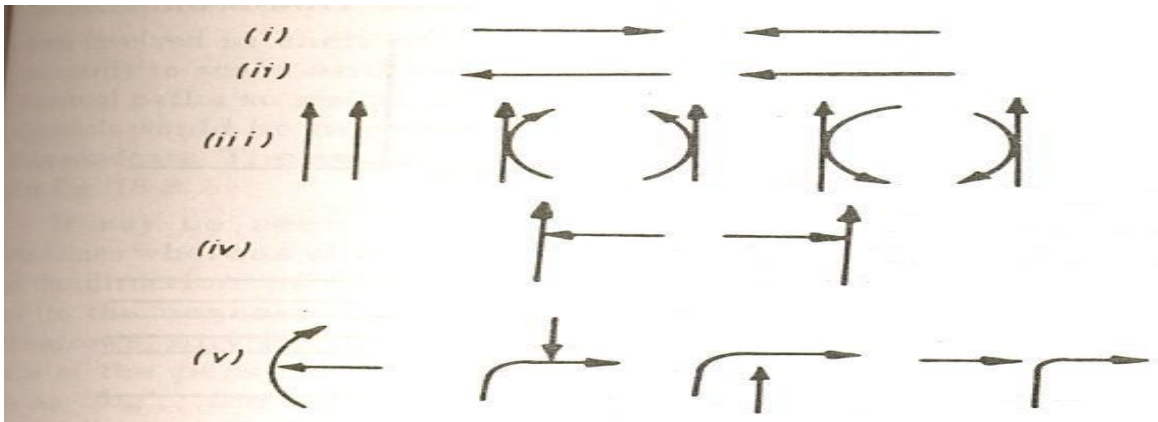


Fig. 18·1

Fig. 18·2. Symbols employed in collision diagrams.

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 to the 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

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: 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 into two types:

i) Prohibitory signs

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

The may be of the following types:

a) Movement prohibition (such as prohibition of right turns, prohibition of overtaking, prohibition of entry, oneway 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 and horn 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

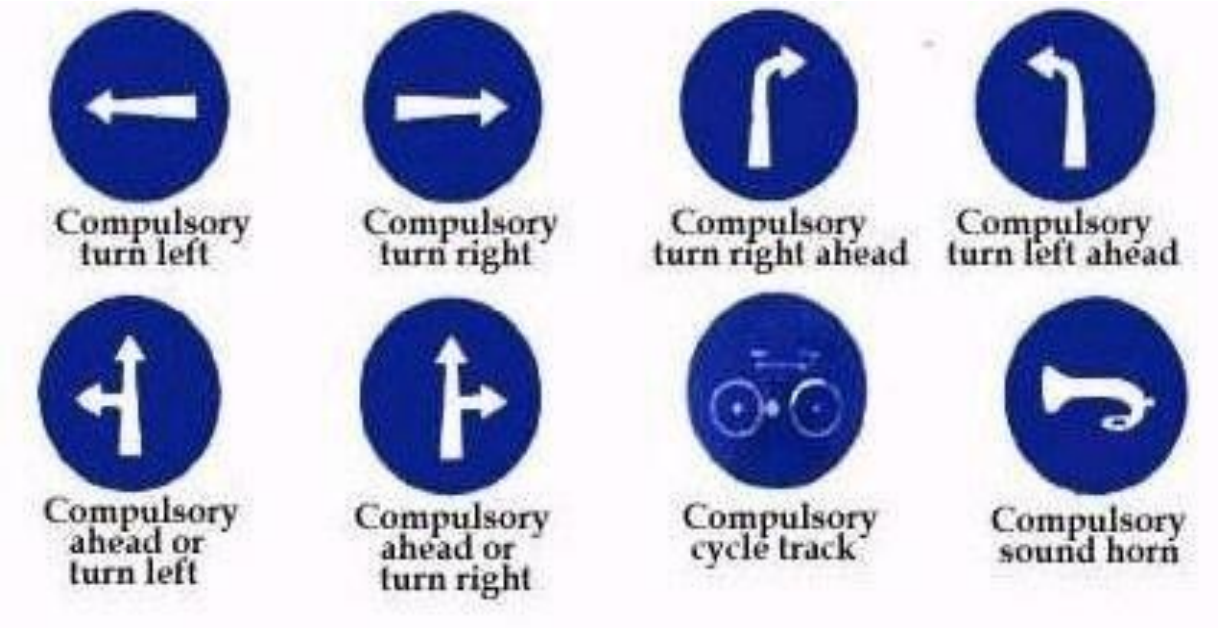
Fig.5 No standing

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 are the (i) **STOP** sign and (ii) **GIVE WAY** sign.

Fig.7 Stop sign

fig.8 Giveway sign

The stop sign requires all vehicles to come to a halt before 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) Un signalized intersection in a signalized area

The stop sign should not be used:

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

. The GIVE WAY sign is used to control the vehicles on a road so as to assign right of way to traffic on other roadways. According to the I.R.C the shape of GIVE WAY sign is downward pointing equilateral triangle having a red border band with white back 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 the major 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,round about, 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 and provide with information to make travel easier, safe and pleasant. The information signs are

- Direction and Place Identification signs
- Facility Information Signs
- Other Useful Information signs
- Parking signs
- Flood Gauge

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

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. T he main requirements of traffic signals are to draw attention, provide meaning and time to respond and to have minimum waste of time.

Advantages of traffic signals:

Properly designed traffic signals have the following uses:

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

Disadvantages of traffic signals:

- The rear-end collisions may increase.
- Improper design and location of signals may lead to violations of the control system.
- Failure of the signal due to electric power failure or any other defect may cause confusion to the road users.

Type of traffic 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 vechicles 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 with the 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.

TRAFFIC SIGNAL CO-ORDINATION

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

Need for co-ordinated control

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

Type of traffic signal system:

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

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

SIMULTANEOUS SYSTEM:

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

The disadvantages of a simultaneous systems are:

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

ALTERNATE SYSTEM:

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

The disadvantages of this systems are:

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

SIMPLE PROGRESSIVE SYSTEM:

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

FLEXIBLE PROGRESSIVE SYSTEM

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

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

GEOMETRIC DESIGN OF INTERSECTIONS

CHANNELIZATION

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

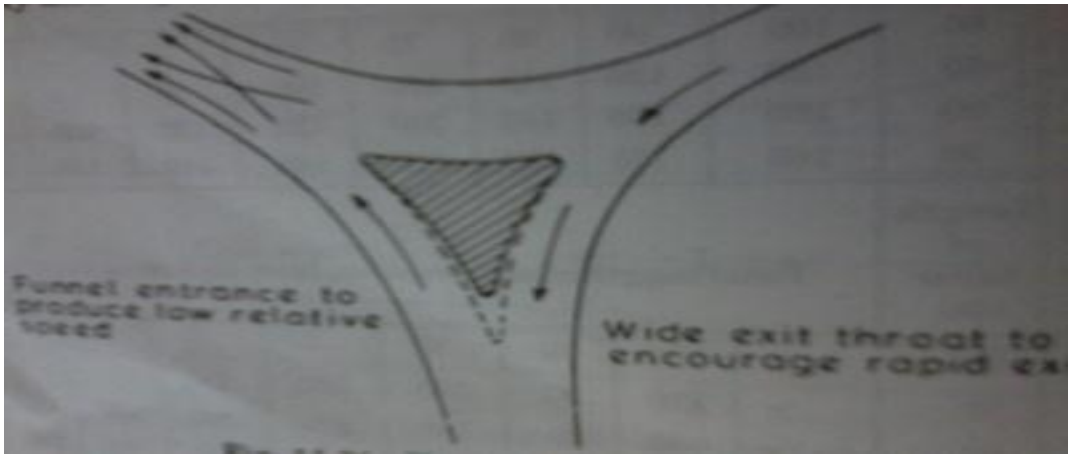
A channelized intersection is one which traffic is directed into definite paths by islands and markings.

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. **Seperation of conflicts**

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

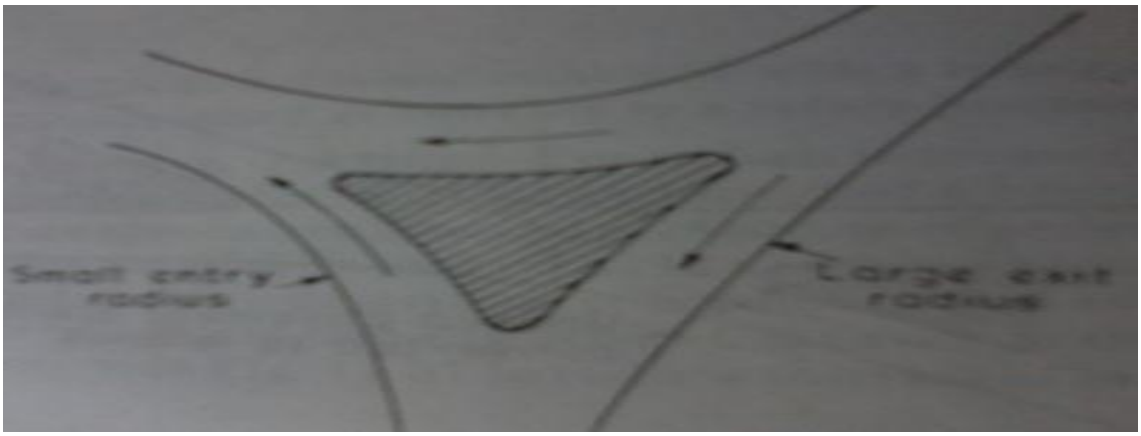


2. **Control of angle of conflicts**

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

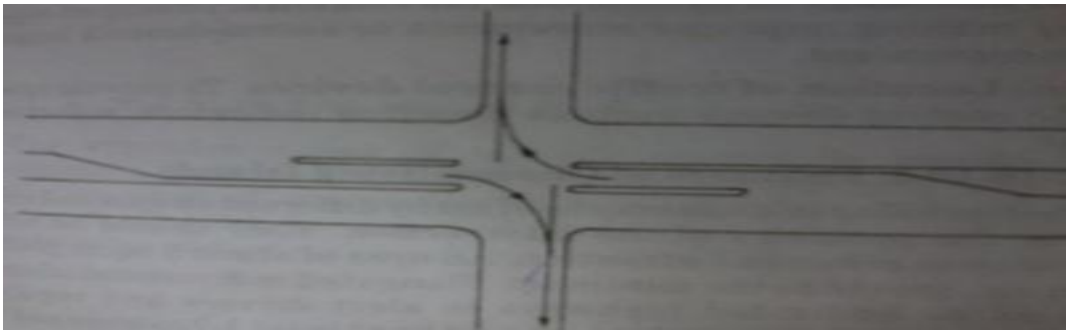
3. **Control of speed**

To reduce the speed of traffic entering the intersection & 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.



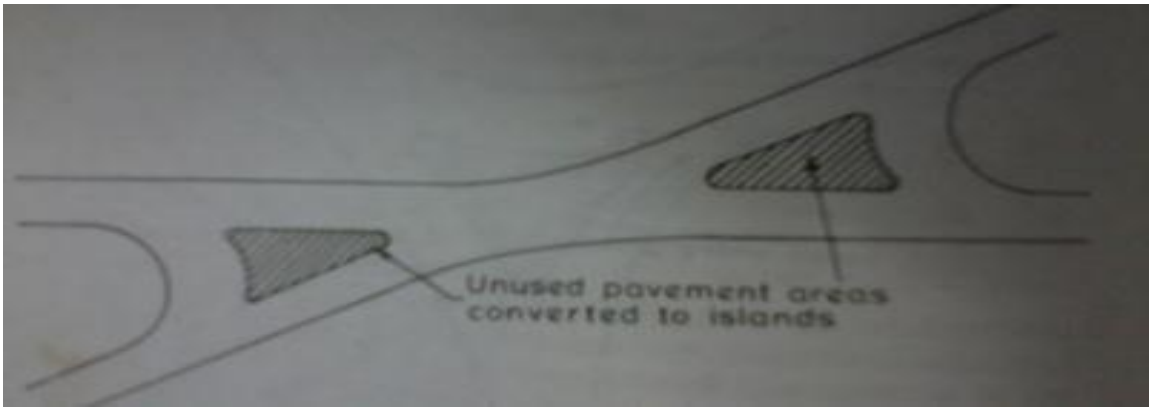
5. **Protection of pedestrians**

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**

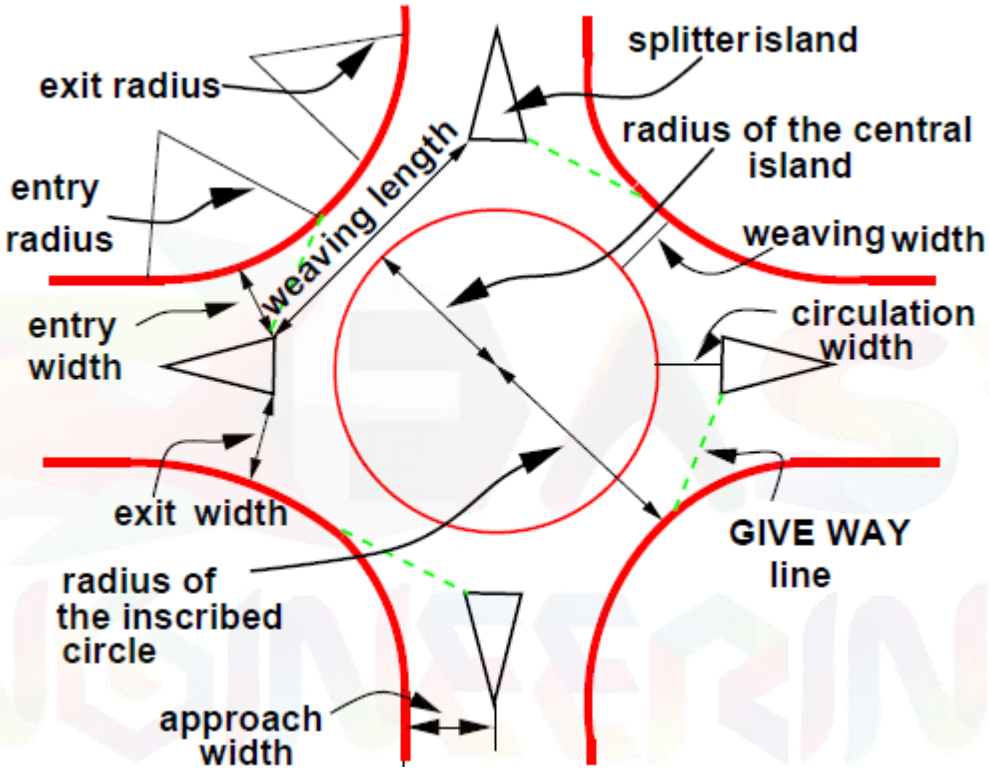
To support regulations by making improper movements or encroachments impossible or inconvenient.

8. **Location of traffic control devices**

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

ROTARY INTERSECTION (ROUNDABOUT)

A rotary intersection is an enlarged road intersection where all converging vehicles are forced to move round 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 cross streams 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 low speed. Frequent stopping & starting are avoided.

- All turns can be made with ease, although little extra travel distance is required for all movements except left turns.
- A rotary is especially suited for intersections legs, and /or where there are right-turning movements.
- For moderate traffic,rotaries are self-governing& need no control by police or traffic signals.

DISADVANTAGES OF ROTARY INTERSECTIONS

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

Guidelines for Selecting a Rotary Type of Intersection

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

ROTARY 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

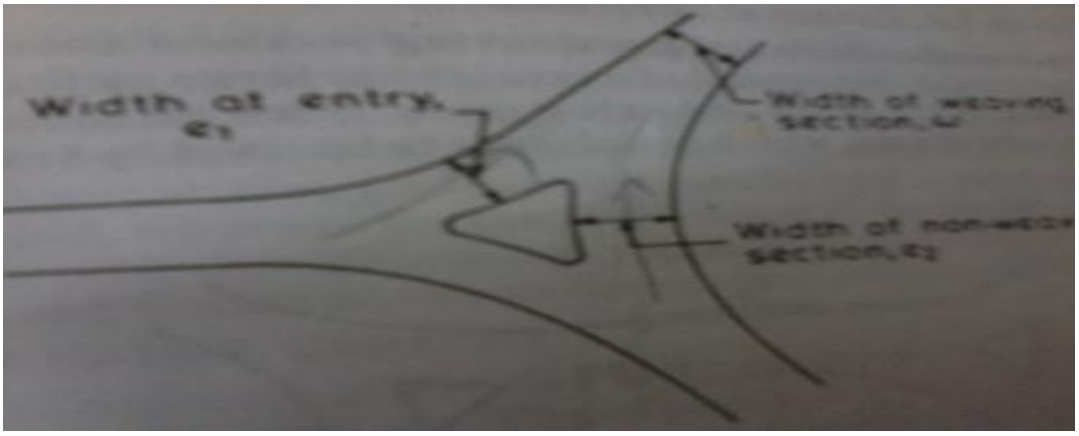
The carriageway width of the intersection legs is governed by the design year traffic entering and leaving the intersection. As per I.R.C minimum width of carriage way of 10m both entry and exit.

g. Width of Rotary Carriageway

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

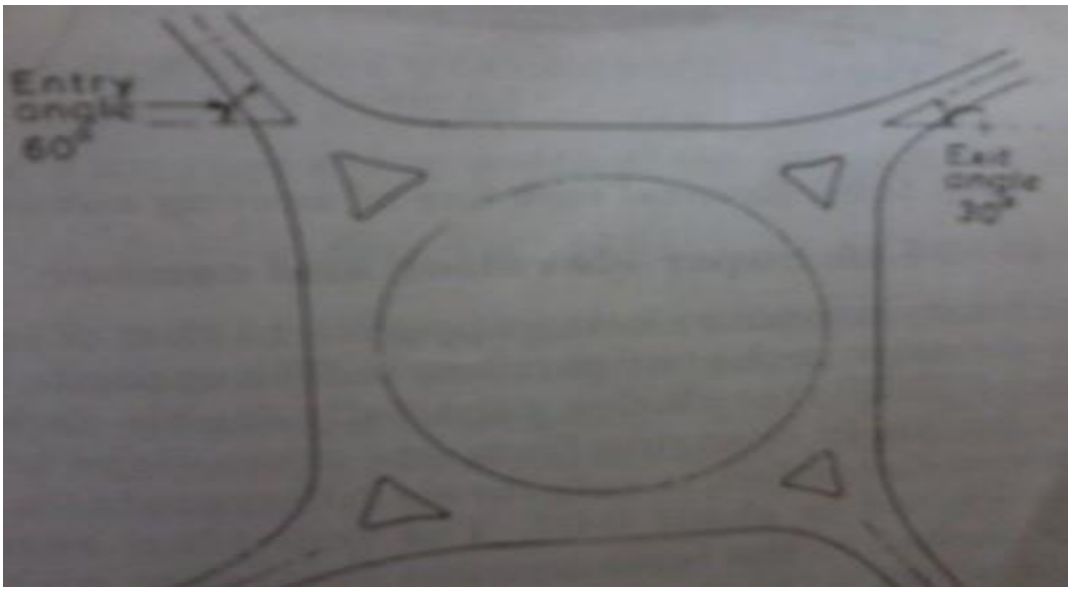
$$W = (e1 + e2)/2 + 3.5$$

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 about 60◦ 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 weaving section.=(b+c)/(a+b+c+d)

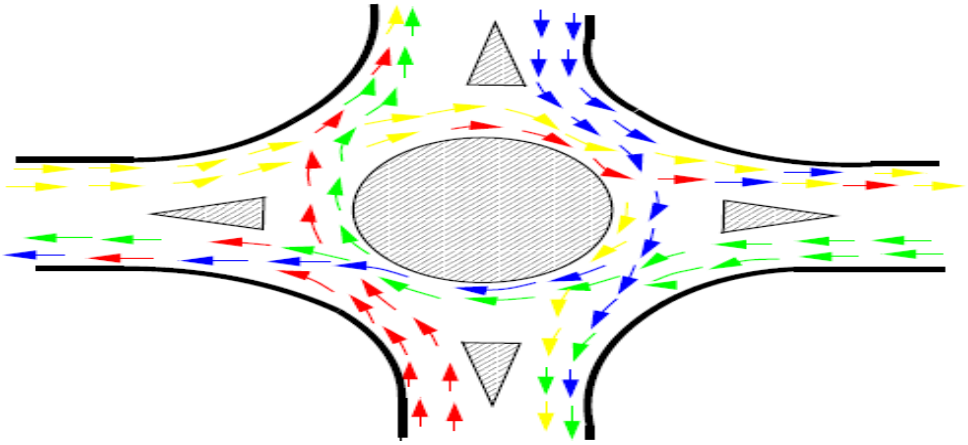
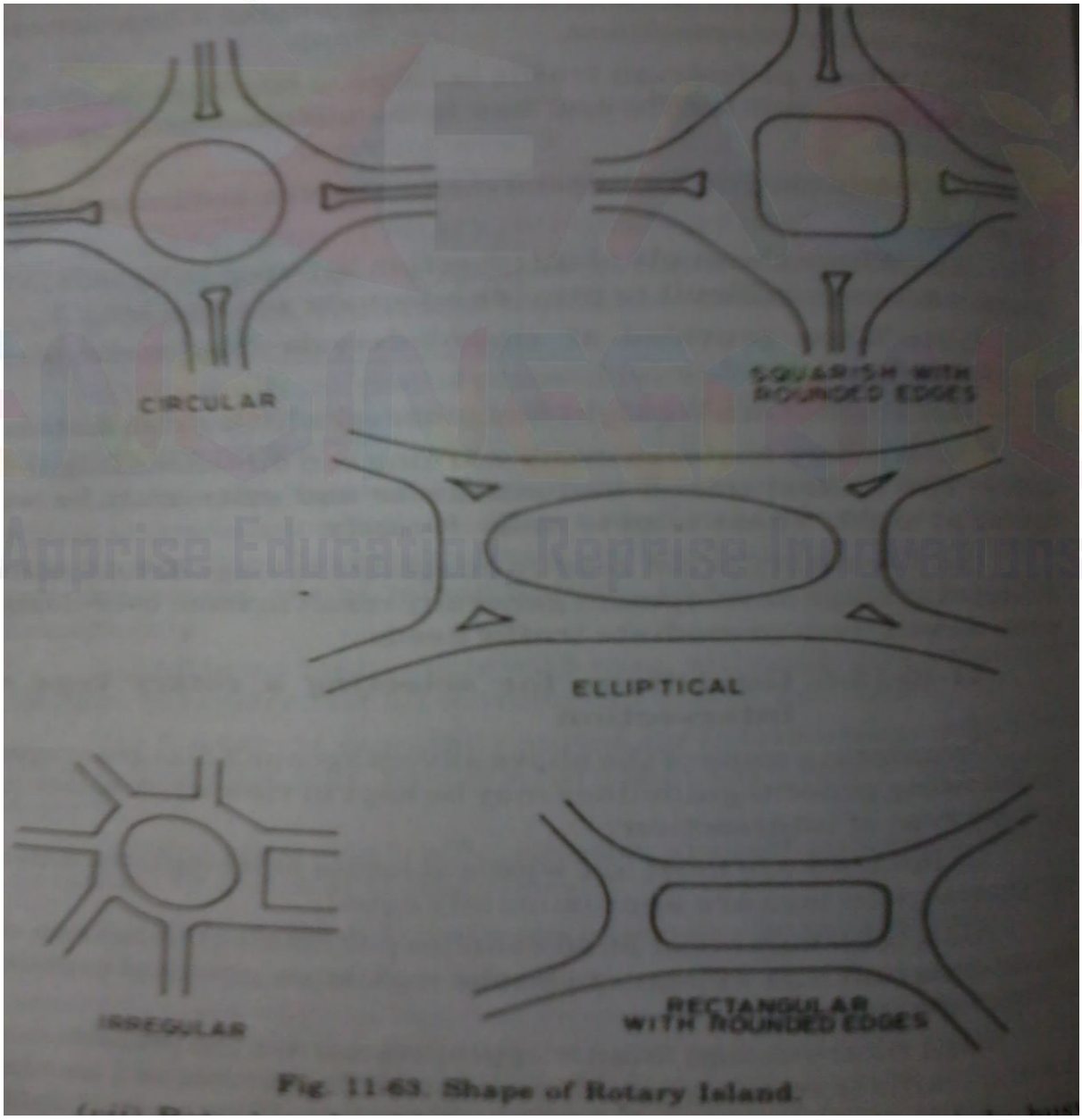


Fig.15 Traffic operation of rotary



Types of Grade –Seperated Intersection

Basically two types are met with:

1. Grade – seperated 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-seperated junction can be considered under the number of legs the intersection serves.Thus the interchanges can be classified as three-leg & multileg, & 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.

TRANSPORTATION MANAGEMENT

Transportation system management

Transportation system management (TSM) is a package of short term measures to make the most productive and cost effective use of existing transport facilities, services and modes.

Travel Demand Management

TDM technique are aimed at reducing traffic flows,especially during the peak hour. Some of the commonly 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 time

TRAFFIC MANAGEMENT MEASURES

Scope of 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

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

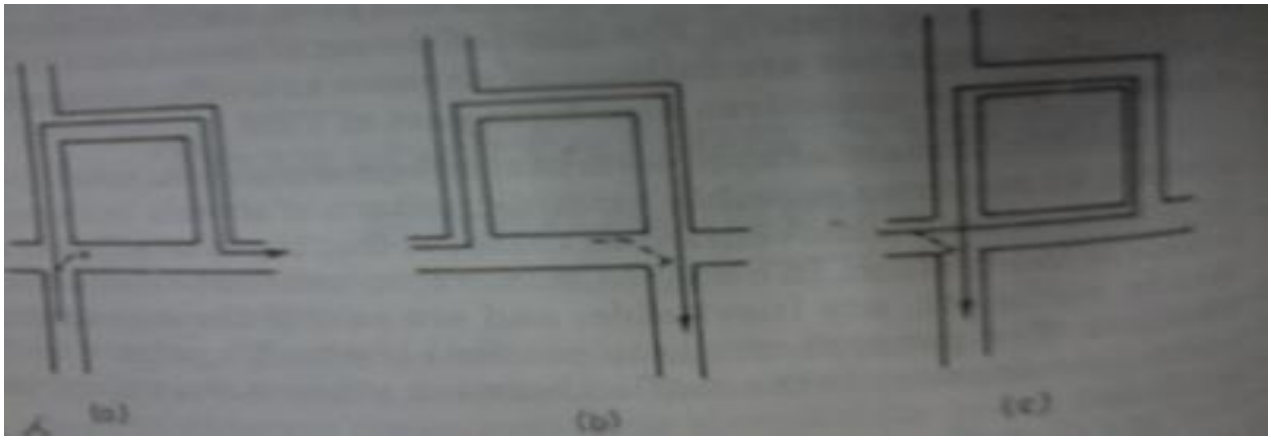
Prohibition of right-turning movement can be established only if the existing street system is capable of accommodating an alternative routing. Depending upon the existing layout of the street system, three methods are available:

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)

Prohibition of right-turning movement is known to increase the saturation flow and the capacity of the junction.

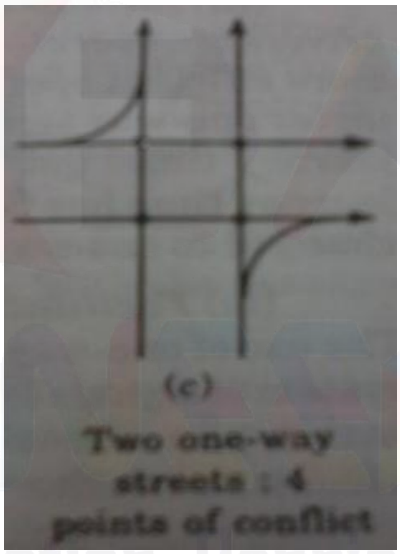


2. ONE-WAY STREETS

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.

iv. **Facilitating the operation of a progressive signal system**. The use of one-way street operation offers advantages in designing a system of signals for an entire area. Progressive system design is easy with a pair of one-way streets.

v. **Improvement in parking facilities.** A two-way street with parking permitted on both sides consumes a good amount of street width. Parking manoeuvres become less dangerous and obstructive when all vehicles face in the same direction.

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.

iv. In the initial stages of its introduction, confusion is likely to be created amongst motorists and pedestrians. With the passage of some time, familiarity sets in.

v. Emergency vehicles (fire services, ambulances etc.) may be blocked by cars in all lanes at intersections waiting for signals to change.

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 method 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.

Special measures needed

With a tidal flow operation, special signing and additional control devices are needed. The assignment of traffic to proper lanes can be achieved by placing overhead signs.

It is desirable to restrict parking on the side of the major flow during the peak periods.

4. CLOSING SIDE-STREETSMethod

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. A spacing of 275 m between signalized intersections is desirable, and this necessitates the closure of all intermediate side streets.

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. Those vehicles which used to

park on the side streets are now deprived of their parking space. This may create congested conditions on the main road and lead to delays and lower speeds.

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. Regularity of the buses can be improved. Viewed in the present context of traffic dilemma caused by the increase in car ownership and the need to patronize public transport, this is a welcome strategy.

TRAFFIC FORECASTING

Need for traffic forcasting

1. Need for estimating the future traffic accurately, whether the plan be for the construction of a new facility or the the improvement of existing facilities.
2. To extent, the accurate estimate of future traffic will influence the engineering design of the facility and the economic decision whether to takeup the project or not.

INTELLIGENT TRANSPORTATION SYSTEM (ITS)

Intelligent Transportation Systems (ITS) is the application of computer, electronics, and communication technologies and management strategies in an integrated manner to provide traveler information to increase the safety and efficiency of the road transportation systems.

These systems involve vehicles, drivers, passengers, road operators, and managers all interacting with each other and the environment, and linking with the complex infrastructure systems to improve the safety and capacity of road systems.

ITS improves transportation safety and mobility and enhances global connectivity by means of productivity improvements achieved through the integration of advanced communications technologies into the transportation infrastructure and in vehicles.

Applications of ITS

ITS covers variety of applications such as:

1. Monitoring traffic flow, provide information to drivers on the congestion on the road, road closures, alternative routes, weather conditions and speeds to be observed.

2. Advanced traveller information system (ATIS) gives information to highway users on traffic jams, road closures, alternative routes and weather conditions.

3. Electronic collection of toll.

4. Electronic road pricing system to decongest the city centers.

5. Traffic control on urban streets by using information on traffic flows and adjusting the signal operations to reduce congestion and delay.

6. Monitoring incidents on the road, such as vehicle breakdown and collisions.

7. Intelligent vehicle-highway system(IVHS), in which vehicles guided longitudinally and laterally by the use of electronic devices.

TRAFFIC CALMING MEASURES

To reduce the number and severity of road casualties and to reduce the number of accidents in which people, particularly children, are killed or seriously injured, we can introduce a variety of traffic-calming measures.

Some of traffic calming measures are:

3E'S of traffic engineering

1. **Engineering**
2. **Education**
3. **Enforcement**