MODULE-1

TRAFFIC PLANNING AND CHARACTERISTICS

Traffic Planning and Characteristics: Road Characteristics-Road user characteristics, PIEV theory, Vehicle Performance characteristics, Fundamentals of Traffic Flow, Urban Traffic problems in India, Integrated planning of town, country, regional and all urban infrastructures, Sustainable approach- land use & transport and modal integration

1.1.INTRODUCTION

It is a phase of Transportation Engineering which deals with planning and geometrical design of roads, streets, and adjoining lands and with traffic operations there on for safe, convenient and economic transportation of persons and goods is known as Traffic Engineering. Present day roads are to serve all types of traffic from pedestrian and animal driven traffic to automobile traffic including military vehicles and are thus liable to traffic congestion. So, to avoid traffic congestion and to provide efficient free and rapid flow of all types of traffic, the studies of traffic characteristics and traffic operations have become essential before planning and designing of any Transportation system. Now these aspects of planning and geometrical design of road and traffic studies have become so important that they constitute a separate branch of civil engineering, known as Traffic Engineering and the person who performs the traffic studies is called traffic engineer.

1.2.OBJECTS OF TRAFFIC ENGINEERING :-

- To provide efficient flow of traffic.
- To provide free flow of traffic.
- To provide rapid flow of traffic.
- To provide safety to the traffic.

1.3.SCOPE OF TRAFFIC ENGINEERING :- Traffic Engineering includes the study of the following phases:-

- Traffic characteristics
- Traffic operations
- Traffic planning

• Traffic geometrical design

• Traffic administration.

Traffic Engineering is the branch of engineering which deals with the improvement of the traffic performance of road networks and terminals. For achieving that we have to perform systematic traffic studies, analysis and then its engineering application. First of the most important scientific study is the study of the traffic characteristics. Traffic can be classified into two classes:

• Road Users.

• Vehicular traffic.

1.4.ROAD USER CHARACTERISTICS

Human beings performing different roles in the traffic are most important elements of the traffic and so we have to study their characteristics and behavior. Various roles of human are such as driver, pedestrians, cyclists etc. The physical, mental and emotional characteristics of human beings affect their ability to operate motor vehicle safely or to service as a pedestrian. Hence it is important for a traffic engineer to study the characteristics and limitations of the road users.

The various factors which affect road user characteristics may broadly be classified under four heads:

• Physical

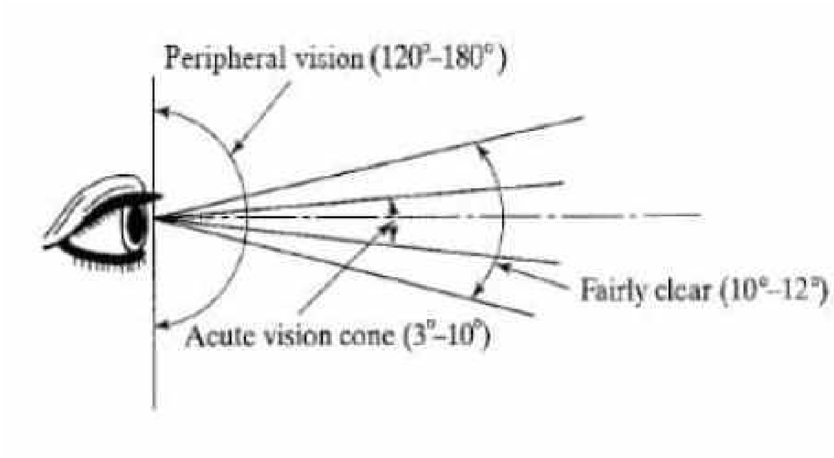
• Mental

• Psychological

• Environmental

a) **PHYSICAL CHARACTERISTICS**: The permanent physical characteristics of the driver are vision, hearing, strength and the general reaction to the traffic situations.

• **Vision** include the acuity of vision, peripheral vision and eye movement; glare vision, glare recovery and depth judgement. Field of accurate, clear vision is about a 3 degrees cone however the vision is fairly satisfactory up 4 to 10 degrees in general and 20 degrees in horizontal plane. In vertical plane the vision may be limited to 2/3 of that in horizontal plane.



- **Hearing** is helpful for drivers but of more important for the pedestrians and cyclists.

- **Strength** is not an important factor in general; lack of strength may make parking maneuvers difficult, particularly for heavy vehicles.

b)MENTAL CHARACTERISTICS: Knowledge, skill, intelligence, experience and literacy can affect the road user characteristics. Knowledge of vehicle characteristics, traffic behavior, driving practice, rules of roads and psychology of road users will be quite useful for safe traffic operations.

c)PSYCHOLOGICAL FACTORS: This affect reaction to traffic situations of road users to a great extent. Attentiveness, anger, fear, anxiety, phobias, superstition, and impatience may affect the traffic performance to great extent.

d)ENVIRONMENTAL FACTORS: The various environmental conditions affecting the behavior of road user are traffic stream characteristics, facilities to the traffic, atmospheric conditions and locality. The traffic stream may consist of mixed traffic or heavy traffic whereas facilities to overtake to the faster vehicles may be limited. The behavior of the driver varies from one traffic stream to another. Similarly the facilities of the traffic separators, multi-lanes etc will affect the performance. Surrounding environment effect the performance of the traffic because one will get slower at the market places and will be faster at the open places.

1.4.1. HUMAN FACTORS AFFECTING TRANSPORTATION : Road users can be defined as drivers, passengers, pedestrians etc. who use the streets and highways. Together, they form the most complex element of the traffic system - the human element - which differentiates Transportation Engineering from all other 5 engineering fields. It is said to be the most complex factor as the human performances varies from individual to individual. Thus, the transportation engineer should deal with a variety of road user characteristics. For example, a traffic signal timed to permit an average pedestrian to cross the street safely may cause a severe hazard to an elderly person. Thus, the design considerations should safely and efficiently accommodate the elderly persons, the children, the handicapped, the slow and speedy, and the good and bad drivers.

1.4.2. VARIABILITY : The most complex problem while dealing human characteristics is its variability. The human characteristics like ability to react to a situation, vision and hearing, and other physical and psychological factors vary from person to person and depends on age, fatigue, nature of stimuli, presence of drugs/alcohol etc. The influence of all these factors and the corresponding variability cannot be accounted when a facility is designed. So a standardized value is often used as the design value. The 85th percentile value of different characteristics is taken as a standard. It represents a characteristic that 85 per percent of the population can meet or exceed.

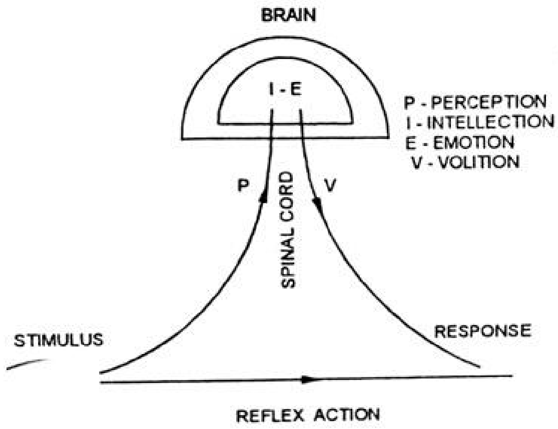
For example. if we say that the 85th percentile value of walking speed is about 2 m/s, it means that 85 per cent of people has walking speed faster than 2 m/s. The variability is thus fixed by selecting proper 85th percentile values of the characteristics.

1.4.3. CRITICAL CHARACTERISTICS :

The road user characteristics can be of two main types, some of them are quantifiable like reaction time, visual acuity etc. while some others are less quantifiable like the psychological factors, physical strength, fatigue, and dexterity.

a) REACTION TIME

The road user is subjected to a series of stimuli both expected and unexpected. The time taken to perform an action according to the stimulus involves a series of stages like:



• Perception: Perception is the process of perceiving the sensations received through the sense organs, nerves and brains. It is actually the recognitions that a stimulus on which a reaction is to happen exists.

• Intellection: Intellection involves the identification and understanding of stimuli.

• 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 execution of the decision which is the result of a physical actions of the driver

According to 'PIEV' theory, the total reaction time of the driver is split into four parts, That is, time taken by the driver for:

1. Perception
2. Intellection
3. Emotion and
4. Volition

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

‘Intellection time’ is the time required for the driver to understand the situation. It is also the time required for comparing the different thoughts, regrouping, and registering new sensations.

‘Emotion time’ is the time elapsed during emotional sensations and other mental disturbances such as fear, anger, or any other emotional feelings like superstition, etc. with reference to the situation. The emotion time varies for different drivers, but even for a particular driver, the emotion time is likely to vary considerably depending upon the situation or the actual problem involved.

‘Volition time’ is the time taken by the driver for the final action, such as brake application.

For example., if a driver approaches an intersection where the signal is red, the driver first sees the signal (perception), he recognizes that is a red/STOP signal, he decides to stop and finally applies the brake(volition). This sequence is called the PIEV time or perception-reaction time. But apart from the above time, the vehicle itself traveling at initial speed would require some more time to stop.

That is, the vehicle traveling with initial speed u will travel for a distance,

$$d = vt$$

where, t is the above said PIEV time. Again, the vehicle would travel some distance after the brake is applied.

It is also possible that the driver may apply brakes or take any other avoiding action like turning, by the 'reflex action', without the normal thinking process, which is probably the minimum time for taking a preventive action like brake application. The PIEV time of a driver also depends on several factors such as the physical and psychological characteristics of the driver, type of problem involved. environmental conditions and temporary factors (eg. motive of the trip, travel speed, fatigue, consumption of alcohol, etc.).

The total reaction time of an average driver may vary from 0.5 seconds for simple situations to as much as 3 to 4 seconds or even more in complex problems.

b)VISUAL ACUITY AND DRIVING:

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 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.

c)WALKING:

Transportation planning and design will not be complete if the discussion is limited to drivers and vehicular passengers. The most prevalent of the road users are the pedestrians. Pedestrian traffic along footpaths, sidewalks, crosswalks, safety zones, 7 islands, and over and under passes should be considered. On an average, the pedestrian walking speed can be taken between 1.5 m/sec to 2 m/sec. But the influence of physical, mental, and emotional factors need to be considered. Parking spaces and facilities like signals, bus stops, and over and under passes are to be located and designed according to the maximum distance to which a user will be willing to walk. It was seen that in small towns 90 per cent park within 185 m of their destinations while only 66 per cent park so close in large city.

d)OTHER CHARACTERISTICS:

Hearing is required for detecting sounds, but lack of hearing acuity can be compensated by usage of hearing aids. Lot of experiments was 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. Two of the important constituents of transportation system are drivers and users/passengers. Understanding of certain human characteristics like perception - reaction time and visual acuity and their variability are to be considered by Traffic Engineer. Because of the variability in characteristics, the 85th percentile values of the human characteristics are fixed as standards for design of traffic facilities.

1.5.VEHICLE FACTORS:

It is important to know about the vehicle characteristics because we can design road for any vehicle but not for an indefinite one. The road should be such that it should cater to the needs of existing and anticipated vehicles. Some of the vehicle factors that affect transportation is discussed below.

1.5.1.DESIGN VEHICLES:

Highway systems accommodate a wide variety of sizes and types of vehicles, from smallest compact passenger cars to the largest double and triple tractor-trailer combinations. According to the different geometric features of highways like the lane width, lane widening on curves, minimum curb and corner radius, clearance heights etc some standard physical dimensions for the vehicles has been recommended.

Road authorities are forced to impose limits on vehicular characteristics mainly:

• To provide practical limits for road designers to work to,

• To see that the road space and geometry is available to normal vehicles,

• To implement traffic control effectively and efficiently,

• Take care of other road users also. Taking the above points into consideration, in general, the vehicles can be grouped into motorized two wheeler's, motorized three wheeler's, passenger car, bus, single axle trucks, multi axle trucks, truck trailer combinations, and slow non motorized vehicles.

1.5.2.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. 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.

1.5.3.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 is also important at an intersection, roundabout, terminals, and parking areas.

1.5.4.VISIBILITY:

The visibility of the driver is influenced by the vehicular dimensions. As far as forward visibility is concerned, the dimension of the vehicle and the slope and curvature of wind screens, windscreen wipers, door pillars, etc should be such that:

- visibility is clear even in bad weather conditions like fog, ice, and rain;
- it should not mask the pedestrians, cyclists or other vehicles;
- during intersection maneuvers.

Equally important is the side and rear visibility when maneuvering especially at intersections when the driver adjusts his speed in order to merge or cross a traffic stream. Rear vision efficiency can be achieved by properly positioning the internal or external mirrors.

1.5.5.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 10 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 makes 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 filled by normal passing maneuvers.

1.5.6.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. The factors on which the braking distance depend are the type of the road and its condition, the type and condition of tire and type of the braking system. The distance to decelerate from one speed to another is given by:

$$d = (v\ 2 - u\ 2) / (f + g)$$

where d is the braking distance,

v and u are the initial and final speed of the vehicle,

f is the coefficient of forward rolling and skidding friction and

g is the grade in decimals.

The main characteristics of a traffic system influenced by braking and deceleration performance are:

- **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. Such a vehicle which is at a distance equal or greater than the stopping sight distance will have to travel a distance equal to the stopping sight distance plus the width of the street, plus the length of the vehicle. Thus the yellow and all red times should be calculated to accommodate the safe clearance of those vehicles.

- **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. From the examples discussed above, it is clear that the braking and reaction distance computations are very important as far as a transportation system is concerned. Stopping sight distance is a product of the characteristics of the driver, the vehicle and the roadway. and so this can vary with drivers and vehicles. Here the concept of design vehicles gains importance as they assist in general design of traffic facilities thereby enhancing the safety and performance of roadways.

1.6.ROAD FACTORS :

1.6.1.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 anti skid 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.

1.6.2.LIGHTING :

Illumination is used to illuminate the physical features of the road way and to aid in the driving task. A luminary is a complete lighting device that distributes light into patterns much as a garden hose nozzle distributes water. Proper distribution of the light flux from luminaries is one of the essential factors in efficient roadway lighting. It is important that roadway lighting be planned on the basis of much traffic information such as night vehicular traffic, pedestrian volumes and accident experience

1.6.3.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.

1.6.4.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.

1.6.5.NIGHT VISIBILITY :

Since most accidents occur at night because of reduced visibility, the traffic designer must strive to improve nighttime visibility in every way he can. 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.

1.6.6.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 elements that cannot be avoided are curves. Near curves, chances of accidents are more. Speed of the vehicles is also affected.

  1.6.7.SKID RESISTANCE Has two components, commonly identified as adhesion and hysteresis.

The adhesive part is the ‘bonding’ of the tyre as the vehicle brakes and the tyre is forced against the surface of the stone under significant pressure.

The second component ‘hysteresis’ is a result of the deformation of the tyre between the stones and the resistance within the tyre to this deformation.

These forces will cause heating which softens the tyre and does have an effect on the friction resistance.

1.6.8.SURFACE TEXTURE :

The two components of skid resistance are related to the two types of texture. Both texture components will have an influence on skid resistance and the degree of influence will change depending upon the speed of the vehicle and the pavement surface characteristics.

a)MACRO-TEXTURE

Macro-texture is the visual texture, large irregularities, observed when examining the broad stone-binder matrix. It is the characteristic deviation of a pavement surface from the true planar surface within the wavelength of 0.5 and 50mm. This type of texture provides escape paths for water under a tyre and controls how rapidly skid resistance drops off with increase in speed due to lack of water egress. This texture of the road surface is associated with the hysteresis component of skid resistance. Initially macro-texture was measured by manual means using the ‘Sand Patch’ method involving the use of a known volume of sand, spread evenly over the road surface and then measuring the size of the patch, finally giving a texture measure, TP346. Texture is now determined using automated laser based systems TP351 & TP352 enabling faster (more) and continuous data collection. This texture characteristic has a greater influence at higher speeds.

b)MICRO-TEXTURE :

Micro-texture is the fine texture felt by running a finger over a stone surface and is not readily observable. It is defined as the characteristic deviation of a pavement surface from the true planar surface below 0.5mm, the finer irregularities of the surface of the stone (generally a result of quarry crushing). This texture will affect adhesion. It is also a function of the stones potential to polish. This characteristic has a greater influence at low speeds

1.7.TESTING OF SKID :

Skid resistance can be determined by a number of pieces of equipment, all are measuring the frictional resistance of a rubber material (vehicle tyre) over the road surface. One of the long standing devices is the manually operated British Pendulum which has a small rubber foot (75x25 mm) attached to a pendulum that swings over the road surface (TP345). The frictional resistance is measured against a scale attached to the equipment. Other more recent and automated devices use tyres that rotate at rates less than that of the tyres of the vehicle they are attached to, resulting in a braking/sliding action. The braking rate may be fixed or variable and the tyre may be straight or set at an angle. Recording of test results is now automated allowing for greater quantities of data to be collected and more easily analysed. Testing can be done using smooth or treaded tyres, but for better and more consistent results the smooth tyre is preferred. Automated testing within the Safety and Services Division utilises a Griptester (TP344). Suitable correlations have been made between the equipment used by DPTI. Examples of automated devices are the Griptester, SCRIM (Sideways-force Coefficient Routine Investigation Machine), Norsemeter ROAR and the American ASTM E-274 braked wheel trailer. Measurements of both characteristics are undertaken by Field Testing staff of the Pavements Engineering Unit, using automated laser based equipment for texture Laser Profilometer and WDM TM2 Texture Meter. Skid resistance testing is determined using a Griptester (general) or a British Pendulum (research & special projects).

1.7.1.SKID RESISTANCE TEST

Procedure (TRRL 1969)

- Select the spot in which the texture depth has been measured.
- Set the apparatus on the road so that the slider will swing in the direction of traffic flow and level the base screws.
- Raise the swinging arm clear of the road and clamp in the horizontal position. Release the arm and check that the pointer reads zero.
- With the pendulum arm free and hanging vertically, place the spacer, attached to a chain on the base of the column, under the lifting handle setting screw to raise the slider. Lower the head of the tester so that the slider just touches the road surface and clamp in position. Remove the spacer.

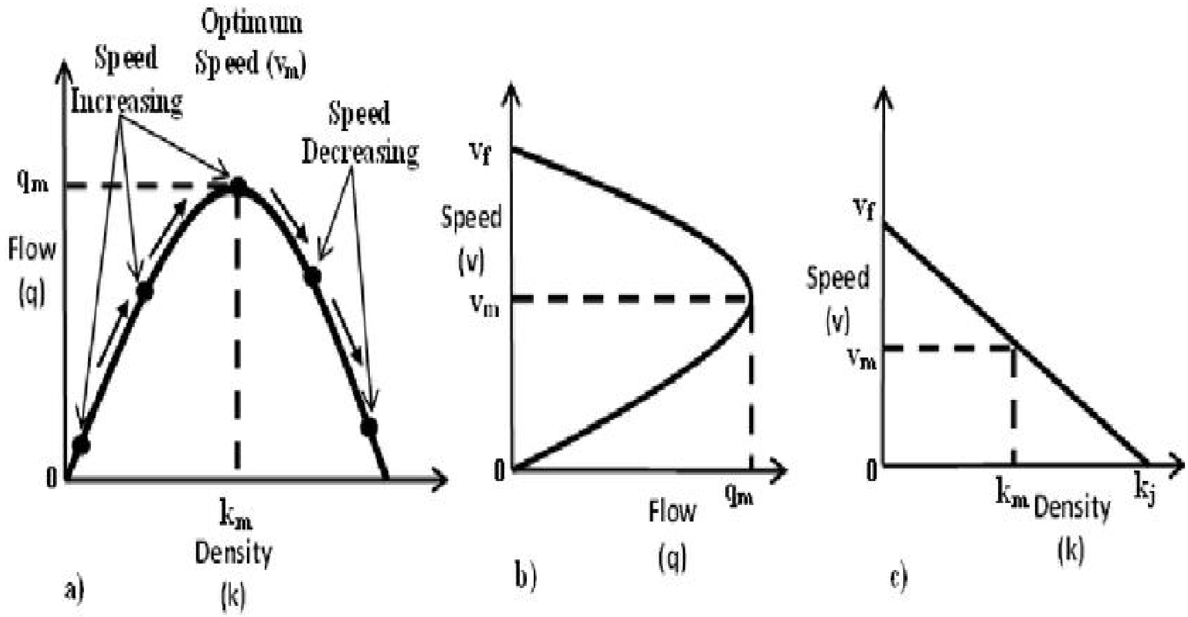
- Check the sliding length of the rubber slider over the road surface by gently lowering the pendulum arm until the slider just touches the surface first on one side of the vertical and then on the other.
- When passing the arm through the vertical, use the lifting handle so that the slider does not touch the road. The sliding length should be between 125 and 127 mm. If not, adjust by raising or lowering the head.
- Place the pendulum arm in the horizontal and clamp in position.
- Wet the road surface and slider with water.
- Bring the pointer to its stop then release the pendulum by pressing the button. Take care to catch the arm on its return swing before it hits the ground.
- Return the arm and pointer to the release position keeping the slider off the road surface by means of the lifting handle. Repeat the test, wetting the surface between swings. Record the mean of five successive readings, provided they do 18 not differ by more than three units. If the range is greater than this, repeat swings until three successive readings are constant; record this value.
- Record the temperature of the water on the road surface.

1.8.BRAKING EFFICIENCY

The function of the vehicle brakes is to control the speed of the vehicle on hills, to reduce the speed when required and to stop the vehicle altogether and hold it stationary. How well a set of brakes fulfills this function depends on many factors; one of which - road surface condition- is in no way under the control of the driver; other factors such as tyre condition and gross vehicle weight, are not directly related to the design and condition of the brakes although they are the responsibility of the driver. The ability of the brakes to perform their function is popularly known as braking efficiency and in most countries, legally enforceable regulations require that all road vehicles have an efficient braking system. In assessing braking efficiency, it is usual to consider the effect which the brakes achieve when they are applied. The action of applying the brakes sets up a force effective at the road surface, which acts in the opposite direction to the motion of the vehicle and causes it to slow down 21 or decelerate. This deceleration is normally compared to a standard value (the acceleration due to gravity g) and reported as a percentage of "g". Defining braking efficiency in such a way directly comparable standards of braking can be established of differing classes of vehicle. Dependent on whether metric or imperial units are used, "g" may be 9.81m/sec/sec or 32 ft /sec/sec in absolute terms. Vehicle construction legislation normally requires various classes of vehicle to have a braking system capable of producing a specific minimum deceleration. In modern vehicles, the braking system is designed so that, provided the vehicle is correctly maintained and the driver applies sufficient pedal pressure, the minimum braking efficiency will be achieved irrespective of whether the vehicle is loaded or not. Only in cases where the brakes are poorly maintained or where the vehicle is loaded significantly above the maximum gross design weight, will the weight of the vehicle affect the braking efficiency and the brakes be unable to achieve the minimum required efficiency. Within the above limits, considerations of the weight of the vehicle can be ignored, since for a particular minimum efficiency required by the regulations, the ratio “Braking force achieved to gross vehicle weight" will be constant.

1.9. FUNDAMENTALS OF TRAFFIC FLOW:

The **fundamental diagram of traffic flow** is a diagram that gives a relation between road traffic flux (vehicles/hour) and the traffic density (vehicles/km). A macroscopic traffic model involving traffic flux, traffic density and velocity forms the basis of the fundamental diagram. It can be used to predict the capability of a road system, or its behaviour when applying inflow regulation or speed limits.



- There is a connection between traffic density and vehicle velocity: The more vehicles are on a road, the slower their velocity will be.
- To prevent congestion and to keep traffic flow stable, the number of vehicles entering the control zone has to be smaller or equal to the number of vehicles leaving the zone in the same time.
- At a critical traffic density and a corresponding critical velocity the state of flow will change from stable to unstable.
- If one of the vehicles brakes in unstable flow regime the flow will collapse.

The primary tool for graphically displaying information in the study traffic flow is the fundamental diagram. Fundamental diagrams consist of three different graphs: flow-density, speed-flow, and speed-density. The graphs are two dimensional graphs. All the graphs are related by the equation "flow = speed * density"; this equation is the essential equation in traffic flow. The fundamental diagrams were derived by the plotting of field data points and giving these data points a best fit curve. With the fundamental diagrams researchers can explore the relationship between speed, flow, and density of traffic.

Speed-density

The speed-density relationship is linear with a negative slope; therefore, as the density increases the speed of the roadway decreases. The line crosses the speed axis, y, at the free flow speed, and the line crosses the density axis, x, at the jam density. Here the speed approaches free flow speed as the density approaches zero. As the density increases, the speed of the vehicles on the roadway decreases. The speed reaches approximately zero when the density equals the jam density.

Flow-density

In the study of traffic flow theory, the flow-density diagram is used to determine the traffic state of a roadway. Currently, there are two types of flow density graphs: parabolic and triangular. Academia views the triangular flow-density curve as more the accurate representation of real world events. The triangular curve consists of two vectors. The first vector is the freeflow side of the curve. This vector is created by placing the freeflow velocity vector of a roadway at the origin of the flow-density graph. The second vector is the congested branch, which is created by placing the vector of the shock wave speed at zero flow and jam density. The congested branch has a negative slope, which implies that the higher the density on the congested branch the lower the flow; therefore, even though there are more cars on the road, the number of cars passing a single point is less than if there were fewer cars on the road. The intersection of freeflow and congested vectors is the apex of the curve and is considered the capacity of the roadway, which is the traffic condition at which the maximum number of vehicles can pass by a point in a given time period. The flow and capacity at which this point occurs is the optimum flow and optimum density, respectively. The flow density diagram is used to give the traffic condition of a roadway. With the traffic conditions, time-space diagrams can be created to give travel time, delay, and queue lengths of a road segment.

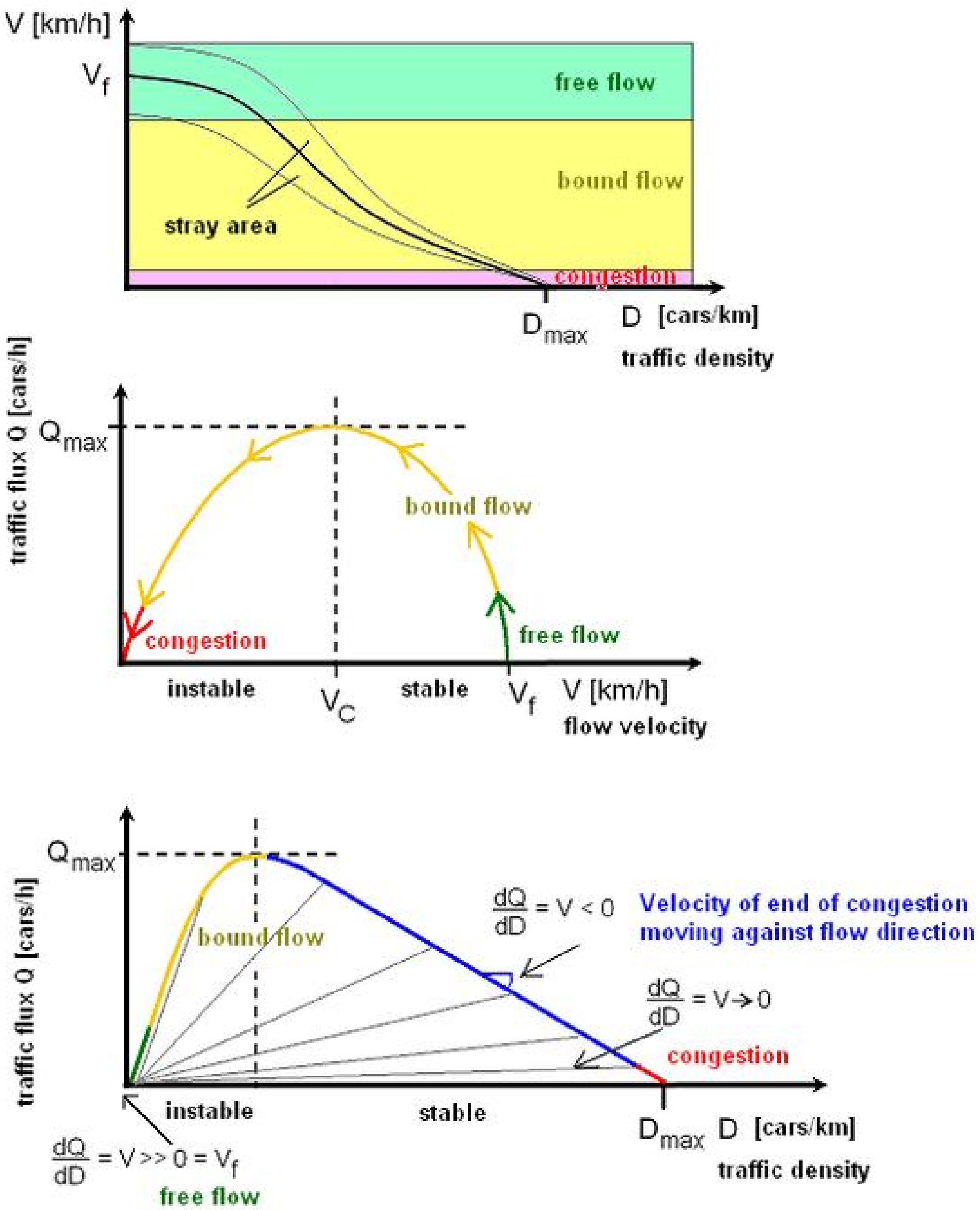
Speed-flow

Speed – flow diagrams are used to determine the speed at which the optimum flow occurs. There are currently two shapes of the speed-flow curve. The speed-flow curve also consists of two branches, the free flow and congested branches. The diagram is not a function, allowing the flow variable to exist at two different speeds. The flow variable existing at two different speeds occurs when the speed is higher and the density is lower or when the speed is lower and the density is higher, which allows for the same flow rate. In the first speed-flow diagram, the free flow branch is a horizontal line, which shows that the roadway is at free flow speed until the optimum flow is reached. Once the optimum flow is reached, the diagram switches to the congested branch, which is a parabolic shape. The second speed flow diagram is a parabola. The parabola suggests that the only time there is free flow speed is when the density approaches zero; it also suggests that as the flow increases the speed decreases. This parabolic graph also contains an optimum flow. The optimum flow also divides the free flow and congested branches on the parabolic graph.

Fundamental diagram of traffic flow

Fundamental equation of traffic flow: $\boxed{Q = D \cdot V}$

Source: Hendrik Ammoser, Fakultät Verkehrswissenschaften, Dresden, Germany

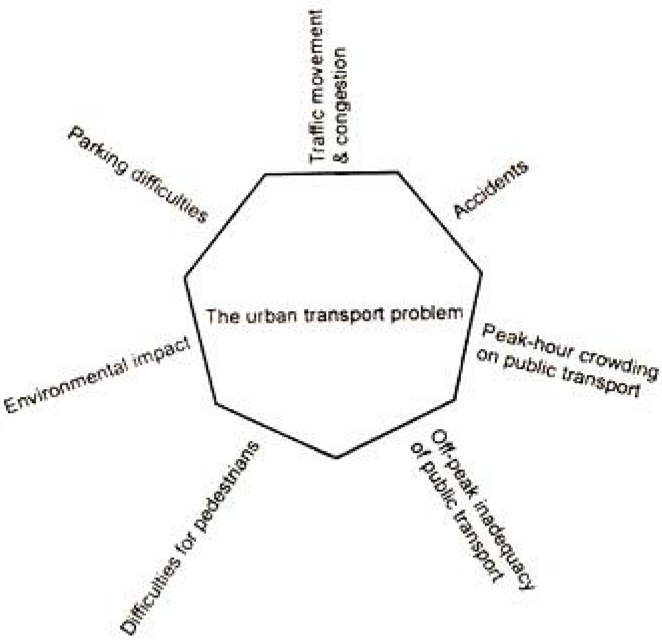


V_f = "free velocity" - maximum velocity on free lane, selectable by the driver depending on car, skill etc.

V_C = "critical velocity" with maximum traffic flux (about 70...100 km/h)

1.10. URBAN TRAFFIC PROBLEMS IN INDIA

Figure 5.2
The Seven Facets of the Urban Transport Problem



1. Traffic Movement and Congestion:

Traffic congestion occurs when urban transport networks are no longer capable of accommodating the volume of movements that use them. The location of congested areas is determined by the physical transport framework and by the patterns of urban land use and their associated trip-generating activities. Levels of traffic overloading vary in time, with a very well-marked peak during the daily journey-to-work periods.

Although most congestion can be attributed to overloading, there are other aspects of this basic problem that also require solutions. In the industrialised countries increasing volumes of private car, public transport and commercial vehicle traffic have exposed the inadequacies of urban roads, especially in older city centres where street patterns have survived largely unaltered from the nineteenth century and earlier.

The intricate nature of these centres makes motorised movements difficult and long-term car parking almost impossible. In developing countries the problem is particularly acute: Indian and South-East Asian cities often have cores composed of a mesh of narrow streets often accessible only to non-motorised traffic.

The rapid growth in private car ownership and use in western cities in the period since 1950 has rarely been accompanied by a corresponding upgrading of the road network, and these increases will probably continue into the twenty-first century, further exacerbating the problem. In less-developed countries car ownership in urban areas is in at a much lower level but there is evidence of an increased rate in recent decades, especially in South America and South-East Asia .

Satisfactory definitions of the saturation level of car ownership vary but if a ratio of 50 cars to 100 persons is taken then in several US cities the figure is now over 80 per 100, whereas in South-East Asian cities the level rarely exceeds 10 per 100. One factor contributing to congestion in developing world cities is the uncontrolled intermixing of motorised and animal-or human-drawn vehicles. The proliferation of pedal and motorcycles causes particular difficulties (Simon 1996).

2. Public Transport Crowding:

The 'person congestion' occurring inside public transport vehicles at such peak times adds insult to injury, sometimes literally. A very high proportion of the day's journeys are made under conditions of peak-hour loading, during which there will be lengthy queues at stops, crowding at terminals, stairways and ticket offices, and excessively long periods of hot and claustrophobic travel jammed in overcrowded vehicles.

In Japan, 'packers' are employed on station platforms to ensure that passengers are forced inside the metro trains so that the automatic doors can close properly. Throughout the world, conditions are difficult on good days, intolerable on bad ones and in some cities in developing countries almost unbelievable every day. Images of passengers hanging on to the outside of trains in India are familiar enough. Quite what conditions are like inside can only be guessed at?

3. Off-Peak Inadequacy of Public Transport:

If public transport operators provide sufficient vehicles to meet peak-hour demand there will be insufficient patronage off-peak to keep them economically employed. If on the other hand they tailor fleet size to the off-peak demand, the vehicles would be so overwhelmed during the peak that the service would most likely break down.

This disparity of vehicle use is the hub of the urban transport problem for public transport operators. Many now have to maintain sufficient vehicles, plant and labour merely to provide a peak-hour service, which is a hopelessly uneconomic use of resources. Often the only way of cutting costs is by reducing off-peak services, but this in turn drives away remaining patronage and encourages further car use. This ‘off-peak problem’ does not, however, afflict operators in developing countries. There, rapidly growing urban populations with low car ownership levels provide sufficient off-peak demand to keep vehicle occupancy rates high throughout the day.

4. Difficulties for Pedestrians:

Pedestrians form the largest category of traffic accident victims. Attempts to increase their safety have usually failed to deal with the source of the problem (i.e., traffic speed and volume) and instead have concentrated on restricting movement on foot. Needless to say this worsens the pedestrian’s environment, making large areas ‘off-limits’ and forcing walkers to use footbridges and underpasses, which are inadequately cleaned or policed. Additionally there is obstruction by parked cars and the increasing pollution of the urban environment, with traffic noise and exhaust fumes affecting most directly those on feet.

At a larger scale, there is the problem of access to facilities and activities in the city. The replacement of small-scale and localised facilities such as shops and clinics by large-scale superstores and hospitals serving larger catchment areas has put many urban activities beyond the reach of the pedestrian. These greater distances between residences and needed facilities can only be covered by those with motorised transport. Whereas the lack of safe facilities may be the biggest problem for the walker in developing countries, in advanced countries it is the growing inability to reach ‘anything’ on foot, irrespective of the quality of the walking environment.

5. Parking Difficulties:

Many car drivers stuck in city traffic jams are not actually trying to go anywhere: they are just looking for a place to park. For them the parking problem is the urban transport problem: earning enough to buy a car is one thing but being smart enough to find somewhere to park it is quite another. However, it is not just the motorist that suffers. Cities are disfigured by ugly multi-storey parking garages and cityscapes are turned into seas of metal, as vehicles are crammed on to every square metre of ground.

Public transport is slowed by clogged streets and movement on foot in anything like a straight line becomes impossible. The provision of adequate car parking space within or on the margins of central business districts (CBDs) for city workers and shoppers is a problem that has serious implications for land use planning.

A proliferation of costly and visually intrusive multi-storey car-parks can only provide a partial solution and supplementary on-street parking often compound road congestion. The extension of pedestrian precincts and retail malls in city centres is intended to provide more acceptable environments for shoppers and other users of city centres. However, such traffic-free zones in turn produce problems as they create new patterns of access to commercial centres for car-borne travellers and users of public transport, while the latter often lose their former advantage of being conveyed directly to the central shopping area.

6. Environmental Impact:

The operation of motor vehicles is a polluting activity. While there are innumerable other activities which cause environmental pollution as a result of the tremendous increases in vehicle ownership, society is only now beginning to appreciate the devastating and dangerous consequences of motor vehicle usage. Pollution is not the only issue.

Traffic noise is a serious problem in the central area of our towns and cities and there are other environmental drawbacks brought about through trying to accommodate increasing traffic volumes. The vast divergence between private and social costs is one, which has so far been allowed to continue without any real check. Perhaps more disturbing is that society is largely unaware of the longer-term effects of such action, and while the motorcar is by no means the only culprit, it is a persistently obvious offender.

Traffic Noise:

It is generally recognised that traffic noise is the major environment problem caused by traffic in urban areas. Noise became a pressing problem late in the 1950s and in 1960 the Government set up a committee to look into the whole issue. This committee, headed by Sir Alan Wilson, pointed out with reference to London that traffic noise "is the predominant source of annoyance and no other single noise is of comparable importance".

Traffic noise is both annoying and disturbing. Walking and other activities in urban areas can be harassing and, perhaps more important, traffic noise penetrates through to the interior of buildings. Working is therefore more difficult since noise disturbs concentration and conversation. High noise levels can also disturb domestic life as sleeping and relaxation become affected.

Traffic noise tends to be a continuous sound, which is unwanted by the hearer. It is caused as a result of fluctuations in air pressure, which are then picked up by the human ear. Whilst other noise phenomena such as aircraft noise and vibrations from a road drill produce a more intense sound, traffic noise is a much more continuous and an almost round-the-clock discomfort. Noise is usually measured on a weighted scale in decibel units, an increase of 10 dB corresponding to a doubling of loudness.

The Wilson Committee published studies, which showed that a decibel noise level of 84 dB was much as people found acceptable and they proposed legislation which would make any engine noise more than 85 dB, illegal. They proposed that there should be a progressive reduction in acceptable limits, but this has not been achieved. In fact, heavy lorries produce a noise level still well in excess of the above acceptable level.

The noise from motor vehicles comes from various sources. The engine, exhaust and tyres are the most important ones but with goods vehicles, additional noise can be given off by the body, brakes, loose fittings and aerodynamic noise. The level of noise is also influenced by the speed of the vehicle, the density of the traffic flow and the nature of the road surface on which the vehicle is operating.

Vehicles, which are accelerating or travelling on an uphill surface, produce more noise than those moving in a regular flow on an even road. The regulations now in force lay down the limits of 84 dB for cars and 89 dB for Lorries. Buses, particularly when stopping and starting, motorcycles and sports cars as well as goods vehicles produce higher noise levels than the average private car.

7. Atmospheric Pollution:

Fumes from motor vehicles present one of the most unpleasant costs of living with the motor vehicle. The car is just one of many sources of atmospheric pollution and although prolonged exposure may constitute a health hazard, it is important to view this particular problem in perspective. As the Royal Commission on Environmental Pollution has stated, "there is no firm evidence that in Britain the present level of these pollutants is a hazard to health".

Traffic fumes, especially from poorly maintained diesel engines, can be very offensive and added to noise contribute to the unpleasantness of walking in urban areas. No urban street is free from the effects of engine fumes and these almost certainly contribute towards the formation of smog. As traffic volumes increase, however, atmospheric pollution will also increase. In the United States, with its much higher levels of vehicle ownership, there is mounting concern over the effects of vehicle fumes. In large cities such as Mexico City, Los Angeles, New York and Tokyo, fumes are responsible for the creation of very unpleasant smog.

Ecologists believe that the rapid increase in the number of vehicles on our roads which has taken place without (as yet) any real restriction is fast developing into an environmental crisis. Exhaust fumes are the major source of atmospheric pollution by the motor vehicle.

The fumes, which are emitted, contain four main types of pollutant:

(i) Carbon monoxide:

This is a poisonous gas caused as a result of incomplete combustion;

(ii) Unburnt hydrocarbons:

This caused by the evaporation of petrol and the discharge of only partially burnt hydrocarbons;

(iii) Other gases and deposits:

Nitrogen oxides, tetra-ethyl lead and carbon dust particles;

(iv) Aldehydes:

Organic compounds containing the group CHO in their structures.

Hydrocarbon fumes are also emitted from the carburettor and petrol tanks, as well as from the exhaust system.

The Royal Commission provides some interesting statistics on the extent of air pollution. In 1970 an estimated 6 million tonnes of carbon monoxide were emitted into the atmosphere. If estimates of vehicle ownership are correct, then by the year 2010, this volume would increase to 14 million tonnes. This figure, however, assumes the current state of engine and fuel technology.

Fears of urban pollution by motor vehicles, are greater in the United States and Japan. In day-time Manhattan, for example, readings of pollutants of 25-30 parts per million have been recorded – exposure has the same effect as smoking two packets of cigarettes per day. USA has imposed certain restrictions on vehicle manufacturers and more stringent levels are proposed, but as in the earlier case of traffic noise, increasing vehicle ownership levels are liable to offset some of the benefits which accrue.

Other Environmental Problems:

Traffic presents many other implications for the urban environment. Some of these issues will be outlined in this final section. It should, however, be stated that individual opinions often determine what constitutes an environmental problem. The British Transport Federation, for example, regard visual impact as one of the most important local environmental factors to be taken into consideration in the design and planning of urban motorways.

They state that "visual problems…are a result of the fundamental conflict in scale and form between a vast linear motorway and the smaller scale and tightly knit pattern of streets and buildings in the adjoining areas". Elevated motorways are particularly conspicuous when they are closely aligned to houses, shops and other small buildings, which are dwarfed in contrast.

This problem is most sensitive in relation to houses since views of motorway traffic can be a constant distraction and coupled with traffic noise serve as a round-the-clock reminder of the motorway's presence. The loss of privacy is just one part of this problem. Elevated motorways can also obstruct daylight and sunlight entering nearby houses and recreation or shopping areas.

Buchanan raises other visual issues: "the intrusion into parks and squares; the garaging, servicing and maintenance of cars in residential streets…; the clutter of signs, signals, bollards, railings and the rest of the paraphernalia which is deemed necessary to help the traffic flow; the dreary, formless car parks, often absorbing large areas of towns and whose construction have involved the sacrifice of the closely knit development which has contributed so much to the character of the inner areas of our towns". These are just some of the added consequences of our living with the motor vehicle and due to the uneasy partnership which exists the relationship produces its own form of blight within the urban environment

Cities are locations having a high level of accumulation and concentration of economic activities and are complex spatial structures that are supported by transport systems. The larger the city, the greater its complexity and the potential for disruptions, particularly when this complexity is not effectively managed.

Among the most notable urban transport problems are:

- Congestion and parking
- Longer commute
- Inadequate public modes
- Difficult in non motorized vehicles
- Minimum public space
- High maintenance cost

1.11. INTEGRATED PLANNING OF TOWN, COUNTRY, REGIONAL AND ALL URBAN INFRASTRUCTURES

Integrated approach to land use planning will benefit roads by contributing to:

- reduce the number of conflict points on roads through imposing minimum driveway spacing and corner clearance spacing; and encouraging frontage roads, service roads, shared pathways etc.
- reduce the amount of kerbside parking by ensuring development sites have sufficient parking within their own premises; and planning parking opportunities elsewhere.
- reduce the number of over sized/ over weight vehicles on roads not suitable for such purposes by locating developments which require constant use of such vehicles away from sensitive road corridors.
- preserve the road capacity and reduce traffic congestion on major road corridors by carefully siting developments to increase the circulation of traffic within local areas thus reducing trips on major road corridors; siting developments to facilitate enhanced public transport, cycling and walking; reducing the number of conflict points on roads; and reducing the amount of kerbside parking.
- reduce speed variations and the number of stops by controlling driveway locations and spacing, and intersection spacing; and reducing the amount of kerbside parking.

• reduce pedestrian traffic on major road corridors by carefully locating pedestrian traffic generating developments away from major road corridors.

• improve safety on major road corridors by reducing traffic congestion; reducing pedestrian traffic; and locating incompatible developments away from 'hazardous goods routes'.

• reduce energy consumption and air pollution by reducing speed variations and number of stops; and reducing traffic congestion.

• reduce adverse impacts of vehicular traffic on road users and adjacent land owners by locating incompatible developments away from sensitive road corridors; and enforcing adjacent developers to take preventive measures to reduce adverse impacts on their developments.

• enhance amenity of sites adjoining traffic routes by reducing traffic congestion; and beautifying adjacent lands.

LAND USE PLANNING MEASURES

Land use planning can be applied to improve the functioning of major road corridors in several ways. This can be used to screen and select appropriate developments, compatible with the functioning of roads, to be located near major road corridors or change the location of proposed developments in such a way to have minimum impacts on adjoining roads. At the same time, land use planning can impose conditions on those developments which are required to be located adjoining major road corridors, requiring modifications to reduce impacts due to these roads. An example of the latter is to request for structural modifications to reduce noise impacts to buildings adjoining major traffic routes. Land use planning measures that can be applied to screen and select incompatible developments and change locations of developments to improve the functioning of major road corridors can be broadly divided into local planning and regional planning measures. Local planning measures are generally confined to local areas. They are usually focused on limiting the number of conflicts points on major road corridors. They include subdivision control and driveway control. Subdivision control includes the following: eliminate or restrict flag lots; lot size and road frontage control; interconnecting parking across lots through shared driveways and cross driveways; and restricting the number of driveways per lot. Driveway controls relevant to land use planning include: restrictions on driveway spacing including corner clearance spacing; use of service roads/ frontage roads; and providing access through roads low in access categorisation. On the other hand, the main focus on regional land use planning measures applicable to road planning is to locate developments in such a way to have minimal adverse impacts on the road network. In addition, these can help to locate incompatible developments away from major road corridors. These measures are applicable to large areas such as regions. Mixed use zoning, multiple-use sites and the location of housing close to activity centres are such examples.

1.12. LAND USE & TRANSPORT

Land uses play a significant role in the planning and implementation of all modes of transportation, but it may be one of the most underappreciated factors when designing and planning transportation. The impacts of land use decisions can add time and money to any transportation project, or can change the volume of travellers using a road or a transit route. Many communities and cities in Texas are growing much faster than the infrastructure, and planning, building, and maintaining infrastructure comes at a cost. Problems with rapid growth include an increase of vehicle miles travelled (VMT), increase in traffic accidents, and communities that lack accessibility (for pedestrians and bicycles). As cities have expanded, so have the distances that people travel to access employment, retail, and recreation. Several factors also encourage dispersed development, including: automobiles, highways, school quality, telecommunications, amenities of low-density neighbourhoods, and land costs. Smart growth planning can aid in the integration of more accessible transportation modes as well as enhance regional mobility.

The preferences of individuals, institutions, and firms have an imprint on land use in terms of their locational choice. The representation of this imprint requires a typology of land use, which can be **formal or functional:**

Formal land use representations are concerned with qualitative attributes of space such as its form, pattern, and aspect and are descriptive in nature.

Functional land use representations are concerned with the economic nature of activities such as production, consumption, residence, and transport, and are mainly a socioeconomic description of space.

There is no single target market for land use considerations. Land uses must be considered at all levels, including smart growth planning for communities in suburban areas, rural areas, and even central business districts.

♣ Adequate land use can reduce the number of single occupancy vehicles on major freeways and highways.

♣ Good design can enhance the quality of life and create a sense of community.

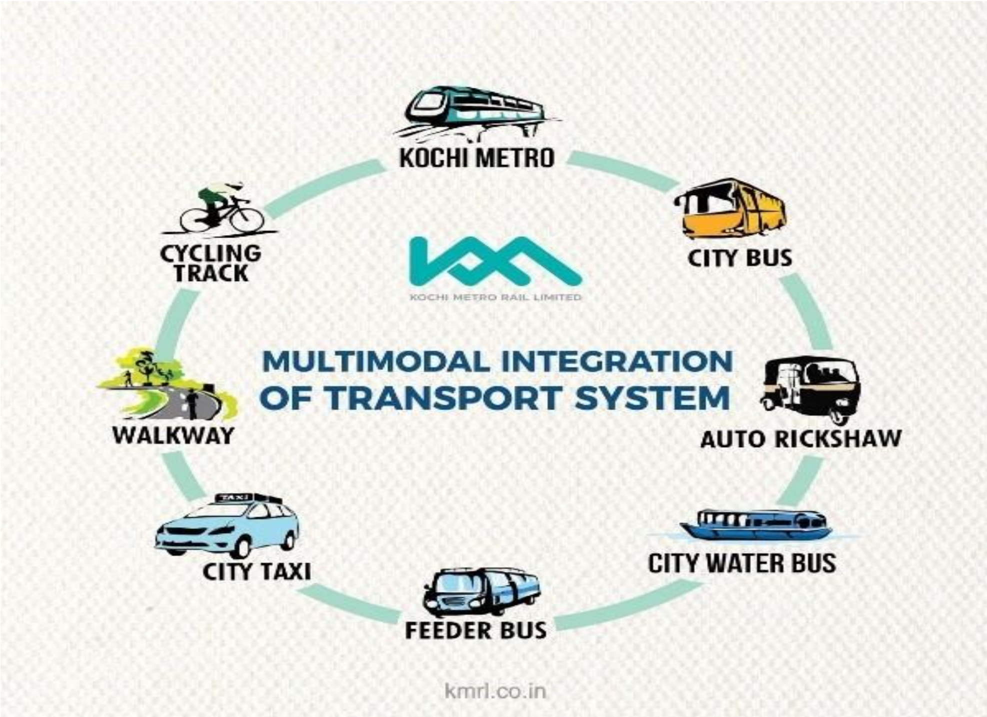
♣ Planning land uses and transportation together creates safer, more walkable environments.

♣ Designing local and regional land uses with accessibility in mind can create more opportunities for access to jobs and shopping, which can greatly influence the local economy.

1.13. MODAL INTEGRATION

Multimodal Planning Concepts Multi-modal planning refers to planning that considers various modes (walking, cycling, automobile, public transit, etc.) and connections among modes. There are several specific types of transport planning which reflect various scales and objectives:

- Traffic impact studies evaluate traffic impacts and mitigation strategies for a particular development or project.
- Local transport planning develops municipal and neighbourhood transport plans.
- Regional transportation planning develops plans for a metropolitan region.
- State, provincial and national transportation planning develops plans for a large jurisdiction, to be implemented by a transportation agency.
- Strategic transportation plans develop long-range plans, typically 20-40 years into the future.
- Transportation improvement plans (TIPs) or action plans identify specific projects and programs to be implemented within a few years.
- Corridor transportation plans identify projects and programs to be implemented on a specific corridor, such as along a particular highway, bridge or route.
- Mode- or area-specific transport plans identify ways to improve a particular mode (walking, cycling, public transit, etc.) or area (a campus, downtown, industrial park, etc.).



The modal integration elements, or those issues which should preferably be addressed in order to provide an integrated and co-ordinated public transport system, include

• An integrated network

• with integrated schedules

• and proper transfer facilities,

• a common ticketing ("through-ticketing") and integrated fare system, and

• a combined information system. It will not always be possible to achieve all these aspects in one project or in one area, but as many as possible should preferably be addressed.

INTEGRATED MULTI-MODAL TRANSPORTATION

Multi-modal commuting combines the benefits of walking, bicycle commuting, or driving with the benefits of rapid transit while balancing some of the major disadvantages of each individual mode.

• Location plays a large role in multi-modal commuting. When the commuter finds the distance between the origin and the destination too far to be enjoyable or practical, commute by car or motorcycle to the station may remain practical, as long as last mile connectivity to destination is practical by walking, a bicycle, or shuttle/ feeder bus.

• In general, locations close to major transit station have higher land value and thus have higher costs of rent or purchase. A commuter can choose to live near or far according to the last mile connection availability like by walking, a bicycle, or shuttle/

feeder bus, and also the rent or purchase affordability in the vicinity of that particular transit station.

- Other cost advantages of multi-modal commuting include lower fuel and maintenance costs; and increased automobile life. These cost benefits are balanced by costs of transit, which can vary in different cases.
- The effectiveness of a multi-modal commute can be measured in many ways: speed to destination, convenience, security, environmental impact, and proximity to mass transit. Because multi-modal commutes rely on a certain degree of coordination, scheduling issues with mass transit can often be an issue. For example, a sometimes-late train can be an annoyance, and an often-late train can make a commute impractical.
- Weather can also be a factor. Even when the use of an automobile is involved, the transition from one mode of transportation to another, often exposes commuters to the adverse weather. As a result, multi-mode commuters often travel prepared for extreme weather conditions.
- In Indian context it is very important to integrate all various modes of transport like bus, feeder services, bicycle, rickshaw, etc. with rapid transit system. It is equally important to integrate non-motorized modes (pedestrian, cycles, rickshaws, etc.) to mass rapid transits.
- It is also important that utilisation of IMMTS to its maximum capacity, depends on mobility of non-motorized vehicles and intermediate para transits.
- For IMMTS the interchanges and seamless travel are significant components of an integrated transport strategy, as these are a part of infrastructure which involves multi-modal activities.
- The biggest challenge for Indian cities would be to achieve the highest level of integration of multiple modes to shift the captive ridership of personalized transport to at least partial usage of public transport for mixed-mode travel.