Chapter 4

Factors affecting transportation

4.1 Overview

The success of transportation engineering depends upon the co-ordination between the three primary elements, namely the vehicles, the roadways, and the road users. Their characteristics affect the performance of the transportation system and the transportation engineer should have fairly good understanding about them. This chapter elaborated salient human, vehicle, and road factors affecting transportation.

4.2 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 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.

4.2.1 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 85^{th} 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 eg. if we say that the 85^{th} 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.

4.2.2 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.

4.2.3 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.

For eg., if a driver approaches an intersection where the signal is red, the driver first sees the signal (perception), he recognizes that is 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.

4.2.4 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.

4.2.5 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, 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.

4.2.6 Other Characteristics

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.

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 85^{Th} percentile values of the human characteristics are fixed as standards for design of traffic facilities.

4.3 Vehicle factors

4.3.1 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.

4.3.2 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.

4.3.3 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.

4.3.4 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, round about, terminals, and parking areas.

4.3.5 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.

4.4 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 filled by normal passing maneuvers.

4.5 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:

$$d = \frac{v^2 - u^2}{f + g} \tag{4.1}$$

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.

4.6 Road factors

4.6.1 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.

4.6.2 Lighting

Illumination is used to illuminate the physical features of the road way and to aid in the driving task. A luminaire 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 luminaires is one of the essential factors in efficient roadway lighting. It is important that roadway lighting be planned on the basis of many traffic information such as night vehicular traffic, pedestrian volumes and accident experience.

4.6.3 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.

4.6.4 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.

4.6.5 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.

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

4.7 Summary

The performance, design and operation of a transportation system is affected by several factors such as human factors, vehicle factors, acceleration characteristics, braking performance etc. These factors greatly influence the geometric design as well as design of control facilities. Variant nature of the driver, vehicle, and roadway characteristics should be given importance for the smooth, safe, and efficient performance of traffic in the road.

4.8 Problems