CHAPTER - 1

TRAFFIC STUDIES
1.1. IMPORTANCE OF TRAFFIC MANAGEMENT UNDER INDIAN CONDITIONS

With manifold growth of traffic in big cities and towns, the need for better traffic management is increasingly felt. The voluminous growth in traffic has resulted in increasing number of accidents and congestion, hampering safe and efficient movement, parking difficulties, environmental pollution and other related problems. It is, therefore, necessary to give immediate and increasing attention to the operational characteristics of better traffic management.

It is against this background, the need for the organisational set-up designed to deal with the attendant problems of growing traffic as a separate unit, is realised. Such units at national, state and city levels are to be under competent traffic engineers. The traffic engineer is concerned with the preparation of traffic and transportation plans to ensure a safe, orderly and fully integrated transportation system. This phase of activity concerns itself with the relation of land use with transportation and study of travel characteristics. Based on the analysis of the results of such a study, mathematical models are formulated to predict how a system will behave under a given set of conditions. Alternative solutions are thought out and are evaluated for their comparative merits and demerits. The optional
solution is then selected and implemented.

Efficient and safe operation of traffic can be ensured through a number of measures such as:

I. Legislation and enforcement measures regulating the driver, vehicle and road users like the pedestrians, cyclists and motor-cyclists.

II. Management measures such as one-way streets, prohibited turnings at junctions and tidal flow arrangements, exclusive bus lanes etc, to get the maximum use out of the available street facilities.

III. Measures for regulation of parking vehicles.

IV. Traffic control devices such as traffic signs, traffic signals, pavement markings and channelization techniques to guide safe and efficient flow of traffic.

1.2 TRAFFIC SURVEYS

Speed is one of the most important characteristics of traffic and is the rate of movement of traffic which is expressed in metric units in kilometres per hour. Speed measurements are needed for a number of purposes namely,

1. Spot speeds are used for geometric design of roads, regulation and control of traffic operations, and for analysing the causes of accidents and identifying any relation between speed and accidents.
2. Journey time studies on a road-network in a town are useful to evaluate congestion capacity, level of services.

Among the methods employed in traffic surveys, the use of photographic techniques, is the most dependable and oft-used method. The congestion caused by the ever-increasing number of vehicles on the roads gave birth to the new science of traffic engineering. Then began the study of the behaviour of different aspects of road traffic such as speed, volume, concentration, accidents and geometric design. Traffic studies constituted major part of traffic engineering and elaborate instrumentation was needed for this purpose. Data collection and analysis by manual methods is cumbersome and inadequate and hence instrumentation with developments in electronics and computers has replaced them. Photographic techniques come under this category of useful instruments.

There are different methods applying the principle of photography in traffic studies, such as:

1. Continuous stereoscopic strip photography from moving aeroplanes or helicopters.
2. Stereo Camera photos from a stationary object on the ground.
3. Conventional air photography, from aeroplanes or helicopters.
4. Time-lapse photography from aeroplanes balloons or helicopters.
5. Time-lapse photography from fixed position of the ground.

6. Video system.

Among all, the most important and much used methods are time-lapse photography and the latest development being video system. Time-lapse photography is used to determine the speeds of vehicles accurately in crowded streets. According to this method, photographs are taken at fixed intervals of time on a special camera. By projecting the film on a screen, the passage of any vehicle can be traced with reference to time.

The video system can be mounted on a car, at a stationary point by the side of a road, or assembled in a laboratory and it consists of:

1. Video Camera to take photographs of traffic, from a moving vehicle or a stationary position.

2. Video recorder and player to record the images taken from the Camera on to video cassettes and to play back the recorded cassettes at any time later.

3. Monitors or T.V screens: The system can be used for speed, speed-volume, fuel consumption, overtaking and crossing studies.

**NEED FOR VEHICLE VOLUME AND CLASSIFICATION**: One of the fundamental measures of traffic on a road system is the
volume of traffic using the road in a given interval of time. The traffic using a road comprises a variety of vehicles ranging from the simple pedal cycles to the motorcars and the heavy commercial vehicles. Each type has its own impact on the performance of the road. A simple volume count, without classifying the vehicles into distinct types, is of limited use. It is, therefore, a normal practice, when the traffic comprises of a number of types of vehicles, to convert the flow into equivalent passenger car unit (P.C.U.) by using certain equivalency factors. The flow is then expressed as PCU per hour or PCU per day. A knowledge of the vehicular volume using a road network is important for understanding the efficiency at which the system works at present and the general quality of service offered to the road-users. The ultimate aim of all the traffic surveys and studies is to ensure safe and comfortable transport of men and goods.

The following methods are available for traffic counts:

1. MANUAL METHODS
2. COMBINATION OF MANUAL AND MECHANICAL METHODS
3. AUTOMATIC DEVICES
4. MOVING OBSERVER METHOD

Manual methods use field personnel to count and classify traffic flowing past a fixed point. 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. It is desirable to record traffic in each direction of travel separately and post separate observers for each direction.

A combination of manual and mechanical methods involves the services of field personnel who operate mechanical devices to count and record the arrival of vehicles at any given point across a road. An example is the pen recorder. A chart moves continuously at the speed of a clock. Different pens record the occurrence of different events on the chart. The actuation of the event recorder pen is by pressing the electric switch associated with each pen recorder. The advantages of this type of recorder being the facility of a permanent record of arrival of each class of vehicles and provision of information such as time-headways between successive vehicles and the arrivals per unit time.

Automatic devices enable account of traffic to be taken at any given location and a record to be kept of the count. These devices consist of an equipment for detecting the passage or presence of a vehicle and another for recording the count. The sensor usually transmits some form of electric impulse which activates the accumulating register or recording chart.

The moving observer method is a special traffic engineering technique which results in the collection of data on the flow and speed of traffic, travel time, delay at junctions and parking.
1.3 TRAFFIC CONTROLS

In order to facilitate people travelling from one country by road into another country where the language may be different, traffic signs are of importance and should be installed only by the authority of law. Traffic signs are of two types:

1. Danger signs also known as warning signs or cautionery signs.
2. Signs giving definite instruction, also known as regulatory signs.

Road markings are used as a means of controlling and guiding traffic and are of two types:

1. Carriage way markings and
2. Object markings

Carriage way markings are:

(a) Centre line markings which are employed for separating traffic in opposite directions.

(b) Traffic lane lines are used for the division of the carriage way into separate lanes for traffic travelling in the same direction on either side of the centre line or median strip helps to promote travel in proper lanes and curb the meandering tendency of the drivers, thus promoting safety and ensuring maximum capacity.

(c) No - overtaking zone markings are provided on summit curves, horizontal curves where
overtaking and passing manoeuvres must be prohibited because of non-availability of safe overtaking sight distances.

(d) Pavement Edge lines are used to indicate the edges of carriage ways which have no kerbs. They serve as a visual guidance for the drivers, indicating to them the limits up to which the driver can safely venture.

(e) Reduction in the carriage way width is made known by a combination of carriage way markings and road signs.

(f) Obstruction approach markings are necessary to guide traffic on the approach to fixed obstructions within the carriage way.

(g) Stop lines are solid white lines provided transversely to the carriage way and used to indicate the point behind which vehicles are required to stop in compliance with a STOP sign traffic signal or traffic police.

(h) Pedestrian crossings are marked at all intersections where there is substantial conflict between vehicle and pedestrian movements.

(i) Cyclist crossings should have the same width as the cycle tracks.
(j) Route direction arrows are used to guide effectively the traffic in the correct direction and lanes.

(k) Word messages are used to convey information to guide, warn or regulate traffic.

(l) For orderly and guided traffic movement at intersections, markings can be a combination of centre-lines, turns markings, lane markings, stoplines, route direction, arrows etc.

(m) The delineation of the parking space limits promotes more efficient use of the parking spaces and helps in preventing encroachment on fire hydrant Zones, busstops, loading Zones and/or the locations where parking of vehicles will be undesirable.

**OBJECT MARKINGS:** Obstructions in the carriage way are marked by alternating black and white stripes, sloping down at an angle of 45 towards the side of the obstruction on which traffic passes. When the vehicle clearance of an underpass is less than the prescribed minimum, the available clearance is marked by painting vertical strips, alternately black and white.

1.4 TRAFFIC SIGNALS

Traffic signals to regulate different streams of vehicular and pedestrian traffic, are a common sight in most of the cities and towns today. The first traffic
signal is reported to have been used in London in 1868. Over the period of time since then traffic signals have been sophisticated in tune with the rapid increase in traffic. Traffic signals, when properly designed, located and operated, have the following advantages.

(a) They help regulate an orderly movement of traffic.

(b) With proper geometric layouts and control measures, they can increase the traffic handling capacity of the intersection.

(c) The frequency of certain types of accidents such as the right-angle type and pedestrian accidents can be reduced.

(d) With everything going right, they can be coordinated to ensure continuous movement of traffic at a specified speed along a given route.

(e) They can be used to interrupt heavy traffic at intervals so that other traffic such as vehicular or pedestrian, to cross.

(f) Traffic signals dispense with manual or police control and can thus be economical.

(g) Properly designed and set, traffic signals, can assign right of way impartially to traffic, unlike manual or police controls which can stop and interrupt traffic steams at personal whim.
If the signals are installed improperly, we have the following disadvantages

(a) During off-peak hours, Excessive delay to vehicles may be caused.

(b) Unwarranted signal installations tend to encourage the disobedience of the signal indications.

(c) Drivers may be induced to use less adequate and less safe routes to avoid delays at signals.

(d) Accident frequency of the rear-end type, may increase.

(e) When the installations break down, due to any fault in the system, total and widespread confusion and difficulties can result.

**SIGNAL INDICATIONS:** A period of 2 seconds is used as a transition interval between termination of related green movement and exhibition of a red indication or between termination of a red indication and commencement of related green movement.

**SIGNAL FACE:** The minimum number of lenses in a signal face is three - red amber and green. The lenses in a signal face can be arranged in a vertical or horizontal straight line. The lenses are normally of two sizes namely 200 mm and 300 mm diameter. The larger size is used where the 85th percentile approach speeds exceeds 65 k.p.h.
The arrows are pointed vertically upward to indicate a straight through movement and in a horizontal direction to indicate a turn at approximately right angles. When the angle of the turn is substantially different from a right angle, the arrow can be positioned on an upward angle approximately equal to that of the turn.

**FIXED TIME SIGNALS AND VEHICLE ACTUATED SIGNALS:** Fixed time signals are those in which the green periods, and hence the cycle lengths are predetermined and are of fixed duration, whereas vehicle actuated signals are those in which the green periods vary and are related to the actual demands made by traffic. This is made possible by installing detectors on all the approaches. An intermediate type, semi-vehicle actuated signals is also available, in which the right of way normally rests with the main roads and detectors are located only on the side roads.

**TYPES OF COORDINATED SIGNAL SYSTEM:** The four basic types of coordinated signal systems are as follows:

1. **SIMULTANEOUS SYSTEM OR SYNCHRONISED SYSTEM:** In this system, all the signals along a given street always display the same indication to the same traffic stream at the same time. The division of the cycle time is the same at all intersections.

2. **ALTERNATE SYSTEM OR LIMITED PROGRESSIVE SYSTEM:** In this system, consecutive signal installations along a given road show contrary indications at the same time. This permits the vehicles to travel one block in half the cycle time.
3. SIMPLE PROGRESSIVE SYSTEM: In this system the various signals along a street display green aspects in accordance with a time schedule to permit, as nearly as possible, continuous operation of platoons of vehicles along the street at a planned rate of motion, which may vary in different parts of the system.

4. FLEXIBLE PROGRESSIVE SYSTEM: In this system it is possible to vary the cycle time and division at each signal depending upon traffic and also possible to introduce flashing or shutdown during off-peak hours.

1.5 THEORY OF TRAFFIC FLOW

The theory of traffic flow can be defined as a mathematical study of the movement of vehicles over road network. Traffic flow theory is concerned with three measurable characteristics of road traffic namely speed, flow and concentration.

When the vehicles are packed from end to end, the flow $Q$ is zero, so also, when the concentration is zero, there are no vehicles hence the flow is zero. As the concentration slowly increases from zero, the flow also increases and a point is reached when the flow is maximum. The maximum flow that is capable of being accommodated in a road is the capacity of the road. Fundamental diagram of traffic flow is shown in figure(1.1).

The relationship between flow and speed, Concentration and speed are shown in figures (1.2) and (1.3).
FIG 1.1: FUNDAMENTAL DIAGRAM OF TRAFFIC FLOW

FLOW (Q)

Q\text{max} = \text{CAPACITY}

K_j = \text{JAMMING CONCENTRATION}

\langle K \rangle \longrightarrow

\text{MEAN FREE SPEED VS. JAMMING CONCENTRATION}
FIG 1.2 : RELATION BETWEEN FLOW AND SPEED

Flow (Q) ---->  

Q_{max} = \text{CAPACITY}

SPEED \langle \bar{v}_s \rangle \longrightarrow
FIG 1.3: RELATION BETWEEN CONCENTRATION AND SPEED
An analogy between the flow of fluids and the flow of traffic is necessary to understand traffic flow. LIGHT HILL and WHITHAM theory based on kinematic waves is applicable to large scale problems and principally to the distribution of traffic on long, crowded roads. The assumptions of this theory are as follows:

1. The equation of continuity, i.e., law of conservation of vehicles, holds good. Thus inflow = out flow storage.

2. At any point on the road, the flow Q is a function of the concentration.

ASSUMPTIONS MADE IN A SIMPLE QUEUEING APPROACH AS APPLIED TO TRAFFIC FLOW: The queueing theory will be developed on the basis of the following assumptions as applicable to traffic flow.

1. The system is in a steady state, and has "settled down". This assumption is valid only when the arrival and the service patterns are sustained for indefinitely long periods of time, and not for "peaking situations" or "transient behaviour". This implies that the traffic intensity (p) which is defined as, the ratio of average rate of arrival (λ) to average rate of service (μ) is less than one. Thus \( p = \frac{\lambda}{\mu} < 1 \).

2. The number of customers is 'discrete'
3. The population of potential customers is infinite.
4. The arrivals are random in nature and Poissonian distribution applies, to the mean rate of arrival.
FLOW AT RAJVIHAR JUNCTION

FIG 14: DIURNAL VARIATION OF TRAFFIC DENSITY

TOTAL NO OF VEHICLES IN ONE HOUR

RAJVIHAR
FIG. 15: DIURNAL VARIATION OF TRAFFIC DENSITY FLOW AT RLY. STATION JUNCTION
5. There will be no simultaneous arrivals.
6. There will be a single service channel. Separate modifications of the approach are available for multiple channels.
7. The queue is single and is of infinite capacity.
8. The order of service is first in first out.
9. There is a single follow-on service discipline.
10. The service times vary and follow an exponential distribution, with a mean rate.

1.6 THE QUEUING THEORY

In daily life, in many situations, one is faced with the problem of providing services for demands originating at random. The simple case of motorists arriving at a toll booth can be taken as an example of such a situation. If the arrival rate of motorists is heavy and the rate of servicing is not able to cope with it, then it is inevitable that a queue builds up and delays occur as consequence. The pioneer investigator of the queuing theory was A. K. Erlang in 1909 and since then the subject has been approached by many other investigators, much research has been done on queuing and the literature available is also very vast.

Most traffic engineering problems concern themselves with the provision of adequate capacity for the average flow of vehicles in the system, so as to avoid congestion and delay under the average conditions. The capacity designed for the average conditions, congestion occurs at peak situations. Occurrence of
queues in traffic flow such as signalised intersections, carparks, toll booths, bottleneck situations and so on are the examples for such queue formations. The easy applicability of queueing theory to these problems has encouraged the traffic engineers to evince great interest in this subject.

**APPLICABILITY OF THE QUEUEING THEORY** : In solving any queueing problem, a number of elements that go as inputs to the process need to be understood and are defined. They are as follows:

1. **Arrival pattern** which can be regular with a rectangular distribution and random with a Poisson, Erlangian or Normal distribution.

2. **Service facility characteristics** can cover the following points:
   
   (a) Single channel.
   
   (b) Multiple channels, with one queue for each channel.
   
   (c) Single queue feeding into multiple channels.
   
   (d) Number of queues greater than one, but less than the number of channels.
   
   (e) Multiple channels in series.
   
   (f) Combination of multiple service channels, some in series, some in parallel.

3. **Queue discipline characteristics** can be the following:
   
   (a) Join a single queue and wait.
(b) The queue is of fixed capacity and further customers returned away.
(c) Not to join the queue at all.
(d) Join the queue and leave, because not served before a certain time.
(e) In a system of multiple queues, to change from one queue to another.

(4) The order of the service can be any one of the following:

(a) First in first out
(b) Last in first out
(c) No regular system of priority
(d) A system of priority

(5) The service time can have the following types:

(a) Rectangular distribution
(b) Random, Exponential, Poisson distribution.

(6) The training and familiarity determine whether the service is affected by the number of customers in the queue and whether there are any different operators.

(7) The service discipline can mean serving only one customer at a time or serving many customers at a time.

It is thus apparent from the above that the problems that arise in queuing approach can be of varied types, each requiring a particular solution.
1.7 ANALYSIS OF TRAFFIC FLOW

Traffic flow studies were made at two important junctions namely Rajvihar junction and Railway Station junction. For sake of simplicity the vehicles have not been divided into fast moving vehicles (Bus, Jeep etc.) and slow moving vehicles (Cycles, Animal drawn carts etc.). The total number of vehicles passing in a road both in the upward direction and downward direction for hourly periods are counted and are plotted for each hour for all roads as Histograms as shown in figures (1.4 and 1.5).

From the figures it is observed that the total number of vehicles in one hour known as Density is low during early hours of the day and from 0600 hours gradually increases and reaches peak values around 1000 hours. The traffic slightly decreases after 1100 hours and again takes high values around 1300 hours. Same traffic flow is maintained up to 1400 hours. There is a small decrease of traffic flow from 1500 hours and from 1600 hours onwards the traffic flow is high up to 1900 hours. Again after 1900 hours the traffic flow reduces and reaches small value after 2200 hours.

For Rajvihar Centre, eventhough diurnal variation of traffic flow is significant, the traffic density in all roads is nearly the same. Whereas, in Railway Station junction, in addition to the diurnal variation it is significant to observe that the traffic densities
in two roads namely Road-1 (Rly.Station), Road-2 (STBC) are very high compared to the traffic densities on the other roads, namely Road-3 (YMCA) registering lowest density, while Road-4 (Mourya Inn) and Road-5 (RTC Busstand) registering moderate densities.

Under normal mode of traffic control same amount of time namely (13 sec) is allocated for allowing the traffic in every road irrespective of the traffic density values and hence it is thought of to develop a Microprocessor based density dependent traffic controller for junctions with a lot of disparity in traffic densities.