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Odisha Public Service Commission

Assistant Executive Engineer

Civil Engineering

Transportation Engineering

Well Illustrated **Theory** *with*
Solved Examples and **Practice Questions**

MADE EASY Publications

Transportation Engineering

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CHAPTER 3

Traffic Engineering

3.1 Introduction

The basic objective of traffic engineering is to achieve a free or rapid flow of traffic with least number of accidents. For this various studies are carried out. These studies are divided into:

(a) Traffic characteristics study

(b) Traffic analysis and study

(c) Traffic control and regulation

3.2 Traffic Characteristics Study

In traffic characteristics, we generally study

(a) Road user characteristics

(b) Vehicular characteristics

(c) Braking characteristics

(a) Road user characteristics: In this mental physical and psychological study of road user is carried out. Ex. Reaction time is estimated based on PIEV theory.

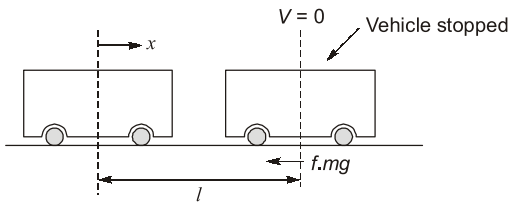
(b) Vehicular characteristics: Length, width, height and weight of vehicle is studies.

(c) Braking characteristics

- Spacing between two consecutive vehicles and SSD are effected by braking characteristics.
- To study the braking characteristics, braking test is conducted to find out the skid resistance of the pavement.

Braking Test: At least two of the following three measurements are required in order to determine the skid resistance of the pavement.

(i) Initial velocity (V) (ii) Braking length (l) (iii) Actual duration of brake application



Braking test

$$a = -\frac{fmg}{m} = -f.g$$

Case-1: When braking length and initial velocity is known

$$V^2 = u^2 + 2as$$
$$0 = u^2 - 2(fg)l$$

$$\therefore \quad f = \frac{u^2}{2gl} \quad (V \text{ in m/sec})$$

Case-2 : When initial speed and actual direction of brake application known:

$$V = u + at$$
$$0 = u - fg \times t$$
$$f = \frac{u}{gt}$$

Case-3 : When braking length and actual duration of brake application is known:

$$S = ut + \frac{1}{2}at^2$$

$$\because \quad u = fgt$$

$$\therefore \quad l = \left(fgt^2\right) - \frac{fgt^2}{2} = \frac{fgt^2}{2}$$

$$f = \frac{2l}{gt^2}$$

NOTE

If sometimes the maximum skid resistance of the pavement surface is already known than we can find the breaking efficiency also.

$$\eta = \text{Breaking efficiency} = \frac{f_{\text{obtained from braking test}}}{f_{\text{max. known}}}$$

Example - 3.1 A vehicle travelling at the speed of 80 kmph speed, stopped within 2.5 seconds after the application of the brakes. Determine the average skid resistance.

Solution:

Given: $u = 80$ km/h, $t = 2.5$ seconds

$$u = 80 \times \frac{5}{18} = 22.22 \text{ m/ sec}$$

Skid resistance,

$$f = \frac{u}{gt} = \frac{22.22}{9.81 \times 2.5} = 0.906$$

Example - 3.2 A vehicle moving at 65 kmph was stopped by applying brake and the length of skid mark was 25.5 m. If the average skid resistance of the pavement surface is known to be 0.7. Determine brake efficiency of test vehicle.

Solution:

Given: $V = 65$ km/h $= \frac{65}{3.6} = 18.05$ m/ s , $l = 22.5$, $f = 0.7$

From braking test, $f = \frac{u^2}{2gl} = \frac{(18.05)^2}{2 \times 9.81 \times 25.5} = 0.6516$

$\therefore$ Brake efficiency $= \frac{0.6516}{0.7} \times 100 = 93.1\%$

3.3 Traffic Analysis and Studies

It helps in analyzing the need for geometrical features of highway and also in taking traffic control features.

- Traffic survey is carried out to collect traffic data and is called traffic census.
- Various studies that carried out are:
  (a) Traffic volume study
  (b) Traffic speed studies
  (c) Origin and destination study
  (d) Traffic flow characteristics and studies
  (e) Traffic capacity studies
  (f) Parking study
  (g) Accident study

3.3.1 Traffic Volume Study

Traffic volume or flow is the number of vehicles crossing a point on a road in unit time. It is used to measure the quantity of traffic flow and is expressed as Vehicle/hr or PCU/hr.

Complete traffic volume study includes:

1. Classified volume study: Number of different types of vehicles are counted.
2. Directional study: Distribution of traffic on different lane is calculated.
3. Turning movement study at intersection: It is done for intersection design.
4. Pedestrian volume study: This study helps in planning, subways, footbridge and in pedestrian signal timing.

It can be determined by $q = \frac{n \times 3600}{T} Vph$

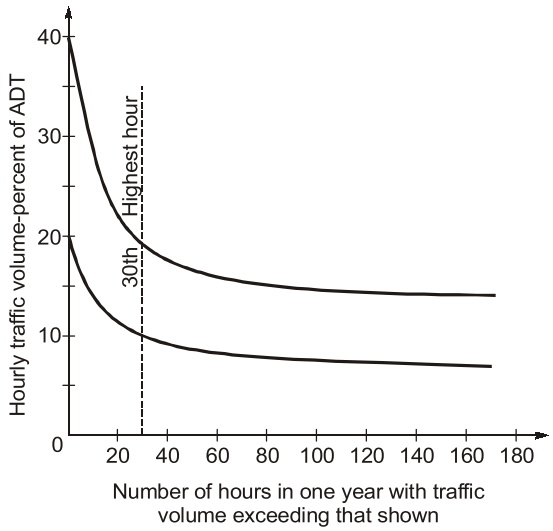
n = The number of vehicles passing a point in the roadway in T(sec).

q = The equivalent hourly flow.

Presentation of Traffic Volume Data

1. **Annual Average Daily Traffic (AADT):** It is the average traffic volume at a location calculated over a full 365 days
   - Total traffic and classified traffic are calculated.
   - It helps in deciding the relative importance of a route and road development.
   - it includes seasonal variation also.
2. **Average Daily Traffic (ADT):** It is the average 24 hour volume at a given location for some period of time less than a year.
   For this minimum of 7 days count is done to include the daily variation like on Saturday and Sunday.
3. **Trend Chart:**
   - Showing volume trends over period of years.
   - These data are useful for planning, future expansion, design and regulation.

4. **Traffic flow map along the route:**
   - It gives an idea of traffic at a glance.
   - Thickness of lines represents traffic volume.
5. **30th highest hourly volume:**
   - It is taken as design hourly volume/design capacity.
   - It is a plot between hourly volume and the number of hours in an year that the traffic volume is exceeded.
   - For this all hourly volumes are arranged in decreasing order and order number is given to each of them. The data at order number 30 is the 30th highest hourly volume.
   - The 30th highest hourly volume is the hourly volume that will be exceeded only 29 times in a year.



Hourly traffic volumes

Periodic Volume counts

Periodic Volume counts are used to calculate expansion factors needed to estimate the annual traffic volume.

$$\text{Hourly expansion factor} = \frac{\text{Total volume for 24 hours period}}{\text{Volume } \textit{for} \text{ particular hour}}$$

$$\text{Daily expansion factor} = \frac{\text{Weekly traffic volume}}{\text{Average 24 hour volume of that particular day}}$$

$$\text{Monthly expansion factor} = \frac{AADT}{ADT \text{ of particular month}}$$

- Peak hour factor (PHF): It is defined as the ratio between the number of number of vehicles counted during peak hour and four times the number of vehicles counted during the highest 15 consecutive minutes.
- Peak hour factor is a measure of the variation in demand during the peak hour.

$$(PHF)_{15} = \frac{\text{Hourly traffic volume}}{\left(\frac{60}{15}\right) \times V_{15}(\max)}$$

$$(PHF)_5 = \frac{\text{Hourly traffic volume}}{\left(\frac{60}{5}\right) \times V_5(\max)}$$

Where, V_{15} = Maximum number of vehicles during any 15 consecutive minutes.

V_5 = Maximum number of vehicle during any 5 consecutive minutes.

NOTE: Value of peak hour factor (PHF) varies between 0.25 and 1.00.

3.3.2 Traffic Speed Study

Speed of different vehicles vary with respect to time and space. To represent these variations various speeds are defined.

1. **Spot speed:** It is the instantaneous speed of a vehicle at a particular location.
   - Spot speed is used in design of horizontal curve, traffic signs (size), traffic signals and also in accident analysis.
   - It is measured using ecoscope, pressure contact tubes, loop deflector and Doppler radar.
2. **Average speed:** It is the average of spot speed of all vehicles passing a given point on the road. It is classified as:
   (a) Time mean speed (V_t)
   (b) Space mean speed (V_s)

(i) Time Mean Speed: It is the average of spot speed of vehicles at a point over a period of time.

$$V_t = \frac{\sum_{i=1}^{n} V_i}{n}$$

where, V_i = Spot speed of i^{th} vehicle at that location.
n = Number of vehicles crossing the location in a given interval of time.

- It is arithmetic mean of spot speed of vehicles passing a given point on a highway in a given interval of time.

(b) Space Mean Speed (V_s): It is the average of spot speed of vehicles taken over a certain stretch of road at a particular instant of time,

- It is obtained by dividing total distance travelled by total time required.

$$V_s = \frac{n_L}{\sum \frac{L}{V_i}} = \frac{n}{\sum_{i=1}^{n} \frac{1}{V_i}} = \frac{1}{\frac{1}{n}\sum_{i=1}^{n} \frac{1}{V_i}}$$

Hence, the space mean speed is the harmonic mean of spot speed of vehicles.

Since, AM > HM

$\therefore$ $V_t > V_s$

V_i = Speed of i^{th} vehicle

L = Length of section of highway.

NOTE

It the speed study data is given in the form of frequency table, then,

Time mean speed (V_t) = $\dfrac{\sum q_i V_i}{\sum q_i}$

Space mean speed (V_s) = $\dfrac{\sum q_i}{\sum \dfrac{q_i}{V_i}}$

Example - 3.3 Result of speed study is given in the form of frequency distribution as below. Calculate, V_t (Time mean speed) and V_s (Space mean speed)

Speed range	Frequency or volume of flow (q_i)
2 - 5	1
8 - 9	4
10 - 13	0
14 - 17	7

Solution:

Speed range	Frequency	Avg. speeed
2 - 5	1	3.5
8 - 9	4	8.5
10 - 13	0	11.5
14 - 17	7	15.5

$\therefore$ $$V_t = \frac{1\times 3.5 + 4\times 8.5 + 0\times 11.5 + 7\times 15.5}{12} = 12.16 \text{ km/h}$$

$$V_s = \frac{1}{\frac{1}{12}\left(\frac{1}{3.5} + \frac{4}{8.5} + \frac{0}{11.5} + \frac{7}{15.5}\right)} = 9.934 \text{ km/h}$$

3. **Running speed:** It is the instantaneous speed of a vehicle at a particular location.

$$\text{Running speed} = \frac{\text{Length of travel}}{\text{Total time in which the vehicle was running}}$$

- It excludes the stopped delays.
- It is used to analyses road condition.

4. **Journey Speed:**

$$\text{Journey speed} = \frac{\text{Length of travel}}{\text{Total journal time}}$$

- Total journey time includes the stopped delays.
- It is used to analyze traffic flow condition.

$$\text{Journey speed} \le \text{Running speed}$$

Interrelationship between Space mean speed and Time mean speed

$$V_t = V_s + \frac{\sigma_s^2}{V_s} \quad \text{and} \quad V_s = V_t - \frac{\sigma_t^2}{V_t}$$

where σ_s^2 and σ_t^2 are variance for space mean speed and time mean speed respectively.

Various type of Speed Studies

(i) Spot speed study
(ii) Speed and delay study

(i) Spot Speed Study:

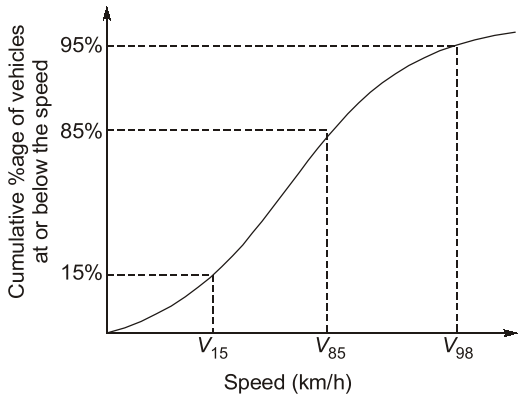
Uses:

- In planning traffic control, and in traffic regulation.
- In accident studies
- To calculate the traffic capacity
- Decide the speed trends
- Compare diverse type of vehicles and drivers under specified condition.
- In geometric design for redesigning existing highways.

It is represents in the form of:

(a) Average speed of vehicles ex. V_t and V_s.

(b) Cumulative speed distribution diagram.



Cumulative speed distribution diagram

(98^{th} percentage speed): It is the speed at or below which 98% of vehicles are moving.

It is taken as design speed.

(85^{th} percentage speed): The speed at or below which 85% of vehicles are moving.

It is also known as safe speed.

(15^{th} percentage speed): Speed at or below which 15% of vehicles are moving.

- It is taken as lower speed limit.
- Attempts are made to segregate the traffic moving at a speed lower than 15^{th} percentage of speed to avoid congestion.

(c) Modal average: Spot speed data can be used to determine the speed at which largest percentage of vehicles are moving this speeds is called modal speed.