POSTAL Book Package 2021

CIVIL ENGINEERING

Highway Engineering

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3 CHAPTER Traffic Engineering

Q.1 On an urban road, the free mean speed was measured as 70 kmph and the average spacing between the vehicles under jam condition as 7.0 m. The speed-flow-density equation is given by:

$$U = U_{sf} = \left[1 - \frac{k}{k_j}\right]$$

where, U = space-mean speed (kmph); U_{sf} = free mean speed (kmph); k = density (veh/km); k_j = jam density (veh/km); q = flow (veh/hr)
Find the maximum flow (veh/hr) per lane for this condition.

Solution:

$$\text{Traffic volume} = \text{Density} \times \text{Speed}$$

$$q = Uk$$

$$\Rightarrow \quad q = U_{sf}\left(1 - \frac{k}{k_j}\right)k$$

$$\Rightarrow \quad q = U_{sf}\left(k - \frac{k^2}{k_j}\right)$$

$$\text{Jam density, } k_j = \frac{1000}{\text{average spacing between vehicles}}$$

$$k_j = \frac{1000}{7} \text{ and } U_{sf} = 70 \text{ kmph}$$

For maximum traffic volume, $\boxed{\frac{dq}{dk} = 0}$

$$\Rightarrow \quad U_{sf}\left(1 - \frac{2k}{k_j}\right) = 0 \qquad [\because U_{sf} \neq 0]$$

$$\Rightarrow \quad 1 - \frac{2k}{k_j} = 0$$

$$\Rightarrow \quad k = \frac{k_j}{2}$$

$\therefore$ Maximum traffic volume,

$$q_{max} = U_{sf}\left(\frac{k_j}{2} - \frac{(k_j/2)^2}{k_j}\right)$$

$$= U_{sf}\left(\frac{k_j}{2} - \frac{k_j}{4}\right) = U_{sf}\left(\frac{k_j}{4}\right)$$

$$= 70 \times \frac{1000}{7 \times 4} = 2500 \text{ veh/hr}$$

Q.2 For designing a 2-phase fixed type signal at an intersection having North-South and East-West road where only straight ahead traffic is permitted, the following data is available.

Parameter	North	South	East	West
Design Hour Flow (PCU/hr)	1000	700	900	550
Saturation Flow (PCU/hr)	2500	2500	3000	3000

Total time lost per cycle is 12 seconds. Find the cycle length (in seconds) as per Webster's approach.

Solution:

For N-S road and E-W road the higher traffic volume will be taken i.e.

$$q_1 = 1000 \text{ and } q_2 = 900$$

$$S_1 = 2500 \text{ and } S_2 = 3000$$

$\therefore$
$$y_1 = \frac{q_1}{S_1} = \frac{1000}{2500} = 0.4$$

and
$$y_2 = \frac{q_2}{S_2} = \frac{900}{3000} = 0.3$$

$\therefore$
$$Y = y_1 + y_2 = 0.4 + 0.3 = 0.7$$

Optimum cycle time,

$$\boxed{C_0 = \frac{1.5\,L + 5}{1 - Y}} = \frac{1.5 \times 12 + 5}{1 - 0.7}$$

$$= 76.67 \approx 77 \text{ seconds}$$

Q.3 The probability that k number of vehicles arrive (i.e. cross a predefined line) in time t is given as $(\lambda t)^k e^{-\lambda t}/k!$, where λ is the average vehicle arrival rate. What is the probability that the time headway is greater than or equal to time t_1?

Solution:

Probability of arriving 'n' number of vehicles in time t,

$$P(n) = \frac{(\lambda t)^n e^{-\lambda t}}{n!}$$

If time headway is greater than or equal to time t, then number of vehicles arriving is zero,

$\Rightarrow$
$$P(o) = \frac{(\lambda t_1)^o e^{-\lambda t_1}}{o!} = e^{-\lambda t_1}$$

Q.4 The speed range and frequency data is given below. Find space mean speed and time mean speed alongwith standard deviation.

Speed Range (kmph)	Frequency (No. of vehicles)
15-25	4
25-35	6
35-45	8
45-55	9
55-65	7
65-75	6

Solution:

Average Speed (kmph)	Frequency
20	4
30	6
40	8
50	9
60	7
70	6
Total =	40

Time mean speed, $V_t = \dfrac{\sum_{i=1}^{n} V_i}{n}$

$$= \frac{20\times4+30\times6+40\times8+50\times9+60\times7+70\times6}{40}$$

$= 46.75$ kmph

Space mean speed, $V_s = \dfrac{n}{\sum_{i-1}^{n} \frac{n_i}{V_i}}$

$$= \frac{40}{\frac{4}{20}+\frac{6}{30}+\frac{8}{40}+\frac{9}{50}+\frac{7}{60}+\frac{6}{70}} = 40.71 \text{ kmph}$$

$$V_t = V_s + \frac{\sigma^2}{V_s}$$

$$\Rightarrow \quad 46.75 = 40.71 + \frac{\sigma^2}{40.71}$$

$$\Rightarrow \quad \sigma = 15.68$$

Q.5 Calculate practical capacity of the weavering section of the rotary in PCU per hour from following data:

(i) Proportional of weaving traffic = 0.72
(ii) Length of weaving section between the ends of channelised section = 55 metres
(iii) Width of weaving section = 13.5 metres
(iv) Average entry width of rotary = 10 metres

Solution:

Given: $p = 0.72$, $L = 55$ m, $W = 13.5$ m, $e = 10$ m

Capacity, $Q = \dfrac{280W\left(1+\frac{e}{W}\right)\left(1-\frac{p}{3}\right)}{\left(1+\frac{W}{L}\right)}$

$$= \frac{280\times13.5\times\left(1+\frac{10}{13.5}\right)\times\left(1-\frac{0.72}{3}\right)}{\left(1+\frac{13.5}{55}\right)}$$

$= 4015$ PCU/hr

Q.6 On a specific highway, the speed-density relationship follows the Greenberg's model [$v = v_f \log_e(k_j/k)$], where v_f and k_j are the free flow speed and jam density respectively. When the highway is operating at capacity, find the density obtained as per this model.

Solution:

Given, $$v = v_f \log_e\left(\frac{k_j}{k}\right)$$

But traffic volume, $$q = \text{traffic density} \times \text{speed} = k \times v$$

$$\Rightarrow \quad q = v_f\, k \log_e\left(\frac{k_j}{k}\right)$$

For maximum traffic volume i.e., traffic capacity

$$\frac{dq}{dk} = 0$$

$$\Rightarrow \quad v_f \times \frac{d}{dk}\left[k \log_e\left(\frac{k_j}{k}\right)\right] = 0$$

$$\Rightarrow \quad k\frac{d}{dk}\log_e\left(\frac{k_j}{k}\right) + \log_e\left(\frac{k_j}{k}\right)\frac{d}{dk}k = 0$$

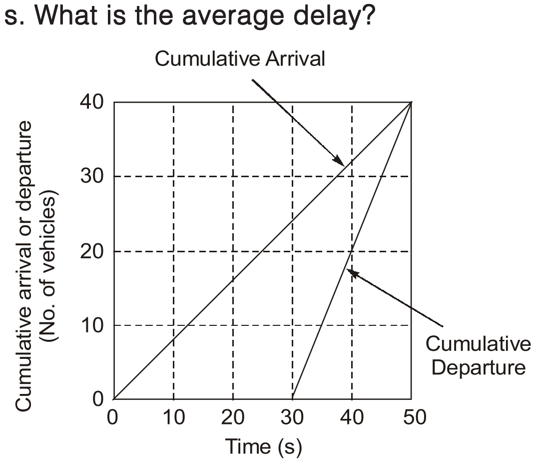
$$\Rightarrow \quad k \times \frac{k}{k_j} \times k_j \times \left(-\frac{1}{k^2}\right) + \log_e\frac{k_j}{k} = 0$$

$$\Rightarrow \quad \log_e\frac{k_j}{k} = 1$$

$$\Rightarrow \quad e = \frac{k_j}{k}$$

$$\Rightarrow \quad k = \frac{k_j}{e}$$

Q.7 The cumulative arrival and departure curve of one cycle of an approach lane of a signalized intersection is shown in the adjoining figure. The cycle time is 50 s and the effective red time is 30s and the effective green time is 20 s. What is the average delay?



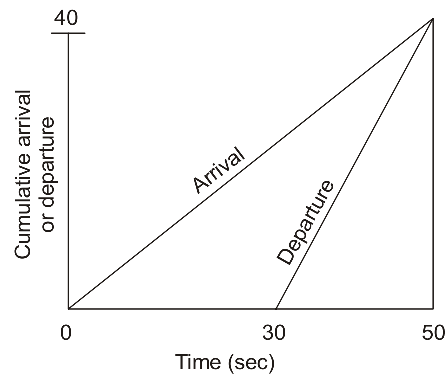
Solution:

Method-I

$$\text{Average delay} = \frac{\begin{pmatrix}\text{Area of triangle formed}\\ \text{by arrival curve}\end{pmatrix} - \begin{pmatrix}\text{Area of triangle formed}\\ \text{by departure curve}\end{pmatrix}}{\text{No. of vehicles}}$$

$$= \frac{\frac{1}{2}\times 40\times 50-\frac{1}{2}\times 40\times 20}{40} = 15 \text{ sec}$$

Method-II



Vehicle 1 arrives at 0 second and departs at 30 seconds.
Vehicle 40 arrivers at 50 seconds and departs at the same time.
Delay for vehicle 1 = 30 second
Delay for vehicle 40 = 0 second

Average delay = $\frac{0+30}{2}$ = 15 seconds

Q.8 A pre-timed four phase signal has critical lane flow rate for the first three phases as 200, 187 and 210 veh/hr with saturation flow rate of 1800 veh/hr/lane for all phases. The lost time is given as 4 seconds for each phase. If the cycle length is 60 seconds, find the effective green time (in seconds) for the fourth phase.

Solution:

Flow rates for the first three phase are given as
q_1 = 200 veh/hr; q_2 = 187 veh/hr and q_3 = 210 veh/hr
Saturation flow rate is 1800 veh/hr/lane

Lost time, $L = 4 \times 4 = 16$ sec

Length of the cycle, $C_0 = 60$ sec

Now, $y_1 = \frac{q_1}{s_1} = \frac{200}{1800}$

$$y_2 = \frac{q_2}{s_2} = \frac{187}{1800}$$

$$y_3 = \frac{q_3}{s_3} = \frac{210}{1800}$$

$$C_0 = \frac{1.5L+5}{1-y}$$

$\Rightarrow$ $60 = \frac{1.5\times 16+5}{1-y} = \frac{24+5}{1-y}$

$\Rightarrow$ $1 - y = \frac{29}{60}$

$\Rightarrow$ $y = \frac{1-29}{60} = \frac{60-29}{60} = 0.517$