lecture ⑤

20/04/19

B] Traffic Studies and analysis

① Traffic volm study ② Traffic flow and capacity Analysis
③ Speed study ④ O and D study ⑤ Accident study
⑥ Parking study.

① Traffic volm study →

PCU = (Passenger car unit) - under mix traffic cond it is difficult to measure traffic volume, traffic density e.t.c, capacity, Hence all class of vehicle is converted into a standard vehicle unit called "PCU" (also known as passenger car equivalent)

(SV = standard vehicle)

$$[PCU]_i = \frac{\text{Speed Ratio}}{\text{length Ratio}} = \frac{\frac{V_{sv}}{V_i}}{\frac{L_{sv}}{L_i}}$$

		PCU
①	car, tempo	1
②	Truck, bus	3
③	Motor cycle	0.5
④	cycle Rikshaw	1.5
⑤	Horse drawn vehicle	4
⑥	small bullock cart	6
⑦	large bullock cart	8

② Traffic volm → No. of vehicle ~~passing~~ crossing a particular section of road per unit time called (T.V)
It is expressed in veh/min, veh/hr and veh/day (q)

Measurement traffic volm :-

① Manual

② Mechanical

① Manual method
can be classified by 24x7 counting is nt possible

② Mechanical method →

① Radar method ② Magnetic detector ③ Pneumatic hose method
(Radar technique) (Magnetic Principle) (Pressure impulse)

Representation of traffic volm data

① AADT (Annual avg daily traffic) = $\left\{ \frac{\text{total no. of vehicle throughout a year}}{365} \right\}$ veh/day

② AAHT (Annual avg hourly traffic) = $\left\{ \frac{\text{total no. of vehicle through a yr}}{365 \times 24} \right\}$ veh/hr

③ AAWT (Annual avg. week days traffic) = $\left\{ \frac{\text{total no. of vehi through a week days in a yr}}{260} \right\}$ veh/day

④ ADT (Average daily traffic) = $\left\{ \frac{\text{total no. of vehicle through over a week}}{7} \right\}$ (veh/day)

Periodic volm count

In order to obtain certain traffic volm data such as AADT it is necessary to obtain data continuously for a long duration of time. However it may not be feasible due to the heavy cost involve. Hence to make reasonable estimate technique of expansion factor can be used.

HEF (hourly expansion factor) = $\left[\frac{\text{Avg. traffic for 24 hour}}{\text{Avg traffic for particular hour}} \right]$

DEF (Daily expansion factor) = $\left[\frac{\text{Avg. traffic for a week}}{\text{Avg. traffic for a particular day}} \right]$

MEF (monthly expansion factor) = $\frac{AADT}{ADT}$

Pb-45 W.B. Avg volm. for 24 hour = $\frac{(500\times25)+(600\times22)+(700\times20)}{3}$ = 13233.34 veh

DEF = $\frac{\text{Avg traffic for a week}}{\text{Avg traffic for a particular 24 hour}}$

$7.9 = \frac{\text{Avg. traffic week}}{\text{Avg traffic for a particular hour}}$ = 13233.34

Avg traffic week = 104543.38 veh

ADT = $\left(\frac{104543.38}{7}\right)$ = 14934.76 veh/hr

MEF = $\frac{AADT}{ADT}$; $1.5 = \frac{AADT}{14934.75}$ = 22402.14 veh/day

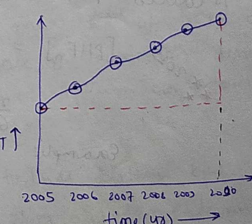
Various chart used in traffic volume →

trend change Show traffic volm trend over a period of time
It is used to calculate rate of growth of traffic

traffic volm after x years

$A = P(1+r)^x$

P → Present traffic volm

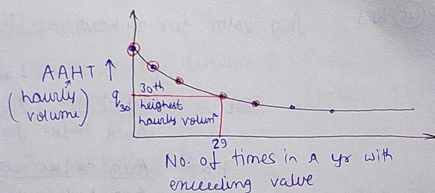


② 30th Heighest hourly volm

it is consider as a hourly volume heigher

It has been observed that 30th higher hourly volm is exceeded only 29 time in a year and all other traffic data will lie lesser than that. As per IRC it gives satisfactory result in term of performance and it's is economical in nature

② 30th heighest hourly volm



Variation chart -
show hourly ~~and~~ daily and seasonal variation

① this chart help in deciding facility and regulation needed during peak traffic duration e.g. during peak flow a particular class of vehicle is restricted on one road which is diverted to another road

② to analysis peak duration factor is used which is called PHF (peak hour factor)

$$[PHF_n] = \left(\frac{\text{Peak hour vol m}}{\frac{60}{n} \times V_n(\max)}\right)$$

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$$\frac{n}{60} \le (PHF_n) \le 1$$

Example: (Peak hour factor for 5 min)

$$PHF_5 = \left(\frac{\text{Peak hour volm}}{\frac{60}{5} \times V_5(\max)}\right)$$

$$\boxed{\frac{5}{60} \le PHF_5 \le 1}$$

Ques- ㊳ Peak hour vehi = $(7\times20) + (3\times30) + (10\times25) + (1\times26) + (11\times4) + (13\times10) + (2\times15) + 8(20) + 5(10) = 1000$ vehicle

max vol of in 5 min (48th min to 52th min)

$$V_5(\max) = 30\times5$$
$$= 150 \text{ veh}$$

Peak hour factor for 5 min

$$[PHF]_5 = \left(\frac{\text{Peak hour vol.}}{\frac{60}{5} \times V_5(\max)}\right) = \frac{1000}{\frac{60}{5}\times150} = 0.55$$

Max volme in 15 min (7th min to 21st min)

$$V_{15\,max} = (20\times1) + (30\times3) + (10\times25) + (1\times26)$$
$$= 386 \text{ veh}$$

$$PHF_{15} = \left(\frac{1000}{\frac{60}{15}\times386}\right) = 0.647$$

~~Traffic flow and capacity analysis~~

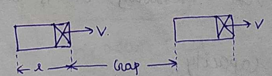
Imp terminology

traffic density (K) = it is define as no of vehicle occupied by unit length of road at any instance of time it is expressed in (vehicle/Km)

Jam density (K_J) = traffic density under Jam cond^n is called Jam density. it is the max ~~no.~~ value of traffic density in case of maximum density which road can accommodate in case of maximum density which Jam cond^n developed congestion become so high due to which Jam cond^n developed under Jam cond^n (speed (V) = 0) ★★★

Space headway = it is the longitudinal distance b/w 2 consecutive vehicle travelling in same dir and same lane (total length of road occupied by 1 vehicle)

$$S = [\text{gap} + l] \quad \text{SSD} \quad \text{9d Jand}$$



otherwise → $\boxed{S = SSD + l}$ oversafe

$$S = L_1 + L_B + l$$
$$= 0.278 V \times 0.7 + l \quad \text{रेलवे}$$
$$= 0.1946 V + l \qquad \boxed{S = 0.2V + l}$$

Traffic Density $= \dfrac{1\,km}{\text{Avg space heady}} = \left(\dfrac{1000\,m}{S(m)}\right)$

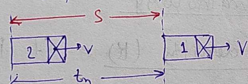
$$\boxed{K = \frac{1000}{0.2V + l}}\ \text{veh/km}$$

- under Jam cond $V = 0$

$$\boxed{K_J = \frac{1000}{l}}$$

time headway →

define as time gap b/w passes of 2 consecutive vehicle



traffic vol^m $= \left(\dfrac{1\,hr}{\text{Avg time headway}}\right)$

$$\boxed{q = \left[\frac{3600}{t_h}\right]}\ \text{veh/hr} \qquad t_h \to \text{sec}$$

Relation b/w traffic density traffic volume and speed →

traffic vol^m = speed × traffic density
(veh/hr) = (km/hr) (veh/km)

$\boxed{q = V \times K}$ $\qquad q = V \times \left(\dfrac{1000}{S}\right) \nearrow q = \left(\dfrac{1000V}{S}\right)$ veh/hr (V km/h, S m)

- Traffic capacity (q_{max})

maximum value of traffic vol^m in any cond is called traffic capacity

Basic capacity

space headway: $q_{max} = \left(\dfrac{1000V}{S}\right)$

Time headway: $q_{max} = \left(\dfrac{3600}{t_h}\right)$

(a) Basic capacity — Traffic capacity in at most ideal cond^n called ** Basic capacity. it is calculated on the basis of-

(b) Pratical capacity — traffic capacity under ordinary cond is called pratical capacity

$0 <$ ordinary capacity $<$ Basic capacity

(c) Possible capacity — it is exist b/w most worst to most ideal cond^n

Ques (28) (Pb) $V = 50\,km/h$, $t_h = 2.52$ second

$V = \dfrac{S}{t_h}$

$0.278 \times 50 \times 2.52 = (S)$

$S = 35\,m$

Q(29) $t_h = 3\,sec$

$q = \dfrac{3600}{3} = 1200$ veh/hr

Q(30) $V = 60\,km/h$, $t_R = 2.4\,sec$, $l = 5\,m$, $f = 0.38$, $q_{max} = ?$

$S = (SSD + l) = \left(0.278 V t_R + \dfrac{V^2}{254 f} + l\right) = 82.33^m$

$q_{max} = \left(\dfrac{1000V}{S}\right) = \dfrac{1000 \times 60}{82.33} = 728.77$ veh/hr

Q-(31) $K = \dfrac{1000}{S} = \dfrac{1000}{50} = 20$ veh/km

Traffic analysis by green shield model

speed v/s density

$$\boxed{V = V_f\left(1 - \frac{K}{K_J}\right)}$$

V_f = free mean speed

K_J = Jam density

Traffic vol^m = speed × traffic density

$q = VK \Rightarrow q = \left[V_f\left(1 - \frac{K}{K_J}\right)\right]K$

$$\boxed{q = V_f\left(K - \frac{K^2}{K_J}\right)}$$

(2) for traffic capacity q to be max

$\dfrac{dq}{dK} = 0 \Rightarrow V_f\left(1 - \dfrac{2K}{K_J}\right) = 0$

$\boxed{K = \frac{1}{2} K_J}$ → max

$q_{max} = V_f\left(\dfrac{K_J}{2} - \dfrac{K_J^2}{4K_J}\right)$

$$\boxed{q_{max} = \frac{1}{4} V_f K_J}$$

Speed at max Flow :

$$V = V_f\left(1 - \frac{\frac{K_J}{2}}{K_J}\right) = \frac{1}{2}V_f$$

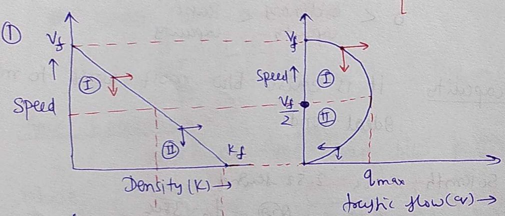
Conclusion -

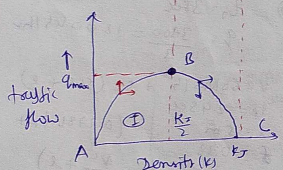
At Max flow :

1] $K = \frac{1}{2}K_J$

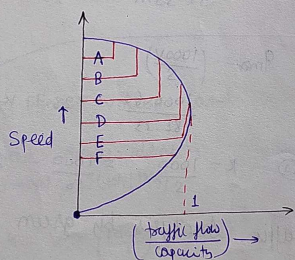
2] $V = \frac{1}{2}V_f$

3] $q_{max} = \frac{1}{4}V_f . K_j$





- **Level of Service (LOS)** ⇒



traffic capacity is the quantitative measure of flow where as level of service is qualitative measure of flow.

- level of service is define as qualitative measure describe operation cond with traffic strain and their perception by drivers.

- from ~~RO~~ LOS_A to LOS_B
- No. of vehicle increase
- traffic density increase
- traffic flow increase
- traffic speed (↓)
- comfort to driver / passenger (↓)
- delay to traffic (↑)

Solution (41) ① free mean speed

$$U = 42.46\left(1 - \frac{K}{\frac{42.46}{0.22}}\right)$$

a] $V_f = 42.46$ km/h

b] $K_J = \frac{42.46}{0.22} = 193$ vehicle / km

At max flow.

i] $K = \frac{1}{2}K_J = \frac{1}{2}\times 193 = 96.5$ veh/km

ii] $V = \frac{1}{2}V_f = \frac{1}{2}\times 42.46 = 21.23$ km/h

iii] $q_{max} = \frac{1}{4}V_f K_J = \frac{1}{4}\times 42.46\times 193 = 2048.69$ veh/hr

iv] $q_{max} = \frac{1000V}{S}$

$2048.69 = \frac{1000V}{S}$, $\boxed{S = 10.36m}$

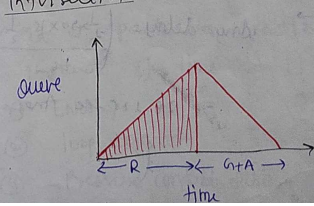
v] $q_{max} = \frac{3600}{t_h}$

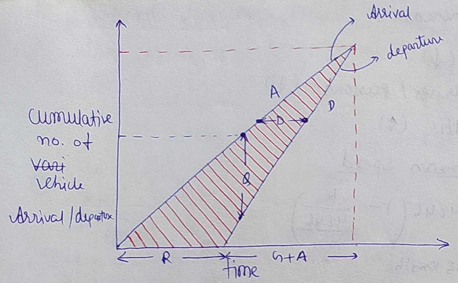
$2048.69 = \frac{3600}{t_h}$, $t_h = 1.76$ sec.

vi] $K_J = \frac{1000}{l}$

$193 = \frac{1000}{l}$, $\boxed{l = 5.18m}$

- **Delay and q ~~analysis~~ Queue analysis at signalized intersection** →





Avg delay = $\left(\dfrac{\text{Area b/w arrival and departure in 1 cycle time}}{\text{cumu. no. of vehicle Arrival per cycle time}}\right)$

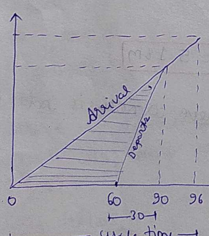
<u>Definition</u> <u>Delay</u> (D) it is define as difference of departure time and arrival time of any vehicle

<u>Queue</u> → it is define as the difference total no. of vehicle arrival and total no. of vehicle departure any any instant of time

<u>Probability ~~of~~ for vehicle arrival</u> →

(9) W.B. (Pb) Avg delay = $\dfrac{\frac{1}{2}\times 50\times 40-\frac{1}{2}\times 20\times 40}{40} = 15$ sec

(12) W.B



Arrival Rate = $\dfrac{10\,veh}{\left(\frac{60}{3600}\right)hr} = 600$ VPH

Departure Rate = $\dfrac{15\,veh}{\left(\frac{30}{3600}\right)hr} = 1800$ VPH

Avg delay = $\left(\dfrac{\frac{1}{2}\times 90\times 15-\frac{1}{2}\times 30\times 15}{16}\right)$

= 28.125 sec Ans

<u>Probability for vehicle Arrival (Poisson distribution)</u>

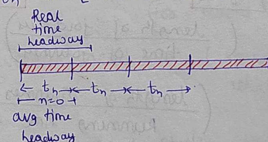
λ = vehicle Arrival rate

t = time interval

Probability of n no. of veh arrival in t sec time interval

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

a] Probability that time headway is greater than equal to t_n or [Probability of vehicle arrival time t_n sec]



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$n=0$

$$\boxed{P = e^{-\lambda t}}$$

b] Probability that time headway is less than t_n

$$\boxed{P = 1-e^{-\lambda t_n}}$$ ★★

Pb. (34) $P(n,t) = \dfrac{(\lambda t)^n \cdot e^{-\lambda t}}{n!} = \dfrac{\left(\frac{240}{3600}\times 30\right)\cdot e^{-\left(\frac{240}{3600}\times 30\right)}}{1!}$

Pb (35) $P = e^{-\lambda t_n} = e^{-\left(\frac{900}{3600}\times 8\right)} = 0.1353$

* Speed Study –

<u>terminology</u>

(Only for 1 vehicle)

(1) <u>Spot speed</u> :- it is an instantaneous speed of vehicle at a particular section of road or a particular instance of time it is measured by –

(1) ENOSCOPE

(2) loop detector

(3) Pressure contact tube

② Average speed → it is avg. speed of spot speed of all the vehicle

time mean speed (V_t) — AM

Space mean speed (V_s) — HM

$$V_t = \left(\frac{V_1 + V_2 + V_3 + \dots V_n}{n}\right)$$

$$V_s = \frac{n}{\left(\frac{1}{V_1} + \frac{1}{V_2} + \frac{1}{V_3} + \dots \frac{1}{V_n}\right)}$$

time mean speed is the arithmetic mean of spot speed of all the vehicle

Arithmetic mean — AM > HM — Harmonic mean

$V_t > V_s$

Space mean speed is Harmonic mean spot speed of all vehicle

③ Journey speed = $\left(\frac{\text{length of journey}}{\text{time of journey}}\right)$

④ Running speed = $\left(\frac{\text{length of Journey}}{\text{Running time}}\right)$

$\boxed{\text{Running time = journey time - delay}}$

Pb (40)

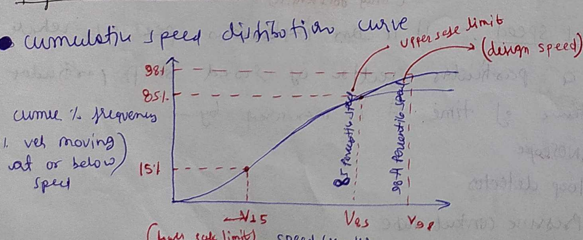
$$V_t = \frac{40\times3 + 50\times4 + 60\times5 + 70\times2}{3+4+5+2}$$

$= 54.28$ km/h

$$V_s = \frac{3+4+5+2}{\left(\frac{3}{40}\right)+\left(\frac{4}{50}\right)+\left(\frac{5}{60}\right)+\frac{2}{70}} = 52.45 \text{ km/h}$$

Representation of spot speed data →

- cumulative speed distribution curve



① 98th % speed — Speed at or below which 98% of is moving and only 2% exceed this limit. this speed is considered as design speed for geometric design.

② 85th % speed — • this speed is considered as upper safe limit of vehicle movement.

③ 50th % speed — • (Medium) called

④ 15th % speed — • (lower safe limit) ⇒ considered (for avoid congestion)

Model average speed → (speed at which max. no. of vehicle moving)

Ques In a spot speed study following data were observed determine design speed, upper and lower safe limit for vehicle movement and model avg speed.

Speed Range	No. of vehicle	Speed
0-10	40	
10-20	80	
20-30	120	
30-40	110	
40-50	210	
50-60	145	

Speed of range	No. of vehicle	
60-70	220	
70-80	320	
80-90	275	
90-100	250	
100-110	300	
110-120	260	

total no. of vehicle = 2330

① $\frac{40}{2330} \times 100 = 1.716$

% vehicle	cum %
1.716	1.716
3.433	5.149
5.150	10.299
4.721	15.02
9.012	24.032
6.223	30.255
9.442	39.697
13.72	53.427
11.802	65.229
10.720	75.961
12.875	88.836
11.158	100

upper safe limit

ⓐ Design speed - (85%)

speed	% frequency
95	75.961 %
102.01 ←	85 %
105	88.836 %

$V_{85} = 102.01$ km/h

ⓑ lower safe limit (15%)

Speed	% frequency
25	10.299
34.91 km/h ←	15%
35	15.02

ⓒ Design speed

speed	% frequency
105	88.836
? →	98%
115	100

$V_{98} = 113.25$ km/h

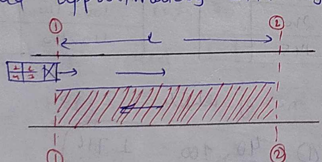
ⓓ Model Avg speed

75 km/h

- Speed and delay study :- ****

By Floating car method this test is conducted on 2 lane 2 way highway.

- In this method a test vehicle is driven over a given length of road approximately with avg. speed of traffic flow.



A group of four observers sitting in the test vehicle record various detail during the test run

Observer ① sitting in the car with 2 stop watches he ~~may~~ measure total Journey time and cumulative delay time

Observer ② to measure (location and reason of congestion) (cause of delay)

Observer ③ count the total no. of vehicle overtaking the test vehicle and overtaken by the test vehicle

Observer ④ count total no. of vehicle (moving and stop) in opposite dirn in adjacent lane.

A/c to this method Traffic flow $\boxed{(q) = \frac{n_a + n_y}{t_w + t_a}}$

Journey time of flow.

$$\boxed{\bar{t} = \left(t_w - \frac{n_y}{q}\right)}$$

Where

t_w = (avg Journey time when the test vehicle is running with the flow)

t_a = (avg Journey time when the test vehicle is running against the flow)

n_y = (avg no. of vehicle overtaking the test vehicle - avg no. of vehicle overtaken the test vehicle

Note : n_y → (may be (+ve) and (-ve) and 0)

n_a = (avg. no. of vehicle on study stretch (length) moving in the dirn flow)

Note :(n_a Forth observer noted by opposite dir side test vehicle)

Dir^n	Journey time		Delay time		No. of vehicle		
	min	sec	min	sec	overtaking	overtaken	opposite
N → S	6	30	1	30	3.5	5	272
S → N	7	36	1	58	3	2	179

For N → S

$t_w = 6\,\text{min}\ 30\,\text{sec} = 6.5\,\text{min}$

$t_a = 7\,\text{min}\ 36\,\text{sec} = 7.6\,\text{min}$

$\text{delay} = 1\,\text{min}\ 30\,\text{sec} = 1.5\,\text{min}$

$n_y = 3.5 - 5 = (-1.5)$

$n_a = 179$

① Traffic flow (q) $= \left(\dfrac{n_a + n_y}{t_w + t_a}\right) = \left(\dfrac{179 + (-1.5)}{6.5 + 7.6}\right)$

$= 12.58\,\text{veh/min}$

② Journey time of flow $= (\bar{t}) = \left(t_w - \dfrac{n_y}{q}\right)$

$= 6.5 - \dfrac{(-1.5)}{12.58} = 6.62\,\text{min}$

Running time = Journey time − delay

$= 6.62 - 1.5$

$= 5.12\,\text{min}$

Journey speed $= \dfrac{\text{Journey } \cancel{\text{time}}\ \text{length}}{\text{Journey time}} = \dfrac{3.5\,\text{km}}{\left(\frac{6.62}{60}\right)\text{hr}} = 31.72\,\text{km/h}$

Running speed $= \dfrac{\text{Journey } \text{length}}{\cancel{\text{Journey}}\ \text{Running time}} = \dfrac{3.5\,\text{km}}{\left(\frac{5.12}{60}\right)} = 41.01\,\text{km/h}$

For South → North

$t_w = 7.6\,\text{min}$

$t_a = 6.5\,\text{min}$

$\text{delay} = 1\,\text{min}\ 56\,\text{sec} = 1.96\,\text{sec}$

$n_y = 3 - 2 = 1$

$n_a = 272$

① (a) Traffic flow $q = \dfrac{(n_a + n_y)}{(t_w + t_a)} = \left(\dfrac{272 + 1}{7.6 + 6.5}\right)$

$= 19.36\,\text{veh/min}$

② Journey time of flow →

$\bar{t} = \left(t_w - \dfrac{n_y}{q}\right) = 7.6 - \dfrac{1}{19.36} = 7.548\,\text{min}$

Running time = Journey time − delay

$= 7.548 - 1.96$

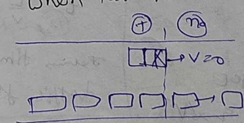
$= 5.588\,\text{min}$

Journey speed $= \dfrac{\text{Journey length}}{\text{Journey time}} = \dfrac{3.5\,\text{km}}{\left(\frac{7.548}{60}\right)\text{hr}} = 27.85\,\text{km/h}$

Running speed $= \dfrac{3.5\,\text{km}}{\frac{5.588}{60}} = 37.63\,\text{kmph}$

Derivation of floating car method Relations →

Step ① When test vehicle is stop and flow is moving



$\left(q = \dfrac{n_o}{T}\right)$

No. of overtaking $= n_o$

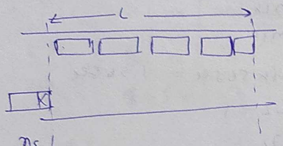
$n_o = qT$

(T = Duration of study)

When test is moving and flow is stop

∴ K = traffic density

n_s = no. of vehicle stopped (or overtaken by the test vehicle)



$\left(K = \frac{n_s}{L}\right)$

(No. of vehi overtaken by test vehi)

$n_s = KL$

Step ③ Test vehicle moving in dirn of flow →

$(n_o - n_s) = q t_w - KL$

$\boxed{n_y = q t_w - KL}$ — ①

Step ④ test vehicle moving in the opposite dirn of flow

$(n_o + n_s) = q t_a + KL$

$\boxed{n_a = q t_a + KL}$ — ②

from ① and ②

$n_y = q t_w - \cancel{KL}$

$n_a = q t_a + \cancel{KL}$

$(n_a + n_y) = q(t_w + t_a)$

Traffic flow

$q = \left(\frac{n_a + n_y}{t_w + t_a}\right)$

from eq ①

$n_y = q t_w - KL$

$n_y = q t_w - \frac{q}{V} \times V\bar{t}$

$n_y = q(t_w - \bar{t})$

$\frac{n_y}{q} = t_w - \bar{t}$

$q = KV$

$K = \frac{q}{V}$

traffic speed

$V = \frac{L}{\bar{t}}$

Journey time of traffic flow

$\bar{t} = \frac{L}{V}$

Journey time of traffic flow

$\boxed{\bar{t} = \left(t_w - \frac{n_y}{q}\right)}$

from eqn ①

$n_y = q t_w - KL$

$n_y = q t_w - K V_w t_w$

IMP $\boxed{\frac{n_y}{t_w} = q - K V_w}$

Relative flow in the dirn of flow

traffic density

from eq ②

$n_a = q t_a + KL$

$n_a = q t_a + K V_a \cdot t_a$

$\frac{n_a}{t_a} = q + K V_a$

Relative flow when test veh in the opposite dirn of flow.

Ques-42

$V_w = 60\ km/h$, $L = 4\ km$

$t_w = \frac{L}{V_w} = \frac{4}{60} = \frac{1}{15}\ hr$

$n_y = 20$

$V_a = 60\ km$

$L = 4\ km$

$n_a = 330$

$q = \left(\frac{n_a + n_y}{t_w + t_a}\right) = \left(\frac{330 + 20}{\frac{1}{15} + \frac{1}{15}}\right)$

2625 veh/hr

Ques-43

$L = 5\ km$

$t_w = 40 - 15 = 25\ min$

$n_y = (60 - 0) = 60$

$n_o = 45$ vehicle, $T = 15\ min$

$q = \frac{n_o}{T} = \frac{45}{15} = 3\ veh/min$

Journey time $= \left(t_w - \frac{n_y}{q}\right) = \left(25 - \frac{60}{3}\right) = 5\ min$

Journey speed $= \frac{L}{t} = \frac{5\ km}{\left(\frac{5}{60}\right) hr} = 60\ km/hr$

Ques - 31

$50 = q - K(20)$

$200 = q + K(30)$

$-150 = -50 \times K$

$K = 3$

and $q = 110$ veh/hr Ans