Questions of Lecture 4

Question 1

The arrival times of four vehicles at two points X and Y that are 500ft apart are as follow:

Vehicle	Point X (sec)	Point Y (sec)
A	Ta	Ta+7
B	Ta+3	Ta+9
C	Ta+6	Ta+12
D	Ta+12	Ta+22

Determine: Time mean speed, Space mean peed, and flow at section XX

Solution

Find the time to pass the section X-Y for each vehicle

Vehicle	Pint X (sec)	Point Y (sec)	Time to pass the section x-y (sec)	Speed (ft/sec)
A	Ta	Ta+7	7	500/7=71.43
B	Ta+3	Ta+9	6	83.33
C	Ta+6	Ta+12	6	83.33
D	Ta+12	Ta+22	10	50.00
			29	288.09

Space mean speed= 500/(29/4)= 68.96 (ft/sec)

Time mean speed= 288.09/4=72.02 (ft/sec)

To find the flow, the headway time between each two successive vehicles should be computed:

Vehicle	Point X (sec)	Headway (sec)
A	Ta	Ta-(Ta+3)=3
B	Ta+3	
B	Ta+3	3
C	Ta+6	
C	Ta+6	6
D	Ta+12	
		Average headway=12/3=4 Min. headway=3

Flow= 3600/4=900 vph

Maximum flow=3600/3=1200 vph

Question 2: The traffic data were collected at two point x and y which are 1500ft apart. Six vehicles (A, B, C, D, E and F) passed section x-y at intervals between each two successive vehicle of 3, 4, 3, 6, and 5 sec respectively. Vehicles speeds are 50, 45, 40, 35, 35 and 45 mph respectively.

a. Draw a schematic showing the locations of the vehicle entered the section x during the 20 sec after the first vehicle passed this section
b. the time mean speed
c. Flow
d. density

Solution:

The first five only are including in the schematic below because the accumulative time when the sixth vehicle is including exceeded 20 sec.

a.

F x…..E……..D…….C…….B……..A y

Time (sec)	5 sec ‘	6 sec ‘	3sec ‘	4 sec ‘	3 sec ‘
Accumulative Time (sec)	4 sec	10 sec	13 sec	17sec	20 sec

b. TMS=(50+45+40+35+35+45)/6=41.67 mph
c. Flow=3600/[(3+4+3+6+5)/5]=3600/4.2=857vph
d. Density=flow/speed=857/41.67=20.57 veh/mi

Question 3: traffic volume data has been collected for 15 min time intervals as shown below. Find the total hourly volume, flow rate and peak hour factor (PHF).

Time	7:30 – 7:45	7:45 – 8:00	8:00 – 8:15	8:15 – 8:30
Volume	250	350	300	200

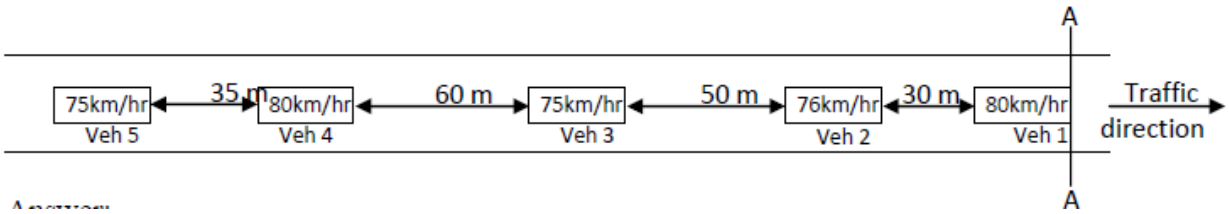
Solution:
Volume = 250+350+300+200 = 1100 veh
Flow rate (q) = peak volume * number of intervals per 1 hour = 350 * 4 = 1400 veh/hr
PHF=1100/1400=0.786

Question 4: traffic volume data has been collected for 10 min time intervals as shown below. Find the total hourly volume, flow rate and PHF.

Time	7:30–7:40	7:40–7:50	7:50–8:00	8:00–8:10	8:10–8:20	8:20–8:30
Volume	150	200	300	200	150	100

Solution:
Volume = 150+200+300+200+150+100= 1100 veh
Flow rate (q) = peak volume * number of intervals per 1 hour = 300 * 6 = 1800 veh/hr
PHF=1100/1800=0.61

Question 5: Five vehicles, as shown in the figure below, are traveling at constant speeds on section of 230m length. Assuming that all vehicles have a same length of 4m and if speeds and clear spacing between vehicles are as shown in the figure, estimate the following:
1) Average space mean speed
2) Average time mean speed
3) Traffic density
4) Average time headway arriving a section A-A



Solutions

1- Space mean speed $\overline{u}_s = \frac{n}{\sum_{i=1}^{n}(\frac{1}{u_i})} = \frac{5}{\frac{1}{80}+\frac{1}{76}+\frac{1}{75}+\frac{1}{80}+\frac{1}{75}} = 77.13 km/hr$

2- Time mean speed $\overline{u}_t = \frac{1}{n}\sum_{i=1}^{n} u_i = \frac{80+76+75+80+75}{5} = 77.2 km/hr$

3- Traffic density $k\ \left(\frac{veh}{km}\right) = \frac{No.of\ vehicles\ on\ a\ segment}{length\ of\ the\ segment\ (km)} = \frac{5}{0.23} = 21.7$veh/km

4- Estimation of average time headway:
Arrival of vehicle 2 (t2)=(30+4)/(76*1000/3600)=1.61 sec

Headway of vehicle 2 (h2)=1.61

Arrival of vehicle 3 (t3) =(80+8)/(75*1000/3600)=4.224 sec

Headway of vehicle 3 (h3)=4.224-1.61=2.614 sec

Arrival of vehicle 4 (t4)= (140+12)/(80*1000/3600)=6.84sec

Headway of vehicle 4 (h4)=6.84-4.224=2.616sec

Arrival of vehicle 5 (t5)= (175+16)/(75*1000/3600)=9.168

Headway of vehicle 5 (h5)=9.168-6.84=2.232sec

Average time headway=(1.61+2.614+2.616+2.232)/4 = 2.268sec

Question 6
A study of freeway flow at a particular site has resulted in the following speed-density relationship as follows:

$$u = 57.5(1 - 0.008k)$$

Where u in units of mi/hr and k in unit of veh/mi
For this relationship, determine: (a) the free-flow speed, (b) jam density, (c) the speed flow relationship, (d) the flow density relationship, and (e) maximum flow (i.e. capacity).

Solution:
The general speed-density relationship is:

$$u = u_f - \left(\frac{u_f}{K_j}\right) * k$$

The relationship in the question could be re-written as follows:

$$u = 57.5 - 0.46k$$

Therefore,

a. u_f=57.5 (mi/hr)

b. u_f/k_j=0.46, kj=57.5/0.46=125 veh/mi

c. The general equation is:

$$q = k_j\, u - \frac{k_j}{u_f}\, u^2$$

By substituting kj=125 and uf=57.5 produce:

$$q = 125\text{u} - \left(\frac{125}{57.5}\right)\text{u}^2$$

$$q = 125u - 2.174u^2$$

or:

$$u = 57.5 - 0.46k$$

, then by substituting k=q/u produces:

$$u = 57.5 - 0.46\frac{q}{u}$$

$$0.46\frac{q}{u} = 57.5 - u$$

$$q = 125u - 2.174u^2$$

d. The general equation is:

$$q = u_f\, k - \frac{u_f}{k_j}\, k^2$$

By substituting kj=125 and uf=57.5 produce:

$$q = 57.5k - 0.46k^2$$

or:

$$u = 57.5 - 0.46k$$

then by multiplying by k produces:

$$q = 57.5k - 0.46k^2$$

e.

$$q_{max} = \frac{k_j . u_f}{4} = \frac{125 * 57.5}{4} = 1796\ veh/hr$$

Question 6: Two sets of vehicles are timed over a kilometer section long and flows are also recorded. In the first set, four vehicles take 53, 56, 63 and 69 seconds when the flow is 1500 veh/hr. In the second set, four vehicles take 70, 74, 77 and 79 seconds when the flow is 1920 veh/hr. Estimate:
1- Estimate the capacity (maximum flow) of a section.
2- Estimate average speed and density at flow rate of 800 veh/hr.
3- If the average speed of traffic is 60km/hr, state the traffic condition (i.e. normal or congested)?

Solution:

1- Estimating the capacity (q_{max}) of a section

Estimation of space mean speed for set 1:

$$\overline{u_s} = \frac{n.L}{\sum_{i=1}^{n} t_i)} = \frac{4 * 1}{(53 + 56 + 63 + 69)/3600} = 59.75km/h$$

K for set 1=q/us=1500/59.75=25.1 veh/km

Estimation of space mean speed for set 2:

$$\overline{u_s} = \frac{n.L}{\sum_{i=1}^{n} t_i)} = \frac{4 * 1}{(70 + 74 + 77 + 79)/3600} = 48km/h$$

K for set 2=q/us=1900/48=39.6 veh/km

By using the fundamental equation of speed-density relationship:

$$u = u_f - (\frac{u_f}{k_j})k$$

using data set 1:

$$59.75 = u_f - \left(\frac{25.1u_f}{k_j}\right) \qquad ---(1)$$

using data set 2 :

$$48 = u_f - \left(\frac{39.6u_f}{k_j}\right) \qquad ---(2)$$

Eq(1)-Eq(2) produces:

$$59.75 - 48 = -\left(\frac{25.1u_f}{k_j}\right) + \left(\frac{39.6u_f}{k_j}\right)$$

$$11.75 = \left(\frac{14.5u_f}{k_j}\right) \text{ , then } k_j = \left(\frac{14.5u_f}{11.75}\right) \qquad \text{---(3)}$$

Substitute eq(3) in eq(1) produces:

$$59.75 = u_f - \left(\frac{25.1u_f}{\frac{14.5u_f}{11.75}}\right) \text{ , then}$$

$$u_f = 80\text{km/hr and } k_j = \frac{14.5*80}{11.75} = 98.72 \text{ veh/km}$$

$$q_{max} = \frac{k_j . u_f}{4} = \frac{80 * 98.72}{4} = 1974 \text{ veh/hr}$$

2- Average speed and density at flow rates of 800 and 2000 veh/hr.

Speed at flow of 800 veh/hr

$$q = u.k_j - (\frac{k_j}{u_f})u^2$$

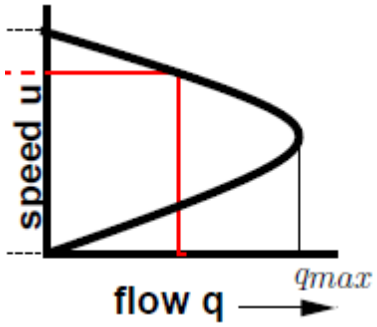
$$800 = 98.72u - (\frac{98.72}{80})u^2$$

1.234u2 - 98.72u + 800 = 0

A=1.234, B= -98.72, C=800

$$u = \frac{-B \mp \sqrt{B^2 - 4AC}}{2A}$$

$$u = \frac{98.72 \mp \sqrt{98.72^2 - 4 * 1.234 * 800}}{2 * 1.234}$$



u=70.85 at normal flow condition and ***u=9.15 at congested flow condition***

Density at flow of 800 veh/hr

k=q/u=800/70.85=11.29 veh/km at normal flow condition

k=q/u=800/9.15=87.43 veh/km at congested flow condition

3- Since the speed of 60km/hr is higher than the speed at maximum flow of 1974veh/hr, speed at $q_{max}=u_f/2$=40km/hr, then we expect that the traffic condition is normal based on fundamental diagram of traffic flow (speed-flow diagram)

Question 7: The daily counts of the current traffic volume for a rural highway and for both directions, for one week of May 2000, are as follows:

Day	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
Daily volume	12000	12500	10500	11500	9500	9000	8500

The traffic composition is 70% passenger cars, 20% buses and 10% trucks. The traffic is expected to be 180% from the current traffic up to May 2020. Find the required number of lanes for the highway if the lane capacity is 1300 pc/hr/ln. Assume k=0.15 and D=0.6

Solution:

ADT=sum of traffic/Number of days

Current ADT= (12000+12500+10500+11500+9500+9000+8500)/7

= 10500 veh/day/2directions

Future ADT=10500*1.8=18900 veh/day/2dir.

DHV=ADT* K=18900*0.15=2835 veh/hr/2dir.

DDHV=DHV*D=2835*0.6=1701 veh/hr

DDHV (pcu/hr)=1701*0.7*1 +1701*(0.3)*1.5=1956 pcu/hr

No. of lanes= = 1956/1300 = 1.5 lanes (use 2 lanes)