2. Consider the following situation: An intersection approach has a flow rate of 1,850 vph, a saturation flow rate of 2,600 vphg, a cycle length of 90 s, and effective green time of for the approach is 54 seconds. What average delay per vehicle is expected under these conditions?

Solution:

Given, s=2600 vph, g=54 sec, C=90 sec and v =1800 vph.

g/C=0.6

Capacity, C=s*g/C=2600*0.6= 1560 vph

v/c= 1.19

UD = C/2*(1-g/C) = 0.5*90*(1-0.6) = 18

OD = T/2*(v/c-1) = 3600/2*(1.19-1) = 342

Total delay, D = UD+OD = 360 sec/veh

7. (i) Describe congestion management measures: both demand and supply side. (ii) Consider a road segment of 6 lanes with a capacity of 2400 veh/hr/lane. It is observed that the storage density is 75 veh/meter and the segment demand is found to be 2800 veh/hr/lane. Given that the duration of analysis sub period is 2 hrs, calculate the queue length that is formed due to congestion.

Solution:

(ii) QL = T*(v-c)/(N*ds)

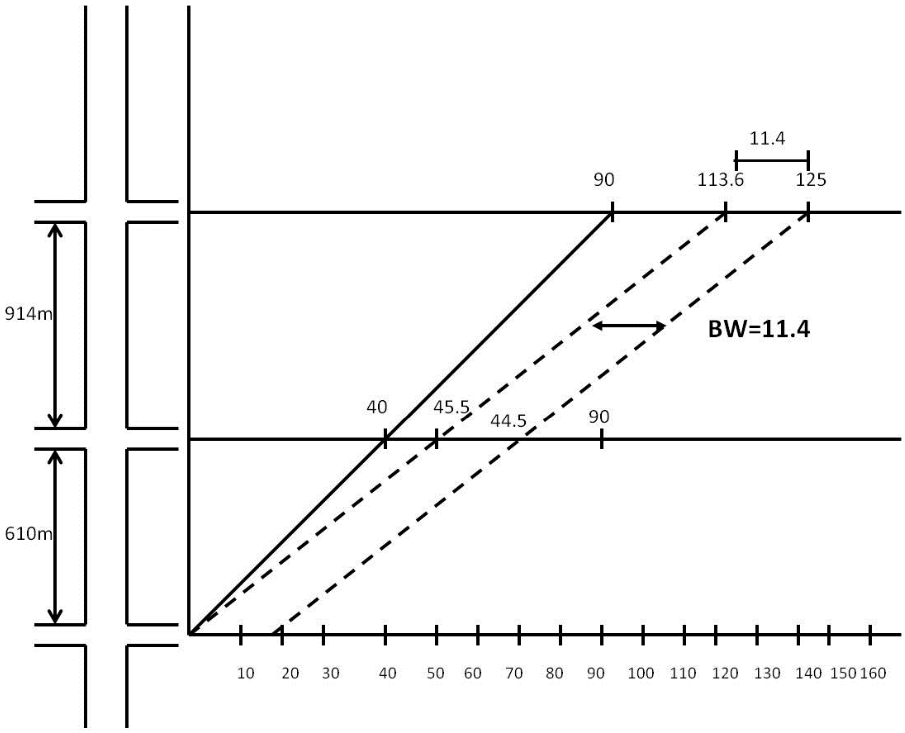
= 2*(2800-2400)*6/(6*75)

= 10.67 km

5. The signals at an intersection of the one-way street have been pre-timed and coordinated as presented in the following table. Given a design speed of 48.3 km/h, determine the width of the resulting through band.

Intersection	Green	Yellow	Red	Offset	Distance from A
A	40	5	35	0	-
B	50	5	25	40	610
C	35	5	40	10	1524

Solution:



Minimum Band Width=11.4s

6. (i) Derive the hyperbolic (explicit) form of LWR model using the following parameters in Greenshield's equation. Free flow speed = 80 kmph; Jam density = 320 veh/km. (ii) Find the values of density at points (t = 1/4hr, x = 15km) and (t = 1hr, x = 70km) using the method of characteristics with the following initial condition.

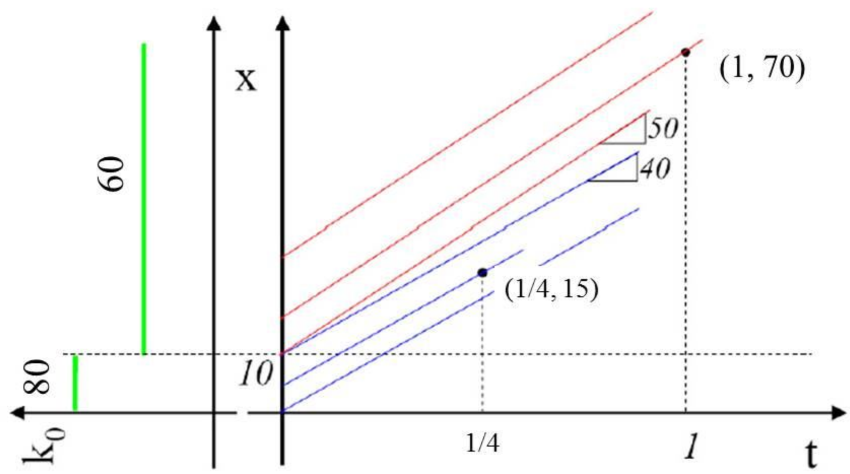
$$k(x,0) = k_0(x)\begin{cases} 80veh/km & if\, 0 < x \le 10km \\ 60veh/km & if\, 0 > 10km \end{cases}$$

Solution:

Free flow speed, v_f = 80km/hr
Jam density, k_j=320
Derivation result: $k_t+(80-k/2)k_x=0$
Between 0<x<10, slope of the characteristics, c = 80-80/2=40
Between x>10, slope of the characteristics, c = 80-60/2=50

From the figure or by analytical method using the equation for line, it can be verified that point (1/4,15) is within the blue line area.

Analytical method for checking:
y=mx+c
y=40x1/4+10=20. Point (1/4, 15) is below this. Therefore it is within the blue line area.



To find out the y-intercept,
15=40x1/4+c
c=5
Therefore, k(1/4,15)=k(0,5)=80

In a similar way, it can be verified that point (1/4, 15) is within the red line area.
k(1,70)=k(0,20)=60

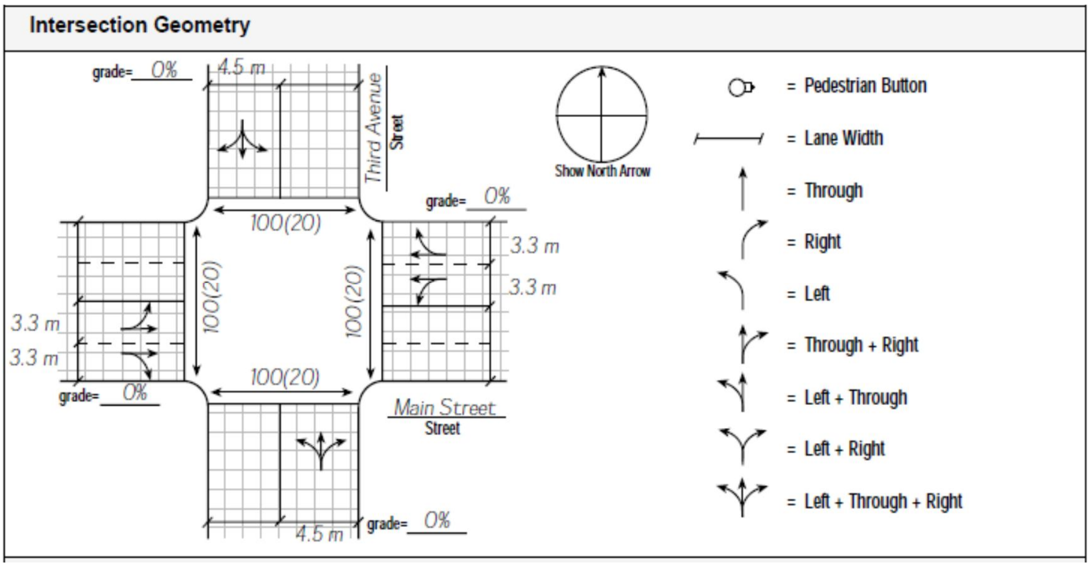
8. If at a toll station, on an average one vehicle arrives every 12 seconds and a toll booth takes an average service time of 10 seconds per vehicle, what is the expected number of vehicles in the system, queue length, delay, time a vehicle will spent the system: (i) There is only one toll booth, (ii) There are two toll booths, but only one queue, and (iii) state the assumptions made in the above calculations.

Solution:

(i) Mean arrival rate, $\lambda = 3600/12 = 300$ vph
Mean service rate, $\mu = 3600/10 = 360$ vph
Utilization factor, $\rho = \lambda/\mu = 0.833$
Percent of time the toll booth will be idle, $P(0) = \rho^0(1-\rho) = 0.167$
Average no. of vehicles in the system, $L = \rho/(1-\rho) = 5$
Average no. of vehicles in the queue, $L_q = \rho^2/(1-\rho) = 4.167$
Average time a vehicle spent in the system, $W = 1/(\mu-\lambda) = 60$ sec
Average time a vehicle spent in the queue, $W_q = \lambda/\mu(\mu-\lambda) = 50$ sec

(ii) Mean arrival rate, $\lambda = 3600/12 = 300$ vph
Mean service rate, $\mu = 3600/10 = 360$ vph
Utilization factor, $\rho = \lambda/\mu = 0.833$
No. of toll booths, N = 2
Percent of time the toll booth will be idle, $P(0) = \left[\sum_{x=0}^{N-1} \frac{\rho^x}{x!} + \frac{\rho^x}{(N-1)!(N-\rho)}\right]^{-1}$
$= 0.33$
Average no. of vehicles in the system, $L = \rho + \left[\frac{\rho^{N+1}}{(N-1)!(N-\rho)^2}\right]P(0) = 0.97$
Average no. of vehicles in the queue, $L_q = \left[\frac{\rho^{N+1}}{(N-1)!(N-\rho)^2}\right]P(0) = 0.14$
Average time a vehicle spent in the system, $W = L/\lambda = 12$ sec
Average time a vehicle spent in the queue, $W_q = L_q/\lambda = 2$ sec

9. The intersection of Third Avenue (NB/SB) and Main Street (EB/WB) is located in the central business district (CBD) of a small urban area. Intersection geometry and flow characteristics are shown below. **Facts/Data/Assumptions:** (a) EB and WB HV = 5 percent (b) NB HV = 12 percent (c) SB HV = 8 percent (d) PHF = 0.9 (e) Two-phase signal (f) 70 sec cycle length (g) NB-SB green = 36 s (h) EB-WB green = 26 s (i) Yellow =4 s (j) Third avenue has two lanes, one in each direction (k) Main street has four lanes, two in each direction (l) No parking at intersection (m) Pedestrian volume = 100 p/h, all approaches (n) Bicycle volume = 20 bicycles/h, all approaches (o) Movement lost time = 4 s (p) Level terrain (q) Assume crosswalk width = 3.0 m for all approaches (r) Assume base saturation flow rate = 1900 pc/h/lane (s) Assume E_T =2.0 (t) No buses (u) Left-turn adjustment factor f_{LT} = 0.937 (v) Pedestrian-Bicycle effects on turning f_{LPb} = 0.999 and f_{RPb} = 0.996. (w) k = 0.5 (x) Analysis duration T = 0.25 (y) Upstream filtering factor I = 1.0 (z) Arrival type AT = 3. The volumes of left-turn, through and right-turn traffic of the NB approach are 10, 80 and 30 veh/hr respectively. v/c ratios of SB, EB and WB are 0.799, 1.026 and 0.842 respectively. Flow ratios (v/s) of SB, EB and WB are 0.410, 0.380 and 0.313 respectively. Compute the delay and peak-hour LOS of the NB approach using HCM 2000 guidelines. (**15**)



Solution:

1	Pedestrians/cycle	1.944
2	Min. eff. Green time for pedestrians	11.2
3	Comparison with actual eff. Green	36>11.2, 26>14.7

4	Proportions of left and right turns	0.083, 0.250
5	Lane width adjustment factor	1.1
6	Heavy-vehicle adjustment factor	0.893
7	Percent grade adjustment factor	1
8	Parking adjustment factor	1
9	Bus blockage adjustment factor	1
10	Area type adjustment factor	0.9
11	Lane utilization adj. factor	1
12	Left-turn adj. factor	0.937
13	Right-turn adjustment factor	0.966
14	Left-turn ped/bicycle adj. factor	0.999
15	Right-turn ped/bicycle adj. factor	0.996
16	Saturation flow	1513
17	Lane group capacity	778
18	v/c ratio	0.17
19	Determining critical lane group in each phase	EB and SB
20	Flow ratio of critical lane groups (given)	0.38
21	Sum of critical flow ratios	0.79
22	Critical flow rate to capacity ratio	0.892
23	Uniform delay	9.06
24	Incremental delay	0.48
25	Progression adjustment factor	1
26	Lane group delay	9.5
27	Approach delay	9.5
28	LOS by approach	A