Module 3-3 tutorial

Solutions

Austroads

Capacity analysis

Question 1. The capacity of a motorway section in Sydney is to be determined as part of a project. The project involves collecting video-tape data of traffic movement on the motorway section. Upon processing the data, the traffic engineer observes a density of 50 veh/km and 33 veh/km at prevailing stream speeds of 45 km/h and 60 km/h respectively. Determine the capacity of the section using Geenshield's model.

Solution to Question 1.

According to Greenshield's model, speed-density (i.e. v-k) follows a linear relationship such that:

At $k = 0$; $v = v_f$, *which represents free-flow speed*

At $v = 0$; $k = k_j$, *which represents jam density*

The capacity is given as:

$$C = \frac{v_f \, . \, k_j}{4}$$ ***Equation 1***

Where: v_f *= free-flow speed*

k_j *= jam density*

C = capacity

Let points A (50, 45) and B (33, 60) be two points on the linear v-k plot. The equation of this v-k plot can be written as:

$$(v - 45) = \frac{60 - 45}{33 - 50} . (k - 50)$$ ***Equation 2***

Substituting $v = 0$ *in the equation gives* $k_j = 101 \; veh/km$

Similarly, substituting $k = 0$ *in the equation gives* $v_f = 89.11 \sim 89 \; km/h$

Thus, the capacity of the motorway section is:

$$C = \frac{89 \, . \, 101}{4} = 2247.25 \sim 2{,}250$$ ***Equation 3***

Hence, capacity = $2{,}250 \; veh/h/ln$

Question 2. A ramp meter on the Monash Freeway (M1) in Melbourne dispatches vehicles at an average rate of 60 vehicles every 5-minutes during afternoon. The average rate of arriving vehicles during afternoon at this location is 80 vehicles every 5-minutes. Answer the following questions:

a) Determine the utilisation factor. Comment on the calculated value
b) Keeping the arrival rate as the same, what should be the service rate in order to achieve a utilisation factor of 0.8
c) Compute the mean queue length, standard deviation of the queue length and the mean delay for this system (i.e. ramp meter)

<u>Solution to Question 2</u>.

Arrival rate $r = \frac{80}{300} = 0.267\ veh/s$

Service rate $s = \frac{60}{300} = 0.2\ veh/s$

(a) The utilisation factor is given below:

$$\rho = \frac{r}{s} = \frac{0.267}{0.2} = 1.34$$ ***Equation 1***

A utilisation factor of 1 or above means that queue length and delay will increase indefinitely, and hence the deterministic formulae cannot be applied.

(b) To achieve a utilisation factor $\rho = 0.8$*, the service rate should be:*

$$s = \frac{r}{\rho} = \frac{0.267}{0.8} = 0.333$$ ***Equation 2***

Thus, service rate = 0.333 veh/s or 100 vehicles per 5-minutes

(c) Mean queue length is given below:

$$n_q = \frac{\rho}{1-\rho} = \frac{0.8}{1-0.8} = 4$$ ***Equation 3***

Thus, mean queue length = 4 vehicles

Variance of mean queue length is given below:

$$\sigma^2(n) = \frac{\rho}{(1-\rho)^2} = \frac{0.8}{(1-0.8)^2} = 20 \qquad \textbf{Equation 4}$$

Thus, variance of mean queue length = 20 vehicles²

Variance of mean queue length is given below:

$$\sigma^2(n) = \frac{\rho}{(1-\rho)^2} = \frac{0.8}{(1-0.8)^2} = 20 \qquad \textbf{Equation 5}$$

Thus, variance of mean queue length = 20 vehicles²

Standard deviation of mean queue length is given below:

$$\sigma(n) = \sqrt[2]{\frac{\rho}{(1-\rho)^2}} = \sqrt[2]{\frac{0.8}{(1-0.8)^2}} = 4.47 \qquad \textbf{Equation 6}$$

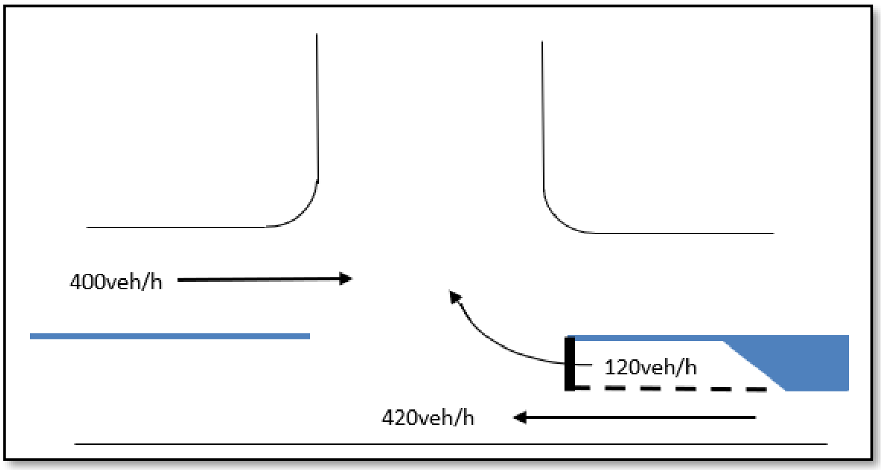
Thus, standard deviation of mean queue length = 4.47 vehicles

Mean delay is given below:

$$w_m = \frac{n_q}{r} = \frac{4}{0.267} = 14.98 \sim 15 \qquad \textbf{Equation 7}$$

Thus, mean delay = 15 seconds

Question 3. For the unsignalised T-intersection given below, determine the length and storage required for the right-turning traffic stream that is not exceeded 95% of the time by the traffic queue. Assume the average vehicle length as 6m. Assume the saturation flow for the right-turning movement is 185 veh/h.



Solution to Question 3.

The right-turning movement must give way to the through traffic stream from the opposite direction.

For the right-turn traffic, the minor stream movement lane volume $r_m = 120\ veh/h$

It is given that the saturation flow $s = 185\ veh/h$ *for the right-turn traffic.*

Thus, the utilisation factor is given below:

$$\rho = \frac{r_m}{s} = \frac{120}{185} = 0.6489 \sim 0.65$$ ***Equation 1***

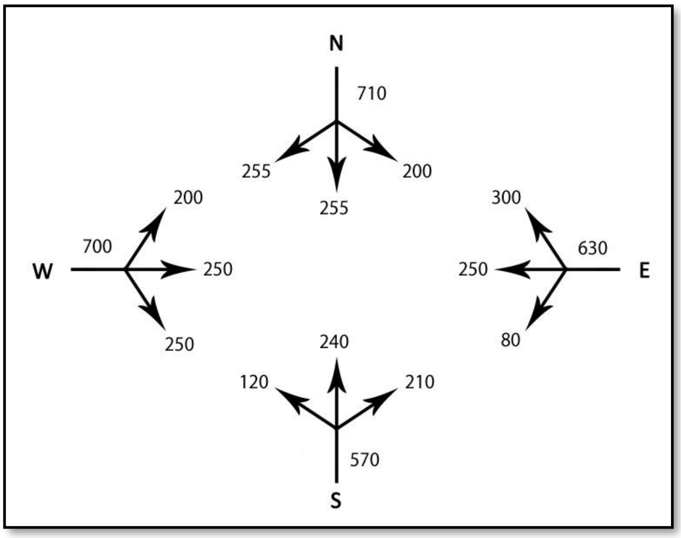
Refer to Figure 6.5 (pg. 68) of AGTM Part 3: Traffic Studies and Analysis which gives the storage space required.

Using a 95% curve and $\rho = 0.65$ *gives a storage space of 6 vehicles.*

Using the average vehicle length of 6 metre.

The storage length for the right-turning traffic is 36 metres.

Question 4. Calculate the capacity of the left-most approach for the single lane roundabout shown below. Assume $t_a = 4$, $t_f = 2$ and $\tau = 2$. Similarly, identify the capacities of the remaining approaches. Identify the critical capacity for this roundabout.



Solution to Question 4.

For the left-most approach, the circulating flow q_p is the summation of

- *Through traffic from South (240 veh/h)*
- *Right-turning traffic from South (210 veh/h)*
- *Right-turning traffic from East (300 veh/h)*

Thus, $q_p = 750\ veh/h$

The capacity of this approach is given by the formula:

$$C_e = \frac{3600.\, q_p(1 - q_p\tau)\exp\left(-q_p(t_a - \tau)\right)}{1 - \exp\left(-q_p t_f\right)}$$ ***Equation 1***

Thus, $C_e = 846.39$ *veh/h/ln*

Similarly, the capacity of other approaches can also be computed. The table below shows the results:

Approach	Circulating Flow q_p (veh/h)	C_e (veh/h/ln)
West	240 + 210 + 300 = 750	846.39
North	250 + 250 + 210 = 710	889.12
East	255 + 255 + 250 = 760	835.84
South	250 + 300 + 255 = 805	789.03

The critical capacity is the lowest capacity value of all four approaches.

Thus, the critical capacity of this roundabout is 789.03 veh/h/ln