Q1 (a) H_0 : Independence between the response and types of users of footpath (i.e. Not related to different users)

H_1 : Otherwise

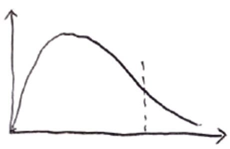
(2 x 4) contingency table

Response	Pedestrian	Cyclists	PMD users	E-Bike Users	Total:
Yes	96 (159)	134 (153.7)	252 (164.3)	48 (53)	530
No	204 (141)	156 (136.3)	58 (145.7)	52 (47)	470
Total:	300	290	310	100	

$$(\text{Expected Value}) = \frac{\text{row total} \times \text{column total}}{\text{Total}}$$

Total surveyed = 1000

$\alpha = 0.05$



$\chi^2_{0.05}$ ($v = (2-1)(4-1)$)
($v = 3$)

$= 7.815$

$$\chi^2_{obs} = \sum_{i=1}^{rc} \frac{(O_i - e_i)^2}{e_i}$$

$$= \frac{(96-159)^2}{159} + \frac{(204-141)^2}{141} + \frac{(134-153.7)^2}{153.7} + \frac{(156-136.3)^2}{136.3} + \frac{(252-164.3)^2}{164.3} + \frac{(58-145.7)^2}{145.7} + \frac{(48-53)^2}{53} + \frac{(52-47)^2}{47}$$

$$= 159.088 > \chi^2_{critical} = 7.815$$

The null hypothesis should be rejected since chi-squared observed is greater than the critical value, and we cannot conclude that the responses are not related to the types of users of footpath.

Q1(b) I would opt for the same number of surveyors for each foot-path user type. The existing survey shows that only 100 E-Bike users are surveyed. I would even consider removing E-bike users for the survey since they are not allowed on footpaths in the first place due to safety reasons, even before the ban on PMD users was imposed by the authorities. Furthermore, PMD users should be removed from the survey since it creates some form of biasness.

Q2(a)

Calculate $c_{m,x}$ of all movements controlled by stop sign along westbound approach

• Movement 6 not controlled by stop sign, it is controlled by yield line towards major street

Movement 5 (Rank 3)

$$V_{c,5} = 0.5V_{12} + V_{11} + 2V_{10} + 2V_7 + V_8 + V_9$$
$$= 0.5(70) + 320 + 2(60) + 2(80) + (370) + 120$$
$$= 1125 \text{ veh/h}$$

$$C_{P,5} = V_{c,5} \frac{e^{-(V_{c,5} \times t_{c,5}/3600)}}{1 - e^{-(V_{c,5} \times t_{f,5}/3600)}}$$

$$= 1125 \times \frac{e^{-1125 \times 6.6/3600}}{1 - e^{-1125 \times 4/3600}} = 200 \text{ veh/h} \Rightarrow C_{m,5} = (200)(0.88)(0.89) = 157 \text{ veh/h}$$

Movement 4 (Rank 4)

$$V_{c,4} = 0.5V_{12} + V_{11} + 2V_{10} + 2V_7 + V_8/2 + 0.5V_2$$
$$= 0.5(70) + 320 + 2(60) + 2(80) + 370/2 + 0.5(76)$$
$$= 858 \text{ veh/h}$$

$$C_{P,4} = 858 \times \frac{e^{-858 \times 7.2/3600}}{1 - e^{-858 \times 3.5/3600}}$$

$$= 273 \text{ veh/h}$$

$$p'' = (0.88)(0.89)(0.54) = 0.423$$

$$p' = 0.65(0.423) - \frac{0.423}{3.423} + 0.6\sqrt{0.423}$$
$$= 0.542$$

$$\Rightarrow C_{m,4} = (273)(0.542) = 148 \text{ veh/h.}$$

Q2(a) $V_4 = 66$ veh/h , $c_{m,4} = 148$ veh/h
$V_5 = 76$ veh/h , $c_{m,5} = 157$ veh/h

Total = 142

$$\Rightarrow C_{SH} = \frac{66+76}{\frac{66}{148}+\frac{76}{157}} = 153 \text{ veh/h}$$

$\frac{3600}{153} = 23.53$

$\frac{142}{153} = 0.928$

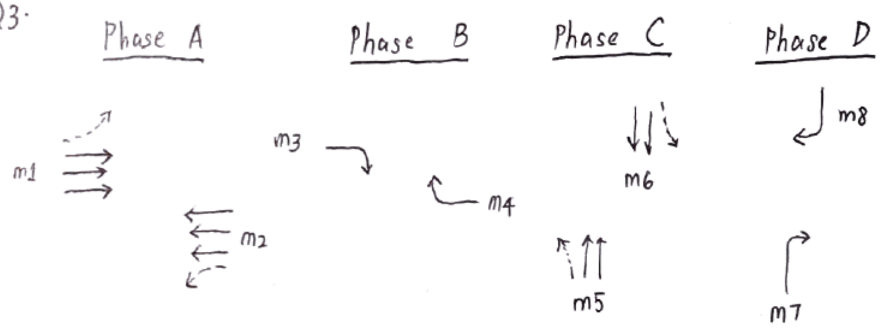
Q2(b)

$$\text{Delay} = \frac{3600}{153} + 900(0.25)\left[\frac{142}{153} - 1 + \sqrt{\left(\frac{142}{153}-1\right)^2 + \frac{\left(\frac{3600}{153}\right)\left(\frac{142}{153}\right)}{450 \times 0.25}}\right] + 5$$

$$= 113.1 \text{ s} \Rightarrow \text{LOS F}$$

LOS F means that the delay is rather significant. Perhaps the lane on the westbound approach can be widened to minimise delay caused by vehicles going straight-through.

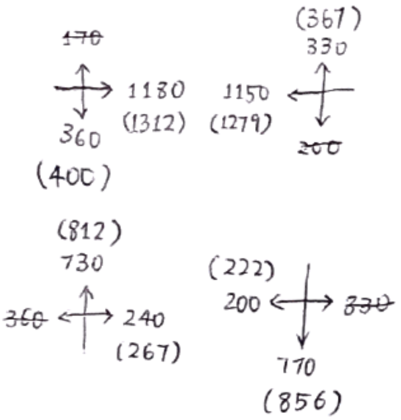
Q3.



- Left Turning traffic omitted from all approaches due to slip roads.

$A \rightarrow B \rightarrow C \rightarrow D \rightarrow A$

$I = Y + AR = 4s$



- 20% HGV
- 1 HGV = 1.56 PCU

$$\text{Traffic adjustment} = x(0.2)(1.56) + x(0.8)$$
$$= x(0.2 \times 1.56 + 0.8)$$
$$= 1.112x$$

Approach Traffic:

$V_1 = 1312$ pcu/h
$V_2 = 1279$ pcu/h
$V_3 = 400$ pcu/h
$V_4 = 367$ pcu/h
$V_5 = 812$ pcu/h
$V_6 = 856$ pcu/h
$V_7 = 267$ pcu/h
$V_8 = 222$ pcu/h

Saturation Flow:

$S_1 = S_2 = 525(3 \times 3.6) = 5670$ pcu/h

$S_3 = S_4 = \dfrac{1800}{1 + \frac{1.52}{16}} = 1644$ pcu/h

$S_5 = S_6 = 525(2 \times 3.6) = 3780$ pcu/h

$S_7 = S_8 = \dfrac{1800}{1 + \frac{1.52}{16}} = 1644$ pcu/h

Flow Ratio ($y = V_i/S_i$)

$y_1 = 1312/5670 = \underline{0.231}$
$y_2 = 1279/5670 = 0.226$
$y_3 = 400/1644 = \underline{0.243}$
$y_4 = 367/1644 = 0.223$
$y_5 = 812/3780 = 0.215$
$y_6 = 856/3780 = \underline{0.226}$
$y_7 = 267/1644 = \underline{0.162}$
$y_8 = 222/1644 = 0.135$

$$\Sigma y = 0.862$$

$$L = nl + \sum_{j=1}^{n} R_i = 4(2) + 4(1) = 12s$$

$$C_0 = \frac{1.5(12) + 5}{1 - 0.862} = 166 \approx 170s$$

$$G = 170 - 4(4) = 154s$$

Allocate Green Time

Phase A: $\frac{0.231}{0.862} \times 154 = 41.3s$
$= 41s > 26s$

Phase B: $\frac{0.243}{0.862} \times 154 = 43.4s$
$= 43s$

Phase C: $\frac{0.226}{0.862} \times 154 = 40.4s$
$= 41s > 33s$

Phase D: $\frac{0.162}{0.862} \times 154 = 28.9s$
$= 29s$

Discussion: The green time allocated is sufficient for pedestrians to cross. For phase A, it needs to be greater than 26s and for phase C, it needs to be greater than 33s.

Q4(a) Density (veh/km), as the unit suggests, refers to the average number of vehicles present along a kilometre stretch of a road. Density is used to estimate Level of Service for a basic freeway segment since it encompasses both speed and flow, both of which affects how the freeway functions. Delay is not used as we are not concerned with the time that each vehicle is stuck behind another vehicle.

Q4(b)

4.8 km stretch of two-lane rural highway segment with 3% upgrade

FFS (measured) = 100 km/h, PHF = 0.92, 20% Trucks & Buses, no RV

V_d = 768 veh/h, V_o = 505 veh/h, 40% no passing zones.

Average Travel Speed (ATS)

$$V_{Pd} = \frac{V}{PHF\, f_G\, f_{HV}} = \frac{768}{0.92 \times 0.97 \times 0.538} = 1600\ pc/h \leq 1700\ pc/h$$

$f_G = 0.97$

$$f_{HV} = \frac{1}{1+0.2(5.3-1)} = 0.538$$

$$ATS_d = FFS_d - 0.0125(V_d + V_o) - f_{np}$$
$$= 100 - 0.0125(1600 + 610) - 2.065$$
$$= 70.3\ km/h$$

$$V_{Po} = \frac{V}{PHF\, f_G\, f_{HV}}$$ (Assume Rolling Terrain)

$f_G = 0.99$ (1.00) (Assume > 600 pc/h)

$$f_{HV} = \frac{1}{1+0.2(1.5-1)} = 0.9091$$ (1.5 / 1.2)

$$V_{Po} = \frac{505}{0.99 \times 0.92 \times 0.9091} = 610\ pc/h \leq 1700\ pc/h$$

⇒ Assumption is correct.

$$f_{np} = 2.1 - 0.7\left(\frac{10}{200}\right) = 2.065$$

Percent Time Spent Following (PTSF)

$f_G = 0.96$

$$f_{HV} = \frac{1}{1+0.2(1.0-1)} = 1.0$$

$$V_{Pd} = \frac{768}{0.96 \times 0.92} = 870\ pc/h$$

$$BPTSF = 100\left(1 - e^{a(V_d)^b}\right)$$

$$a = -0.057 - \left(\frac{160}{200}\right)0.043 = -0.0914$$
$$b = 0.479 - \left(\frac{160}{200}\right)0.066 = 0.4262$$

$$BPTSF = 100\left(1 - e^{a(870)^b}\right)$$
$$= 80.52\%$$

$$PTSF_d = 80.52 + \left(12.1 - 4.6\left(\frac{160}{200}\right)\right) = 88.9\%$$

⇒ LOS E

Assume Rolling Terrain & > 600 pc/h

$f_G = 1.00$

$f_{HV} = 1.0$

$$V_{Po} = \frac{505}{0.92} = 549\ pc/h$$

Assume < 600 pc/h

$$V_{Po} = \frac{505}{0.92 \times 0.9091} = 604\ pc/h$$

Note for Q4(b): The above workings assume rolling terrain. If we assume level terrain, we get the following:

For ATS:

f_G = 1.00, f_{HV} = 0.962, V_{p0} = 571 pc/h, ATS_d = 70.8 km/h

For PTSF:

Assume level terrain & $V_p < 600$ pc/h

$f_G = 1.00$

$$f_{HV} = \frac{1}{1 + 0.2(1.1 - 1)} = 0.98$$

$V_{P0} = 505 / (0.92 \times 0.98) = 560$ pc/h

$PTSF_d$ = 89.2%

LOS is E.

Q5(a)

One-server queuer ensures that there will be fairness since everyone will be served at the same counter. There is also no customer anxiety induced regarding the queue choice. Having only one queue also prevents problems of "cutting in" and jockeying whereby people are continuously trying to switch lines to get to the counter faster.

Q5(b)(i)

Vehicles arrive at 40km/hr ⇒ $40 = 50 - 0.25k$

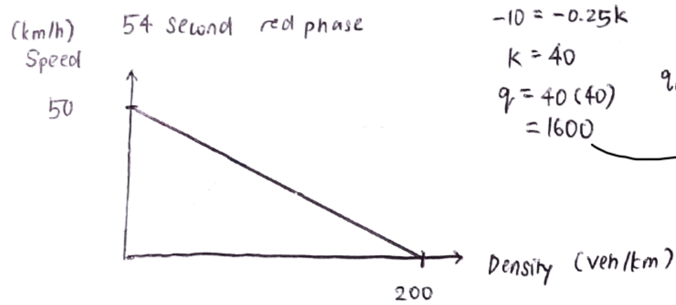
54 second red phase

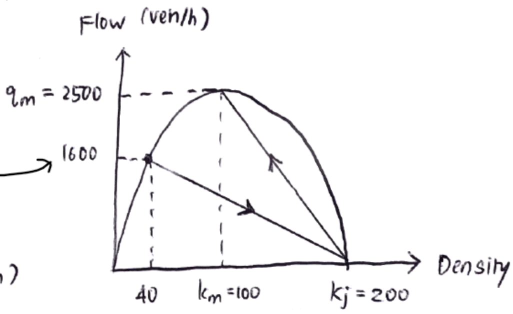
$-10 = -0.25k$

$k = 40$

$q = 40(40)$

$= 1600$





$q_m = k_m \times u_m$

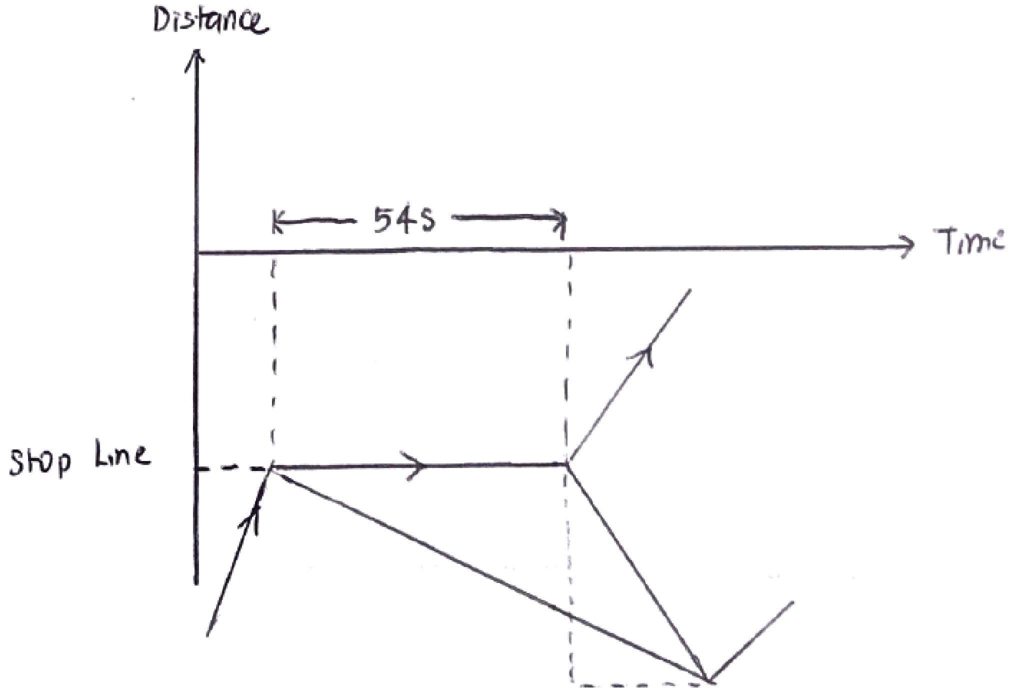
$= \frac{k_j}{2} \times \frac{u_f}{2} = \frac{200}{2} \times \frac{50}{2} = 2500$

Density due to red phase

$= k_j$

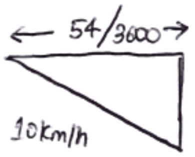
$= 200$ veh/km

Q5(b)(ii)



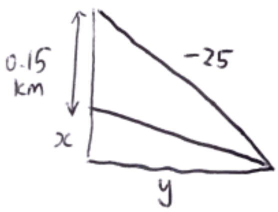
Speed of forming shockwave

$$= \frac{1600 - 0}{40 - 200} = -10 \text{ km/h}$$



$$\frac{x}{0.015} = 10$$

$$x = 0.15\text{km}$$



Speed of clearing Shockwave

$$= \frac{2500 - 0}{100 - 200} = -25 \text{ km/h}$$

$$\frac{x}{y} = 10$$

$$10y = x$$

$$0.15 + 10y = 25y$$

$$15y = 0.15$$

$$y = 0.01\text{hr}$$

$$x = 0.1\text{km}$$

Max Queue Length = 0.1 + 0.15 km

= 0.25 km //

Q6(a)(i)

$$\text{Demand Price Elasticity} = \frac{\%\Delta \text{ in Demand}}{\%\Delta \text{ in Price}} \qquad \%\Delta = \frac{\text{new} - \text{old}}{\text{old}}$$

5 to 5:15 1300 / 15 mins = 5200 veh/hr
5:15 to 5:30 1500 / 15 mins = 6000 veh/hr
5:30 to 5:45 1500 / 15 mins = 6000 veh/hr
5:45 to 6:00 1300 / 15 mins = 5200 veh/hr

Average Flow = 5600 veh/hr

$$\text{Current } v/c = 5600/6000 = 0.9333$$

To obtain 0.80 v/c ratio:

$$-0.20 = \frac{\frac{0.80 - 0.933}{0.933}}{\frac{x - 200}{200}} \qquad x \approx 342.5 ¢ = \$3.43$$

To obtain 0.60 v/c ratio:

$$-0.20 = \frac{0.60 - 0.933}{0.933} \Big/ \frac{x - 200}{200}$$

$$\Rightarrow x \approx 556.5 = \$5.57$$

Q6(a)(ii)

I will recommend higher charges we want to now consider the congestion caused to other vehicles and can be visualised in economic terms, which is also known as the marginal external congestion cost.

Q6(b)

The shortcomings of the 4-step travel forecasting process is as follows:

- The sequential nature of the model does not represent actual human decision-making process
- Aggregation of user behaviour, represented by the average behaviour of group of travellers
- Lack of behavioural considerations that constitutes a more realistic decision-making framework
- The models have a deterministic nature

Q6(c)

Generally, traffic congestion is caused by imbalance of supply and demand. Solutions can mainly be classified as demand-oriented or supply-oriented. Supply-oriented measures mainly aim to make better use of existing roads by ensuring road users use the roads in an orderly manner, following road markings and demarcations, and ensuring timely dispatch of information to road users. Demand-oriented measures generally aim to provide road users with different travel options, causing them to reconsider their travel, time of travel or their mode of travel.

- END -