UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 4 Examination in Engineering: November 2017

Module Number: CE4304 **Module Name: Transportation Engineering**

[Three Hours]

[Answer all questions. Each question carries **TWELVE** marks]
All Standard Notations denote their regular meanings.
Assume all needed parameters reasonably

Q1. Sri Lankan government has appointed a committee (SLSTC) submit a proposal to convert the transportation system of Sri Lanka into a sustainable one. Assume that you are one of the members of SLSTC and answer the following questions.

a) As part of the proposal by SLSTC, it is needed to define the finite nature petroleum reserves. Briefly describe the phrase 'Finite nature of petroleum reserves'.

[3.0 Marks]

b) SLSTC proposes several new modes of public transportation to Colombo city. List five modes of public transportation modes suitable for a large city like Colombo.

[2.5 Marks]

c) SLSTC also proposes to use renewable fuel for public transportation modes in Colombo. List five types of renewable fuel suitable for public vehicular transport.

[2.5 Marks]

d) Through a separate proposal, Colombo city has introduced 'Bus Priority Lanes' (BPL) in several routes. Explain what is meant by bus priority lanes and list one advantage and a disadvantage of BPL.

[4.0 Marks]

Q2. SLSTC committee, stated in Q1, understands that it requires an extensive array of traffic surveys to support it's every decision. Further, many of such traffic surveys need specialised equipment that needed to be purchased or hired from outside.

a) To conduct a certain traffic survey, "Speed Camera" installation was suggested by a consultant to SLSTC. With the aid of neat sketches explain the working principle of a top mounted speed camera.

[3.0 Marks]

b) Loop detector is also in the suggested equipment list by the consultant to SLSTC. Committee decided to purchase loop detectors consisting with air tubes. Briefly explain how a loop detector determines,

i. vehicle's direction;
ii. vehicle's class; and
iii. number of axels of vehicle.

[3.0 Marks]

c) Table Q2-1 and Table Q2-2 show data obtained from a traffic count survey using ATC at a link in front of a School 'A' in Colombo. Using the data calculate the daily adjustment factors of AADT for the 7 days of the week and the monthly adjustment factor of AADT for the 12 months.

[3.0 Marks]

d) Due to limited number of ATCs in possession of SLSTC, it was decided to use the data obtained in front of School 'A' as the master station for some other similar schools in Colombo. One-day counts were done at those other schools and shown in Table Q2-3. Using the data shown in Table Q2-3 determine the AADT in the roads front of other schools in Colombo.

[3.0 Marks]

Q3. a) As part of the SLSTC proposals project several intersections in Colombo are to be signalised. Turning movement volume count details and relevant data obtained for such an intersection in Colombo is shown in Figure Q3-1. Answer the following questions based on data provided.

i. Check for the right-turns assess whether they need protection.
ii. Draw the phase diagram based on minimum phases needed
iii. Convert volumes in each turning movement volume to through vehicle equivalents volumes (Fill the Table Q3-1 use Table Q3-2 and Table Q3-3)

[6.0 Marks]

b) Determine the critical volumes for each phase determined in Q3 a).

[2.0 Marks]

c) Assuming an amber time of 3 s and all red time of 3 s determine the total lost time per phase.

[1.0 Mark]

d) Determine the total desirable cycle length and the effective green time for each phase.

[2.0 Marks]

e) Explain the term traffic signal coordination.

[1.0 Mark]

Q4. Reduction of heavy traffic flow between Node 'A' and Node 'B' of Colombo city was an issue taken up by SLSTC (stated in Q1) meetings. Node A and Node B can be travelled by three routes namely, Route 1 (2 lanes), Route 2 (4 lanes), and Route 3 (4 lanes). All three roads have the same length. Traffic along the Route 1 can be approximated by Greensburg's model while traffic in Route 2 and Route 3 follows Greenshield's model. Route 2 has free flow speed of 120 km/h and jam density of 200 veh/km/lane while those for Route 3 are 100 km/h and 135 veh/km/lane respectively. At morning peak time, it is estimated that 24,700 vehicles arrive at Node A to proceed towards Node B over a 90-min time period at a constant rate.

a) Need to calibrate the Greensburg's model for the Route 1 was highlighted by SLSTC. Calibrate the model using the data given in Table Q4-1. You may use graphical method or equations provided at the end of the paper. Hence find the speed at the maximum flow condition; and jam density.

[3.0 Marks]

b) SLSTC proposes that Route 1 and 2 to be converted in to one-way roads carrying traffic from Node A towards B. It is assumed that in such a scenario, traffic would be divided into Route 1 and 2 so that travel time via both roads will be equal.

   i. Considering the macroscopic models stated, write flow and speed equations for a single lane in Route 1 and 2.
   ii. Equate travel time in route 1 and 2 to get an equation for density of Route 2 (K_2) in terms of density of Route 1 (K_1).
   iii. Equate the total incoming flow rate to the total flows in Route 1 (2 lanes) and Route 2 (4 lanes) to obtain another equation in K_1 and K_2.
   iv. Solve equations obtained in part (ii) and (iii) to find all possible values of K_1 and K_2.
   v. Determine all possible combinations of flow rates in Route 1 and 2.

[7.0 Marks]

c) After the implementation of one-way scheme on Rote 3 has to carry the evening peak volume from Node B towards A, 24,700 vehicles arrive at Node B over 2 hr period at a constant rate starting from 4:30 pm, calculate the density of Route 3.

[2.0 Marks]

Q5. Length of ques at petroleum station was also discussed SLSTC proposals. Consultant to SLSTC (stated in Q1) showed that for an $M/M/1/\infty/FCFS$ queue system, probability of the system being in state n (P_n) in usual notations is given by $P_n = P_0 \times \rho^n$, where $\rho = \lambda/\mu < 1$.

a) Using the above information, you are asked to prove the following equations for an $M/M/1/\infty/FCFS$ queue.

   i. Probability of empty state is given by $P(Empty) = 1 - \rho$
   ii. Expected length of the queue $L_q = \dfrac{\rho^2}{1-\rho}$
   iii. Probability of no que $P(No\ Queue) = 1 - \rho^2$

[4.0 Marks]

b) According to a SLSTC study conducted, vehicles arrive to the petroleum stations at an average rate of 15 vehicles per hour to obtain super petrol while the service time for one vehicle is on average 2.5 minutes. This petroleum station has one super petrol pump and it can accommodate 5 vehicles (including the one served) in its premises 6th vehicle onwards queue will over flow on to the main road. By assuming that vehicles waiting in the que as a $M/M/1/\infty/FCFS$ queue system and determine the following.

   i. Total time in a day when the petrol station is empty
   ii. Total time in a day when a queue will not be present
   iii. Total time in a day when the super petrol queue will overflow onto the main road

[8.0 Marks]

Tables and Figures

Table Q2-1 Traffic flow details of a link in front of school "A"

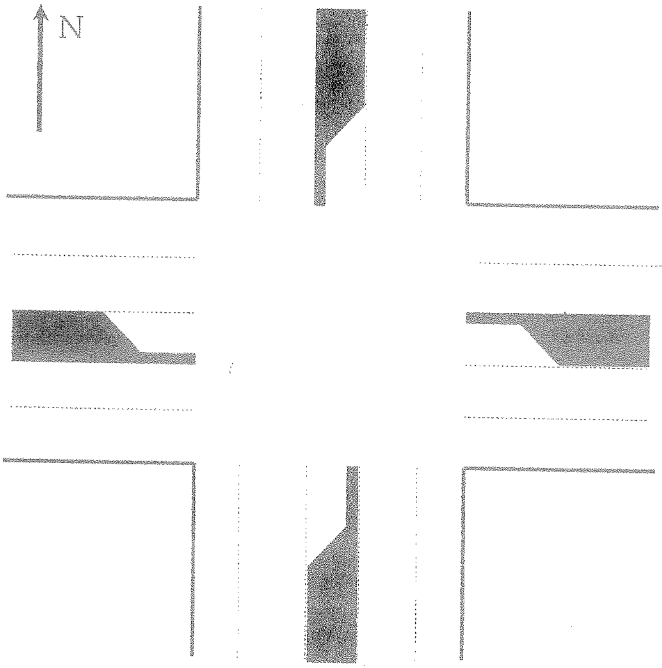
Day of the week	Yearly Average Daily Volume for the Day (Veh/Day)
Monday	1670
Tuesday	1200
Wednesday	1143
Thursday	1300
Friday	1289
Saturday	979
Sunday	890

Table Q2-2 Traffic Flow Details of a Link in front of School "A"

Month	Monthly Total Volume (Veh)
January	39,680
February	33,320
March	42,470
April	54,600
May	43,770
June	42,560
July	43,304
August	48,016
September	51,240
October	42,700
November	58,580
December	39,462

Table Q2-3 Traffic Flow Details of a Link in front of Some Schools

School Name	Day	Month	Total Volume (Veh/day)
School 1	Monday	April	1250
School 2	Tuesday	April	3450
School 3	Wednesday	June	1290
School 4	Thursday	June	976
School 5	Friday	June	1560



PHF= 0.90
Target (v/c) ratio=0.80
Driver reaction time=1 s
Pedestrian walking speed=1.1m/s
Speed limit (all approaches) = 70km/h
Moderate pedestrian volumes
Level grades
Deceleration rate of vehicle=3.0 m/s²
Cross walk width=3.3 m
Driver Encroachment =2s
Default l_1= 2s
Default e= 2s
Lane width=3.5 m

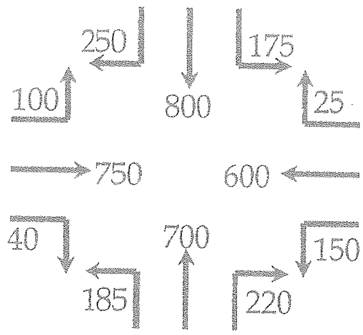


Figure Q3-1 Traffic Flow Details of an Intersection

Table Q3-2 Adjustment for Right Turn Equivalence (TRB)E_{RT}

Opposing through plus left flows (vph)	Number of Lanes		
	1	2	3
0 – 199	1.1	1.1	1.1
200 – 399	2.5	2.0	1.8
400 – 599	5.0	3.0	2.5
600 – 799	10.0	5.0	4.0
800-999	13.0	8.0	6.0
1000-1199	15.0	13.0	10.0
≥1200	15.0	15.0	15.0
Adjustment for Right Turn Equivalence with protection = 1.05			

Table Q3-3 Left Turning Multiplicative Factors for Pedestrians MovementsE_{LT}

Pedestrian flow per hour	Multiplicative Factor
None (0)	1.18
Low (50)	1.21
Moderate (200)	1.32
High (400)	1.52
Extreme (800)	2.14

Table Q4-1 Speed and Density Data

Density (veh/km/lane)	Space mean speed (kmph)
30	66.4
39	57.2
45	52.2
50	48.5
75	34.3
180	3.7
95	26.1
60	42.1
110	20.9
115	19.4
140	12.5
120	17.9
170	5.7
20	80.6

Table for Calculations Q3-1 (*Fill and attach it to you answer script*)

Approach	*Movement*	*Volume (Veh/h)*	E_{RT} *or* E_{LT}	*Volume (tvu/h)*	*Lane group vol (tvu/h)*	*Vol/Lane (tvu/h)*
East Bound	R					
	T					
	L					
West Bound	R					
	T					
	L					
North Bound	R					
	T					
	L					
South Bound	R					
	T					
	L					

Equations

$$a = \frac{1}{n}\sum_{i=1}^{n} y_i - \frac{b}{n}\sum_{i=1}^{n} x_i = \bar{y} - b\,\bar{x}$$

$$b = \frac{\sum_{i=1}^{n} x_i y_i - \frac{1}{n}\left(\sum_{i=1}^{n} x_i\right)\left(\sum_{i=1}^{n} y_i\right)}{\sum_{i=1}^{n} x_i^2 - \frac{1}{n}\left(\sum_{i=1}^{n} x_i\right)^2}$$

$$R^2 = \frac{\sum_{i=1}^{n}(Y_i - \bar{y})^2}{\sum_{i=1}^{n}(y_i - \bar{y})^2}$$

$$C_{des} = \frac{L}{1 - \sum_{i=1}^{p}\left(\frac{Y_i}{PHF \times \left(\frac{v}{c}\right)}\right)}$$

$$g_i = \frac{q_{ci}}{q_c} \times (C_{des} - L)$$

$$ar = \frac{P + L_v}{1.47 \times S_{85}}$$

$$q_{LT} \geq 200\,\frac{veh}{h}$$

$$q_{LT} \times \left(\frac{q_o}{N_0}\right) \geq 50{,}000$$

$$N = \left(\frac{Z_C \times \sigma}{E}\right)^2$$

$$\bar{T}_S = T_S + \frac{O_S - P_S}{V_S}$$

$$V_N = \frac{N_S + O_N - P_N}{T_N + T_S}$$

$$\frac{\Delta t_1}{\Delta t - \Delta t} = \frac{m - p}{q - p}$$

$$P(x) = \frac{(\lambda t)^x e^{-\lambda t}}{x!}$$

$$P(h \geq t) = e^{-\lambda(t - \tau)}$$

$$UD_o = 0.5C\left[1 - \frac{g}{C}\right]$$

$$OD = \frac{T_1 + T_2}{2} \times (X - 1)$$

$$UD = \frac{C}{2}\frac{\left[1 - \left(\frac{g_i}{C}\right)\right]^2}{\left[1 - \frac{q}{s}\right]}$$

$$q = U_f \times k - \frac{U_f}{k_j} \times k^2$$

$$q = c \times k \times \ln\left[\frac{k_j}{k}\right]$$

$$U = U_f - \frac{U_f}{k_j} \times k$$

$$U = c \times \ln\left[\frac{k_j}{k}\right]$$

$$W = W_q + \frac{1}{\mu}$$

$$L_q = \lambda \times W_q$$

$$L = \lambda \times W$$

$$L - L_q = \rho$$

$$\rho = \frac{\lambda}{\mu}$$