UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 4 Examination in Engineering: December 2018

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

[Three Hours]

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

Q1. Many countries are aiming to convert their transportation into a sustainable transportation system. Implementation of a sustainable transportation system has many facets like accident reduction and fuel conversion.

a) Identify two facets of sustainable transportation system other than the two stated in above paragraph.

[2.0 Marks]

b) Explain how converting fuel for the buses from diesel to corn-based ethanol will be sustainable.

[3.0 Marks]

c) State six sources of renewable fuels suitable for vehicular transport other than corn.

[3.0 Marks]

d) Identify four operational shortcomings of public bus transportation in Sri Lanka which cause delay and propose one measure to overcome each shortcoming.

[4.0 Marks]

Q2. Traffic and Transportation Engineering is based on many surveys which are used to fulfil many needs.

a) Methods to determine spot speed of a vehicle stream can be divided in to two. Explain the two methods giving relevant equations, examples and figures.

[4.0 Marks]

b) Explain how a pneumatic loop detector determine
   i. direction of vehicle; and
   ii. vehicle type.

[2.0 Marks]

c) Data obtained in a long term traffic volume count survey at a link in front of a private hospital 'A' is shown in Table Q2-1 and Table Q2-2. Determine the daily expansion factors and the monthly expansion factors for this location.

[3.0 Marks]

d) Due to limited number of long term traffic volume count surveys at links in front of three proposed hospitals 'B', 'C' and 'D', it was decided to use the data location obtained in Q2.c) as the master station for other proposed hospitals. One-hour counts were done at the proposed hospitals 'B', 'C' and 'D'. Assuming the hourly expansion factor 2:00-3:00 pm to be 14.320 and using the data shown in Table Q2-3 determine the AADTs at links in front of three proposed hospitals 'B', 'C' and 'D'.

[3.0 Marks]

Q3. a) Turning movement count details and relevant data of T intersection is shown in Figure Q3-1. Answer the following questions based on data provided.

i. Check for the right-turn and assess whether that need protection.
ii. Draw the phase diagram based on minimum phases needed
iii. Convert volumes in each turning movements to through vehicle equivalents (Fill the Table Q3-1 use Table Q3-2 and Table Q3-3)
iv. Explain the principle behind the calculation of amber time

[7.0 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]

Q4. Junction A and Junction B of a city can be travelled by three routes namely, Route 1 (4 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 with a optimum speed of 40 km/h and a density of 200 veh/km 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 165 veh/km/lane while those for Route 3 has 100 km/h and 135 veh/km/lane respectively. At morning peak time, it is estimated that 26,000 vehicles arrive at node A to proceed towards Node B over a 90 min time period at a constant rate.

a) It is proposed that Route 1 and 2 to be converted in to one-way roads carrying traffic from Node A towards B. It is suggested 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.

[10.0 Marks]

b) After the implementation of one-way scheme on Rote 3 has to carry the evening peak volume from Node B towards A. If 26,000 vehicles arrive at Node B over 2 hr period starting from 4:30 pm, calculate the density of Route 3. If there is no real solution to density what could be done to solve this problem.

[2.0 Marks]

Q5. For an M/M/1/∞/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/∞/FCFS queue.

   i. Probability of state n is given by $\rho(1-\rho^n)$

   ii. Expected length of the queue $L_q = \dfrac{\rho^2}{1-\rho}$

   iii. Expected number of units in the system $E_q = \dfrac{\rho}{1-\rho}$

[4.0 Marks]

b) Vehicle to a doctor's office arrive at with a Poisson distribution with an average rate of 20 patients per hour while the average service time for one patients 2.5 minutes with a negative exponential distribution. By assuming that patients waiting in the que as a M/M/1/∞/FCFS queue system, doctor's office is working for 10 hrs and determine the following.

   i. Total time the doctor's office is empty
   ii. Total time without a queue
   iii. Expected number of people in the system
   iv. Expected time of vehicles waiting in the que

[8.0 Marks]

Tables and Figures

Table Q2-1 AADT by day of a link in front of hospital 'A'

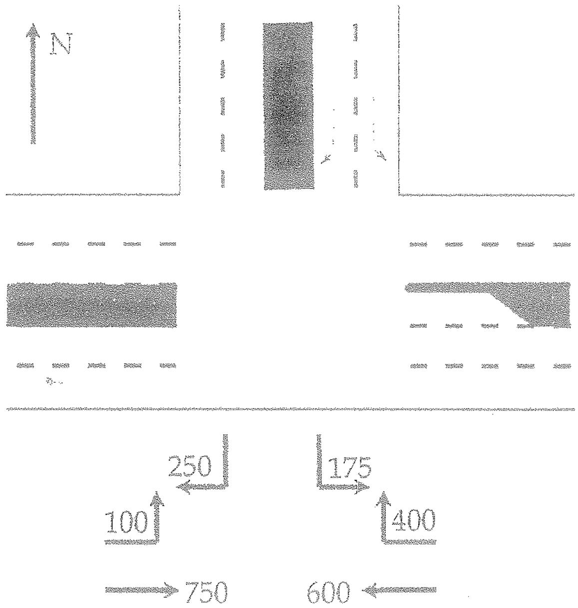
Day of the week	AADT for the Day (Veh/Day)
Monday	18,780
Tuesday	16,300
Wednesday	15,430
Thursday	16,300
Friday	19,285
Saturday	10,979
Sunday	5,890

Table Q2-2 AADT by month of a link in front of hospital 'A'

Month	AADT of Monthly (Veh/Day)
January	18,700
February	19,650
March	16,470
April	15,600
May	14,770
June	14,560
July	14,304
August	13,016
September	15,240
October	14,700
November	15,580
December	23,462

Table Q2-3 Traffic Flow Details of a link in front of School

Hospital	Day	Month	Traffic Volume (Veh/hour)
B	Monday	April	678
C	Tuesday	April	765
D	Wednesday	June	995



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=3.0 m/s²
Cross walk width=3.3 m
Driver Encroachment =2s
Default h = 2s
Default e= 2s

Figure Q3-1 Traffic Flow Details of a 'T' Intersection

Table Calculations Q3-1

Approach	*Movement*	*Volume (Veh/h)*	E_{RT} *or* E_{LT}	*Volume (tvu/h)*	*Lane group vol (tvu/h)*	*Vol/Lane (tvu/h)*
EB	R					
	T					
	L					
WB	R					
	T					
	L					
NB	R					
	T					
	L					

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

Opposing through plus left flows	*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

Equations

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

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

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

$$q_{LT} \geq 200 \text{ veh/h}$$

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

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

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

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

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

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

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

$$L_q = \lambda \times W_q$$

$$L - L_q = \rho$$

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

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

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

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

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

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

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

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

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

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

$$L = \lambda \times W$$

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

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

$$DEF = \frac{\text{Average total volume for week}}{\text{Average volume for particular day}}$$

$$MEF = \frac{AADT}{\text{ADT for particular month}}$$

$$HEF = \frac{\text{Total volume for 24hr period}}{\text{Volume for particular hour}}$$