UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 4 Examination in Engineering: November 2016

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. Ministry of Transportation in Sri Lanka is compiling a master plan to develop Colombo and its suburbs as a mega polis (CMP). Among many considerations, transportation planning plays an important role in CMP. Assume that you are appointed as a committee member of the team responsible for transportation planning inside CMP.

a) CMP committee wants to understand the problems related to sustainability in Sri Lankan transportation. List four distinct issues related to sustainability in Sri Lankan transportation.

[2.0 Marks]

b) Some CMP committee members do not understand the phrase "Finite nature of petroleum reserves". Briefly describe the above phrase.

[3.0 Marks]

c) One of the proposals by CMP committee deals with a new monorail metro. List two viable fuel sources for the proposed monorail metro considering sustainability.

[3.0 Marks]

d) CMP committee determined that air quality would be a large issue in future Colombo mega polis. Tabulate four possible air quality issues and corresponding solutions.

[4.0 Marks]

Q2. CMP committee stated in Q1 requires extensive array of traffic surveys to support it's every decision. Many traffic surveys need specialised equipment that needed to be purchased by the CMP committee.

a) To conduct a certain traffic survey, "ANPR" camera installation was suggested by a consultant to CMP. With the aid of neat sketches explain the working principle of an ANPR camera.

[3.0 Marks]

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

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

[3.0 Marks]

c) Speed data collected on an urban roadway yielded a standard deviation of 6.5 km/h.

i. If an engineer wishes to estimate the average speed on the roadway at a 95% (two tailed test) confidence level so that the estimate is within ±3 km/h of the true average, how many spot speeds should be collected?

ii. If the estimate of the average must be within ±1 km/h, what should the sample size be?

[2.0 Marks]

d) Table Q2-1 shows data collected in a travel time study on a section of urban highway using the moving-vehicle technique. Estimate: the volume in each direction at this section of the highway; and

i. the travel time in each direction.

[4.0 Marks]

Q3. a) On a certain signalised intersection coming under Colombo mega polis area, it was found that northern arm (single lane) of the intersection receives very high flow rate for 2 hours during the morning peak. It was also found that flow rate showed deterministic characteristics; not random. Due to the varying nature of the inflow, consultant advised the CMP committee (Stated in Q1) that theoretical or empirical models cannot be applied and the delay has to be calculated going to fundamental theory. Flow rate and the signal details of the intersection are given in Table Q3-1 and Table Q3-2. Assume that at exactly 6:30 am, an effective green starts for the northern approach and at that same time there are no vehicles leftover from previous signal cycles.

i. Draw the graph indicating the cumulative vehicles in y axis and time in the x axis from 6:30 am to 10:00 am (No need to indicate effective red and effective green).

ii. Determine the capacity of the northern arm of this intersection and draw it on the graph on section (i).

iii. Determine the uniform delay for each vehicle for the time from 6:30 am to 8:30 am.

iv. Determine overflow delay for each vehicle from the graph in part (ii) above for the time from 6:30 am to 8:30 am. *(Hint: aggregate delay is the area in between in and out the graphs)*

v. Determine the total delay for each vehicle for the time from 6:30 am to 8:30 am.

vi. From the graph, determine the time when queue will totally dissipate.

[8.0 Marks]

b) CPM committee decides to investigate delay occurring at an un-signalized intersection to vehicles on minor road that are waiting to merge with/cross the major road vehicles. The arrival of the major road vehicles can be described by Poisson distribution, and the average peak hour flow rate is 1,100 veh/h. Table Q3-3 shows data on accepted and rejected gaps of vehicles on the minor road of an un-signalized intersection.

i. Determine the critical gap from table (without graphical method).
ii. Determine the expected number of accepted gaps that will be available for minor road vehicles during the peak hour.

[4.0 marks]

Q4. Traffic flow between Wellawatta to Kollupitya was an issue discussed at CMP committee (stated in Q1) meetings. Wellawatta to Kollupitya can be travelled by three routes namely, Marine Drive (2 lanes), Galle Road (4 lanes), and R.A. De Mel Mawatha (3 lanes). All three roads have roughly the same length. Traffic along the route Marine Drive can be approximated by Greensburg's model while traffic in Galle Road and R.A. De Mel Mawatha follows Greenshield's model. Galle Road has free flow speed of 120 km/h and jam density of 165 veh/km/lane while those for R.A. De Mel Mawatha has 100 km/h and 135 veh/km/lane respectively. At morning peak time, it is estimated that 33,000 vehicles arrive at Wellawatta to proceed towards Kollupitya over a 90 minute time period.

a) Marine Drive has undergone many changes so that the existing Greensburg's model is proved useless. Calibrate the Greensburg's 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) CMP committee proposes that Marine Drive and Galle Road will be converted to one-way roads carrying traffic from Wellawatta to Kollupitya. Consultant suggests that in such a scenario, traffic would be divided into Marine Drive and Galle Road so that travel time via both roads will be equal.

i. Write flow and speed equations for a single lane in Marine drive and Galle road
ii. Equate travel time in Galle Road and Marine Drive to get an equation for density of Galle Road (K_M) in terms of density of Marine Drive (K_G).
iii. Equate the total incoming flow rate to Marine Drive flow(2 lanes) and Galle Road flow(4 lanes) and obtain an equation in K_G and K_M.
iv. Solve equations obtained in part (ii) and (iii) to find all possible values of K_G and K_M.
v. Determine flow rates in Marine Drive and Galle Road.

[7.0 Marks]

c) After the implementation of one-way scheme on Marine Drive and Galle Road R.A. de Mel Mawatha has to carry the evening peak volume from Kollupitya to Wellawatta. If 33,000 vehicles arrive at Kollupitya over 2 hr period starting from 4:30 pm, calculate the density of .A. de Mel Mawatha.

[2.0 Marks]

Q5. a) Consultant to CMP committee (stated in Q1.) showed that 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 $\rho = \lambda/\mu < 1$. Using the above information you are asked to prove the following equations for an M/M/1/∞/FCFS queue.

i. Probability of empty state is given by $1 - \rho$

ii. Expected number of the units in the system. $L = E(n) = \rho/_{1-\rho}$

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

[4.0 Marks]

b) CMP committee is proposing Ragama as multi modal (Railway, Bus, Rapid Transit Bus, and Taxi) transportation hub. Under this proposal, a single taxi bay is to be established which will operate for 18 hrs/day. Here passengers who want to get a taxi come to the bay and take a taxi waiting there or wait in the queue and get a taxi. Average time taken for the driver to park a taxi, passengers to load the luggage and get into the taxi and leave can be described as an exponential function with mean rate of 3 minutes per service. It is also estimated that there will be an average need for 15 taxis per hour with Poisson distribution. By assuming that, one person per one group of people wait in the queue, and taking above scenario as M/M/1/∞/FCFS queue and determine the following.

i. Total time the taxi bay is empty
ii. Total time without a queue
iii. Expected number of people in the system
iv. Expected time of people waiting in the system
v. Expected length of the queue
vi. Expected time of people waiting in the queue

[8.0 Marks]

Table Q2-1 Data Collected from Moving Vehicle Method

Run direction/ Number	Travel time (min)	Number of vehicles travelling in opposite direction	Number of vehicles that overtook test vehicle	Number of vehicles overtaken by test vehicle
Northward				
1	5.25	100	2	2
2	5.08	105	2	1
3	5.3	103	3	1
4	5.15	110	1	0
5	5.00	101	0	0
6	5.51	98	2	2
7	5.38	97	1	1
8	5.41	112	2	3
9	5.12	109	3	1
10	5.31	107	0	0
Southward				
11	4.95	85	1	0
2	4.85	88	0	1
3	5.00	95	0	1
4	4.91	100	2	1
5	4.63	102	1	2
6	5.11	90	1	1
7	4.83	95	2	0
8	4.91	96	3	1
9	4.95	98	1	2
10	4.83	90	0	1

Table 3-1 Flow Rate of the Intersection

Time		Flow rate (Veh / h)
From (am)	To (am)	
	Until 6:30	800
6:30	6:45	1000
6:45	7:00	1200
7:00	7:30	1400
7:30	8:00	1200
8:00	8:15	1100
8:15	8:30	1000
8:30 onwards		800

Table 3-2 Traffic Signal Details of the Intersection

Signal parameter	Value (Sec)
Cycle length	100.0
Effective green time	55.0
Saturation Headway	2.0

Table Q3-3 Number of Rejected and Accepted Gaps

Gap(t)(s)	Number of rejected gaps >t	Number of accepted gaps >t
1.5	92	3
2.5	52	18
3.5	30	35
4.5	10	62
5.5	2	100

Table Q4-1 Speed and Density Data

Density (veh/km/lane)	Space mean speed (kmph)
25	71.7
39	53.9
50	43.9
65	33.4
70	30.5
29	65.7
91	20.0
95	18.3
110	12.4
112	11.7
140	2.8
133	4.8
67	32.2
45	48.2

Equations

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$L = \lambda \times W$$

$$L_q = \lambda \times W_q$$

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

$$L - L_q = \rho$$

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