UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 5 Examination in Engineering: March 2026

Module Number: CE5306 **Module Name: Traffic and Transport Engineering(C-18)**

[Three Hours]

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

Q1. Conventional bus transport systems in many developing cities suffer from low ridership, unreliable schedules, long dwell times, and a poor image despite being economically affordable. Bus Rapid Transit (BRT) has emerged as a high-capacity, cost-effective solution. Answer all five parts based on engineering principles and system design.

a) List any three operational problems of conventional bus transport and briefly explain how each problem degrades system performance.

[3.0 Marks]

b) A city proposes to convert a congested 10-km arterial corridor into a BRT system with dedicated median lanes, off-board fare collection, and level boarding. Estimate the expected reduction in cycle time (round-trip time) compared to the existing conventional bus system. State **three** assumptions you make for your estimation and show the calculation approach.

[4.0 Marks]

c) Compare and contrast median-aligned BRT lanes versus curb-aligned BRT lanes in terms of their impacts on mixed-traffic turning movements, pedestrian access to stations, and interactions with emergency vehicles. Use schematic diagrams or bullet-point reasoning.

[3.0 Marks]

d) You are the transport engineer for a fast-growing mid-sized city. The mayor insists that BRT is "just a bus with paint" and argues for a light rail transit (LRT) system instead. Propose **two engineering arguments** in favour of BRT over LRT for this context, and for each argument, mention one **technical limitation** of BRT that must be managed

[2.0 Marks]

Q2. a) At an off-peak time, the northbound approach of the intersection has a traffic flow rate of 800 veh/h. The saturation flow rate for that approach is estimated at 2,800 veh/hg/lane, with a cycle length of 120 s and an effective green time of 42 s. Determine the following

[4.0 Marks]

i) Determine the capacity of the approach.

ii) Determine the type of delay in the leg.

iii) Calculate the vehicle delay during this off-peak period.

b) The same northbound approach experiences chronic oversaturation for one hour each day. During this period, vehicles arrive at a rate of 1,400 veh/h. determine the

i) Average control delay per vehicle for the full hour.
ii) The average control delay per vehicle for the first 15 minutes.
iii) The average control delay per vehicle for the last 15 minutes.

[4.0 Marks]

c) Other approach of the intersection has two lanes, permitted right-turn phasing, 10% right -turning vehicles, and a right -turn equivalent factor of 4.5. The saturation headway for through vehicles is 2.2 s/veh. Determine the equivalent saturation flow rate and headway for all vehicles on this approach.

[4.0 Marks]

Q3. a) If the probability of the system being in state n for an M/M/1/∞/FCFS queue system is given by b, then $P_n = P_0 \times \rho^n$ $(\rho = \lambda/\mu < 1)$, derive the following.

i. Probability of having at least n in the system
ii. Expected length of the queue
iii. Expected number of units in the system
iv. Probability of having no queue

[4.0 Marks]

b) Vehicle arrivals to a toll booth have a Poisson distribution with an average of 20 vehicles per hour. The server at the toll booth has an average service time of 1.0 minutes, following a negative exponential distribution. Determine the following by assuming this as a M/M/1/∞/FCFS queue system.

i. Total time the toll booth is empty
ii. Total time without a queue
iii. Expected number of vehicles in the system
iv. Expected time of vehicles waiting in the queue
v. Probability of having 10 vehicles or more in the queue

[6.0 Marks]

c) If the queue length exceeds 10 vehicles, the queue will extend in the expressway. What can be done to prevent this from happening?

[2.0 Marks]

Q4 Two alternative routes connect the same two urban centers. The traffic along one route can be approximated by the model given in Equation Q4-1.

$$U_s = c \ln \left(\frac{a}{K}\right) \quad \text{Equation Q4-1}$$

To calibrate the above model, a survey was conducted, and the results are shown in Table Q4-1. Traffic in route **B** follows the Greenshields model with a free-flow speed of 100 km/h and a jam density of 100 veh/km. Traffic route A is at its optimal flow, while traffic route B has a density of 20 vehicles per km.

On a particular day, a part of the traffic flow on route A was diverted to route B. Therefore, the density of route A decreased to 30 vehicles per km, and the density of route B increased close to its jam density. Answer the following questions based on the data provided.

a) Using least square-based regression, determine the constants a and c in Equation 1

[3.0 Marks]

b) Determine the speed and density at the optimal flow rate for route A.

[2.0 Marks]

c) Calculate the flow after diversion on Route A and Route B

[3.0 Marks]

d) Calculate the densities and, hence, the resulting speeds for routes A and B.

[3.0 Marks]

e) Calculate the total time saved or lost due to this diversion

[1.0 Marks]

Q5 Analysing shockwaves at signalized intersections is crucial because of the concern for the length of queues interfering with upstream flow movements, such as queues extending out of left-turn lanes into through traffic lanes, and queues extending upstream to block adjacent intersections.

a) i) Draw a Distance-Time diagram to show the shockwaves at a signalised intersection and clearly mark the flow states and shockwaves

ii) Write down the expressions for the shockwaves marked in the Distance-Time diagram

[4.0 Marks]

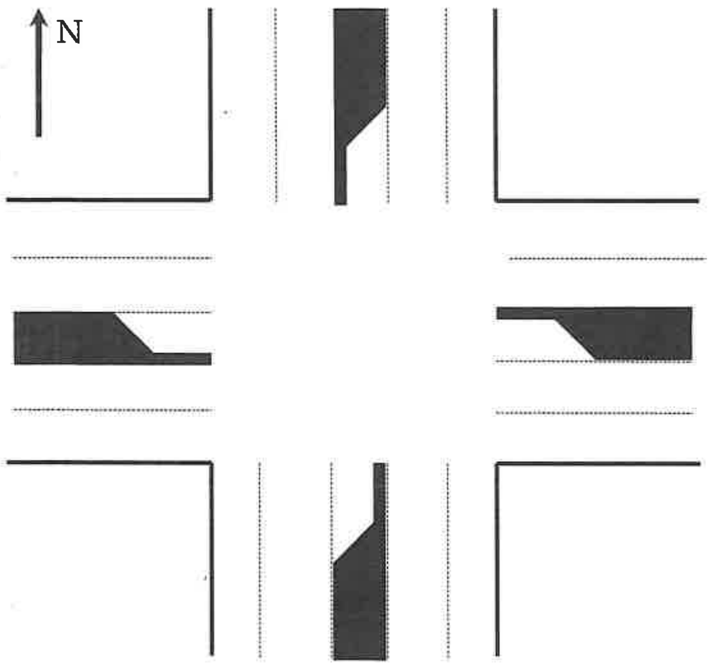
b) The individual lanes on a long, tangent, two-lane directional freeway exhibit identical traffic behaviour, and each flow follows a linear speed-density relationship. It has been observed that the maximum flow rate is 2000 vehicles per hour per lane, occurring at a speed of 40 km/h. On one particular day, when the input flow rate was 1800 vehicles per hour per lane, and the speed was 50 km/h, an accident occurred. The road was completely blocked, causing a traffic jam. After 1 minute, the accident was cleared, and traffic returned to normal.

i) How many vehicles were in the queue at the time of the accident
ii) Calculate the maximum queue length
iii) Time taken to the maximum queue length after the accident was removed

[8.0 Marks]

Figures, Tables, and Equations

PHF = 0.92
Target (v/c) ratio=0.90
Driver reaction time = 1 s
Pedestrian walking speed = 4fps
Speed limit (all approaches) = 45mi/h
Moderate pedestrian volumes
Level grades
Deceleration rate= 10ft/s^2
Cross walk width= 10ft
Driver Encroachment =2s
Default l_1= 2s
Default e= 2s



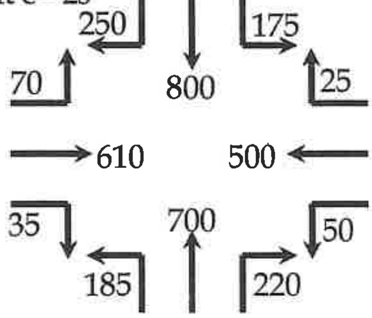


Figure Q3 Traffic Flow Details of an Intersection

Table 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					
SB	R					
	T					
	L					

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

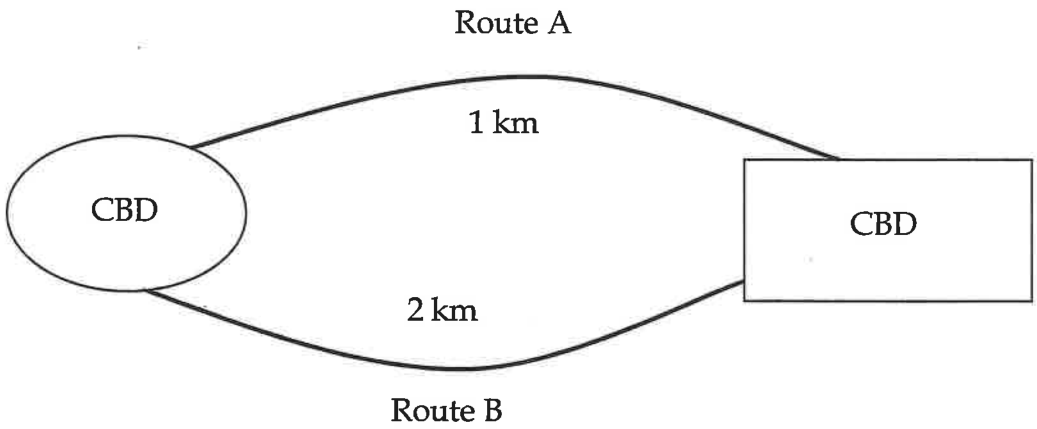


Figure Q4: Route option between two central business districts

Table Q4

Density (veh/km)	Speed (kmph)
30	60.2
35	52.5
60	25.5
70	17.8
75	14.4
40	45.8
30	60.2
37	49.7
66	20.8
39	47.1
40	45.8
80	11.2
85	8.1
20	80.5
22	75.7

Equations

$$\boldsymbol{a = \bar{y} - b\bar{x}}$$

$$\boldsymbol{b = \frac{n\sum(xy) - \sum x \sum y}{n\sum(x^2) - (\sum x)^2}}$$

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

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

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

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

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

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