NATIONAL EXAMINATION DECEMBER 2019

16-Civ-B7, Transportation Planning & Engineering

3 HOURS DURATION

Notes:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper a clear statement of any assumptions made.
2. Candidates may use one of two calculators, the Casio approved model or the Sharp approved model.
3. This is a closed book-examination. One two-sided aid sheet is permitted.
4. Any **five** questions constitute a complete examination and only the first five questions, as they appear in your answer book, will be marked.
5. All questions are of equal value (20 marks)

QUESTION 1:

(a) Explain the interaction between residential land development and transit use.

(b) List the factors that will potentially increase trip production at i) zonal level; ii) household level; and iii) person level (one factor for each level). Explain why.

(c) Describe potential travel demand management strategies which can increase average vehicle occupancy during commuter peak hours. Explain how these strategies would change travel patterns, travel time and fuel consumption.

QUESTION 2:

Vehicles arrive a toll booth at the rate of 10 vehicles/min from 8:00 am to 8:10 am. Then their arrival rate decreases to 8 vehicles/min from 8:10 am to 8:25 am and further decreases to 2 vehicles/min thereafter. The maximum service rate of the toll booth is 6 vehicles/min.

(a) Sketch a queueing diagram (cumulative arrival and departure curves over time) from 8:00 am to the time when the queue dissipates.

(b) Calculate the maximum queue length (maximum number of vehicles in the queue).

(c) Calculate 1) the total vehicle delay and 2) the average delay per vehicle.

QUESTION 3:

The following table shows the trip rate (number of trips per household) for different combinations of the household size and vehicle ownership:

Trip rate (number of trips/household)

	Vehicles ownership		
Household size	0	1	2+
1	2.6	4.0	4.0
2	4.8	6.7	8.2
3	7.4	9.2	11.2
4	9.2	11.5	14.7
5+	11.2	13.7	17.2

(a) Calculate the forecasted number of trips for each household size and vehicle ownership for a target year if the number of households is forecasted as follows.

Forecasted number of households in a target year

	Vehicles ownership		
Household size	0	1	2+
1	100	300	150
2	110	250	50
3	90	250	50
4	150	210	60
5+	20	50	30

(b) Alternatively, the trip rate for each household can be estimated using the following regression equation which was fit to the above observed data:

Trip rate = -0.85 + 2.6289 * HSIZE + 2.0115 * VEH

where
HSIZE = household size (if 5 or more, HSIZE = 5);
VEH = vehicles ownership (if 2 or more, VEH = 2).

Calculate the forecasted number of trips for each household size and vehicle ownership for a target year using this estimated trip rate.

(c) Compare the methods used in (a) and (b) in terms of underlying assumptions and limitations.

QUESTION 4:

Consider a single-lane highway with the free-flow speed of 80 km/hour and the jam density of 100 vehicles/km. In normal traffic condition, vehicles are travelling at the speed of 64 km/hour. On one day, a heavy truck with the speed of 8 km/hour entered the highway, traveled 0.5 km at the same speed and exited the highway. Consequently, the vehicles immediately behind the truck had to lower the speed to 8 km/hour behind the truck and formed a platoon with the density of 90 vehicles/km and the flow of 720 vehicles/hour. Apply the Greenshields' model or the shock wave theory to determine:

(a) The capacity and the density at capacity of the vehicle flow;

(b) The length of the platoon immediately after the truck exited;

(c) The time it took for the platoon to dissipate after the truck exited. Assume that there was no congestion on the road further downstream of the point where the truck exited.

QUESTION 5:

Consider two zones – zone 1 and zone 2. The total trip productions from both zones 1 and 2 are 75. The total trip attractions to zones 1 and 2 are 50 and 100, respectively. The travel time between zone 1 and zone 2 (inter-zonal) is 5. The travel time within the same zone (intra-zonal) is 2.

(a) Estimate the number of intra-zonal and inter-zonal trips using the gravity model. The friction factor between zone i and zone j (F_{ij}) is defined as follows:

$$F_{ij} = \frac{1}{t_{ij}} \qquad \text{where } t_{ij} = \text{travel time between zone } i \text{ and zone } j.$$

(b) Assume that the total trip productions from both zones 1 and 2 will increase to 125 in a target year. The total trip attractions to zones 1 and 2 will also increase to 75 and 175, respectively, in a target year. The intra-zonal and inter-zonal travel times remain the same. Estimate the forecasted number of intra-zonal and inter-zonal trips in the target year using the gravity model.

(c) List the potential factors affecting trip distribution other than travel time.

QUESTION 6:

There are two major routes – Routes 1 and 2 – between the residential zone and the commercial zone. These two routes do not overlap each other. The travellers in the residential zone take one of these two routes to reach the commercial zone. The travel time functions for these two routes are as follows:

$$t_1 = 22 + 2\left(\frac{V_1}{225}\right), t_2 = 12 + \left(\frac{V_2}{100}\right)$$

where t_i = travel times on Route i (minutes) and V_i = number of vehicles on Route i. Assume that the total number of vehicles from the residential zone to the commercial zone is 3,600 vehicles.

(a) Compute the number of vehicles and travel time on each route at the user-equilibrium (UE) condition. Also compute the total vehicle travel time using the following equation:

$$T = V_1\left(\frac{t_1}{60}\right) + V_2\left(\frac{t_2}{60}\right)$$

where T = total vehicle travel time (vehicles-hour).

(b) Compute the number of vehicles and travel time on each route at the system-optimal (SO) condition when the total vehicle travel time is minimized. Also, compute the total vehicle travel time in the SO condition.

(c) Compare the total vehicle travel times between the UE and SO conditions. Discuss why they are different and how to manage travel demand to change the UE condition to the SO condition.

QUESTION 7:

Workers can choose one of the three available modes of travel (auto, bus and light rail) for their work trips. The calibrated utility function for each mode is specified as follows:

Auto: $V_a = 1.1 - 0.05 \cdot TT_a - 0.25 \cdot TC_a$
Bus: $V_b = 0.1 - 0.05 \cdot TT_b - 0.25 \cdot TC_b$
Light rail: $V_r = - 0.05 \cdot TT_r - 0.25 \cdot TC_r$

where,
V_i = observable utility for mode i ;
TT_i = travel time for mode i (minutes);
TC_i = cost of travel for mode i ($).

The travel time and cost for each mode are shown below.

Mode	TT	TC
Auto	16 min	$3.50
Bus	30 min	$2.00
Light rail	25 min	$2.50

(a) Calculate the shares of the three modes using the multinomial logit model.

(b) In the part (a), the bus company plans to lower bus fare from $2.00 to $1.00 to increase its mode share for work trips. Assume that bus fare is the only cost of travel for bus. Predict the shares of the three modes after the bus fare reduction.

(c) The result in part (b) may not make intuitive sense due to unrealistic assumption of the logit model. Explain this assumption of the logit model and how you would account for such unrealistic assumption in this mode choice problem.

Marking scheme:

Question	Sub-questions	Marks
1	(a)	7
	(b)	6
	(c)	7
2	(a)	10
	(b)	4
	(c)	6
3	(a)	8
	(b)	8
	(c)	4
4	(a)	4
	(b)	12
	(c)	4
5	(a)	8
	(b)	8
	(c)	4
6	(a)	6
	(b)	8
	(c)	6
7	(a)	5
	(b)	7
	(c)	8