NATIONAL EXAMINATION MAY 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). Full Marking Scheme on page 7.

QUESTION 1:

(a) Explain the effects of residential development in low-density suburban areas on commuters' mode choice and travel distance of their work trips.

(b) Explain how length and frequency of trips are different between work trips and non-work trips.

(c) Discuss how advanced vehicle technology (e.g., connected and autonomous vehicles) will affect travel demand in the future.

QUESTION 2:

The flow rate on a section of a one-way two-lane freeway is typically 12 veh/min. The capacity of this freeway section is 18 veh/min. On one day, an accident occurred and it blocked two lanes for 10 minutes. While the accident was being cleared, one of the two lanes was open for 25 minutes and the capacity was 6 veh/min during this time period. After the accident was cleared, two lanes were open.

(a) Sketch a queueing diagram (cumulative arrival and departure curves over time) from the beginning of the road closure and determine the time when the queue cleared.

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

(c) Calculate 1) the total vehicle delay and 2) the average delay per vehicle caused by the road closure.

QUESTION 3:

The following tables show household trip rates and the forecasted household composition in a target year for a residential zone:

Trip rate (trips per household)

Number of cars in household	Number of workers in household			
	0	1	2	3 or more
0	1.1	2.3	3.6	5.5
1	2.3	3.6	3.8	7.6
2 or more	-	4.0	4.6	8.4

Forecasted number of households

Number of cars in household	Number of workers in household			
	0	1	2	3 or more
0	130	90	70	40
1	60	220	280	250
2 or more	-	50	80	200

(a) Calculate the forecasted number of trips for each household type (classified by number of workers in household and number of cars in household) in a target year.

(b) The expected trip rate by a household can also be estimated using the following linear regression equation:

Trip rate = 0.79 + 1.62 * WORKER + 0.88 * CAR

where
WORKER = number of workers in household (3 or more = 3);
CAR = number of cars in household (2 or more = 2).

Describe the effects of number of workers and number of cars in household on the trip rate.

Calculate the forecasted number of trips for each household type in a target year using this expected trip rate.

(c) Compare the methods used to estimate the forecasted number of trips in (a) and (b), and discuss their underlying assumptions and limitations.

QUESTION 4:

Vehicles are approaching a signalized intersection on one urban street at a speed of 45 km/hour and a density of 20 veh/km in normal traffic conditions. The urban street has a free-flow speed of 60 km/hour and a capacity of 1200 veh/hour. Vehicles must stop during the red interval. The duration of red interval is 30 seconds per cycle. Determine the followings using the Greenshields' model or the shock wave theory:

(a) The jam density and the density at capacity.

(b) The maximum length of the queue during the red interval.

(c) The time it would take for the queue to dissipate after the red interval ends. Assume that there was no congestion downstream of the intersection.

QUESTION 5:

Consider trip distribution between 2 zones in an area. The total trip productions from zones 1 and 2 are 450 and 550, respectively. The total trip attractions to zones 1 and 2 are 700 and 300, respectively. The travel distance between zone 1 and zone 2 is 10 km. The travel distance within the same zone is 5 km.

(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:

$$F_{ij} = \frac{1}{d_{ij}^2}$$

where d_{ij} = distance between zone i and zone j.

(b) Assume that the total trip productions from zones 1 and 2 will increase to 600 and 800, respectively, and the total trip attractions to zones 1 and 2 will increase 950 and 450, respectively, in a target year. The intra-zonal and inter-zonal travel distances 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 distance.

QUESTION 6:

A residential area is linked to a commercial area by two highways - Highway 1 and Highway 2. The travel time functions for these two highways are described as follows:

$$t_1 = 10 + \frac{V_1}{110}, t_2 = 10 + \frac{V_2}{150}$$

where t_1, t_2 = travel time on Highway 1 and Highway 2, respectively (minutes) and V_1, V_2 = volume on Highway 1 and Highway 2, respectively (vehicles/hour). Total volume from the residential area to the commercial area is 8,000 vehicles/hour.

(a) Compute the traffic volume and travel time on the two highways at the User Equilibrium (UE) condition.

(b) To alleviate the congestion on the two existing highways, a new highway (Highway 3) is added. The travel time function of the highway is described as follows:

$$t_3 = 10 + \frac{V_3}{140}$$

where t_3, V_3 = travel time and volume on Highway 3, respectively. Compute the new traffic volumes and travel times on the three highways at the UE condition. Will the travel time in each highway be reduced?

(c) Why does the addition of a new highway sometimes increase travel times on all highways at a UE condition?

QUESTION 7:

Commuters choose auto or bus for their trips. The utility function for each travel mode was calibrated as follows:

$$V_{Auto} = -0.33 - 0.10 * WT - 0.13 * TT - 0.12 * PT - 0.0045 * OPC$$
$$V_{Bus} = -0.27 - 0.10 * WT - 0.13 * TT - 0.12 * PT - 0.0045 * OPC$$

where

V_{Auto}, V_{Bus} = observable utilities for auto and bus, respectively;
WT = waiting time (min);
TT = in-vehicle travel time (min);
PT = parking time (min);
OPC = out-of-pocket cost (cents).

The values of the parameters in the above utility function for each mode are shown below.

Mode	WT (min)	TT (min)	PT (min)	OPC (cents)
Auto	0	20	5	225
Bus	10	35	0	100

(a) Calculate the mode splits of auto and bus using the multinomial logit model.

(b) In the part (a), the new light rail will be added as the third mode of travel. The utility function for light rail (V_{Rail}) is as follows:

$$V_{Rail} = -0.10 * WT - 0.13 * TT - 0.12 * PT - 0.0045 * OPC$$

The values of the parameters for light rail are shown below.

Mode	WT (min)	TT (min)	PT (min)	OPC (cents)
Light rail	15	25	0	150

Predict the mode splits of auto, bus and light rail using the multinomial logit model.

(c) Does the result in (b) make intuitive sense? Comment on the result based on the independent of irrelevant alternatives (IIA) property of the multinomial logit model and suggest how to overcome the limitations of the IIA property 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)	6
	(b)	8
	(c)	6
4	(a)	4
	(b)	12
	(c)	4
5	(a)	8
	(b)	8
	(c)	4
6	(a)	6
	(b)	10
	(c)	4
7	(a)	5
	(b)	7
	(c)	8