NATIONAL EXAMINATION DECEMBER 2017

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). Marking Scheme details on Page 7.

QUESTION 1:

(a) Explain how commercial land development and accessibility to transportation services are associated.

(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) As vehicle and communication technologies emerge, it is expected that many drivers will receive information via vehicle-to-vehicle and vehicle-to-infrastructure communications in the future. Discuss how these new technologies can be applied to traffic management.

QUESTION 2:

Vehicles begin arriving at a signalized intersection at $t = 0$ when the red interval starts. Vehicles arrive at the rate, $\lambda(t) = 0.9 - 0.005 \cdot t$ where $\lambda(t)$ = the rate in veh/s at time t and t = time in seconds. The cycle length for this intersection is 60 s, and the green and red intervals for this approach are 27 s and 33 s, respectively. Assume that vehicles waited in a queue during the red interval and depart from the intersection during the green interval at a maximum flow rate of 3600 veh/h. Assume that vehicles can only move during the green interval and there is no yellow interval. Also assume that vehicles start moving immediately after the green interval starts.

(a) Determine the time when the queue will clear.

(b) Sketch a queueing diagram (cumulative arrival and departure curves over time) from $t = 0$ to the time when the queue clears.

(c) Calculate the total vehicle delay from $t = 0$ to the time when the queue clears.

QUESTION 3:

The following tables show household trip rates and the forecasted household composition in an urbanized area:

Trip rates (trips/household)

	Vehicles/household		
Persons/household	0	1	2 or more
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 or more	11.2	13.7	17.2

Forecasted number of households

	Vehicles/household		
Persons/household	0	1	2 or more
1	100	300	150
2	110	250	50
3	90	250	50
4	150	210	60
5 or more	20	50	30

(a) Calculate the forecasted number of trips for each household type (classified by the number of persons per household and the number of vehicles per household).

(b) Alternatively, trip rate can be estimated using the following linear regression equation:

Trip rate = – 0.85 + 2.63 * NPERSON + 2.01 * NVEH

where
NPERSON = no. of persons per household (if 5 or more, NPERSON = 5);
NVEH = no. of vehicles per household (if 2 or more, NVEH = 2)

Calculate the forecasted number of trips for each household type using this estimated trip rate.

(c) Explain the effects of the number of persons per household and the number of vehicles per household on the trip rate based on the linear regression equation in (b). Does this make intuitive sense?

(d) Compare the methods used in (a) and (b) in terms of underlying assumptions and data requirements.

QUESTION 4:

On one day, the traffic is flowing at a density of 10 veh/km on a one-lane highway. A free-flow speed is 120 km/hour and a capacity is 1800 veh/hour for this highway. Assume that a truck with a speed of 40 km/h enters the highway, travels for 2 km and exits the highway. When the truck enters the highway, all the cars immediately behind the truck are forced to lower their speed to 40 km/h. Assume the Greenshields' model applies, determine the followings using the shock wave theory:

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

(b) The length of the platoon immediately after the truck exits.

(c) The speed of the front of the platoon after the truck exits.

(d) The time it would take for the platoon to dissipate after the truck exits. Assume that there is no congestion on the highway further downstream of the exit point.

QUESTION 5:

Consider the trip distribution in zone 1 and zone 2. The total trip productions from zones 1 and 2 are 150 and 150, respectively. The total trip attractions to zones 1 and 2 are 100 and 200, respectively. The travel distance between zone 1 and zone 2 (inter-zonal travel time) is 20 km. The travel distance within the same zone (intra-zonal travel time) is 10 km.

(a) Estimate the numbers 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:

$$F_{ij} = \exp(-0.1 \cdot d_{ij}) \quad \text{where } d_{ij} = \text{travel distance between zone } i \text{ and zone } j;$$

(b) Assume that the total trip productions from zones 1 and 2 will increase to 200 and 200, respectively, in a target year. The total trip attractions to zones 1 and 2 will also increase 150 and 250, respectively, in the 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 with the same friction factor in part (a).

(c) Explain the effect of friction factor on trip distribution based on the results in parts (a) and (b).

QUESTION 6:

Travellers can choose one of the following four modes of travel – automobile, bus, rail and bike. The utility functions for each mode are as follows:

$$V_i = -0.075 * AT_i - 0.05 * WT_i - 0.04 * RT_i - 0.002 * TC_i$$

where

V_i = observable utilities for mode i;
AT_i = access time for mode i (minutes);
WT_i = waiting time for mode i (minutes);
RT_i = riding time for mode i (minutes);
TC_i = out-of-pocket travel cost for mode i (cents).

The values of each mode attribute are shown below.

	Attribute			
Mode	Access time (minutes)	Waiting time (minutes)	Riding time (minutes)	Out-of-pocket cost (cents)
Auto	6	1	25	300
Bus	10	15	40	60
Rail	7	10	30	75
Bike	1	0	60	10

(a) Calculate the share of each mode using the multinomial logit model.

(b) The city will construct bike paths to encourage people to use bikes. The city expects that the bike paths will reduce riding time by bikc to 45 min. Assume that the values of all other mode attributes remain the same as above. What will be the new share of each mode?

(c) Explain thc independent of irrelevant alternatives (IIA) property of the multinomial logit model. Suggest how to overcome the limitations of the IIA property in predicting mode choice using the multinomial logit model.

QUESTION 7:

Consider the commuter work trips from the residential zone to the commercial zone. Commuters can choose one of two major routes – Route 1 and Route 2. The travel time functions for the two routes are as follows:

$$t_1 = 12 + 0.01V_1,\ t_2 = 10 + 0.006V_2$$

where t_1 and t_2 = travel times on Routes 1 and 2, respectively (minutes), and V_1 and V_2 = volumes on Routes 1 and 2, respectively (vehicles/hour). The total commuter volume from the residential zone to the commercial zone is 2,800 vehicles/hour.

(a) Compute the traffic volume and travel time on the two routes at a user-equilibrium (UE) condition.

(b) To reduce the travel time on Routes 1 and 2, the new route, Route 3, has been added. Route 3 does not overlap with the two existing routes. This new route has the following travel time function:

$$t_3 = 10.2 + 0.006V_3$$

where t_3 = travel time on Route 3 (minutes) and V_3 = volume on Route 3 (vehicles/hour). Compute the new traffic volumes and travel times on the three routes at a UE condition.

(c) In the above problems, it was assumed that drivers always take the shortest path. Discuss the limitation of this assumption and how you would overcome the limitation in this route choice problem

Marking scheme:

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