NATIONAL EXAMINATION MAY 2018

16-Civ-B7, Transportation Planning and 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) Describe the factors affecting trip production and trip attraction in a zonal level. Explain their effects on trip generation and why.

(b) 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.

(c) Explain how residential development in low-density suburban areas affects mode choice and travel distance of work trips.

QUESTION 2:

Vehicles arrive in a single approach for two consecutive cycles at a signalized intersection. The signal has a 60-second cycle time which consists of a 30-second green interval and a 30-second red interval (ignore yellow interval). The arrival rates are assumed to be constant in both cycles. The arrival rate was 1,080 vehicles/hour in the first cycle and it decreased to 720 vehicles/hour in the second cycle. Assume that all vehicles in the queue formed on red pass through the intersection during the subsequent green interval at the saturation flow rate of 1,800 vehicles/hour immediately after the start of the green interval.

(a) Sketch a queueing diagram (cumulative arrival and departure curves over time) the approach during the two cycles.

(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 during the two cycles.

QUESTION 3:

The following is the number of trips and the number of households by the number of persons per household and the level of household income in a given traffic zone.

	Income					
	Low		Medium		High	
Persons/household	No. of households	No. of trips	No. of households	No. of trips	No. of households	No. of trips
1	93	222	149	616	96	360
2	72	341	138	853	27	205
3	59	417	125	1025	33	381
4	120	1010	109	1186	40	471
5 or more	13	107	37	457	33	423

The forecasted number of households in the study area for a target year is shown below.

	Income		
Persons/household	Low	Medium	High
1	120	280	130
2	100	220	40
3	90	190	50
4	150	180	70
5 or more	30	60	60

(a) Calculate the forecasted number of trips for each combination of the number of persons per household and the level of household income.

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

Trip rate = 0.46 + 1.96 * NPERSON + 1.66 * HINCOME

where
NPERSON = no. of persons per household (= 5 for 5 or more persons in household);
HINCOME = level of household income (= 0 for low income, = 1 for medium income, = 2 for high income)

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

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

QUESTION 4:

Consider the traffic flow on a one-lane road leading to a railway grade crossing. The capacity and free-flow speed of the traffic flow are 1,500 vehicles/hour and 60 km/hour, respectively. Traffic flow in normal traffic condition is characterized by a volume of 1,260 vehicles/hour and a speed of 42 km/hour. On one day, the gate was closed to allow a train to pass through the crossing and the vehicles stopped behind the gate while the train was passing. Six minutes later, the gate was opened and the vehicles immediately started crossing. Apply the Greenshields' model or the shock wave theory to determine:

(a) The maximum density and the density at capacity of the traffic flow.

(b) The length of the platoon immediately after the gate was opened.

(c) The speed of the front of the platoon after the gate was opened.

(d) The time it would take for the platoon to dissipate after the gate was opened. Assume that there is no congestion on the road further downstream of the railway grade crossing.

QUESTION 5:

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:

$$F_{ij} = \frac{1}{d_{ij}^2} \qquad \text{where } d_{ij} = \text{distance between zone i and zone j;}$$

(b) Assume that the total trip productions from zones 1 and 2 will increase to 600 and 800, respectively, in a target year. The total trip attractions to zones 1 and 2 will also increase 950 and 450, respectively. 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:

Consider the commuter work trips from residential areas to a central business district (CBD) during the morning peak period. Two major routes, Routes 1 and 2, connect residential areas to CBD. These two routes do not overlap each other. Assume that the link performance functions for these two routes are as follows:

$$t_1 = 11 + \left(\frac{V_1}{225}\right),\ t_2 = 6 + \left(\frac{V_2}{200}\right)$$

where t_i = travel times on Route i (minutes), and V_i = volume on Route i (vehicles/hour). Assume that the total peak hour volume from residential areas to CBD is 1,800 vehicles/hour.

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

(b) Assume that a new route, Route 3, is added. The route does not overlap with Routes 1 and 2. The link performance function of Route 3 is as follows:

$$t_3 = 7 + 2\left(\frac{V_3}{225}\right)$$

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 time on the three routes at UE conditions. Will the travel time in each route be reduced?

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

QUESTION 7:

Workers choose one of the following three travel modes for their trips: automobile, bus and light rail. Assume that the utility functions for travel by each mode are as follows:

$$V_a = 0.1 - 0.02 * IVTT_a - 0.15 * OVTT_a - 0.03 * TC_a$$
$$V_b = 0.2 - 0.03 * IVTT_b - 0.15 * OVTT_b - 0.03 * TC_b$$
$$V_r = -0.03 * IVTT_r - 0.15 * OVTT_r - 0.03 * TC_r$$

where

V_i = observable utilities for mode i (a = auto, b = bus, r = light rail);
$IVTT_i$ = in-vehicle travel time for mode i (minutes);
$OVTT_i$ = out-of-vehicle travel time for mode i (minutes);
TC_i = travel cost for mode i (dollars).

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

Mode	In-vehicle travel time (minutes)	Out-of-vehicle travel time (minutes)	Travel cost (dollars)
Automobile	12	7	2.5
Bus	20	12	0.75
Light rail	18	10	1.2

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

(b) In the part (a), the bus company increases the number of service routes and frequency of services to reduce passengers' waiting time. It is expected that in-vehicle travel time and out-of-vehicle travel time by bus will be reduced to 15 and 10 minutes, respectively. Assume that the travel costs for all modes are unchanged. Predict the probability of choosing each mode 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)	6
	(b)	7
	(c)	7
2	(a)	10
	(b)	5
	(c)	5
3	(a)	8
	(b)	8
	(c)	4
4	(a)	4
	(b)	10
	(c)	2
	(d)	4
5	(a)	8
	(b)	8
	(c)	4
6	(a)	6
	(b)	10
	(c)	4
7	(a)	7
	(b)	7
	(c)	6