NATIONAL EXAMINATION DECEMBER 2009

98-Civ-A6, 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) What is the expected shape of trip length distribution for trips made by automobile? Make a rough sketch of a trip length distribution for an urban area.

(b) Give two examples of travel demand management strategies to reduce fuel consumptions and emissions from vehicles. How would you predict these environmental impacts of the proposed strategies?

(c) Explain how land use development patterns affect transportation systems and how improved transportation facilities can induce new land use developments. Why is this important in travel demand forecasting?

QUESTION 2:

Suppose the observed arrival flow rate at an approach of a signalized intersection is 675 veh/hour. The signal has a 80-second cycle time with a 40-second green interval and a 40-second red interval (ignore yellow interval). Assume that all the vehicles in the queue formed on red pass through the intersection during the subsequent green interval at the saturation flow rate of 1800 veh/h (i.e. no spill over queue to the next cycle). Ignore driver reaction time and vehicle acceleration time at the start of the green interval.

(a) Sketch a queueing diagram (cumulative arrival and departure curves over time) for the approach in one cycle (80 seconds). Find the time when the queue clears after the green interval starts.

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

(c) Calculate the waiting time of the vehicle that arrives at the end of red interval.

(d) For one cycle, calculate 1) the total vehicle delay and 2) the average delay per vehicle.

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 number of persons per household and 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) Compare the methods used in (a) and (b) in terms of underlying assumptions and data requirements.

QUESTION 4:

Traffic flow on an one-lane road in normal conditions is characterized by a speed of 30 kilometres/hour and a density of 20 vehicles/kilometre. The capacity of the road is 1000 vehicles/hour and the free-flow speed is 37.5 kilometres/hour. On one day, one vehicle suddenly lost power and became stalled on the road. Thus, all the following vehicles had to stop behind the stalled vehicle. Six minutes later, the stalled vehicle regained power and started moving again. Apply the Greenshields' model or the shock wave theor y to determine:

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

(b) The length of the platoon immediately after the vehicle started moving again..

(c) The time it would take for the platoon to dissipate after the vehicle started moving again. Assume that there is no congestion on the road further downstream of the vehicle.

QUESTION 5:

Consider trip distribution within 4 zones in an area. The total trip production from zone 1 is 100. The travel times from zones 1 to zones 1, 2, 3 and 4 are 20, 50, 100, and 150 minutes, respectively. The trip attraction to zones 1, 2, 3 and 4 are 50, 200, 75, and 675, respectively. Assume that the number of trips produced from zone 1 to zone j (j = 1, 2, 3 and 4) is inversely proportional to the square of the travel time from zone 1 to zone j.

(a) Estimate the number of trips from zone 1 to zones 1, 2, 3 and 4 using the gravity model.

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

(c) Discuss the limitations of the gravity model.

QUESTION 6:

Consider the commuter work trips from the residential zone in a suburban area to the commercial zone in a downtown during the morning peak period. There are two major routes – Route 1 and Route 2. The travel time functions for the two routes are as follows:

$$t_1 = 22 + 24\left(\frac{V_1}{2700}\right), \quad t_2 = 12 + 18\left(\frac{V_2}{1800}\right)$$

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 peak hour volume from the residential zone to the commercial zone is 3,600 vehicles/hour.

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

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

$$t_3 = 14 + 32\left(\frac{V_3}{1800}\right)$$

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.

QUESTION 7:

Suppose there are three travel modes – automobile, bus and light rail. The calibrated utility functions for travel by each mode are as follows:

$$V_a = -0.30 - 0.04 * IVTT_a - 0.1 * OVTT_a - 0.03 * TC_a$$
$$V_b = -0.50 - 0.04 * IVTT_b - 0.1 * OVTT_b - 0.03 * TC_b$$
$$V_r = -0.40 - 0.04 * IVTT_r - 0.1 * OVTT_r - 0.03 * TC_r$$

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	8	2.5
Bus	20	13	1
Light rail	18	10	1.2

(a) Explain the effects of travel time and cost on mode choice based on the above utility functions. Do they make intuitive sense?

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

(c) In the part (b), the bus company improved the operational service through realigning routes and running more buses to reduce passengers' waiting time. Thus, in-vehicle travel time and out-of-vehicle travel time by bus are now reduced to 16 and 9 minutes, respectively. Assume that the travel cost is unchanged. Predict the probability of choosing each mode.

(d) Does the result in (c) make intuitive sense? Comment on the result based on the IIA (independent of irrelevant alternatives) property of the multinomial logit model.

Marking scheme:

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