CEE 123 Transport Systems 3: Planning & Forecasting

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Homework #3 -- Performance, Demand, Equilibration [S O L U T I O N S]

Problem 1 (10 points)
Three routes connect an origin and a destination with performance functions given as:

- Route #1: $t_1 = 5 + 1.5\ x_1$
- Route #2: $t_2 = 12 + 3.0\ x_2$
- Route #3: $t_3 = 2 + 0.2[x_3]^2$

with travel time t (in minutes), and route volume x (in kvph). The total O/D demand is 4.0 kvph.

a. Determine user equilibrium flows (volumes and travel times)

Test for Routes Used:

1. At x=0, t_1=5, t_2=12, and t_3=2 , so R#3 is used 1st, R#1 2nd, R#2 last;
2. At t_3=5, x_3=3.873 kvph. Until this volume is exceeded, all traffic uses R#3;
3. At t_2=12, x_3=7.07 kvph and x_1=4.67 kvph. Until total demand > 11.74 kvph, R#2 is not used;
4. At T_{od}=4 kvph, only routes 1 and 3 are used.

Solution

1. O/D Demand: T_{od} = 4.0 kvph
2. Perf Fct 1: $t_1 = 5 + 1.5\ x_1$
3. Perf Fct 3: $t_3 = 2 + 0.2[x_3]^2$
4. User Equil: $t_1 = t_3$
5. Solve simultaneously:
   x_1 =0.065 kvph, t_1 = 5.1 min
   x_3 =3.935 kvph, t_3 = 5.1 min

b. If all routes are not used, at what volume will all routes be used?

Solution: See "Test for Routes Used (above). The total O/D volume must exceed 11.74 kvph.

Problem 2 (10 points)
A multilane highway has two southbound lanes, each with a capacity c of 1.2 kvph per lane. Southbound traffic consists of 2.5 kvph with 1 occupant, 0.5 kvph with two occupants, 0.3 kvph with 3 occupants, and 20 buses per hour with 50 occupants each (assume a bus is represented as 1 passenger car equivalent (PCE). The BPR-type performance functions is:

$t_1 = t_o\ [1 + 1.15(x/c)^{6.87}]$

with travel time t (in minutes), 15 minute initial travel time, and route volume x and capacity c (both in kvph). Flows on the facility are currently in user equilibrium. An additional lane is being added (with c = 1.2 kvph). Assume that all qualified higher occupancy vehicles will use the new lane. What would the *total person-hours of travel* be if this new lane was open to:
(a) All traffic?
(b) Vehicles with 2 or more occupants only?
(c) What would the results would be if the new lane was restricted to vehicles with 3 or more occupants?

Solution:

(a) New lane open to all traffic:

1. Number of vehicles/hour N = 2.5 + 0.5 + 0.3 + 0.02 = 3.32 kvph
2. Number of persons/hour M = 2.5 + 0.5(2) + 0.3(3) + 0.02(50) = 5.4 kpph
3. $t_1 = 15\ [1 + 1.15(3.32/3.6)^{6.87}] = 24.89$ min (since 3 lanes for all traffic)
4. (24.89 min)(5.4 kpph)/(60 min/hr) = 2.24 k-person hours per hour

(b) New lane open to HOV2+ only:

<u>In 2 SOV lanes</u>

1. Number of vehicles/hour N_1 = 2.5 kvph
2. Number of persons/hour M_1 = 2.5(1) = 2.5 kpph
3. $t_1 = 15\ [1 + 1.15(2.5\text{kvph}/2.4)^{6.87}] = 37.83$ min
4. (37.83 min)(2.5 kpph)/(60 min/hr) = 1.576 k-person hours per hour

<u>In 1 HOV2+ lane</u>

1. Number of vehicles/hour N_2 = 0.5 + 0.3 + 0.02 = 0.82 kvph
2. Number of persons/hour M_2 = 0.5(2) + 0.3(3) + 0.02(50) = 2.9 kpph
3. $t_1 = 15\ [1 + 1.15(0.82\text{kvph}/1.2)^{6.87}] = 16.26$ min
4. (16.26 min)(2.9 kpph)/(60 min/hr) = 0.786 k-person hours per hour

=> 1.576+0.786 = 2.362 k-person hours per hour (0.122 k-person hours greater than (a))

(c) New lane open to HOV3+ only:

Given the results of part (b) that showed an increase in total person-hours traveled in the GP lanes when the new lane was restricted to HOV2+, it is likely that further restriction that increases volume in the GP lanes would increase total vehicle-hours traveled by more than it would be reduced in the HOV3+ lane (which is already close to free flow).

Problem 3 (20 points)
This problem is part of the Miasma Beach Project and provides you the opportunity to estimate trip generation models using Excel (as was done in HW 1). using the data provided in Task 3, Tables 2 and 3, estimate a home-based other (HBO) trip production and a home-based other (HBO) trip attraction model for the six internal TAZs.

1. Pick an explanatory variable from Table 2 that you think would be most strongly related to HBO productions in a TAZ. Estimate this model.
2. If this model gives acceptable results, add a second variable that you think would also be strongly related to HBO productions (if results are not acceptable, choose another single variable). Estimate this model.
3. Compare the two models. Which would you choose and why?
4. Repeat parts 1-3 for HBO attractions.

Solution Approach
HBO trip production models will be estimated as part of the CEE123 course project in Task 3. The objective of this exercise was to begin the process of model development. Attached is a copy of a spreadsheet containing the Miasma Beach data set and results for HBW trips (not for HBO). Included are five intuitive bivariate HBW production models (using the five residential variables), and a **sample** multivariate production model (adding CARS to the POP model) and two **sample** HBW attraction models (with total and retail employment, but not suggesting that other employment variables would not be viable choices). The bottom line is that building models is an art. There's no "right" answer, although there are many wrong answers (based on statistical or logical problems, or both). Note also that models estimated on 6 data points are virtually never acceptable.

Problem EC (10 points) [Extra Credit for 123; Required for 223]
Solution available to those who submit extra credit attempt.

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