

Operations & Management I

Exam

14 April 2010

13:30-17:00

	Points
Question 1 (a: 3, b: 5, c: 2, d: 10)	20
Question 2 (a: 3, b: 3, c: 4)	10
Question 3 (a: 4; b: 4, c: 2)	10
Question 4 (a: 5, b: 5, c: 5, d: 5)	20
Question 5 (a: 2, b: 4, c: 4, d: 5)	15
Question 6 (5)	5
Question 7 (a: 6, b: 6, c: 3, d: 5)	20
Total	100

The exam consists of 7 questions. Points are listed in the table above. There are two parts and you are asked to use separate sheets for each part.

Good luck,

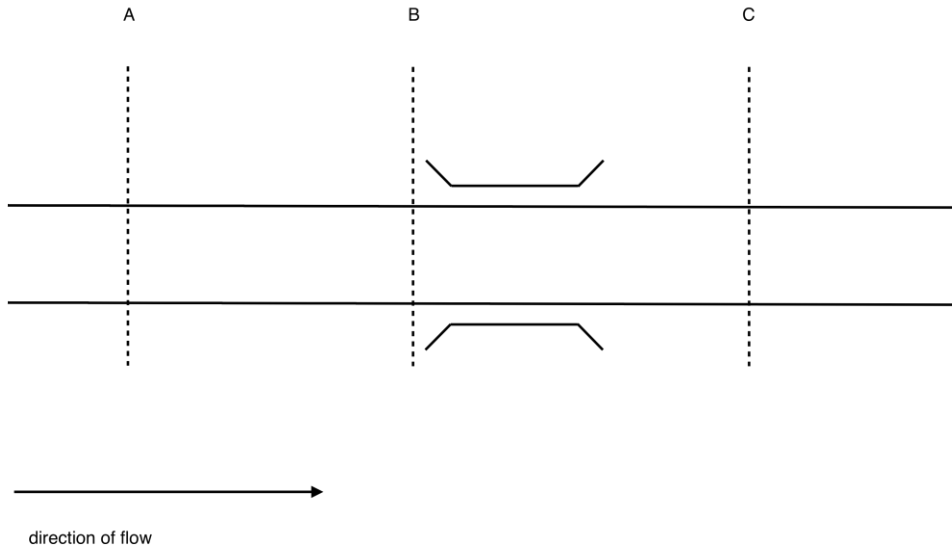
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Part 1

Please write your derivations and answers for part 1 on separate paper sheets.

Question 1

Consider a stretch of highway with a bottleneck as depicted below. Further at three locations A, B and C pairs of inductive loop detectors are installed.



- Which traffic flow characteristics can be measured using these loop detectors?
- On a regular day demand is relatively low before the peak, during the peak congestion occurs, and after the peak, demand is low again. Draw measurements in the speed-flow plane (x-axis = flow, y-axis is speed) for each location A, B and C for this period (pre-peak, peak and post-peak).
- With these measurements the road authority wants to estimate capacity. From which location (A, B or C) do you think it is best to use measurements for this purpose? Explain.
- In the table below speed-flow measurements are listed. Determine the capacity using the product-limit method

Flow (veh/h)	1800	1900	1950	2000	2050	2100	2150	2200	2250	2280	2300	2350	2400
Speed (km/h)	100	90	60	90	70	90	30	80	50	85	40	87	50

Question 2

The BPR function gives the link travel time as a function of the link flow rate q ,

$$TT(q) = TT_f \cdot \left[1 + \alpha \cdot \left(\frac{q}{c} \right)^\beta \right]$$

Here,

TT_f – travel time under free flow conditions,

c – design capacity,

α, β – constants.

- What practical phenomenon does the constant β signify? Give a typical value of β .
- The BPR function is based on the assumption that flow arrives in a uniform pattern (i.e. same speed, equal headways). In reality it is usually not the case. How does this assumption affect the accuracy of the results?
- In order to calibrate the BPR function for a particular network link, what procedures have to be taken?

Question 3

The Webster formula gives the average delay per vehicle at a signalised intersection as

$$\bar{W} = \frac{C(1-u)^2}{2(1-y)}.$$

Here,

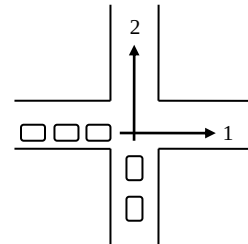
C – cycle time (s),

u – effective green ratio,

y – flow ratio, $y = q/s$,

q – flow arrival rate (veh/hr),

s – flow departure rate (veh/hr).



Consider a particular intersection where only two movements are present (see Figure).

The flow rates are given as

Movement	q	s
1	900	1800
2	600	1800

- Given that $C=60s$ and $u_1=u_2=0.5$, calculate the average delay for each movement.
- Given that $C=60s$ and $u_1+u_2=1$, design a signal pattern so that the total delay is minimised.
- Discuss how, according to the model as well as in practice, the duration of C affects the results of (a) and (b).

Question 4

A suburb road has only one lane in each direction. For safety reasons, overtaking is not allowed (double solid centrelines). On a particular day, traffic had been travelling steadily at speed 60km/h with headway 2s. At time t , a truck entered this road at junction n . The truck had a speed of 30km/h. Accordingly, upstream vehicles had to adjust to this speed and as such formed a queue behind the truck. It is known that traffic density in this queued area is x (veh/km). The truck left the road at junction $n+1$, which is 1km downstream of junction n . Afterwards vehicles in the queue started to resume their normal speed.

- a) Calculate the shockwave speed for the end of the queue (as an expression of x).
- b) Analyse the movement of the queued area over time.
- c) Discuss the practical relevance of shockwaves in general, and the implications for traffic management that we can draw from queue movements.
- d) Shockwave is a macroscopic description of traffic flow. In the scenario above, we have made some implicit assumptions on a microscopic level. Discuss whether these assumptions are realistic or not and how they affect the macroscopic modelling results.

Part 2:

Please write your derivations and answers for part 2 on separate paper sheets.

Question 5

Principal Component Analysis (PCA) and Cluster Analysis are two data editing methods.

a) What is the difference between PCA and clustering. You may give examples.

Consider the following 6 data points (or items): [1,3], [2,4], [3,4], [5,2], [6,4] and [8,1].

b) Plot these points in a graph. Use euclidean distance to cluster these items according to the **nearest** neighbour method. For each iteration, give the clusters and the cluster size (of the new clusters). The latter is the distance between the data-points that are connected in the given iteration.

c) Plot the same points in a new graph. Use euclidean distance to cluster these items according to the **farthest** neighbour method. For each iteration, give the clusters and the cluster size (of the new clusters).

d) Make a dendrogram (number of clusters vs. cluster size) for both clustering methods. How many clusters would you choose according to the dendrogram? Suppose you choose to cluster the points in 2 clusters: use the answers from b) and c) to draw these two clusters in the respective graphs. Considering both clustering results, which clustering method would you use in this case? Explain your answers.

Question 6

Consider observed route choices of two different OD pairs. For both OD pairs, 3 routes occur in the observations. These are denoted by r_1 , r_2 , r_3 .

- The first OD-pair yields: [r_1 , r_2 , r_2 , r_3 , r_1 , r_1 , r_3 , r_1 , r_2 , r_3]
- The second OD-pair yields: [r_1 , r_1 , r_2 , r_1 , r_1 , r_1 , r_3 , r_1 , r_1 , r_1]

We now consider two route choice models in which the model probabilities are the same for all travelers per OD pair.

- For the first OD pair, the first model yields: $p_1 = 0.40$, $p_2 = 0.35$, $p_3 = 0.25$
- For the second OD pair, the second model yields: $p_1 = 0.60$, $p_2 = 0.20$, $p_3 = 0.20$

Give the log likelihoods for the first model-OD pair and second model-OD pair. Also, give the maximum log likelihood for both OD pairs. These maximum likelihoods are the likelihoods for which the probabilities p_1 , p_2 , p_3 (of r_1 , r_2 , r_3 respectively) describe the observations in the best way. Comparing the log likelihoods of the models with the maximum likelihoods, which model do you think is better? Explain your answer.

Question 7

Consider two cycle paths in opposite directions. For both paths, daily volumes were measured for 10 days. For cycle path 1 and 2, the volumes are given by q_1 and q_2 respectively:

- $q_1 = [299, 398, 871, 255, 987, 1065, 340, 342, 472, 192]$
- $q_2 = [313, 397, 877, 259, 1001, 1061, 345, 347, 479, 198]$.

a) Are the mean volumes $mean(q_1)$ and $mean(q_2)$ significantly different? Use a 2-sigma confidence level. Explain all steps.

The volumes of cycle path 1, q_1 , are fitted by the following model, q_{model} :

$$q_{model} = q_0 \exp[0.1(t_s - t_p)], \quad \text{with}$$

- q_0 : the volume during “average” weather conditions
- t_s : the duration of sunshine (in hours)
- t_p : the duration of rain (in hours)

From the fit the values 0.1, and $q_0 = 500$ (per day) were obtained.

From the weather station, we got: $t_s = [2, 4, 7, 1, 9, 9, 3, 3, 5, 0]$ and $t_p = 10 - t_s$.

The total amount of hours during the day (excluding the night) was thus 10, and there is a correlation of -1 between t_s and t_p (note that in reality the correlation is less strong, but this was done for convenience).

The errors are: $err(q_0) = 10$, $err(t_s) = 0.2$ and $err(t_p) = 0.2$. The errors in q_0 and errors in t_s (and in t_p) are uncorrelated. Due to the negative correlation between t_s and t_p , the individual errors in t_s and in t_p are also negatively correlated with correlation coefficient -1. Finally, there is random variation in the observed q_1 . This variation is estimated to be $err(q_1) = \sqrt{q_{model}}$

b) Give an approximation of the model error, $err(q_{model})$, as function of $err(q_0)$, $err(t_s)$ and $err(t_p)$. Put the values of $err(q_0)$, $err(t_s)$ and $err(t_p)$ in your approximation

c) Give the model values q_{model} , model errors $err(q_{model})$, “observation” errors $err(q_1)$ and total errors of model and observation combined for all 10 days.

d) Perform a Chi-square goodness of fit test for the model. Should the model be rejected? Take a 99% confidence interval.