

UNIVERSITY OF TWENTE.

Traffic Operations
201100005

Examination

17 April 2014
13:45-17:15

Questions	Points
PART I	50
Question 1 (a: 5, b: 5)	10
Question 2 (a: 4, b: 2, c: 2, d: 2)	10
Question 3 (a: 3, b: 2, c: 2, d: 3)	10
Question 4 (a: 3, b: 3, c: 2)	8
Question 5 (a: 2, b: 4, c: 3, d: 3)	12
PART II	50
Question 6 (a: 4, b: 3)	7
Question 7 (a: 4, b: 6)	10
Question 8 (a: 3, b: 7, c: 5, d: 4, e: 6, f: 4, g: 4)	33
Total	100

The exam consists of 8 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.

Eric van Berkum, Sander Veenstra and Tom Thomas

Part I

Please write your derivations and answers for Part I on separate paper sheets.

Question 1 (10 points)

A much-used assumption for a fundamental k - q diagram is that it is triangular in shape,

(a) Make realistic assumptions concerning free speed, capacity, jam density, optimal density, speed at capacity etc. and draw the k - q diagram.

(b) Derive the shape of the associated k - u and q - u diagrams, and also make a drawing.

Question 2 (10 points)

The *psycho-spacing model* (Wiedemann, 1974) describes drivers' car-following behaviour and is widely used in simulation softwares such as VISSIM. It observes that drivers as human beings are not able

- to observe a *stimulus* lower than a given value (perception threshold),
- to evaluate a situation and determine the response precisely,
- to manipulate the gas & brake pedals precisely,

and that drivers do not want

- to be permanently occupied with the car-following task.

(a) What is the stimulus used in the psycho-spacing model? Consider the scenario where vehicle j is approaching vehicle i ($u_j > u_i$): describe the car-following stages according to the psycho-spacing model.

(b) Are there any other stimuli present in reality? Describe their relevance in car following models (in general).

(c) What element(s) is (are) introduced in the psycho-spacing model to capture the effect that drivers cannot react precisely?

(d) What element(s) is (are) introduced in the psycho-spacing model to capture the effect that drivers do not want to be constantly occupied with the car-following task?

Question 3 (10 points)

Shock waves describe the boundary conditions in the time-space domain that demark a discontinuity in flow-density conditions. It captures the transition of different traffic states (esp. congested zone vs. non-congested zone). Theoretical analysis of shock wave speed often assumes that this transition takes place in an instantaneous manner.

- (a) Consider a microscopic simulation software that is capable of realising this phenomenon of instantaneous transition. What would be the control rules for an individual vehicle encountering the shock wave? Use symbols and formulae if necessary.
- (b) What is the unrealistic part of the above control rules? How do drivers actually behave in reality?
- (c) Compared to instantaneous transition, how do shock waves look like in reality?
- (d) Consider the shock waves caused by a traffic accident which partially blocks the highway. Qualitatively describe the shock wave and queue movements in this case; discuss the implications for traffic management that we can draw from this shock wave analysis.

Question 4 (8 points)

Read the following text on delay at intersections and answer the questions below.

The inherent lost time that comes from each signal change is wasted time that does not occur when intersections are uncontrolled. It comes at quite a surprise to most of the Western World, where traffic signals are plentiful, but there are intersections that perform quite well without any form of control. There is an infamous video on YouTube that shows an uncontrolled intersection in India where drivers somehow navigate through a busy, chaotic environment smoothly and efficiently. The video is humorous to watch, but it shows a valid point that uncontrolled intersections can indeed work and are quite efficient. However, the placement of traffic signals is for safety, as drivers entering an uncontrolled intersection have a higher likelihood of being involved in a dangerous accident, such as a T-bone or head-on collision, particularly at high speed.

- (a) In the Netherlands, the majority of intersections without traffic signals can be best described as rule-controlled. Give an example of such rule-controlled intersections and describe the rules; use drawings if necessary.
- (b) In the Netherlands, many signal-controlled intersections switch to an all-yellow period at night. During this time, traffic signals at all directions show a flashing yellow. Describe the type of intersections that this design is suitable for and discuss the rationale behind this design.
- (c) In the concept of *Shared Space*, intersections are uncontrolled. What are the pro's and con's of shared space regarding intersection delay and safety?

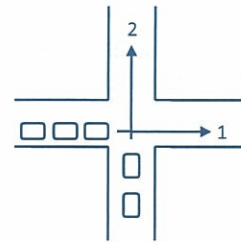
Question 5 (12 points)

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

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

where,

- 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

- (a) Given that $C=60s$ and $u_1=u_2=0.5$, calculate the average delay for each movement.
- (b) Given that $C=60s$ and $u_1+u_2=1$, design a signal pattern so that the total delay is minimised.
- (c) Discuss how, according to the model as well as in practice, the duration of C affects the results of (a) and (b).
- (d) How does *traffic signal actuation* contribute to the reduction of delays at intersections?

Part II

Please write your derivations and answers for Part II on separate paper sheets.

Question 6 (7 points)

- (a) Draw a dendrogram and use this illustration to explain the main concept behind cluster analysis.
- (b) Hierarchical clustering is one way to cluster items. Mention two other cluster methods. Explain the difference between these two methods.

Question 7 (10 points)

For two OD pairs, revealed mode choices are observed. In both cases, the respondents can choose between car (c), bicycle (b) and public transport (pt).

- The first OD-pair yields: [c, b, b, c, b, b, b, c, pt, pt]
- The second OD-pair yields: [c, c, c, b, b, b, c, c, c, c]

We now consider a mode choice model, called the MC-model. According to this model, probabilities are the same for all travellers per OD pair.

- For the first OD pair: $p_{car} = 0.4$, $p_{bike} = 0.3$, and $p_{PT} = 0.3$
- For the second OD pair: $p_{car} = 0.7$, $p_{bike} = 0.2$, and $p_{PT} = 0.1$

- (a) Give the $\ln$ (log with base e) likelihood of obtaining the observed choices given the MC model. Do this separately for both OD pairs.
- (b) Give the maximum likelihood, i.e. the likelihood of obtaining these observations given the best model for these observations (yielding the maximum likelihood). Do this separately for both OD pairs. How would you evaluate the reliability of the MC-model result for OD 1 compared to that for OD 2?

Question 8 (33 points)

The daily bicycle intensity on a cycle path has been measured during seven days. The following intensities were observed: [220, 114, 110, 93, 183, 60, 187]. For these days, the amount of precipitation has also been measured. Their respective values (in mm) are: [0, 2, 2, 3, 0, 7, 1]. The following (exponential) model is fitted to these observed intensities:

$$q = q_0 e^{aP} \quad \text{for } P \geq 0, \text{ with}$$

- q : daily bicycle demand
- q_0 : demand during dry days
- P : amount of daily precipitation (in mm)
- $a < 0$: factor that describes how fast the demand decreases with increasing P

(a) For these observed intensities, the model fit yields $q_0 = 200$ and $a = -0.20$. Plot the model intensities versus the observed intensities. Plot the model values along the x-ordinate, and the observed values along the y-ordinate. Do you think the model is a good fit to the observations? Motivate your answer.

(b) Due to variation in the process, observed intensities are expected to be randomly distributed according to a Poisson distribution. Given this uncertainty, use a significance level of $\alpha = 0.01$ to test whether the model should be rejected or not.

For questions (c) – (g), consider the following:

- q_0 and a are variables (thus not fixed at respectively 200 and -0.20) unless indicated otherwise.
- the (standard) errors in q_0 and a are respectively $err(q_0)$ and $err(a)$.
- $abs(err(a) / a) = 2 * abs(err(q_0) / q_0)$: the magnitude of the relative error in a is twice the magnitude of the relative error in q_0 .

(c) Express the error in q due to the error in q_0 as function of $err(q_0)$, and express the error in q due to the error in a as function of $err(a)$.

(d) Suppose: $q_0 = 200$ and $a = -0.20$. Which of the two errors, error in q_0 or error in a , has the largest influence on the error in q ?

(e) The individual errors in q_0 and a are negatively correlated with correlation coefficient of -1 . Express the total error in q (due to the errors in both q_0 and a) as function of $err(a)$ or as function of $err(q_0)$, but not as function of both.

(f) Would the error in q be smaller, similar or larger when the individual errors in q_0 and a would be uncorrelated? Explain your answer.

(g) Suppose: $q_0 = 200$, $a = -0.20$, and $err(q_0) / q_0 = 0.1$ (10%). Estimate the total relative error in q , i.e. $err(q) / q$, for different amounts of precipitation, namely $P = 0, 3$ and 6 mm. Explain the differences in the obtained errors.

T-distribution: Critical values of t

Df	Significance level						
	Two-tailed test:	0.1	0.05	0.02	0.01	0.002	0.001
	One-tailed test:	0.05	0.025	0.01	0.005	0.001	0.0005
1		6.314	12.706	31.821	63.657	318.309	636.619
2		2.920	4.303	6.965	9.925	22.327	31.599
3		2.353	3.182	4.541	5.841	10.215	12.924
4		2.132	2.776	3.747	4.604	7.173	8.610
5		2.015	2.571	3.365	4.032	5.893	6.869
6		1.943	2.447	3.143	3.707	5.208	5.959
7		1.894	2.365	2.998	3.499	4.785	5.408
8		1.860	2.306	2.896	3.355	4.501	5.041
9		1.833	2.262	2.821	3.250	4.297	4.781
10		1.812	2.228	2.764	3.169	4.144	4.587
11		1.796	2.201	2.718	3.106	4.025	4.437
12		1.782	2.179	2.681	3.055	3.930	4.318
13		1.771	2.160	2.650	3.012	3.852	4.221
14		1.761	2.145	2.624	2.977	3.787	4.140
15		1.753	2.131	2.602	2.947	3.733	4.073
16		1.746	2.120	2.583	2.921	3.686	4.015
17		1.740	2.110	2.567	2.898	3.646	3.965
18		1.734	2.101	2.552	2.878	3.610	3.922
19		1.729	2.093	2.539	2.861	3.579	3.883
20		1.725	2.086	2.528	2.845	3.552	3.850
21		1.721	2.080	2.518	2.831	3.527	3.819
22		1.717	2.074	2.508	2.819	3.505	3.792
23		1.714	2.069	2.500	2.807	3.485	3.768
24		1.711	2.064	2.492	2.797	3.467	3.745
25		1.708	2.060	2.485	2.787	3.450	3.725
26		1.706	2.056	2.479	2.779	3.435	3.707
27		1.703	2.052	2.473	2.771	3.421	3.690
28		1.701	2.048	2.467	2.763	3.408	3.674
29		1.699	2.045	2.462	2.756	3.396	3.659
30		1.697	2.042	2.457	2.750	3.385	3.646
40		1.684	2.021	2.423	2.704	3.307	3.551
50		1.676	2.009	2.403	2.678	3.261	3.496
60		1.671	2.000	2.390	2.660	3.232	3.460
70		1.667	1.994	2.381	2.648	3.211	3.435
80		1.664	1.990	2.374	2.639	3.195	3.416
90		1.662	1.987	2.368	2.632	3.183	3.402
100		1.660	1.984	2.364	2.626	3.174	3.390
200		1.653	1.972	2.345	2.601	3.131	3.340
300		1.650	1.968	2.339	2.592	3.118	3.323
400		1.649	1.966	2.336	2.588	3.111	3.315
500		1.648	1.965	2.334	2.586	3.107	3.310
600		1.647	1.964	2.333	2.584	3.104	3.307
Z		1.645	1.960	2.326	2.576	3.090	3.291

χ^2 (Chi-Squared) Distribution: Critical Values of χ^2

Df	Significance level									
	One Tailed Test:	0.2	0.15	0.1	0.05	0.025	0.01	0.005	0.0025	0.001
1		1.64	2.07	2.71	3.84	5.02	6.63	7.88	9.14	10.83
2		3.22	3.79	4.61	5.99	7.38	9.21	10.60	11.98	13.82
3		4.64	5.32	6.25	7.81	9.35	11.34	12.84	14.32	16.27
4		5.59	6.74	7.78	9.49	11.14	13.23	14.86	16.42	18.47
5		7.29	8.12	9.24	11.07	12.83	15.09	16.75	18.39	20.51
6		8.56	9.45	10.64	12.53	14.45	16.81	18.55	20.25	22.46
7		5.80	10.75	12.02	14.07	16.01	18.48	20.28	22.04	24.32
8		11.03	12.03	13.36	15.51	17.53	20.09	21.95	23.77	26.12
9		12.24	13.29	14.68	16.92	19.02	21.67	23.59	25.46	27.83
10		13.44	14.53	15.99	18.31	20.48	23.21	25.19	27.11	29.59
11		14.63	15.77	17.29	19.68	21.92	24.72	26.76	28.73	31.26
12		15.81	16.99	18.55	21.03	23.34	26.22	28.30	30.32	32.91
13		15.58	18.90	19.81	22.36	24.74	27.69	29.82	31.88	34.53
14		18.15	19.4	21.06	23.68	26.12	29.14	31.32	33.43	36.12
15		19.31	20.60	22.31	25.00	27.49	30.58	32.80	34.95	37.70
16		20.47	21.79	23.54	26.30	28.85	32.00	34.27	36.46	39.25
17		21.61	22.98	24.77	27.59	30.19	33.41	35.72	37.95	40.79
18		22.76	24.16	25.99	28.87	31.53	34.81	37.16	39.42	42.31
19		23.90	25.33	27.20	30.14	32.85	36.19	38.58	40.88	43.82
20		25.04	26.50	28.41	31.41	34.17	37.57	40.00	42.34	45.31
21		26.17	27.66	29.62	32.67	35.48	38.93	41.40	43.78	46.80
22		27.30	28.82	30.81	33.92	36.78	40.29	42.80	45.20	48.27
23		28.43	29.98	32.01	35.17	38.08	41.64	44.18	46.62	49.73
24		29.55	31.13	33.20	36.42	39.36	42.98	45.56	48.03	51.18
25		30.68	32.28	34.38	37.65	40.65	44.31	46.93	49.44	52.62
26		31.79	33.43	35.56	38.89	41.92	45.64	48.29	50.83	54.05
27		32.91	34.57	36.74	40.11	43.19	46.96	49.64	52.22	55.48
28		34.03	35.71	37.92	41.34	44.46	48.28	50.99	53.59	56.89
29		35.14	36.85	39.09	42.56	45.72	49.59	52.34	54.97	58.30
30		36.25	37.99	40.26	43.77	46.98	50.89	53.67	56.33	59.70
40		47.27	49.24	51.81	55.76	59.34	63.69	66.77	69.70	73.40
50		53.16	60.35	63.17	67.50	71.42	76.15	79.49	82.66	86.66
60		68.97	71.34	74.40	79.08	83.30	88.38	91.95	95.34	99.61
80		90.41	93.11	96.58	101.9	106.6	112.3	116.3	120.1	124.8
100		111.7	114.7	118.5	124.3	129.6	135.8	140.2	144.3	149.4