UNIVERSITY OF BOLTON

SCHOOL OF THE BUILT ENVIRONMENT & ENGINEERING – RAK CAMPUS

BSc (HONS) CIVIL ENGINEERING

SEMESTER ONE EXAMINATION 2009/2010

TRANSPORT ENGINEERING

MODULE NO: BLT2020

Date: Friday 22 January 2010 **Time: 2.00 pm – 4.00 pm**

INSTRUCTIONS TO CANDIDATES:

There are FOUR questions.

Answer THREE questions.

All questions carry equal marks.

Marks for parts of questions are shown in brackets.

Total 75 marks for the paper.

There are two pages of a transportation data sheet attached.

School of the Built Environment & Engineering – RAK Campus
BSc (Hons) Civil Engineering
Semester One Examination 2009/2010
Transport Engineering
Module No. BLT2020

1) a) Differentiate between types of traffic survey that might be used for volume counts as against origins and destinations. Do so by specifying the major components of data collected in each type of survey. Also, suggest uses to which each type of data might be put.

(6 marks)

b) Estimate the 95% confidence interval for Annual Average Daily Traffic from a 12 hour count of 35,000 vehicles, which itself has a 95% confidence interval of 10% and is taken an inter-urban road in May. Comment on the size of the estimated confidence interval relative to that of the original count. Relevant factors and coefficients of variation are provided in Table A1.1 and Table A1.2 in Appendix 1. A 95% confidence interval is represented by ±1.96 standard deviations from the mean.

(14 marks)

c) Estimate the eighty-fifth percentile speeds on two roads where the mean speeds and standard deviations of speed have been determined as follows: Road A: $\bar{x} = 50.2kph$, and $s = 8.2kph$, Road B: $\bar{x} = 54.2kph$, and $s = 1.7kph$. Suggest, with reasons, which road may be more susceptible to speed related collisions.

(5 marks)

Total 25 marks

Please turn the page

2) a) i) Differentiate between an accident investigation and a safety audit and summarise the stages in a single site investigation and the different stages of a safety audit.

(6 marks)

ii) Comment on the unreliability of police recorded STATS19 accident data.

(2 marks)

b) Accident data for Bolton show a reduction in child killed and seriously injured (KSI) accidents from 75 in the period 2003 to 2005 inclusive to 49 in the period 2006 to 2008 inclusive. With no other information about district wide changes in accident numbers, is the reduction in child KSI accident numbers significant at the 5% level?

(8 marks)

c) All non-child KSI accidents in the district in 2003 to 2005 inclusive were 4489 reducing to 3545 in the period 2006 to 2008 inclusive. Is the reduction in child KSI in (b) significant at the 5% level against this general decline in accident numbers?

(9 marks)

Total 25 marks

Please turn the page

3) a) What functions do traffic signals perform, and what are their advantages and disadvantages relative to other forms of junction design.

(4 marks)

b) A four arm junction is controlled by traffic signals.

i) Draw a Stage diagram for the operation of the junction based on the following information:

- All movements are allowed at the junction (traffic may turn left and right and proceed straight on from every approach).
- There are two approach lanes from the North and the South, and one approach lane from the East and the West.
- No traffic other than right turning traffic uses the offside lane on the approaches from the North and the South.
- There are three stages, movements from the East and West, followed by the right turns from the North and South, followed by only the straight on and left turn movements from the North and the South.

(2 marks)

ii) The right turn lanes from the North and the South are both 3.5 metres wide and on the level. The radius of turn for both movements is 15 metres. Calculate the saturation flow for these lanes assuming that they do not hook.

(2 marks)

iii) Calculate the optimum cycle time and the actual green times for each stage from the morning peak data provided in Table Q3 and the saturation flows determined in (ii) above. Assume that the intergreen is 5 seconds, the amber is 3 seconds and the starting and ending lost times before and after each green aspect total 2 seconds.

Table Q3

Road	Left turn flow pcu/hr	Straight on flow pcu/hr	Right turn flow pcu/hr	Nearside Saturation flow pcu/hr
North Road	195	355	225	2000
East Road	55	480	60	1900
South Road	210	425	200	2000
West Road	60	440	70	1900

PCU represents passenger car units

(12 marks)

Question 3 continued over the page…

Question 3 continued

c) A developer wishes to construct a housing development which will feed traffic onto the junction via West Road. By considering the relative sizes of the 'y' values for the West and the East Road, suggest how many additional passenger car units per hour the development would be allowed to introduce to the junction without affecting the optimum cycle time.

(5 marks)

Total 25 marks

4 a) Figure Q4 shows the layout of a priority junction and Table Q4 provides demand flows in passenger car units per hour. Assuming the width of the major road is 8.5 metres, and the visibility to the right for the turn from Arm C to Arm B is 150 metres, determine the ratio of flow to capacity for the movement from Arm C to Arm B. is it below an acceptable limit?

Figure Q4

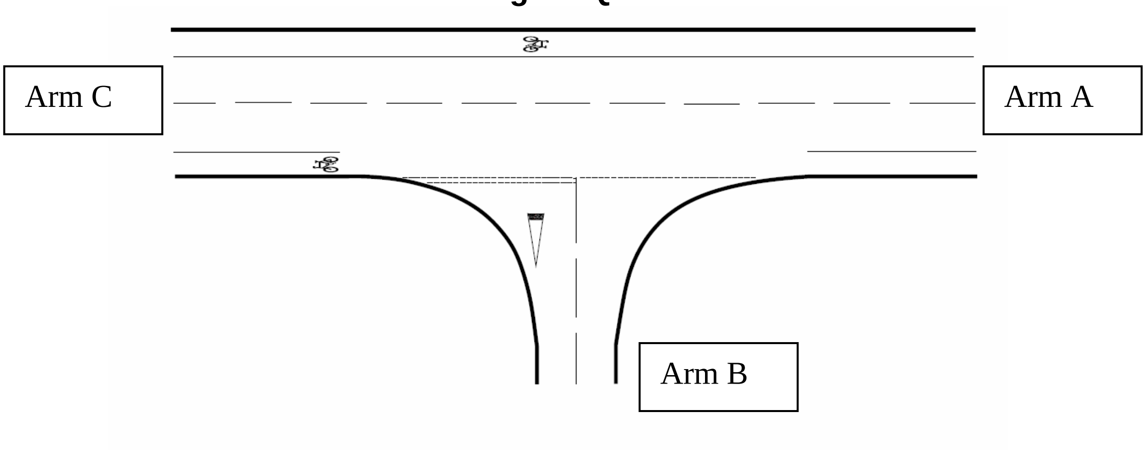

Table Q4

Arm	Left turn flow (pcu/hr)	Straight on flow (pcu/hr)	right turn flow (pcu/hr)
A	50	350	-
B	500	-	470
C	-	350	330

(6 marks)

Question 4 continued over the page…

Question 4 continued

b) The junction in part (a) is to be converted to a roundabout. Based on an inscribed circle diameter of 30 metres, an entry radius of 20 metres, an entry angle of 30^0, and an approach half width of 3.65 metres, determine a suitable entry width, and flare length for Arm B.

(15 marks)

c) Without performing the calculation, comment on the capacity provides by the priority junction depicted in part (a) for the minor road flows.

(4 marks)

Total 25 marks

END OF QUESTIONS

Please turn the page

School of the Built Environment & Engineering – RAK Campus
BSc (Hons) Civil Engineering
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Appendix 1

Table A1.1: E-Factors for Converting 12-hour to 16-hour Flows

Road Type	E	CV_E
Main-Urban	1.18	4%
Inter-Urban	1.15	3.5%
Recreational/Inter-Urban	1.13	2.5%

Table A1.2: M-Factors for Converting 16-hour Flows to 24-hour AADT

	Main Urban		Inter-Urban		Recreational/ Inter-Urban	
	M	CV_M	M	CV_M	M	CV_M
April	1.016	6.5%	1.115	8%	1.271	12%
May	0.989	6.5%	1.071	8%	1.140	10%
September	1.005	6.5%	1.016	8%	0.962	11%
October	1.000	6.5%	1.068	8%	1.142	12%

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Transport Engineering and Planning
Transport Data Sheet

Appendix A

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Traffic Signal Control

$$l = l_1 + l_2 ; \qquad L = \sum_{stages}(I - a) + \sum_{stages} l$$

$$y = \frac{q}{s} ; \qquad Y = \sum_{stages} y_{\max}$$

$$C_0 = \frac{1.5L + 5}{1 - Y} ; \qquad g'_n = \frac{y_n}{Y}(C_0 - L)$$

$$g_n = g_n' - a + l$$

l = total lost time per stage, l_1 = starting lost time
l_2 = stopping lost time
I = intergreen, a = amber time, L = lost time per cycle
q = flow (PCU/hr)
s = saturation flow per hour (see below)
C_0 = optimum cycle time
y_{max} = largest y value for stage
g'_n = effective green time allocated for stage n
$y_n = y_{max}$ value for stage n
g_n = actual green time
g'_n = effective green time

$$S_1 = (S_0 - 140\delta_n)/(1 + 1.5\frac{f}{r})$$ (un-opposed flow saturation)

$$S_0 = 2080 - 42\delta_g G + 100(w_l - 3.25)$$

$$S_2 = S_g + S_c$$ (opposed flow saturation)

$$S_g = (S_0 - 230)/(1 + (T - 1)f)$$

$$T = 1 + \frac{1.5}{r} + \frac{t_1}{t_2}$$

$$t_1 = 12X_0^2/(1 + 0.6(1 - f)N_s)$$

$$t_2 = 1 - (fX_0)^2$$

$$S_c = P(1 + N_s)(fX_0)^{0.2}3600/\lambda c$$

$$X_0 = q_0/\lambda n_l s_0$$

δ_n = nearside lane dummy variable
f = proportion of turning vehicles in a lane
r = radius of curvature of vehicle path
δ_g = gradient dummy variable
G = gradient (percent)
W_l = lane width at entry (m)
N_s = number of storage spaces for right turners which do not block straight ahead movement
P = PCU factor= $1 + [P_1\%(P_1 - 1)] + [P_2\%(P_2 - 1)] + [P_3\%(P_3 - 1)] + ...$
λ = proportion of cycle effectively green for phase under consideration
c = cycle time
q_0 = flow on opposing arm (excluding non-hooking right turners)
n_l = number of lanes on opposing arm
s_0 = saturation flow per lane of opposing arm

$$d = \frac{c(1-\lambda)^2}{2(1-\lambda x)} + \frac{x^2}{2q(1-x)} - 0.65\left(\frac{c}{q^2}\right)^{1/3} x^{(2+5\lambda)}$$

d = delay in seconds
c = cycle time in seconds
λ = effective green time / cycle time
q = flow (converted to PCU per second)
s = saturation flow (PCU per second)
x = degree of saturation of the approach (=q / λs)

Queue Length is the larger of $qd + \frac{qr}{2}$ or qr where r is the length of effective red ($c - g'_n$).

Roundabout Design

$$S = 1.6\frac{e - v}{l'} ; \qquad x_2 = v + \frac{e - v}{1 + 2S} ; \qquad M = e^{\left(\frac{D-60}{10}\right)}$$

$$t_D = 1 + \frac{0.5}{1 + M} ; \qquad F = 303x_2 ; \qquad f_c = 0.210t_D(1 + 0.2x_2)$$

$$k = 1 - 0.00347(\phi - 30) - 0.978(\frac{1}{r} - 0.05)$$

$$\boxed{Q_e = k(F - f_cQ_c)}$$; and

$$\boxed{Q_e = k(1.11F - 1.4f_cQ_c)}$$ (grade separation)

where:
e = entry width
v = approach half width
l' = average effective flare length
D = Inscribed Circle Diameter
Φ= entry angle
r = entry radius

Priority Junction Design

$$q^S_{B-A} = X_1\{627 + 14W_{CR} - Y[0.364q_{A-C} + 0.144q_{A-B} + 0.229q_{C-A} + 0.520q_{C-B}]\}$$

$$q^S_{B-C} = X_2\{745 - Y[0.364q_{A-C} + 0.144q_{A-B}]\}$$

$$q^S_{C-B} = X'_2\{745 - 0.364Y[q_{A-C} + q_{A-B}]\}$$

$$Y = (1 - 0.0345W)$$

$$X_1 = (1 + 0.094(w_{B-A} - 3.65))(1 + 0.0009(V_{rB-A} - 120))(1 + 0.0006(V_{lB-A} - 150))$$

$$X_2 = (1 + 0.094(w_{B-C} - 3.65))(1 + 0.0009(V_{rB-C} - 120))$$

$$X_2' = (1 + 0.094(w_{C-B} - 3.65))(1 + 0.0009(V_{rC-B} - 120))$$

where
w_{B-A} = width of minor road right turning stream as average of five measurements 0m, 5m, 10m, 15m, and 20m from the give way line for the right hand side of the approach
w_{B-C} = width of minor road left turning stream as average of five measurements 0m, 5m, 10m, 15m, and 20m from the give way line for the left hand side of the approach
w_{C-B} = width of the right turning lane from the major road, 2.1m if no specific provision
V_{rB-A} = visibility to the right for the right turning stream from the minor road
V_{lB-A} = visibility to the left for the right turning stream from the minor road
V_{rB-C} = visibility to the right for the left turning stream from the minor road
V_{rC-B} = visibility to the right for right turning traffic from the major road.
W_n = nearside major road lane width, average of widths either side of minor road
W_f = far side major lane road width, average of widths either side of minor road
W = width of major road lane widths ($W_n + W_f$)
W_{CR} = width of central reserve
q_{O-D} = flow of traffic from origin O to destination D

Moving Observer Method Formulae

$$q_{a-b} = \frac{x_{a-b} + y_{a-b}}{t_{a-b} + t_{b-a}} \qquad \bar{t}_{a-b} = t_{a-b} - \frac{y_{a-b}}{q_{a-b}}$$

Mean, SD and 85%ile estimate formula for grouped data

$$\bar{y} = \frac{\sum yf}{\sum f} \qquad \sigma_y^2 = \frac{\sum y^2 f}{\sum f} - \frac{\left(\sum yf\right)^2}{\left(\sum f\right)^2} \qquad 85\%ile = \bar{y} + 1.037\sigma_y$$

Coefficient of variation of a variable, X : $$CV_x = \frac{\sigma_x}{x}$$

Combination of coefficients of variation: $$CV_{1,2} = \sqrt{CV_1^2 + CV_2^2}$$

Variance of a product: $$\sigma^2(x_1.x_2) = \sigma^2_{x_1}.\sigma^2_{x_2} + x_1^2.\sigma^2_{x_2} + x_2^2.\sigma^2_{x_1}$$

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Transport Data Sheet

Appendix A

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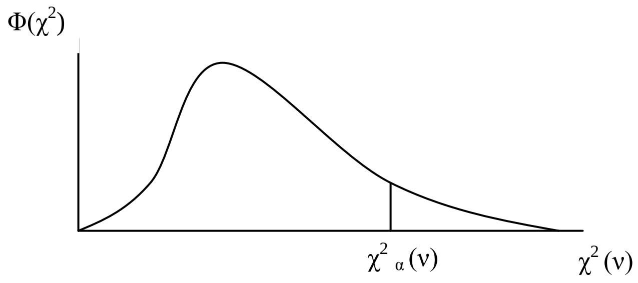
Percentage points of the chi-squared distribution



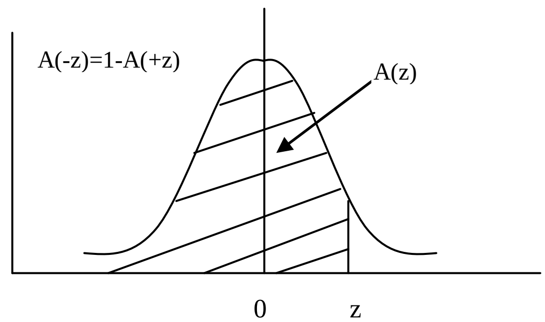
The function tabulated is χ^2 defined by the equation $\alpha = \int_{\chi^2_\alpha}^{\infty} \phi(\chi^2) d\chi^2$ and $\phi(\chi^2)$ is the probability density function of the χ^2 distribution with ν degrees of freedom and α is the probability that $\chi^2(\nu) > \chi^2_\alpha(\nu)$

α	0.10	0.05	0.025	0.01
ν				
1	2.71	3.84	5.02	6.63
2	4.61	5.99	7.38	9.21
3	6.25	7.81	9.35	11.34
4	7.78	9.49	11.14	13.28
5	9.24	11.07	12.83	15.09
6	10.64	12.59	14.45	16.81
7	12.02	14.07	16.01	18.48
8	13.36	15.51	17.53	20.09
9	14.68	16.92	19.02	21.67
10	15.99	18.31	20.48	23.21
11	17.28	19.68	21.92	24.73
12	18.55	21.03	23.34	26.22
13	19.08	22.36	24.74	27.69
14	21.06	23.68	26.12	29.14
15	22.31	25.00	27.49	30.58
16	23.54	26.30	28.85	32.00
17	24.77	27.59	30.19	33.41
18	25.99	28.87	31.53	34.81
19	27.2	30.14	32.85	36.19
20	28.41	31.41	34.17	37.57
21	29.62	32.67	35.48	38.93
22	30.81	33.92	36.78	40.29
23	32.01	35.17	38.08	41.64
24	33.20	36.42	39.36	42.98
25	34.38	37.65	40.65	44.31
26	35.56	38.89	41.92	45.64
27	36.74	40.11	43.19	46.96
28	37.92	41.34	44.46	48.28
29	39.09	42.56	45.72	49.59
30	40.26	43.77	46.98	50.89
40	51.81	55.76	59.34	63.69
50	63.17	67.50	71.42	76.15
60	74.40	79.08	83.30	88.38
70	85.53	90.53	95.02	100.4
80	96.58	101.9	106.6	112.3
90	107.6	113.1	118.1	124.1
100	118.5	124.3	129.6	135.8

Estimate of χ^2: $$x^2 = \sum \frac{(observed - \exp ected)^2}{\exp ected}$$

Yates' correction: $$x^2 = \sum \frac{(|observed - \text{expected}| - 0.5)^2}{\text{expected}}$$

The normal probability integral



The function tabulated is $A(z) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{z} e^{-\frac{1}{2}u^2} .du$. A(z) is the probability that a random variable, having a normal distribution with mean zero and unit variance (a standardised normal deviate) will have a value less than z, i.e. the shaded area in the diagram.
If x has a normal distribution with mean μ and variance σ^2, z = (x- μ) / σ.

Z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
.0	.5000	.5040	.5080	.5120	.5160	.5199	.5239	.5279	.5319	.5359
.1	.5398	.5438	.5478	.5517	.5557	.5596	.5636	.5675	.5714	.5753
.2	.5793	.5832	.5871	.5909	.5948	.5987	.6026	.6064	.6103	.6141
.3	.6179	.6217	.6255	.6293	.6331	.6368	.6406	.6443	.6480	.6517
.4	.6555	.6591	.6628	.6664	.6700	.6736	.6772	.6808	.6844	.6879
.5	.6915	.6950	.6985	.7019	.7054	.7088	.7123	.7157	.7190	.7224
.6	.7257	.7291	.7324	.7357	.7389	.7422	.7454	.7486	.7517	.7549
.7	.7580	.7611	.7642	.7673	.7703	.7734	.7764	.7794	.7823	.7852
.8	.7881	.7910	.7939	.7967	.7995	.8023	.8051	.8078	.8106	.8133
.9	.8159	.8186	.8212	.8238	.8264	.8289	.8315	.8340	.8365	.8389
1.0	.8413	.8438	.8461	.8485	.8508	.8531	.8554	.8577	.8599	.8621
1.1	.8643	.8665	.8686	.8708	.8729	.8749	.8770	.8790	.8810	.8830
1.2	.8849	.8869	.8888	.8907	.8925	.8944	.8962	.8980	.8997	.9015
1.3	.9032	.9049	.9066	.9082	.9099	.9115	.9131	.9147	.9162	.9177
1.4	.9192	.9207	.9222	.9236	.9251	.9265	.9279	.9292	.9306	.9319
1.5	.9332	.9345	.9357	.9370	.9382	.9394	.9406	.9418	.9429	.9441
1.6	.9452	.9463	.9474	.9484	.9495	.9505	.9515	.9525	.9535	.9545
1.7	.9554	.9564	.9573	.9582	.9591	.9599	.9608	.9616	.9625	.9633
1.8	.9641	.9649	.9656	.9664	.9671	.9678	.9686	.9693	.9699	.9706
1.9	.9713	.9719	.9726	.9732	.9738	.9744	.9750	.9756	.9761	.9767
2.0	.9772	.9778	.9783	.9788	.9793	.9798	.9803	.9808	.9812	.9817
2.1	.9821	.9826	.9830	.9834	.9838	.9842	.9846	.9850	.9854	.9857
2.2	.9861	.9865	.9868	.9871	.9875	.9878	.9881	.9884	.9887	.9890
2.3	.9893	.9896	.9898	.9901	.9904	.9906	.9909	.9911	.9913	.9916
2.4	.9918	.9920	.9922	.9925	.9927	.9929	.9931	.9932	.9934	.9936
2.5	.9938	.9940	.9941	.9943	.9945	.9946	.9948	.9949	.9951	.9952
2.6	.9953	.9955	.9956	.9957	.9959	.9960	.9961	.9962	.9963	.9964
2.7	.9965	.9966	.9967	.9968	.9969	.9970	.9971	.9972	.9973	.9974
2.8	.9974	.9975	.9976	.9977	.9977	.9978	.9979	.9980	.9980	.9981
2.9	.9981	.9982	.9983	.9983	.9984	.9984	.9985	.9985	.9986	.9986
3.0	.9987	.9987	.9987	.9988	.9988	.9989	.9989	.9989	.9990	.9990
3.1	.9990									
3.2	.9993									
3.3	.9995									
3.4	.9997									
3.5	.9998									
3.6	.9998									
3.7	.9999									
3.8	.9999									
3.9	.9999									
4.0	.9999									