MANAGEMENT STUDIES TRIPOS

Wednesday 2 May 2007   9.00 – 12.00

Paper M2

QUANTITATIVE METHODS AND OPERATIONS MANAGEMENT

*Answer **four** questions, **two** from Section **A** and **two** from Section **B**.*

*Answers to Sections **A** and **B** must appear in two separate booklets.*

*All **eight** questions carry the same number of marks.*

**N.B. THE FINAL TWO PAGES OF THIS EXAMINATION PAPER
CONSIST OF SPECIAL DATA SHEETS**

STATIONERY REQUIREMENTS   SPECIAL REQUIREMENTS
2 x 20 Page Booklets   *Approved calculators allowed*
Rough Work Pads

You may not start to read the questions
printed on the subsequent pages of this
question paper until instructed that you
may do so by the Invigilator

SECTION A

1 (a) Explain "the flaw of averages" and its application using two simple real-world examples.

(b) Name two or more quantitative strategies, discussed in the course MS2 Quantitative Methods, which can help you to reduce risk in a business environment. Give one sentence apiece to describe each of these strategies and why it is useful.

(c) TeleMart is a medium-sized supermarket in the United States and employs a number of drivers for transporting goods between warehouses and retailing shops and for delivering goods to customers. TeleMart's Human Resource Office has conducted a study for all drivers employed by TeleMart. The study shows that 65% of all drivers in the United States who work for TeleMart are satisfied with the condition of their vehicles, the average time per day spent in the vehicle is 7.5 hours with a standard deviation of 3 hours, and the average distance driven per day is 450 miles with a standard deviation of 200 miles. The table on the next page is the data for all drivers who work specifically for TeleMart in the state of New Mexico.

    (i) Do you think the drivers in the state of New Mexico are as satisfied with their vehicles as TeleMart drivers are in the whole country? Verify your answer quantitatively.

    (ii) Do you think that the drivers in the state of New Mexico drive as many miles per day as TeleMart drivers do in the whole country? Verify your answer quantitatively.

    (iii) What is the smallest significance level at which the average time per day spent in the vehicle for all drivers in the state of New Mexico is significantly different from the national average?

Data for drivers working for TeleMart in the state of New Mexico

Index	Satisfaction with vehicle	Gender	Number of hours per day in vehicle	Miles driven per day
1	Yes	Male	10	450
2	Yes	Male	5	370
3	No	Male	12	580
4	No	Male	6	300
5	Yes	Male	21	1000
6	Yes	Male	16	840
7	Yes	Male	15	1400
8	Yes	Male	5	300
9	Yes	Male	15	850
10	Yes	Male	10	700
11	Yes	Male	5	350
12	Yes	Male	30	1500
13	No	Female	6	280
14	Yes	Female	4	400
15	Yes	Female	3	420
16	Yes	Male	10	675
17	No	Female	15	800
18	No	Female	4	300
19	Yes	Male	3	400
20	Yes	Female	8	400
21	No	Female	10	700
22	Yes	Female	10	720
23	Yes	Female	10	450
24	Yes	Female	15	1000
25	No	Male	5	350
26	Yes	Female	10	800
27	Yes	Female	2	200
28	Yes	Female	8	350
29	Yes	Female	4	150
30	No	Female	5	175
31	Yes	Female	5	355
32	Yes	Male	5	150
33	No	Male	10	600
34	Yes	Female	11	600
35	Yes	Female	4	300
36	No	Male	4	275
37	No	Male	6	285
38	No	Female	5	400
39	Yes	Female	5	350
40	No	Female	10	600
41	Yes	Female	10	700
42	Yes	Female	10	600
43	Yes	Male	5	400
44	Yes	Male	5	350
45	Yes	Female	5	250
46	Yes	Female	6	355
47	Yes	Female	5	175
48	No	Female	5	300
49	Yes	Female	5	350
	35 Yes and 14 No	**28 Female & 21 Male**	**Average is 8 hours**	**Average is 502 miles**
			Standard deviation is 5 hours	**Standard deviation is 295 miles**

2   SuperTrek is a bicycle supplier in the UK and has obtained the data related to predicting the level of business (Usage level) from a survey of purchasing managers of customers. SuperTrek thinks that the most significant factors affecting Usage level of customers are the following:

- Price level, which is the perceived level of price charged by product suppliers;
- Overall service, the overall level of service necessary for maintaining a satisfactory relationship between supplier and purchaser;
- Product quality, the perceived level of quality of a particular product.

Responses on the above three variables were obtained using a graphic rating scale, where a 10-centimeter line was drawn between endpoints labelled "poor" and "excellent". Respondents indicated their perceptions using a mark on the line, which was measured from the left endpoint. Based on the data, SuperTrek developed a multiple regression model as shown below.

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.773
R Square	0.598
Adjusted R Sq.	0.585
Standard Error	5.790
Observations	100

ANOVA

	df	SS	MS	F	Significance F
Regression	3	4781.700736	1593.9	47.54133	6.403E-19
Residual	96	3218.555664	33.52662		
Total	99	8000.2564			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 88.0%	Upper 88.0%
Intercept	19.475	4.048	4.811	0.000	11.439	27.511	13.124	25.826
Price level	-3.083	0.697	-4.426	0.000	-4.466	-1.700	-4.176	-1.990
Overall service	10.944	0.980	11.163	0.000	8.998	12.890	9.406	12.482
Product quality	0.288	0.452	0.638	0.525	-0.609	1.185	-0.421	0.997

(a) Write down the regression equation based on the summary output and explain the meaning of each variable and parameter.

(b) Based on the summary output, identify the value for the R-square statistic and explain its meaning.

(c) Based on the summary output, estimate Usage level of a particular customer whose Price level, Overall service level, and Product quality are 3, 4, and 5 units, respectively. Explain your answer intuitively.

(d) Based on the summary output, estimate the average Usage level of all customers when their Price level, Overall service level, and Product quality are 3, 4, and 5 units, respectively.

(e) What is a 95% confidence interval for the slope of Price level? Calculate a rough 99% confidence interval for the slope of Overall service level.

(f) What is the impact on Usage level for an increase of two units in Product quality?

(g) Discuss whether this model is acceptable as a means of predicting Usage level. Support your answer.

3 CellPower is a large battery company in a developing country and is faced with a serious lawsuit over allegations of damage from pollution generation. The CEO of CellPower has gathered much of the corporate legal staff as well as other top decision makers to discuss their options. They have agreed to take one of three possible options: settle completely, negotiate patiently, or fight in court directly. The outcome of their discussion is shown below.

- Settle completely. They will lose $4.8 billion.
- Negotiate patiently:
  - There is a 50% chance of settling for $2 billion.
  - There is a 50% chance of the following choices:
    - Settle for $5 billion.
    - Fight in court with a 40% chance to win with a legal cost of $200 million and a 60% chance to lose with a loss of $8 billion.
- Fight in court directly. They will have a 40% chance to win with a legal cost of $100 million and a 60% chance to lose with $10 billion.

(a) Construct a decision tree and identify the expected monetary value of each of the three options and identify the optimal option.

(b) What would be a risk profile if CellPower chose the negotiation option?

(c) Assuming all other parameters unchanged, do you think CellPower would change its decision if the chance to lose in option "fight in court directly" is reduced? Discuss your answer.

(d) What rationale might lead to a different decision than that of minimizing the expected monetary value? Discuss your answer.

4 (a) Market Consultants Network is a marketing research firm based in London, which handles consumer surveys. One of its clients is a national newspaper that periodically conducts political polls on issues of widespread interest. In a survey for the newspaper, Market Consultants Network must fulfil the following six requirements to draw meaningful conclusions on one sensitive issue related to the UK drinking laws:

- Survey at least 2,000 people in total in the UK (both urban and rural areas).
- Survey at least 1,000 people who are 30 years of age or younger.
- Survey at least 500 people who are between 31 and 60 years of age.
- Ensure that at least 25% of those surveyed live in rural areas.
- Ensure that at least 20% of those surveyed are 30 years of age or younger and live in urban areas.
- Ensure that no more than 20% of those surveyed are 61 years of age or over and live in rural areas.

Market Consultants Network decides that all surveys should be conducted in person. It estimates the costs of reaching people in each age and region category are as shown in the table below. The goal for Market Consultants Network is to meet the six sampling requirements at the minimum cost.

	Age 0 - 30	Age 31 - 60	Age 61 and over
Urban	£7.00	£7.20	£6.00
Rural	£7.50	£7.80	£6.50

(i) Formulate a linear program for Market Consultants Network. You are <u>not</u> required to solve your optimization problem.

(ii) If the total of number of people surveyed in rural areas is equal to or greater than 500, then Market Consultants Network must assign an additional expert for coordination, which will require an extra expense of £1000. Formulate an integer linear program by taking this additional condition into account in your model in (i). You are <u>not</u> required to solve your optimization problem.

(b) Consider the following Solver output of a linear program for a minimization problem, which is solved by a manufacturer and retailer of three types of mobile phone transmitters.

(i) If the unit cost for variable "Make Model 2" increases by 10 units, and if all other parameters are unchanged, what would be the change in the optimal objective function value? Explain how you calculate it.

(ii) What would be the change in the optimal objective function value if you increase resource "Harnessing Used" by 100 units, and if the other parameters are unchanged? Explain how you calculate it.

(iii) What would be the change in the optimal objective function value if you increase resource "Wiring Used" by 10 units, and if the other parameters are unchanged? Explain how you calculate it.

Adjustable Cells

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
B6	- Make Model 1	3,000	0.00	50	4	57
C6	- Make Model 2	550	0.00	83	14	8
D6	- Make Model 3	900	0.00	130	8	137
B7	- Buy Model 1	0	4.00	61	1E+30	4
C7	- Buy Model 2	1,450	0.00	97	8	14
D7	- Buy Model 3	0	8.00	145	1E+30	8

Constraints

Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
B13	# Available Model 1	3,000	57.00	3000	380	2900
C13	# Available Model 2	2,000	97.00	2000	1E+30	1450
D13	# Available Model 3	900	137.00	900	211.11111	900
E17	- Wiring Used	9,525	0.00	10000	1E+30	475
E18	- Harnessing Used	5,000	-7.00	5000	633.33333	1100

TURN OVER

SECTION B

5 (a) For most inventory scenarios, what is the most significant component of inventory holding cost?

(b) When future demand is not constant, optimal lot sizes are provided by which, rather technical, algorithm?

(c) State in 30 words or less the *Least Unit Cost* algorithm.

(d) A few years ago, *Business Week* published an article entitled 'Invoice? What's an Invoice?', which discussed the advantages of using the Internet for business communication. The article included the following passage:

> 'Most business-to-business sales still are done with paper forms—a reminder, in triplicate, of outdated methods. If you eliminate paper, you spend less time and money re-keying information into different computers and correcting the resulting errors. By some estimates, e-commerce could slash the cost of processing a purchase order from £150.00 to as little as £25.00.'

Based on the information in the above passage, explain the effect that e-commerce could have on average inventory levels. Be as specific as you can.

(e) Based on the information in the passage in part (d), explain the effect that e-commerce could have on ordering frequency. Be as specific as you can. State any assumptions you may require.

6 This question refers to the *National Cranberry Cooperative (NCC)* case.

(a) What are the two *main* problems at Receiving Plant No. 1 (RP1) to which the National Cranberry Cooperative must respond?

(b) These two problems referred to above were probably two symptoms of a common ailment. What is that ailment?

(c) Virtually all discussion of potential changes at RP1 focused on peak harvest days. Why? [Answer in 35 words or less.]

(d) Compare the effect of *adding additional dryers* versus *increasing the capacity of existing dryers*. [Answer in 35 words or less.]

7 Revising for your M2 examination has forced you to neglect your responsibilities as a writer for TCS (formerly known as 'The Cambridge Student'). Your feature story is due tomorrow! As you queue for lunch at your college hall's sandwich counter, you experience a brainwave, namely, you will write a story entitled: 'Why Students on the Management Studies Tripos Should Run My College Hall'. Realising that a picture is worth a thousand words, you pop up to your rooms, grab your mobile that has a built-in camera, pop back to hall, and spend the next 30 minutes taking snaps of the queues of students in the four food service areas and at the tills.

A reporter's ethical norms demand that you run a representative photograph, not the best or worst, but one that depicts the average situation. You carefully select the appropriate snap from amongst the 15 you have taken, and submit it with your ingenious title, along with your story. The photo shows that, at the four food service areas together with the tills, there are 56 people in total. Specifically, at the food service areas, the numbers are:

  ▪ Salad Bar:
    6 people in queue

  ▪ Sandwich Counter:
    16 people in queue

  ▪ Delicacies (Spotted Dick, Haggis, Welsh Rarebit, & Ulster Fry):
    8 people in queue

  ▪ Fizzy drinks:
    6 people in queue

Late that afternoon, the TCS editor finds you at college. He is very excited, having come up with a new title: 'Why Does It Take ___ Minutes to Buy a Sarnie at My College?'

All he requires of you is the correct number to fill in. You realise that you had not recorded any actual data, and Hall has already closed. Oh no! You quickly walk over to Hall to find the college caterer and ask her for help.

The caterer replies that she has never timed the process. However, she estimates that, on a typical day, about 300 people buy lunch between 12.30 and 13.30, and that about 40 per cent of them purchase sandwiches.

Is this sufficient information for you to make an estimate of the average time it takes to order a sandwich at Hall and pay for it? If not, write No, and explain why there is insufficient information. If this information is sufficient, write Yes, and derive the appropriate number to use in TCS. Be sure to state clearly any assumptions you may require.   TURN OVER

8 This question refers to the book *The Goal*.

(a) According to Jonah, what is the goal of a corporation?

(b) What are Jonah's three measurements that express the goal but which also permit one to develop operational rules for running one's plant?

(c) Jonah recommends that the production quantity [which the book calls the EBQ (Economic Batch Quantity) and we call the EOQ with production] be cut in half, and then in half again, on non-bottleneck machines. Assuming that the EOQ was calculated correctly to begin with, how much (in per cent) will total cost per period increase when the batch size is cut to 25% of its current value? Be sure to show your calculations.

(d) In his conversation with Julie, Alex found that total cost did *not* in fact increase with the change described in part (c), which implies that the EOQ had been incorrectly calculated in the first place. What was wrong with the EOQ calculation? [Hint: Think about Alex's statement: 'The measurement assumes that all of the workers in the plant are always going to be fully occupied, and therefore, in order to do more setups, you have to hire more people. That isn't true.']

(e) What would be the dominant—i.e., most representative or most common—type of production process at UniCo's Bearington plant, which is managed by Alex Rogo? Would it be: (i) Mass production, (ii) Batch production, or (iii) One-off (project) production? Choose one, and support your choice.

END OF PAPER

SPECIAL DATA SHEET 1
Formulae for Correlation and Regression Analysis

Consider data pairs (X_1, Y_1), (X_2, Y_2), ..., (X_n, Y_n).

Let m_X and m_Y denote the respective means of the X and Y data.

Let s_X and s_Y denote the respective standard deviations of the X and Y data.

The formula for covariance is given by the sum

$$\text{cov}(X, Y) = \frac{\sum_{i=1}^{n}(X_i - m_X)(Y_i - m_Y)}{n}.$$

The formula for the regression coefficient is

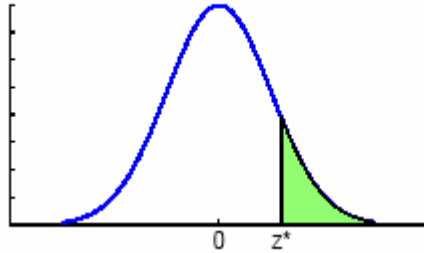$$\text{correl}(X, Y) = r = \frac{\text{cov}(X, Y)}{s_X s_Y}.$$

The formula for the line of best fit is

$$Y - m_Y = \frac{r s_Y}{s_X}(X - m_X).$$

SPECIAL DATA SHEET 2
Standard Normal Distribution Table
(Areas under the standard normal curve beyond z*, i.e., shaded area)

z*	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.5000	0.4960	0.4920	0.4880	0.4840	0.4801	0.4761	0.4721	0.4681	0.4641
0.1	0.4602	0.4562	0.4522	0.4483	0.4443	0.4404	0.4364	0.4325	0.4286	0.4247
0.2	0.4207	0.4168	0.4129	0.4090	0.4052	0.4013	0.3974	0.3936	0.3897	0.3859
0.3	0.3821	0.3783	0.3745	0.3707	0.3669	0.3632	0.3594	0.3557	0.3520	0.3483
0.4	0.3446	0.3409	0.3372	0.3336	0.3300	0.3264	0.3228	0.3192	0.3156	0.3121
0.5	0.3085	0.3050	0.3015	0.2981	0.2946	0.2912	0.2877	0.2843	0.2810	0.2776
0.6	0.2743	0.2709	0.2676	0.2643	0.2611	0.2578	0.2546	0.2514	0.2483	0.2451
0.7	0.2420	0.2389	0.2358	0.2327	0.2296	0.2266	0.2236	0.2206	0.2177	0.2148
0.8	0.2119	0.2090	0.2061	0.2033	0.2005	0.1977	0.1949	0.1922	0.1894	0.1867
0.9	0.1841	0.1814	0.1788	0.1762	0.1736	0.1711	0.1685	0.1660	0.1635	0.1611
1.0	0.1587	0.1562	0.1539	0.1515	0.1492	0.1469	0.1446	0.1423	0.1401	0.1379
1.1	0.1357	0.1335	0.1314	0.1292	0.1271	0.1251	0.1230	0.1210	0.1190	0.1170
1.2	0.1151	0.1131	0.1112	0.1093	0.1075	0.1056	0.1038	0.1020	0.1003	0.0985
1.3	0.0968	0.0951	0.0934	0.0918	0.0901	0.0885	0.0869	0.0853	0.0838	0.0823
1.4	0.0808	0.0793	0.0778	0.0764	0.0749	0.0735	0.0721	0.0708	0.0694	0.0681
1.5	0.0668	0.0655	0.0643	0.0630	0.0618	0.0606	0.0594	0.0582	0.0571	0.0559
1.6	0.0548	0.0537	0.0526	0.0516	0.0505	0.0495	0.0485	0.0475	0.0465	0.0455
1.7	0.0446	0.0436	0.0427	0.0418	0.0409	0.0401	0.0392	0.0384	0.0375	0.0367
1.8	0.0359	0.0351	0.0344	0.0336	0.0329	0.0322	0.0314	0.0307	0.0301	0.0294
1.9	0.0287	0.0281	0.0274	0.0268	0.0262	0.0256	0.0250	0.0244	0.0239	0.0233
2.0	0.0228	0.0222	0.0217	0.0212	0.0207	0.0202	0.0197	0.0192	0.0188	0.0183
2.1	0.0179	0.0174	0.0170	0.0166	0.0162	0.0158	0.0154	0.0150	0.0146	0.0143
2.2	0.0139	0.0136	0.0132	0.0129	0.0125	0.0122	0.0119	0.0116	0.0113	0.0110
2.3	0.0107	0.0104	0.0102	0.0099	0.0096	0.0094	0.0091	0.0089	0.0087	0.0084
2.4	0.0082	0.0080	0.0078	0.0075	0.0073	0.0071	0.0069	0.0068	0.0066	0.0064
2.5	0.0062	0.0060	0.0059	0.0057	0.0055	0.0054	0.0052	0.0051	0.0049	0.0048
2.6	0.0047	0.0045	0.0044	0.0043	0.0041	0.0040	0.0039	0.0038	0.0037	0.0036
2.7	0.0035	0.0034	0.0033	0.0032	0.0031	0.0030	0.0029	0.0028	0.0027	0.0026
2.8	0.0026	0.0025	0.0024	0.0023	0.0023	0.0022	0.0021	0.0021	0.0020	0.0019
2.9	0.0019	0.0018	0.0018	0.0017	0.0016	0.0016	0.0015	0.0015	0.0014	0.0014
3.0	0.0013	0.0013	0.0013	0.0012	0.0012	0.0011	0.0011	0.0011	0.0010	0.0010