Loughborough University

MANAGEMENT SCIENCE METHODS

21BSB120

Semester 1 2021/22 (1b) Exam paper

Answer ALL FOUR questions.

Questions carry the marks shown.

This is a (1b) online examination, meaning you have a total of **2 hours plus an additional 30 minutes** to complete and submit this paper. The additional 30 minutes are for downloading the paper and uploading your answers when you have finished. If you have extra time or rest breaks as part of a Reasonable Adjustment, you will have further additional time as indicated on your exam timetable.

It is your responsibility to submit your work by the deadline for this examination. You must make sure you leave yourself enough time to do so.

It is also your responsibility to check that you have submitted the correct file.

Exam Help

If you are experiencing difficulties in accessing or uploading files during the exam period you should contact the exam helpdesk. For urgent queries please call **01509 222900**.
For other queries email examhelp@lboro.ac.uk

You may handwrite and/or word process your answers, as you see fit.

You may use any calculator (not just those on the University's approved list).

This is an **open book exam** and you may refer to module materials, notes or textbooks when answering. However, you **must produce your own responses** to the exam questions and you **should not copy or reproduce content** from a source without quotation marks and a citation. Students who do this will be marked down for poor scholarship or the work will be considered for Academic Misconduct in line with regulation XVIII.

You must clearly identify the question and part, as required, in your answer, either through the numbering system or by including the relevant exam question and/or part as a heading.

You may include headings, bullet points etc to help with clarity as required. Graphs and images may also be included and should be appropriately referenced.

In text citations should use the Harvard style in accordance with the School of Business and Economics guidelines. You do not need to include a reference list.

1. A family farm produces two varieties of ice cream, Strawberry and Forest Fruit. The production of ice cream is measured in litres.

Both varieties use locally produced fresh cream whose supply is limited to 24 litres per day. 1 litre of Strawberry ice cream requires 0.4 litres of fresh cream, and 1 litre of Forest Fruit requires 0.3 litres of fresh cream.

Also, both products require locally sourced wild strawberries whose supply is limited to 12 kilograms (kg) per day. 1 litre of Strawberry ice cream requires 0.1 kg of strawberries, while 1 litre of Forest Fruit requires 0.3 kg.

Based on historical sales, the amount of Forest Fruit ice cream (in litres) should be no less than 25% of the total production of both varieties of ice cream. Also, the amount of Strawberry ice cream should be no less than 75% of the amount of Forest Fruit variety (note, this is not the total amount of both varieties as in the previous requirement).

The farm sells Strawberry ice cream at £24 per litre and Forest Fruit at £12 per litre.

a) State the above problem as a linear program, identifying decision variables, objective function, and all constraints. [5 marks]

b) Draw the feasible region of this linear program. Make sure that you clearly identify it on your drawing. Solve the linear program using this graph. Explain how much of each variety of ice cream the farm should make? What is the maximum revenue that can be achieved? [10 marks]

c) Does your solution fully use the available supply of fresh cream and wild strawberries? If not, how much of each is left unused? [3 marks]

d) The farm considers reducing the price of Strawberry ice cream from the current price £24. The new price would still be not less than £12 per litre. Explore and explain how any such price change may affect the optimal production plan and the revenue. (Note that full marks are awarded only for a well-reasoned and detailed answer.) [7 marks]

[Total for Question 1: 25 marks]

2. A company produces two brands of snack: Energy and Sport. Both are made by mixing caramelized Almonds, Hazelnuts and Macadamia nuts.

The supply of Almonds is limited to 200 kilograms (kg), Hazelnuts to 300 kg and Macadamia nuts to 150 kg per day.

Almonds cost £10, Hazelnuts £8 and Macadamia nuts £16 per kilogram.

Production costs of the two brands are £2 per kg of Energy and £3 per kg of Sport.

The Energy brand requires that at least (not less than) 50% of its ingredients be Hazelnuts. Sport brand requires that at least 30% of its ingredients be Macadamia nuts.

Energy snacks sell at £30 per kg and Sport at £35 per kg.

The management wants to use linear programming to identify the production plan that would maximise the overall profit obtained by producing and selling the two brands of snack.

Note: DO NOT solve your linear program. Only the formulation is required as stated below.

a) Identify and describe the decision variables in your linear program. Write down the objective function and briefly explain its meaning. [7 marks]

b) Write down all constraints. Explain their meaning. [5 marks]

c) Market research suggests that the demand for the Energy brand should be at least (not less than) 30% of the overall production volume of both brands together. It has been suggested that a new constraint reflecting this research should be added to the model. Write down this constraint. Explain how the incorporation of this new constraint may affect the optimal solution and the maximum profit. [8 marks]

[Total for Question 2: 20 marks]

3. Generate THREE sample values for each of the following distributions. Working should be shown and all sample values should be rounded to 1 decimal place:

a) Continuous Uniform Distribution – Minimum = 25, Maximum = 100
Random Digits: 03, 22, 99 [5 marks]

b) Discrete Distribution

Outcome	Percentage
Low	47%
Medium	18%
High	35%

Random Digits: 35, 64, 65 [5 marks]

c) Histogram Distribution

Range	Percentage
100 to <200	23%
200 to <250	46%
250 to <275	31%

Random Digits (Category): 22, 23, 68
Random Digits (Uniform): 90, 75, 05 [8 marks]

d) Normal Distribution – Mean = 175, Standard Deviation = 34
Random Digits: 15, 40, 83. [6 marks]

e) Negative Exponential Distribution – Mean = 40
Random Digits: 15, 23, 62. [6 marks]

[Total for Question 3: 30 marks]

4. PhoneFix provide a telephone line repair service to customers in a small town. Customers report faults with their telephone line to PhoneFix who then run diagnostic tests to determine the nature of the fault. This diagnostic test takes on average 3 minutes and varies according to a negative exponential distribution. The diagnostic test identifies whether the phone line can be repaired remotely (in 70% of cases), or whether it requires a site visit by an engineer (in 30% of cases). The time taken to perform a remote repair is normally distributed with a mean of 5 minutes and a standard deviation of 1 minute.

Engineers that undertake site visits take anywhere between 10 and 40 minutes to travel to the customer's location. Once at the location, the repair time is distributed as follows:

Repair Time (minutes)	Percentage
10 to <30	30%
30 to <50	50%
50 to <70	20%

A simulation of five cases (repairs) has been carried out and results are shown in the table below:

Case	Diagnostic Test (minutes)	Remote repair or Site visit?	Remote repair time (minutes)	Travel time to site (minutes)	Site repair time (minutes)
1	1.4	Site visit	3.6	36.6	69.7
2	1.8	Remote	5.1	27.8	65.5
3	1.7	Remote	5.8	19.8	49.0
4	1.9	Site visit	4.5	25.3	67.5
5	0.4	Remote	4.7	13.0	26.8

a) For each case, calculate the total time taken to repair the telephone line, i.e. by adding up the appropriate values for the various stages. [5 marks]

b) Calculate the theoretical minimum, average and maximum times for each stage and hence, calculate the overall theoretical minimum, average and maximum times required to repair telephone lines. [10 marks]

c) Briefly describe and analyse the ways in which the company could seek to reduce the total time taken for telephone lines to be repaired. [10 marks]

[Total for Question 4: 25 marks]

ALAN FRENCH

Random Sampling Table – Normal Distribution

Prob	Z	Prob	Z	Prob	Z	Prob	Z	Prob	Z
0.00	-3.0000	0.20	–0.8416	0.40	–0.2533	0.60	0.2533	0.80	0.8416
0.01	–2.3263	0.21	–0.8064	0.41	–0.2275	0.61	0.2793	0.81	0.8779
0.02	–2.0537	0.22	–0.7722	0.42	–0.2019	0.62	0.3055	0.82	0.9154
0.03	–1.8808	0.23	–0.7388	0.43	–0.1764	0.63	0.3319	0.83	0.9542
0.04	–1.7507	0.24	–0.7063	0.44	–0.1510	0.64	0.3585	0.84	0.9945
0.05	–1.6449	0.25	-0.6745	0.45	–0.1257	0.65	0.3853	0.85	1.0364
0.06	–1.5548	0.26	–0.6433	0.46	–0.1004	0.66	0.4125	0.86	1.0803
0.07	–1.4758	0.27	–0.6128	0.47	–0.0753	0.67	0.4399	0.87	1.1264
0.08	–1.4051	0.28	–0.5828	0.48	–0.0502	0.68	0.4677	0.88	1.1750
0.09	–1.3408	0.29	–0.5534	0.49	–0.0251	0.69	0.4959	0.89	1.2265
0.10	–1.2816	0.30	–0.5244	0.50	0.0000	0.70	0.5244	0.90	1.2816
0.11	–1.2265	0.31	–0.4959	0.51	0.0251	0.71	0.5534	0.91	1.3408
0.12	–1.1750	0.32	–0.4677	0.52	0.0502	0.72	0.5828	0.92	1.4051
0.13	–1.1264	0.33	–0.4399	0.53	0.0753	0.73	0.6128	0.93	1.4758
0.14	–1.0803	0.34	–0.4125	0.54	0.1004	0.74	0.6433	0.94	1.5548
0.15	–1.0364	0.35	–0.3853	0.55	0.1257	0.75	0.6745	0.95	1.6449
0.16	–0.9945	0.36	–0.3585	0.56	0.1510	0.76	0.7063	0.96	1.7507
0.17	–0.9542	0.37	–0.3319	0.57	0.1764	0.77	0.7388	0.97	1.8808
0.18	–0.9154	0.38	–0.3055	0.58	0.2019	0.78	0.7722	0.98	2.0537
0.19	–0.8779	0.39	–0.2793	0.59	0.2275	0.79	0.8064	0.99	2.3263

Note: Technically there is no Z value corresponding to a probability of 0.00, but –3 will suffice.

Random Sampling Table – Negative Exponential Distribution

Prob	Z	Prob	Z	Prob	Z	Prob	Z	Prob	Z
0.00	0.0000	0.20	0.2231	0.40	0.5108	0.60	0.9163	0.80	1.6094
0.01	0.0101	0.21	0.2357	0.41	0.5276	0.61	0.9416	0.81	1.6607
0.02	0.0202	0.22	0.2485	0.42	0.5447	0.62	0.9676	0.82	1.7148
0.03	0.0305	0.23	0.2614	0.43	0.5621	0.63	0.9943	0.83	1.7720
0.04	0.0408	0.24	0.2744	0.44	0.5798	0.64	1.0217	0.84	1.8326
0.05	0.0513	0.25	0.2877	0.45	0.5978	0.65	1.0498	0.85	1.8971
0.06	0.0619	0.26	0.3011	0.46	0.6162	0.66	1.0788	0.86	1.9661
0.07	0.0726	0.27	0.3147	0.47	0.6349	0.67	1.1087	0.87	2.0402
0.08	0.0834	0.28	0.3285	0.48	0.6539	0.68	1.1394	0.88	2.1203
0.09	0.0943	0.29	0.3425	0.49	0.6733	0.69	1.1712	0.89	2.2073
0.10	0.1054	0.30	0.3567	0.50	0.6931	0.70	1.2040	0.90	2.3026
0.11	0.1165	0.31	0.3711	0.51	0.7133	0.71	1.2379	0.91	2.4079
0.12	0.1278	0.32	0.3857	0.52	0.7340	0.72	1.2730	0.92	2.5257
0.13	0.1393	0.33	0.4005	0.53	0.7550	0.73	1.3093	0.93	2.6593
0.14	0.1508	0.34	0.4155	0.54	0.7765	0.74	1.3471	0.94	2.8134
0.15	0.1625	0.35	0.4308	0.55	0.7985	0.75	1.3863	0.95	2.9957
0.16	0.1744	0.36	0.4463	0.56	0.8210	0.76	1.4271	0.96	3.2189
0.17	0.1863	0.37	0.4620	0.57	0.8440	0.77	1.4697	0.97	3.5066
0.18	0.1985	0.38	0.4780	0.58	0.8675	0.78	1.5141	0.98	3.9120
0.19	0.2107	0.39	0.4943	0.59	0.8916	0.79	1.5606	0.99	4.6052