Monash University

Faculty of Information Technology

FIT5097 Business Intelligence Modelling

2nd Semester 2022

Assignment: Linear Programming, Sensitivity Analysis, Network Modelling and Integer Linear Programming - and Inventory Management - using Microsoft Excel Solver

This assignment is worth 32% of your final mark (subject to the hurdles described in the FIT5097 Unit Guide and links therein). Among other things (see below), note the need to hit the `Submit' button (and the requirement of an interview).

Due Date: Thursday 22nd September 2022, 11:55 pm

Method of submission: Your submission should consist of 2 files:

1. A Microsoft Excel spreadsheet named as:

   FamilyName-StudentId-2ndSem2022FIT5097.xlsx

2. A text-based .pdf file named as: *FamilyName-StudentId-2ndSem2022FIT5097.pdf*

   Both the files must be uploaded on the FIT5097 Moodle site by the due date and time. The text-based .pdf file will undergo a similarity check by Turnitin at the time you submit to Moodle. Please read submission instructions on last page carefully regarding the use of Moodle.

Total available marks: 60 + 26 + 14 = **100 marks**.

Note 1: Please recall the Academic Integrity exercises from week 1 and the start of semester. In submitting this assignment, you acknowledge both that you are familiar with the relevant policies, rules and regulations regarding Academic Integrity and also that you are familiar with the consequences of being deemed to be in contravention of these policies.

Note 2: And a reminder not to post even part of a proposed partial solution to a forum or other public location. This includes when you are seeking clarification of a question. If you are seeking to understand a concept better, then try to word your question so that it is a long way removed from the Assignment. You are reminded that Monash University takes academic integrity very seriously.

Note 3: As previously advised, it is your responsibility to be familiar with the special consideration policies and special consideration process. Please see the relevant

links within FIT5097 Moodle. Students should be familiar with the special consideration policies and the process for applying.

Note 4: As a general rule, don't just give a number or an answer like `Yes' or `No' without at least some clear and sufficient explanation - or, otherwise, you risk being awarded 0 marks for the relevant exercise. Make it easy for the person marking your work to follow your reasoning. Your .pdf should typically cross-reference the corresponding answer in your spreadsheet. For each sub-question and exercise, provide a clearly labelled spreadsheet tab with clear content, accompanied with clearly cross-referenced clear .pdf explanation. Without clear cross-reference between .pdf and spreadsheet tab – and without a separate spreadsheet tab for each sub-question - there is the possibility that any such exercise will be awarded 0 marks.

Note 5: As a general rule, if there is an elegant way of answering a question without unnecessarily re-running the Solver, try to do it that way. (Recall, e.g., sensitivity report and some notions from Week 4.) More generally, more elegant solutions are preferable - and will at least sometimes be given more marks (possibly many more marks). Among other things, if a problem is a linear programming (LP) problem, then it would be more elegant to solve it using the linear simplex model. In a similar vein, a linking constraint (where appropriate) will be far preferable to a seemingly equivalent use of the IF() function.

Note 6: All of your submitted work should be in machine readable form, and none of your submitted work should be hand-written.

Note 7: If you wish for your work to be marked and not to accrue (possibly considerable) late penalties, then make sure to upload the correct files and (not to leave your files as Draft but) also to hit 'Submit' to make sure that your work is submitted.

Note 8: The notation 1E-12 corresponds to 1×10^{-12}, or 0.000000000001. If you see a figure of approximately this magnitude or comparable magnitude, then consider whether or not it might be round-off error for something else.

Note 9: Save your file regularly. Most of the time, the Solver will run quickly. But for problems with many variables and many constraints – especially involving integers – please be mindful that if you are not careful to do some of the things mentioned in Lecture 6 to help your program finish more quickly, then your program might possibly go through at least tens or hundreds of thousands of subproblems and become very slow (as you wait and wait and …). If you save your file before starting a run that could be long and slow, then you can safely stop the program – if it becomes very slow – with reduced risk of losing your edit changes.

Note 10: As a general rule for solving a problem using MicroSoft Excel Solver, please consider carefully whether the various solver (settings or) Options (which you might be able to access after clicking on `Options', which might be on the right about two-thirds of the way down after you click on `Solver') might affect the results provided by the solver. Put another way, rather than just use the default settings, make sure to check the solver settings and be willing to appropriately modify them if and as required.

Question 1 – Linear Programming and Sensitivity Analysis

[6 + 6 + 4 + 2 + 3 + 2 + 4 + 3 + 4 + 4 + 3 + 3 + 6 + 6 + 4 = 60 marks]

A manufacturer produces several types of products and the unit profit of each is shown in the table below:

	Product1	Product2	Product3	Product4	Product5
Unit Profits	$380	$520	$390	$580	$455

Each product requires different amount of resources to produce. The following table shows the number of units of each resources required to manufacture each product. The last column indicates the availability of each type of resources for the next production run:

	Product1	Product2	Product3	Product4	Product5	Available
Resource1	1	1	1	0	0	200
Resource2	0	6	3	4	0	1566
Resource3	0	0	6	5	9	2880
Resource4	1	7	0	0	3	336
Resource5	11	0	6	0	8	1256
Resource6	11	10	0	6	0	2700

The manufacturer wishes to maximise total profit.

The questions follow below:

a) Formulate a Linear Programming (an LP) formulation for this problem. Save your formulation in the text-based .pdf file [*FamilyName-YourStudentId-2ndSem2022FIT5097*.pdf]. **(6 marks)**

b) Create a spreadsheet model for this problem. Store the model in your Excel workbook [FamilyName-YourStudentId-2ndSem2022FIT5097.xlsx] and name your spreadsheet something like (e.g.) 'ProductsAndResources' **(6 marks)**

c) Solve the problem - using Microsoft Excel Solver. Generate the Sensitivity report for the problem and name your spreadsheet (e.g.) 'Qu 1 ProductsAndResources Sensitivity Rep'. **(4 marks)**

Using the Microsoft Excel Solver sensitivity report, provide answers (in the .pdf file) to the following questions: (**You must include explanations with your answers**.)

d) What is the optimal production plan (X_1, X_2, X_3, X_4, X_5) and the associated profit? Refer to your answers to any of a), b) and/or c) above as appropriate. **(2 marks)**

For the remaining parts of this question, explain your answer(s), typically referring to relevant spreadsheet entry/ies and/or specific relevant parts of spreadsheet reports.

Throughout, recall **Note 4** above: ``**Note 4**: As a general rule, don't just give a number or an answer like `Yes' or `No' without at least some clear and sufficient explanation - or, otherwise, you risk being awarded 0 marks for the relevant exercise. Make it easy for the person marking your work to follow your reasoning. Your .pdf should typically cross-reference the corresponding answer in your spreadsheet. For each sub-question and exercise, provide a clearly labelled spreadsheet tab with clear content, accompanied with clearly cross-referenced clear .pdf explanation. Without clear cross-reference between .pdf and spreadsheet tab – and without a separate spreadsheet tab for each sub-question - there is the possibility that any such exercise will be awarded 0 marks.''

e) Following on from the end of part 1d), it is proposed to make a new product which uses exactly 1 (i.e., exactly one) of each resource. This new product would sell for $125. Should we make this? If we should make it, by how much could we lower the price and yet it would still be worthwhile to make it? If we should not make it, how much more profitable would it need to be for us to make it? Show all working and explain.**(3 marks)**

Return to the end of part 1d).

f) How much would profit change by, if we were to have an extra 3 of Resource1? Show all working and explain. **(2 marks)**

Return to the end of part 1d).

g) It is proposed to make the following changes. The profitability of Product1 increases by 2, the profitability of Product2 decreases by 16, the profitability of Product4 decreases by 16, and the profitability of Product5 increases by 6. **(4 marks)**

   Can you say whether or not the optimal production plan (X_1, X_2, X_3, X_4, X_5) will change from the value in part 1d)?

   Show your working and explain your answer.

Return to the end of part 1d), but now require that all the X_i must take integer values.

h) Continuing from the end of part d), suppose that at most 4 products can be made (i.e., that at most 4 of the Xi have non-zero values). What is the optimal production plan (X_1,

X_2, X_3, X_4, X_5) and the associated profit? Show your working and explain your answer. **(3 marks)**

Return to the end of part 1d), but with the requirement that all the X_i must take integer values.

i) Continuing from the end of part d), suppose that at most 3 products can be made (i.e., that at most 3 of the Xi have non-zero values). What is the optimal production plan (X_1, X_2, X_3, X_4, X_5) and the associated profit? Show your working and explain your answer. **(4 marks)**

Return to the end of part 1d), but with the requirement that all the X_i must take integer values.

j) Continuing from the end of part d), suppose that at most 2 products can be made (i.e., that at most 2 of the Xi have non-zero values). What is the optimal production plan (X_1, X_2, X_3, X_4, X_5) and the associated profit? Show your working and explain your answer. **(4 marks)**

Return to the end of part 1d), but with the requirement that all the X_i must take integer values.

k) Continuing from the end of part d), suppose that at most 1 product can be made (i.e., that at most 1 of the Xi has non-zero values). What is the optimal production plan (X_1, X_2, X_3, X_4, X_5) and the associated profit? Show your working and explain your answer. **(3 marks)**

Return to the end of part 1d), but with the requirement that all the X_i must take integer values.

l) If Product4 is made then Product2 must be made. **(3 marks)**

m) Return to the end of part 1d), but with the requirement that all the Xi must take integer values.

We now introduce set-up costs (or start-up costs).

	Product1	**Product2**	**Product3**	**Product4**	**Product5**
Start-up cost	$10,000	$12,000	$14,000	$16,000	$18,000

What is the optimal production plan (X_1, X_2, X_3, X_4, X_5) and the associated profit? Show your working and explain your answer. **(6 marks)**

Return to the end of part 1m), and with the requirement that all the X_i must take integer values.

n) We include the requirement that at most one of the values X_1, X_2, X_3, X_4, X_5 is more than 200.

What is the optimal production plan (X_1, X_2, X_3, X_4, X_5) and the associated profit? Show your working and explain your answer. **(6 marks)**

o) If Product4 is produced then X4 has to be 150, 200, or 240

What is the optimal production plan (X_1, X_2, X_3, X_4, X_5) and the associated profit? Show your working and explain your answer. **(4 marks)**

Question 2 – Network Modelling

[6 + 3 + 3 + 1 + 6 + 3 + 4 = 26 marks]

Vic Medic Emergency operates a fleet of emergency vehicles covering the South-Eastern suburb of Melbourne. The emergency vehicles can be despatched from 3 locations, i.e. source/starting points (A, B, C) to 3 (sink) destinations (J, K, L).

The distances (in kilometres) are given as follows:

To / From	B	C	D	E	F	G	H	I	J	K	L
A	4.0	3.0	6.0							12.0	
B		2.0	1.0	4.0	8.0		5.0				
C			3.0	6.0		1.0					
D				3.0	6.0						
E					2.0	5.0					
F						6.0	2.0	3.0			
G							5.0	6.0	4.0		
H								2.0	3.0		
I									6.0	6.0	
J										7.0	2.0
K											2.0

For each part of this question, answer both in .pdf and in spreadsheet tab. Clearly explain and clearly show all working.

2a) What is the shortest path from A to J? Show the path and the total distance. **(6 marks)**

2b) What is the shortest path from B to K? Show the path and the total distance. **(3 marks)**

2c) What is the shortest path from C to L? Show the path and the total distance. **(3 marks)**

2d) What is the sum of your answers to 2(a), 2(b) and 2(c)? **(1 mark)**

In each of 2(a), 2(b) and 2(c), we were moving 1 emergency vehicle (or 1 electric vehicle) from 1 starting point to 1 destination. In 2(d), we moved 3 emergency vehicle (or 3 electric vehicle) from 3 starting point to 3 destinations.

2e) If we require that the vehicles have to go from (A, B, C) to (J, K, L) with each destination having exactly one vehicle arrive there, what is the shortest total distance? **(6 marks)**

2f) Is your answer to 2(e) longer, equal to, or less than your answer to 2(d)? Explain as clearly as you can - and why. **(3 marks)**

Return now to the problem in 2(e)

2g) For every edge, we introduce a modified cost. If there is flow of more than 1 along an edge, then any additional flow is at double the cost. As an example, the cost along the edge DE was given as 3 in the problems 2(a) to 2(f). We now modify this so that the 1st unit of flow along DF costs 3 but any other unit of flow would cost 6 per unit. Similarly, the cost along the edge DF was given as 6, but we now modify this so that the 1st unit of flow along DF costs 6 but any other unit of flow would cost 12 per unit.

What is the shortest total cost? **(4 marks)**

Question 3 – Inventory Modelling

[4 + 5 + 5 = 14 marks]

3a) A product is required with monthly demand of 10,000. The cost of each product is $5, order costs are $100 per order, and storage costs are 0.1 = 10%.
Showing calculations (both in .pdf and also in spreadsheet), what is the Economic Order Quantity (EOQ)? **(4 marks)**

3b) Suppose that the product cost reduces by 5% for orders of at least 8,800.

- Showing calculations (both in .pdf and also in spreadsheet), what is the EOQ?
- Also show calculations (both in .pdf and also in spreadsheet) for the optimal Q*.

(5 marks)

3c) Let us now return to the problem from part (a) - i.e., there is no discount for larger orders (as there was in part (b)). Assume that we are permitted to run out of stock, but there is a back-order penalty of $10 on each product for which we are out of stock for a month.

- Showing calculations (both in .pdf and also in spreadsheet), what is the EOQ?
- Also show calculations (both in .pdf and also in spreadsheet) for the optimal Q*.

(5 marks)

Throughout, recall **Note 4** above: ``**Note 4**: As a general rule, don't just give a number or an answer like `Yes' or `No' without at least some clear and sufficient explanation - or, otherwise, you risk being awarded 0 marks for the relevant exercise. Make it easy for the person marking your work to follow your reasoning. Your .pdf should typically cross-reference the corresponding answer in your spreadsheet. For each sub-question and exercise, provide a clearly labelled spreadsheet tab with clear content, accompanied with clearly cross-referenced clear .pdf explanation. Without clear cross-reference between .pdf and spreadsheet tab – and without a separate spreadsheet tab for each sub-question - there is the possibility that any such exercise will be awarded 0 marks.''

A note about your Spreadsheet Model

When building your model, bear in mind the goals and guidelines for good spreadsheet design as discussed in Lecture 3. Marks are given for good spreadsheet design. Marks will possibly also be given for originality. Format both your models clearly with comments (and, if possible, shading), etc. so that it is easy for the user to distinguish which cells are occupied by decision variables, LHS and RHS constraints, and the objective function. Include a textbox in each worksheet that describes the formulation in terms of cell references in your model.

Instructions:

You are to upload your submission on the FIT5097 Moodle site and should include the following:

1. A text-based .pdf document (save as: FamilyName-StudentId-2ndSem2022FIT5097.pdf) that includes all your answers to Questions 1 and 2 and 3 (except for the Microsoft Excel Solver part of each question); and

2. A Microsoft Excel workbook (save as: FamilyName-StudentId-2ndSem2022FIT5097.xlsx) that includes the following spreadsheets:
   i. the spreadsheet model for Question 1;
   ii. Sensitivity Rep – the sensitivity report for the Question 1 model (and any other relevant parts);
   iii. other relevant things (including any calculations) for Question 1;
   iv. relevant things (including any calculations) for Question 2
   v. relevant things (including any calculations) for Question 3

Recall that, at the time you submit (1 and 2) to Moodle, the text-based .pdf will undergo a similarity check by Turnitin. This is done at the time you upload your assignment to Moodle. It is also our intention to perform such a check on your .xls/.xlsx file at the same time.

(This ends the submission instructions. Please read them and the notes on pages 1-2 carefully. Also recall that, as a general rule, when answering questions, don't just give a

number or an answer like `Yes' or `No' without at least some clear and sufficient explanation.)

Late penalties:

Work submitted after the deadline (possibly with a small amount of grace time) will be subject to late penalties in accordance with the FIT5097 Unit Guide and Faculty and University policies, and certainly no less than 5% per calendar day.

If you do not submit matching .pdf and .xls/.xlsx files (e.g., if you submit two files but one is blank or unreadable, or if you only submit one file), then your work will be deemed late - and will be subject to the relevant penalties, possibly receiving a mark of 0.

Work submitted 10 or more calendar days after the deadline will possibly be given a mark of 0.

Plagiarism declaration:

You are required to state explicitly that you have done your own work, however the Moodle assignment submission details permit you to declare this.

For example, if you are presented with an 'Assignment Electronic Plagiarism Statement', then you are required to complete the 'Assignment Electronic Plagiarism Statement' quiz on the FIT5097 Moodle site and accept the Student Statement (electronic version of the Assignment cover sheet). If you do not accept the Student Statement, then your assignment may not be marked, and you may be given a mark of 0.

Recall instructions above and notes on pages 1 to 2 (including but not only, e.g., **Note 4**, Academic Integrity, Special Consideration, make sure to hit the `Submit' button, etc.), and please follow these carefully.

And a reminder not to post even part of a proposed partial solution to a forum or other public location. This includes when you are seeking clarification of a question. If you are seeking to understand a concept better then try to word your question so that it is a long way removed from the Assignment. You are reminded that Monash University takes academic integrity very seriously.

*** END FIT5097 Assignment Faculty of I.T., Monash University 2nd semester 2022 ***