Monash University
Faculty of Information Technology
FIT5097 Business Intelligence Modelling
2nd Semester 2021

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

This assignment is worth 30% 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 23rd September 2021, 11:55pm

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

1. A Microsoft Excel spreadsheet named as:
   FamilyName-StudentId-2ndSem2021FIT5097.xlsx
2. A text-based .pdf file named as: *FamilyName-StudentId-2ndSem2021FIT5097*.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 re use of Moodle.

Total available marks: 45 + 50 + 10 = 105 marks, but maximum possible is **100 marks**.

Any student who obtains 100 marks or more than 100 marks will receive 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 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 x 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 very slow (as you wait and wait and 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 – Many products, many components [6 + 6 + 4 + 2 + 3 + 3 + 3 + 3 + 3 + 3 + 3 + 3 = 45 marks]

Consider several types of product: P_1 (product 1), …, P_i (product i), and P_3 (product 3), with the production of products P_1, ..., P_i, …, P_6 in quantities X_1, ..., X_i ..., X_3. These are made up of 4 components (or resources or things) : $Component_1$, …, $Component_j$, …, $Component_4$. (We will possibly sometimes use the terms L_i and X_i interchangeably; we will possibly use the terms component and resource interchangeably.) The profit for each of X_1, ..., X_i, …, X_3 is c_1, ..., c_i..., c_3 shown below. Unless stated otherwise, you should not assume that the X_i are integers. We also show below the amounts of $Component_1$, …, $Component_j$, ..., $Component_4$ required to make each of P_1, ..., P_3; and, for each of $Component_1$, ..., $Component_4$, we show how much of that component (or resource) is available.

	P1	P2	P3	Available
Component1	1	1	2	1577
Component2	9	6	11	1990
Component3	12	15	23	1321
Component4	24	30	40	1920
Profit	350	300	550	

We wish to produce the number 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-2ndSem2021FIT5097*.pdf]. (6 marks)

b) Create a spreadsheet model for this problem. Store the model in your Excel workbook [*FamilyName-YourStudentId-2ndSem2021FIT5097*.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) 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) Continuing from the above (the end of part (d)), and now setting $X_1 = X_3$, what is the optimal production plan and the associated profit? Clearly explain why, showing the optimal production plan. (3 marks)

f) In part (e), which constraints – if any - are binding? Explain clearly. (3 marks)

g) Returning to the end of part (d), add the requirement that $X_1 = X_2 = X_3$. What is the optimal production plan and the associated profit? Clearly explain. (3 marks)

h) For the problem in part (d), what is the effect on the optimal solution (i.e., on the objective function) if we increase the amount of Resource1 available by 3? Explain clearly. (3 marks)

i) For the problem in part (d), suppose we change the profitability of each product as follows: we decrease the profitability of P_1 by 25, we decrease the profitability of P_2 by 5, and we increase the profitability of P_3 by 3.
What effect – if any - will this have on (X_1, X_2, X_3)? Clearly explain why. (3 marks)

j) The company has committed to filling an order of (150, 100, 50) of (P_1, P_2, P_3). For the various quantities required, goods can be made in house by the company (given the constraints) or goods can be purchased at prices of ($370, $320, $540) each for ($P_1$, P_2, P_3) respectively.
Show the optimal production plan and the optimal value of the objective function, explaining your working.
Would this result in an overall profit or an overall loss? And what would be this overall profit or overall loss? Make sure to show all working. (3 marks)

The introduction above to Question 1 included the statement: ``Unless stated otherwise, you should not assume that the X_i are integers.'' This applies to 1a-1j above. For each of the remainder of Question 1 below, throughout the rest of this question, state clearly whether or not you are assuming that all the X_i are integers.

k) Let us continue on from the end of part 1(j) above. We add the requirement that, for at least one of the products, it is totally made in house and none are bought. Show the optimal production plan and the optimal value of the objective function, clearly explaining your working. In the case where you instead believe that no feasible solution exists, please state so clearly and please also clearly explain why you believe such a production plan to be infeasible. (3 marks)

l) Let us continue on from the end of part 1(d) above. Assume now that we have start-up (or set-up) costs of ($8000, $5000, $100) respectively. Show the optimal production plan and the optimal value of the objective function, clearly explaining your working. (3 marks)

m) Let us now continue on from the end of part 1(l) above. For every good which is produced (i.e., for all P_i for which $X_i > 0$), we add the constraints that X_i must be an odd number (i.e., 1, 3, 5, 7, 9, 11, or …). Show the optimal production plan and the optimal value of the objective function, clearly explaining your working. (3 marks)

Throughout – both above (in Question 1) and below - recall **Note 4** above on page 1: ``**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.''.

Question 2 – Trans-shipment [7 + 7 + 6 + 6 + 5 + 5 + 4 + 4 + 3 + 3 = 50 marks]

We have supply (or source) of 100 and 80 each at A and B respectively. We wish to move these goods to other locations with their respective demands, possibly via various intermediate nodes. Details follow below.

Transportation costs along edges are as follows:

To / From	C	D	E
A	5	8	7
B	4	1	5

To / From	F	G	H
C	8	3	4
D	4	8	9
E	10	13	12

To / From	J	K
F	11	5
G	6	7
H	10	9

As in earlier instructions (e.g., **Note 4**), show your answer clearly both in your .pdf and a corresponding cross-referenced spreadsheet tab – and clearly explain your working.

2a) In the first problem, there is demand of 60 at C, 60 at D and 60 at E. Solve for the flow along all edges giving rise to the minimum total cost. Clearly show and explain your working. (7 marks)

2b) The problem from 2a above is now modified. In the new problem, C, D and E serve only as intermediate nodes. There is demand of 60 at F, 60 at G and 60 at H. Solve for the flow along all edges giving rise to the minimum total cost. As in earlier instructions and through at least this question, show your answer clearly both in your .pdf and a corresponding cross-referenced spreadsheet tab – and clearly explain your working. (7 marks)

2c) The problem from 2a and 2b above is now modified. In the new problem, C, D, E, F, G and H serve only as intermediate nodes. There is demand of 90 at J and 90 at K. Solve for the flow along all edges giving rise to the minimum total cost. As in earlier instructions and through at least this question, show your answer clearly both in your .pdf and a corresponding cross-referenced spreadsheet tab – and clearly explain your working. (6 marks)

2d) Following on from the problem at 2c), we introduce a new edge, directly from A to K, with cost \$12/unit. Solve for the flow along all edges giving rise to the minimum total cost. As in earlier instructions and through at least this question, show your answer clearly both in your .pdf and a corresponding cross-referenced spreadsheet tab – and clearly explain your working. (6 marks)

2e) Following on from your answer at 2d), suppose the cost along AC were to decrease by \$1, the cost along CF were to increase by \$2 and the cost along CG were to decrease by \$1. Providing the most elegant solution that you can, what would happen to the amounts of flow and what would happen to the objective function? In other words, answering as elegantly and clearly as possible, how much would the amounts of flow and the objective function change by – and why? (5 marks)

2f) Following on from the problems at 2d) and 2e), we introduce a penalty for each edge with positive flow (i.e., for each edge where the flow along the edge is greater than 0). The penalty is $10 for each edge with positive flow. Solve for the flow along all edges giving rise to the minimum total cost. As in earlier instructions and through at least this question, show your answer clearly both in your .pdf and a corresponding cross-referenced spreadsheet tab – and clearly explain your working. (5 marks)

2g) Following on from the problem at 2f), if there is any flow from G to J then we restrict this to be one of 5, 25, 50, 86, 91. Solve for the flow along all edges giving rise to the minimum total cost. As in earlier instructions and through at least this question, show your answer clearly both in your .pdf and a corresponding cross-referenced spreadsheet tab – and clearly explain your working. (4 marks)

2h) Following on from the problem at 2f), we add $250 to the minimum solution from 2f) and note this as a new cost. We then seek the minimum number of edges with non-zero flow which could achieve that cost. As in earlier instructions and through at least this question, show your answer clearly both in your .pdf and a corresponding cross-referenced spreadsheet tab – and clearly explain your working. (4 marks)

2i) Following on from the problem at 2f), we add some new constraints. Of the edges AC, BD, CG and DF, at most one of these edges is allowed a flow of more than 50. We then seek the minimum number of edges with non-zero flow which could achieve that cost. As in earlier instructions and through at least this question, show your answer clearly both in your .pdf and a corresponding cross-referenced spreadsheet tab – and clearly explain your working. (3 marks)

2j) Following on from the problem at 2f), on the edge AK we have two different prices – depending upon the amount of flow. For amounts of flow <= 5 the cost of the edge is $12/unit. Beyond 5 units, every unit of flow on AK costs $14/unit. As in earlier instructions and through at least this question, show your answer clearly both in your .pdf and a corresponding cross-referenced spreadsheet tab – and clearly explain your working. (3 marks)

Throughout – both above and (in Question 3) below - 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.''

Question 3 – Economic Order Quantity (EOQ) [4 + 4 + 2 = 10 marks]

This question is based on the economic order quantity (EOQ) theme.

OurNon-ExistentWidgetCompany needs 1200 widgets every month. Widgets cost $500 each, but every time that it orders one or more widgets, there is an order (or delivery) cost of $20. The annual holding cost of a widget is 20% of the purchase cost of a widget.

a) Based on the Economic Order Quantity (EOQ) model, what is the optimal number of widgets to order at a time? Show clear calculations to get your result, with clearly documented cross-reference to any spreadsheet tab that you might use. Such a spreadsheet tab should also be clearly laid out. Clearly explain your working. (4 marks)

b) Following on your answer to a) immediately above, how many orders should be placed per annum? Again, show clear calculations to get your result, with clearly documented cross-reference to any spreadsheet tab that you might use. Such a spreadsheet tab should also be clearly laid out. Clearly explain your working. (4 marks)

c) Re-visiting (a) above but now require that the number of widgets that must be ordered is an integer. What is the optimal number of widgets to order at a time? Again, show clear calculations to get your result, with clearly documented cross-reference to any spreadsheet tab that you might use. Such a spreadsheet tab should also be clearly laid out. Clearly explain your working. (2 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-2ndSem2021FIT5097.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-2ndSem2021FIT5097.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
vi. etc.
vii. Anything else you deem sufficiently relevant.

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.

Any student who obtains 100 marks or more than 100 marks will receive 100 marks – i.e., the maximum possible is 100 marks.

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 2021 ***