Analytic Decision Making

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Homework 1

Instructions:

1. The homework is an **INDIVIDUAL** graded assignment.

2. Due date: **May 9th, 2024 at 1pm.**
    a. Late assignments won't be graded.
    b. No extension.

3. Please submit a Jupyter notebook with your answers and codes. I will use https://colab.research.google.com/ to check the notebooks, so make sure they work on this platform. You can also submit a word document saved in PDF and the codes independently.

4. If you create a data set to answer questions, submit it as well.

5. In your optimization models, feel free to add comments throughout the code (e.g., "#This kind of comment") to help me follow what you are doing. No need to comment every line.

6. Please submit a copy of your assignment on Canvas.

7. 70% of the evaluation will be based on the quality of your analysis; 30% of the evaluation will be based on the quality of the presentation.

Per the Syllabus regarding the use of AI:
Any written work (including coding) in which students do not explicitly identify writing, text, or media generated by AI will be assumed as original to the student. Any AI use must be tracked and acknowledged through means such as highlighting the text and explaining what parts have been AI-generated. If violations to this policy are detected, students will receive a "0" for their submission. If a student is unsure of how to adhere to this policy, they should reach out to the instructor to ask for guidance**.**

Exercise 1: Operations Excellence

You operate 2 sites, i.e., BIC and CIB. Each sites makes two products, "standard" and "deluxe". A unit of standard gives a profit contribution of $10, while a unit of deluxe gives a profit contribution of $15.

Each site uses two production processes, cooking and filtering, for manufacturing its products. The BIC site has a cooking capacity of 80 hours per week and filtering capacity of 60 hours per week. For the CIB site, these capacities are 60 and 75 hours per week, respectively.

The cooking and filtering times in hours for a unit of each type of product in each factory are given in the tables below.

For BIC Site

	Standard	Deluxe
Cooking	4	2
Filtering	2	5

For CIB Site

	Standard	Deluxe
Cooking	5	3
Filtering	5	6

It is possible, for example, that the CIB site has older machines than plant the BIC site, resulting in higher unit processing times. In addition, each unit of each product uses 4 kg of a raw material, which we refer to as raw. The company has 120 kg of raw available per week. To start with, we will assume that the BIC site is allocated 75 kg of raw per week and the CIB site the remaining 45 kg per week. Each plant can build a very simple linear programming model to maximize its profit contribution.

1. Write the optimization models for each plant, i.e., make sure to detail the decision variables, the objective function and the constraints.
2. Provide the optimal solutions and profit levels for each factory. Give the values of the decision variables and the optimal objective function value.
3. Now, write the optimization model for the joint optimization of both sites, and provide the optimal solution and profit levels.
4. Please comment on the results? How do they compare to the results obtained in Question 2.
5. In one paragraph (no more than 300 words), detail the recommendations you would provide to the CEO of the company to improve the firm's operations?

Exercise 2: Hotel L'Escargot

L'Escargot is a hotel chain considering adding more locations to its portfolio. L'Escargot used data on 100 existing inn locations to build a linear regression model to predict "Profitability", computed at the operating margin, or earnings before interest and taxes divided by total revenue. Several models were estimated and the final model that was retained is:

$$\begin{aligned} Profitability = 39.05 &- (5.41 \times State\ Population\ per\ Inn) \\ &+ (5.86 \times Price\ of\ the\ Inn) \\ &- (3.09 \times Square\ Root\ of\ the\ Median\ Income\ in\ the\ area) \\ &+ (1.75 \times College\ Students\ in\ the\ Area) \end{aligned}$$

All independent variables are significant and were normalized to have mean zero and standard deviation 1.

1. According to the regression equation given above, which variable positively affect Profitability? Which variable negatively affect Profitability? Does this intuitively make sense? Why?
2. Using this regression equation, L'Escargot created a spreadsheet model to predict profitability. L'Escargot collected data for several locations in California, which is provided in the excel spreadsheet on Canvas "L'Escargot". Using this spreadsheet, compute the profitability for each hotel. Which one has the highest profitability? Which one has the lowest profitability?
3. L'Escargot has a budget of $10 million to spend on hotels. Suppose we use a "greedy" approach where we select the most profitable hotels until we ran out of budget. So we would start by the most profitable, and then if we had enough budget left, we would buy the hotel we predict to be the second most profitable, and so on.
    a. Describe what we would do with this approach, i.e., which hotels would we purchase?
    b. What would our total predicted profitability be? (This is the sum of the predicted profitability of all hotels we purchase.)
    c. If we are trying to maximize our total predicted profitability, is this a good approach? How about if we were trying to maximize the average predicted profitability of the hotels we select? How about if we had a budget of $20 million instead of $10 million?
4. Now, build an optimization model to select hotels given the $10 million budget.
    a. Write out the optimization problem. Make sure to detail the decision variables, the objective function and the constraints.
    b. What is the optimal solution? Give the values of the decision variables and the optimal objective function value.
    c. Does the optimal solution make sense intuitively? How does it compared to the greedy solution?
5. L'Escargot thinks that buying too many hotels in one city is probably not a good idea and would prefer to diversify across as many cities as possible. Add constraint(s) to your model to limit the number of hotels purchased in any city to at most 2.
    a. What are the constraints that you need to add to the model? Intuitively, do you expect the new optimal objective function value to be larger, smaller or the same as before?
    b. Write the new optimization model.
    c. Solve the new model. Give the values of the decision variables and the optimal objective function value. How does this compare to the previous solution?
6. In one paragraph (no more than 300 words), describe how you would present your results to L'Escargot. Do you have any recommendations for them to improve the regression model? How about to improve the optimization model?

Exercise 3: Matching for a Dating Platform

You run an online dating app that specializes in matching people based on compatibility scores. When signing up, each person writes down their score for 5 activities: playing sports, going to the theater, attending religious services, enjoying the outdoors and eating out. The scores vary from -2 (strong dislike) to +2 (strong like). The activity scores chosen by 16 people in a particular location are available here (also on Canvas):

https://raw.githubusercontent.com/ormarketing/OD/master/OD.csv

When you create a match, the value of the match is equal to the sum of the products of the 5 different activity scores of the two individuals. For example, if you match Laura and Ralph, the match score would be:

Score(Laura & Ralph) = $0\times0+2\times2+(1)\times2+0\times2+2\times(-1) = 0+4-2+0-2 = 0$

1. Assume all of the individuals in the data set would like to be matched to people of the opposite gender. What matches would you choose to maximize the aggregate match score?
2. How would the results change if each person is presented with two possible matches?