Case 1: Optimizing network flow

You work in a team within a consulting company and just received an email with your next assignment. Your next client is going to be a coffee beans company named Beanie Limited. Your main contact for this engagement is Charles Murray, Beanie Limited's COO (Chief Operations Officer). Charles is responsible for the entire manufacturing and supply chain organization of Beanie Limited in Europe and reports directly to Beanie Limited's CEO.

Given Charles role, he gets involved in large, strategical and long-term decisions for the company. One of the hot topics that is currently in Charles mind is the next plan for coffee beans reception in European docks. Charles' office has reached out to you to prepare a report to assist in this highly important decision by using optimisation techniques.

As you are probably aware of, coffee beans are not grown in Europe. World production is divided across South/Central America, Africa and South East Asia. Beanie Limited purchases all of its coffee beans from different providers in America, mainly in Brasil and Colombia (these two countries account for almost 40% of the world production). Beanie Limited procurement teams execute purchases with local providers at those locations and then the coffee beans are shipped in container cargo ships to European docks.

Docks are a natural bottleneck in supply chains. Dock capacity in europe is limited, and both storage and handling (the activities related with loading and unloading goods on ships) in docks are expensive services. Charles thinks that Beanie Limited has not paid enough attention to this part of the supply chain since covid-19 radically changed the landscape (total costs for trans-oceanic freight of standard containers have seen five-fold increases during the pandemic) and wants to evaluate if the current way of working can be improved.

Currently, Beanie Limited takes a very simple approach: all the beans purchased in America reach Europe on the Rotterdam docks (the largest in Europe). The Amsterdam docks are used sparingly whenever there are high activity periods or the Rotterdam docks are under a lot of stress. Charles believes that there is an opportunity to reduce costs and make their supply chain more resilient if the company distributes their reception points across more docks in Europe.

Charles' team has initiated conversations with 8 different docks throughout Europe:

- Rotterdam
- Antwerp
- Hamburg
- Amsterdam
- Marseille

- Algeciras
- Valencia
- Genoa

In the upcoming months, Charles' team must sign contracts with some of these docks to ensure incoming capacity for the coffee beans coming from America. This means they will agree with the docks on the expected handled volumes and thus they must decide with which docks they want to work and how much volume they will assign to each. The team has collected the details provided by the docks' companies for you to study. This information includes the capacity the docks could commit for Beanie Limited, as well as the prices for handling Beanie Limited's 40 feet containers through the dock.

Charles wants you to use your optimization skills to assess the different options and recommend the best decisions for the company regarding how much volume to put through each dock. He hopes you can come up with a plan where Beanie Limited ensures it will have enough capacity, while at the same time costs are as low as possible.

Detailed task definition

- Below you will find four levels of questions. Levels 1 to 3 are compulsory. Level 4 is optional.
- You need to write a report document where you answer the questions of the different levels. This report should be directed towards Charles, should give him clear recommendations and should justify these recommendations. It's important for you to reflect your methodology to back your proposals.
- Each level is worth 2 points out of a total of 10. The 2 missing points will grade the clarity and structure of your report and code.
- You need to use a Python notebook to solve all levels. A helper notebook is provided. Please attach a notebook that shows your solution/proposal/analysis.
- For the areas of the report where you have built an optimization model, please provide a formal definition of the problem in mathematical terms. This sould include the target function, decision variables and constraints.
- Include your team number, names and student IDs in all your deliverables.

Data

A few facts:

- Charles' team estimates that Beanie Limited will need to receive 1,500,000 metric tons of coffee beans in European docks during next year.
- The category being negotiated is 40 feet containers. 40 feet containers have a capacity of 66 cubic meters.
- One cubic meter of coffee beans weights approximately 450 kgrs.

Charles' team has shared with you a table (prices_and_capacities.csv) with the next year's prices proposed by the different docks for 40ft containers. You can also find the maximum capacity that the dock is willing to provide to Beanie Limited (the capacity is described as a count of 40ft containers).

Notebook

A notebook with some helping code has been provided. The code contains examples on how to use `pulp`, a python package for modeling and solving optimization problems. You can use it to get familiar with how to solve linear, integer and mixed programming problems.

Levels

Level 1

Examine the data about the last year operations provided below and the current proposals data. Do you think there is a chance to reduce costs? Why? And will next year's total cost lower?

You can assume that last year, around 80% of Beanie Limited's containers entered through Rotterdam and the remaining 20% through Amsterdam. Total volume was around 24,000 40ft containers. Although they don't have more granular numbers at hand, Charles mentioned that they had a total expense of 13,700,000€ on docks fees.

Level 2

With the price and capacity data provided for each dock, Charles would like you to find out what is the optimal distribution across the different options for next year. He is expecting you to provide the exact numbers, as well as the expected costs that would result from your proposal.

Level 3

As it tends to be in these projects, sometimes new information appears in the middle of the project. Charles' team has reached out to let you know that they have some additional details from the different ports.

The following docks have a sign-up fee. This means that, if Beanie Limited wants to do any business with them at all, they need to pay this fee. This fee is only paid once and is independent of the container volume that goes through the dock.

- Algeciras: 800,000€
- Marseille: 500,000€
- Antwerp: 1,000,000€

Also, after presenting your initial results from level 2, Charles is very happy with your work, although there is something bothering him. Even though your proposal

sounds reasonable, he is concerned that splitting the operations between too many docks might make land logistics operations too complex and end up causing higher costs in their truck transportation that cancel the potential savings that could be obtained in docks operations.

Charles doesn't have numbers currently, so there is no way to tackle this properly in an empirical way. To have the necessary information to think about this in the future, he would like you to repeat your analysis with a new condition in place: to only use a maximum of 3 docks in your proposal. Charles wants to know what would be the optimal decision while restricting the used docks to that number.

Charles wants you to reassess the situation with the new data and provide the adequate solution with the new options. He also would like to understand how these changes impact the solution you provided for level 2 and the overall results for Beanie Limited.

Level 4

Now that it seemed you finally had a proper proposal in place, Charles is calling again with more concerns and asking you to go the extra mile with a final assessment.

Apparently, some rumours have reached Charles ears. It seems that some new regulations in Spain might affect taxes related to dock activities. Charles believes this could have an impact on the prices in Valencia and Algeciras, putting pressure on them to increase their prices because additional taxes would increase their own costs. The issue is: Charles doesn't know for sure what will happen. His expert opinion is that the following is possible:

- For Valencia, Charles thinks the price can end up somewhere between today's price (310€/40ft) and 390€/40ft. He says the probability of any price is in that range is equal.
- For Algeciras, Charles thinks the price can end up somewhere between today's price (280€/40ft) and 330€/40ft. Again, he says the probability of any price is in that range is equal.

Charles heard you are not only experts in optimization, but also in simulation. Charles' can't request you to do any simulation work as part of the current engagement, because that would be out of the scope that was agreed upon. But nevertheless, he would appreciate if you could explain to him how would you use simulation to make the decision with this new uncertainty in place. What would be your methodology? What kind of results could you provide to him?

With that information, he might decide to spend some more money with our company to pursue that stream of work. And that would definitely make your bosses very happy!