CORK INSTITUTE OF TECHNOLOGY
INSTITIÚID TEICNEOLAÍOCHTA CHORCAÍ

Computing@CIT

DECISION ANALYTICS

Assignment 2: Linear Programming

DUE DATE

This assignment should be submitted to Canvas before 11:59pm on **Friday 01/05/2020**.

Please submit a single ZIP file with your student number and name in the filename. Your submission should contain:

- A detailed documentation of all code you developed, including the tests and evaluations you carried out. Please make sure that you include a document with every result you produced referencing the exact subtask and lines of code.

- All Python code you developed in a single .py file that can be executed and that generates the outputs you are referring to in your evaluation. Please make sure that you clearly indicate in your comments the exact subtask every piece of code if referring to.

You can achieve a total of 50 points as indicated in the tasks.

TASK 1 (supply chain optimisation, 30 points)

In this task you will optimise the cost of sourcing raw material from different suppliers, manufacturing products in different factories and delivering these products to customers. The input data for this task is contained in the Excel file "Assignment_DA_2_a_data.xlsx" and can be downloaded from Canvas. The file contains 8 sheets:

- Supplier stock
  A table indicating how many units of each raw material each of the suppliers has in stock.
- Raw material costs
  A table indicating how much each of the suppliers is charging per unit for each of the raw materials.
- Raw material shipping
  A table indicating the shipping costs per unit of raw material (the units for each material are the same) from each supplier to each factory

- Product requirements
  A table indicating the amount of raw material required to manufacture one unit of each of the products.
- Production capacity
  A table indicating how many units of each product each of the factories is able to manufacture.
- Production cost
  A table indicating the cost of manufacturing a unit of each product in each of the factories.
- Customer demand
  A table indicating the number of units of each product that have been ordered by the customers
- Shipping costs
  A table indicating the shipping costs per unit for delivering a product to the customer.

Factories can order suppliers from multiple suppliers and products can be delivered to customers from multiple factories.

The goal of this task is to develop and optimise a Liner Programming model that helps decide what raw material to order from which supplier, where to manufacture the products, and how to deliver the manufactured products to the customers so that the overall cost is minimised.

A. Load the input data from the file "Assignment_DA_2_a_data.xlsx" [1 point]. Note that not all fields are filled, for example Supplier C does not stock Material A. Make sure to use the data from the file in your code, please do not hardcode any values that can be read from the file.
B. Identify and create the decision variables for the orders from the suppliers [1 point], for the production volume [1 point], and for the delivery to the customers [1 point] using the OR Tools wrapper of the GLOP_LINEAR_PROGRAMMING solver.
C. Define and implement the constraints that ensure factories produce more than they ship to the customers [2 points].
D. Define and implement the constraints that ensure that customer demand is met [2 points].
E. Define and implement the constraints that ensure that suppliers have all ordered items in stock [2 points].
F. Define and implement the constraints that ensure that factories order enough material to be able to manufacture all items [2 points].
G. Define and implement the constraints that ensure that the manufacturing capacities are not exceeded [2 points].
H. Define and implement the objective function. Make sure to consider the supplier bills comprising shipping and material costs [2 points], the production cost of each factory [2 points], and the cost of delivery to each customer [2 points].
I. Solve the linear program and determine the optimal overall cost [1 point].

J. Determine for each factory how much material has to be ordered from each individual supplier [1 point].
K. Determine for each factory what the supplier bill comprising material cost and delivery will be for each supplier [1 point].
L. Determine for each factory how many units of each product are being manufactured [1 point]. Also determine the total manufacturing cost for each individual factory [1 point].
M. Determine for each customer how many units of each product are being shipped from each factory [1 point]. Also determine the total shipping cost per customer [1 point]
N. Determine for each customer the fraction of each material each factory has to order for manufacturing products delivered to that particular customer [1 point]. Based on this calculate the overall unit cost of each product per customer including the raw materials used for the manufacturing of the customer's specific product, the cost of manufacturing for the specific customer and all relevant shipping costs [2 points].

TASK 2 (airport taxiway optimisation, 20 points)

In this task you will optimise the taxi movements for arriving and departing aircraft moving between runways and terminals. The input data for this task is contained in the Excel file "Assignment_DA_2_b_data.xlsx" and can be downloaded from Canvas. The file contains 3 sheets:

- Flight schedule
  This table outlines the arrival and departure times for all flights of the day.
- Taxi distances
  This table outlines the taxi distances between the different runways and terminals of the airport.
- Terminal capacity
  This table shows the gate capacity of each terminal, i.e. how many planes can be present at the terminal at any given time.

The same runway cannot be occupied at the same time, neither for arrival nor for departure. For example, Flight B departing at 10:00 and flight L arriving at 10:00 cannot be assigned the same runway. Further to that, planes are occupying their allocated gate the whole timespan between arrival and departure during which the gate capacity of the terminal needs to be taken into consideration when allocating terminals. Planes have to taxi from the allocated arrival runway to the allocated terminal and then from the allocated terminal to the allocated departure runway. Arrival and departure runways can be different. The total taxi distance for each flight is the distance from the arrival runway to the allocated terminal and the way back from the terminal to the departure runway.

The goal of this task is to develop and optimise an Integer Liner Programming model for allocating an arrival runway, a departure runway and a terminal for each flight so that the overall taxi distance of all planes is minimised.

A. Load the input data from the file “Assignment_DA_2_b_data.xlsx” [1 point]. Make sure to use the data from the file in your code, please do not hardcode any values that can be read from the file.
B. Identify and create the decision variables for the arrival runway allocation [1 point], for the departure runway allocation [1 point], and for the terminal allocation [1 point] using the OR Tools wrapper of the CBC_MIXED_INTEGER_PROGRAMMING solver.
C. Define and create auxiliary variables for the taxi movements between runways and terminals for each flight [1 point].
D. Define and implement the constraints that ensure that every flight has exactly two taxi movements [1 point].
E. Define and implement the constraints that ensure that the taxi movements of a flight are to and from the allocated terminal [1 point].
F. Define and implement the constraints that ensure that the taxi movements of a flight include the allocated arrival and departure runways [1 point].
G. Define and implement the constraints that ensure that each flight has exactly one allocated arrival runway [1 point] and exactly one allocated departure runway [1 point].
H. Define and implement the constraints the ensure that each flight is allocated to exactly one terminal [1 point].
I. Define and implement the constraints that ensure that no runway is used by more than one flight during each timeslot [1 point].
J. Define and implement the constraints that ensure that the terminal capacities are not exceeded [1 point].
K. Define and implement the objective function [1 point]. Solve the linear program and determine the optimal total taxi distances for all flights [1 point].
L. Determine the arrival runway allocation [1 point], the departure runway allocation [1 point], and the terminal allocation [1 point] for each flight. Also determine the taxi distance for each flight [1 point].
M. Determine for each time of the day how many gates are occupied at each terminal [1 point].