Programming Assignment 1

COMP331/COMP557 Optimisation

Semester 1 2025

Submit by 17:00 on October 30, via Canvas

This assignment counts for 15% of the total module mark.

1 Introduction

In this assignment, you will solve a logistics problem for a fictional company named *Soltari*. The goal is to decide where Soltari should open facilities, what to produce at each of these facilities, and where to ship products, in order to maximise total revenue under a global budget that covers both resource costs for production and shipping.

2 Problem Description

As the head of Soltari logistics, you are faced with the following task. Soltari is expanding its operations into a new region and plans to open several facilities to manufacture a range of products for customers. Facilities can be opened at different locations. Each location comes with restrictions on the total number of units that can be manufactured: on the one hand, economies of scale dictate that a minimum total number of units (across all products) must be produced at a facility; on the other hand, local environmental regulations impose an upper limit on total production. These bounds may vary between facilities. Opening a facility does not incur any additional fixed cost; the opening decision matters only because of the lower and upper production bounds.

Facilities can produce multiple products, and each product requires a certain number of resource units. Production technology is standardised across facilities, so each product has the same resource requirements everywhere, and every product can be manufactured at every location. However, resource prices may differ by facility.

Soltari also manages shipping from its facilities to demand locations (last-mile delivery is handled by other operators and can be ignored here). Shipping costs per unit of product depend on the product type and the distance between the facility and demand location. Each demand location has its own demand for each product, and the selling price per unit varies by location.

You must make the following decisions:

- Which facilities to open.
- How many units of each product to produce at each open facility.
- How many units of each product to ship from each facility to each demand location.

Revenue is earned for every unit delivered to a demand location (up to its demand limit). A single global budget must cover *all* resource and shipping costs.

Modelling assumptions.

1. Revenue is only generated from shipping products; unused budget does not contribute to revenue.
2. A product shipped to a demand location generates revenue only up to that location's demand for the product; additional units do not earn revenue.
3. Demands need not be fully satisfied: it is permissible to ship fewer units of a product than the demand at a given location.
4. Shipping costs are calculated as (distance) $\times$ (units) $\times$ (per-unit product shipping cost).
5. Quantities are sufficiently large that units of product can be modelled as nonnegative real numbers.

3 Example

As a starting point, we consider an example with 5 potential facility locations (A through E), 6 demand locations (1 to 6), 4 resources and 3 products. Resource prices by facility location, lower and upper bounds on production, resource requirements for each product, unit shipping costs for each product, product prices by demand location, and product demands by demand location are given below.

Resource Prices

Facility	Steel	Plastic	Energy	Labour
A	5.0	4.0	3.5	6.0
B	4.5	4.2	3.8	6.5
C	5.2	3.8	3.6	5.8
D	4.8	4.5	4.0	6.2
E	5.5	3.9	3.7	6.1

Bounds on Production

Facility	Lower	Upper
A	200	800
B	150	1000
C	50	600
D	250	1200
E	180	900

Resource Requirements

Product	Steel	Plastic	Energy	Labour
Alpha	2	3	5	4
Beta	4	1	2	3
Gamma	1	4	3	2

Shipping Costs

Product	
Alpha	4
Beta	3.5
Gamma	2

Product Prices

Demand Location	Alpha	Beta	Gamma
1	65	50	42
2	60	45	55
3	48	70	38
4	80	65	42
5	55	30	25
6	90	85	40

Product Demand

Demand Location	Alpha	Beta	Gamma
1	205	380	590
2	475	215	800
3	600	490	270
4	900	675	450
5	350	750	100
6	80	950	410

Distances between facility locations and demand locations are given as edge labels in the graph shown in Figure 1. When there is no edge between a facility location and a demand location, it is not possible to ship products from that facility to the demand location. **The global budget for resources and shipping in this example is set to 500,000.**

4 Instructions

Your task is to model and solve the planning problem described above for the example instance in Section 3. The total budget available for this instance is 500,000. Your model must ensure that total resource and shipping costs do not exceed this budget.

Although you are asked to solve the given example, your implementation should not hard-code any details of the instance. Instead, design a generic input format that can easily be adapted to other problem instances with different numbers of facilities, demand locations, products, resources, costs, demands, and distances.

Your program should:

- read the input data in your chosen representation,

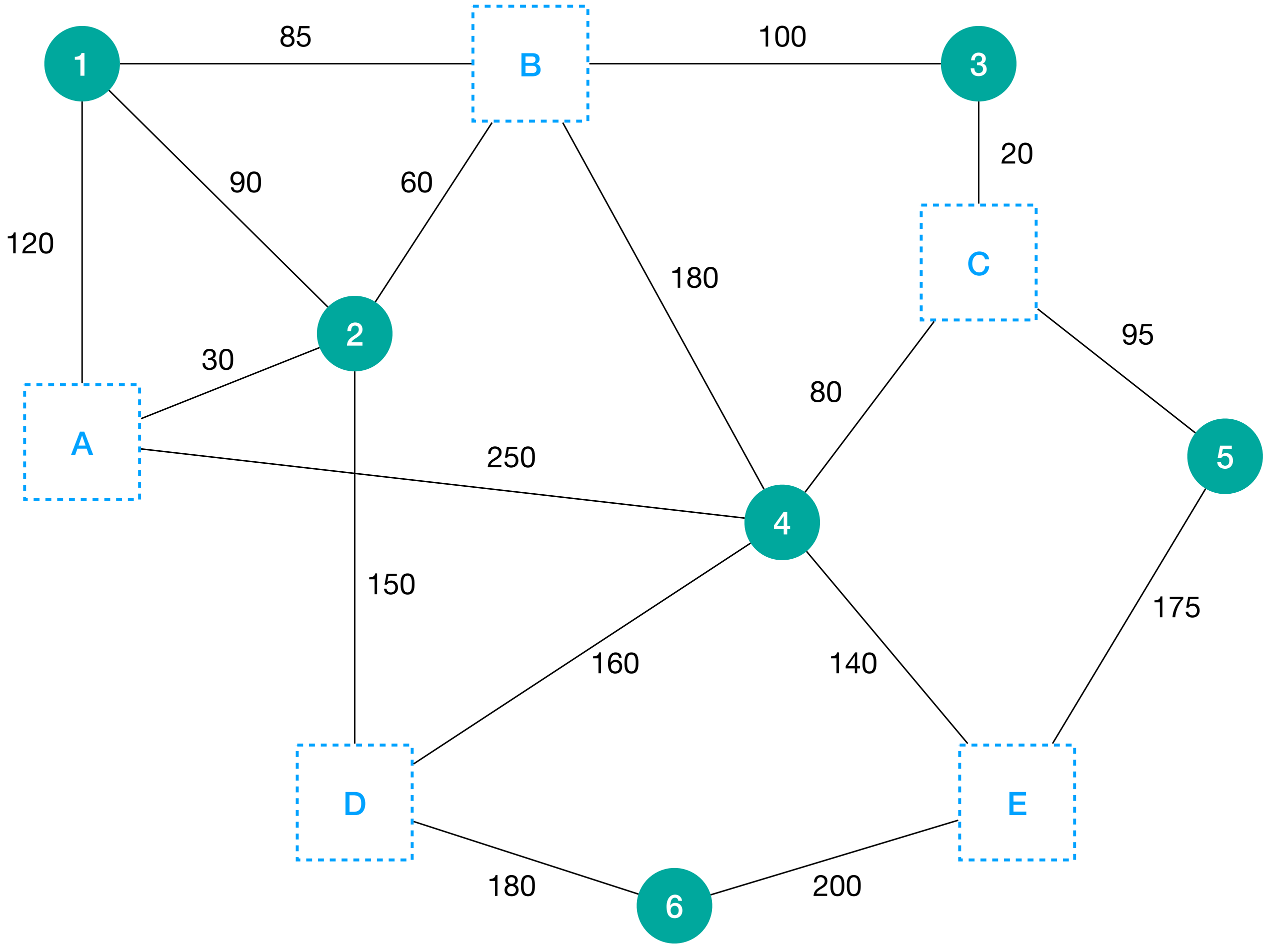

Figure 1: Distances between facility and demand locations in the example.

- build and solve a `GurobiPy` model,
- output the optimal decisions in an easily interpreted way, including:
  - which facilities are opened,
  - how many units of each product are produced at each open facility,
  - how many units of each product are shipped to each demand location,
  - the total revenue.

You are free to choose how to represent the output internally, but it must be printed and presented in a way that is easily interpreted by a reader (e.g. clear tables, structured dictionaries, or formatted text).

Sanity check. You may want to calculate the *theoretical maximum revenue*, defined as the sum of demand times selling price across all products and demand locations, and compare your achieved revenue to this upper bound.

Deliverables

Submit:

- Your Python implementation as a Python file or Jupyter notebook (well-commented).
- A short report (max. 1 page) describing decision variables, the objective, and constraints, and commenting on the optimal solution for the instance given in Section 3.

5 Assessment

This assignment contributes 15% of the total module mark. Marks will be awarded for:

- Correctness of the optimisation model and code.
- Clarity of documentation and explanations.
- Quality of the short write-up.