Operations Research
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Fall 2025

Project: Supply-Chain Network Optimization

Introduction

This project addresses a supply chain optimization problem for a retail network located in the country of **CATAN**. The region is modeled as a grid of square regions with dimensions $N \times M$. Each square represents a specific terrain type: *City*, *Forest*, *Grassland*, *Mountain*, *Desert*, or *Swamp*.

A **path** is defined at the boundary where any two squares meet. The network includes several ports where ships unload cargo. The objective is to minimize the cost of transporting these goods from the ports to retail stores by traversing only the defined paths.

Transport Costs

The cost of transporting goods along a path is determined by the two regions adjacent to that path. Specifically, a fixed cost associated with each terrain type is added to the path's traversal cost. Movement between two adjacent regions of the same terrain type is **prohibited** (i.e., one cannot traverse their common boundary).

The costs associated with each terrain type are variable and will be specified for each case. The table below demonstrates an example:

Terrain Type	Cost Added to Adjacent Path
City	20
Mountain	60
Grassland	40
Forest	50
Desert	90
Swamp	110

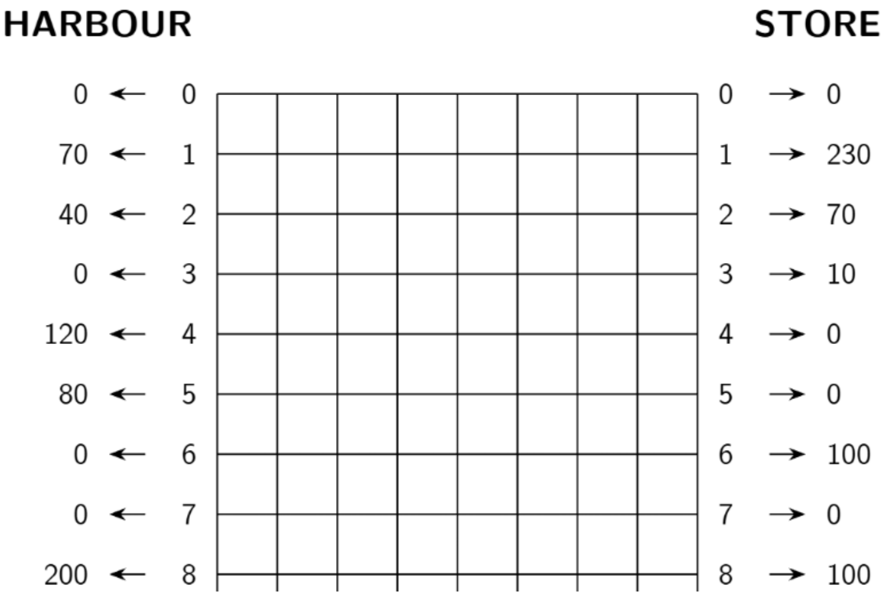
As every path lies between two regions, the total cost of traversing a path is the **sum** of the fixed costs of the two adjacent regions.

Figure 1: Example of a map configuration

Network Configuration

- **Ports:** Located on the left boundary of the map. Their positions and supply quantities are defined by the vector `harbour`.
- **Stores:** Located on the right boundary of the map. Their positions and demand requirements are defined by the vector `stores`.
- **Inventories:** Candidate sites for establishing inventory facilities are restricted to specific locations.

The `harbor` and `stores` vectors are represented as one-dimensional arrays. The values in these lists represent the supply capacity at each port and the demand required by each store, respectively.



Flow of Goods

In this problem, goods cannot be shipped directly from ports to stores. They must first be transported to an **inventory** facility and then shipped to a **customer**.

Inventory Location Constraints

- Inventories may only be established at **intersections**, as illustrated in Figure 2.
- **Opening Cost:** Opening an inventory incurs an initial setup cost. This cost is variable and case-dependent. The cost of establishing an inventory depends on the regions surrounding the intersection. For example, the following costs are added for each region adjacent to the chosen intersection:

Adjacent Region	Cost Added to Inventory Setup
City	1200
Mountain	600
Grassland	1000
Forest	700
Desert	500
Swamp	300

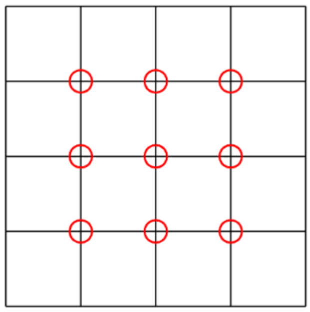


Figure 2: Valid Inventory Locations at Intersections

Operational Constraints

1. **Locations:** Inventory facilities may only be placed at valid intersections.
2. **Capacity:** Each inventory facility has a specific capacity limit.
3. **Facility Count:** The total number of active inventory facilities is constrained by a minimum (min) and a maximum (max) limit.
4. **Minimum Distance:** Inventory facilities must be located at a minimum distance of **3 edges** (paths) from any other inventory facility and from any port.
5. **Shortage Penalty:** If a product fails to reach its destination, a penalty cost p is incurred.

Project Tasks

The presented configuration constitutes a network model. The objective is to determine an optimal solution to this transshipment problem.
The project consists of **two** distinct parts:

Part 1: Algorithmic Solution

In this phase, you are required to find a solution to the problem using an algorithm or heuristic of your choice. However, you are **not permitted** to use any exhaustive search (brute-force) approaches. Furthermore, the application of standard Operations Research methods is restricted in this part; alternative algorithmic methods are preferred. Please note that the final solution obtained in this phase will be graded relative to the best solution found. Additionally, time complexity is a component of the assessment, and students who implement the most efficient solutions (best time complexity) will receive a **bonus** score.

Part 2: Operations Research Solution

Retaining the previously defined configuration, the problem must be solved to optimality using Linear or Mathematical Programming. You are required to implement and solve your models using MiniZinc.

***Bonus* Part**

In this section, the configuration is slightly modified. You are required to provide a new model and find the optimal solution based on the following constraints:

- Each supplier must transfer its goods to **exactly one** inventory facility.
- Inventory capacity constraints are assumed to be infinite.
- Customers must receive their demanded goods from **exactly one** inventory facility.

Grading

Assessment will be based on the final minimized cost achieved and the trade-off between the computational time required to find the optimal solution and the solution's value.

Overall expectations and deliverables:

- Comprehensive documentation of your solution, mathematical models and the methods employed.
- All developed code or scripts must accompanied by clear comments and sufficient clarity.
- Your MiniZinc models (must be included within the documentation).
- All code and MiniZinc models must be legible, traceable, and interpretable.
- Both group members must contribute and be prepared to present the project individually.
- Cite for any additional assistance or references.

Good luck!