ISL project Ethiopia

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Introduction

This report outlines a linear optimization model designed to optimize the flow of commodities (food items) from several different countries to a number of beneficiary camps across East-Africa, ranging from around 2.500 to 85.000 beneficiaries. The model will minimize the costs of acquiring these commodities from different countries and transporting them through ports and warehouses, finally distributing them to the beneficiary camps. All of these routes and elements of the supply chain face several costs and constraints, namely:

- Nutritional demand (ensuring beneficiary camps receive required quantities).
- Acquisition costs (varying by country and commodity).
- Transportation costs (from countries to ports, ports to warehouses, and warehouses to villages).
- Handling costs (at ports and warehouses, dependent on total weight).
- Capacity constraints (when buying and transporting the commodities)

The goal is to determine the optimal flow of commodities across the supply chain while minimizing total costs.

Problem Description

Key Components:
1) Commodities (i): Different goods to be acquired (e.g., food, medical supplies).

2) Countries (c): Sources where commodities are procured, each with different acquisition costs.

3) Ports (p): Intermediate hubs where goods are consolidated and handled.

4) Warehouses (w): Storage and distribution centers before final delivery.

5) Beneficiary camps (v): Final destinations with specified demand for each commodity.

Cost Structure

- Acquisition costs:
  1) (C_{ic}) cost of commodity i from country c
- Transportation costs:
  1) From country c to port p (S_{icp})
  2) From port p to warehouse w (L_{ipw})
  3) From distribution centers to each of the villages v (T_{iwv})
- Handling costs:
  1) Handling cost in each of the ports calculated on total weight (P_p)
  2) Handling cost in each of the distribution centers calculated on total weight (W_w)

Mathematical Model

Objective function:

$$min_{x_{icp},y_{ipw},z_{iwv}} \sum_{\text{all } i,c,p} (C_{ic}+S_{icp})x_{icp}+\sum_{\text{all } p}(P_p \sum_{\text{all } i,c} x_{icp})+\sum_{\text{all } p,w} (L_{p,w} \sum_{\text{all } i} y_{ipw})+\sum_{\text{all } w} W_w \sum_{\text{all } i,p} y_{ipw}+\sum_{\text{all } w,v} T_{wv} \sum_{\text{all } i} z_{iwv}$$

Constraints

Country of origin capacity constraint

$$\sum_{\text{all } p} x_{icp} \leq R^c_{ic} \ \forall i,c$$

- R^c_{ic} is the maximum amount of commodity i that can be bought from country c (in mT/month)

Port capacity constraint

$$\sum_{\text{all } i,c} x_{icp} \leq R^p_p \ \forall p$$

- R^p_p is the maximum amount of goods that can be handled at port p (in mT/month)

Warehouse capacity constraint

$$\sum_{\text{all } i,p} y_{ipw} \leq R^w_w \ \forall w$$

- R^w_w is the maximum amount of goods that can be handled at warehouse w (in mT/month)

Balance equations for x, y and z

$$\sum_{\text{all } c} x_{icp} = \sum_{\text{all w}} y_{ipw} \ \forall i,p$$

$$\sum_{\text{all } p} y_{ipw} = \sum_{\text{all } v} z_{iwv} \ \forall i,w$$

Sufficient nutrient constraint

$$\sum_{\text{all } i}(A_{in} \sum_{\text{all } w} z_{iwv}) \geq R^v_{nv} \ \forall n,v$$

- A_{in} denotes the amount of nutrient n in commodity i (in weight/mT)
- R^v_{nv} denotes the amount of nutrient n required in beneficiary camp v

Solution Approach

The problem is solved through Linear Programming using optimization solvers (Gurobi, CPLEX, or open-source tools like PuLP).

Expected Outcomes

- Optimal shipment quantities: $x_{icp}, y_{ipv}, z_{iwv}$
- Minimum total cost of the supply chain.
- Insights into cost-saving opportunities and pressure points.