PROJECT REPORT:

Campus City Emergency Supply Distribution

1. Problem Statement:

A campus city relies on multiple warehouses to store and distribute emergency resources to various facilities such as hospitals, dormitories, academic buildings, and public centers.However, operating all available warehouses is economically inefficient due to high fixed and transportation costs. Additionally, demand varies across facilities, and the system must operate under strict budgetary and operational constraints.The problem is to select an optimal set of warehouses and determine supply allocation such that all facility demands are met while minimizing the total annual cost of operations and transportation, subject to physical and business constraints.

2. Mathematical Formulation:

To resolve the location-allocation problem, a **Mixed-Integer Linear Programming (MILP)** model was developed.

2.1 Decision Variables

- $y_w \in \{0, 1\}$: Binary variable; 1 if warehouse w is selected for construction/operation, 0 otherwise.
- $x_{w,f} \geq 0$: Continuous variable representing the quantity of units shipped from warehouse w to facility f per day.

2.2 Objective Function

Minimize the total annual cost (Z):

$$Z = \sum_{w \in W} \left(\frac{\text{Const}_w}{10} + (\text{Op}_w \times 365) \right) y_w + \sum_{w \in W} \sum_{f \in F} (\text{Trans}_{w,f} \times x_{w,f} \times 365)$$

$$Z = \underbrace{\sum \left(\frac{Const_w}{10} + (Op_w \times 365) \right) y_w}_{\text{Fixed Costs of your 2 chosen warehouses}} + \underbrace{\sum\sum (Trans_{w,f} \times x_{w,f} \times 365)}_{\text{Variable cost of every delivery made in a year}}$$

Const_w= Construction Cost, Op_w - Daily Operational Cost , Trans_{w,f}- Unit Transportation Cost

- **Term 1:** Annualized construction cost (10-year amortization) and fixed daily operations.
- **Term 2:** Variable annual transportation costs based on daily shipment volumes.

2.3 Constraints

1. **Redundancy Requirement:** $\sum_{w \in W} y_w = 2$ (Exactly two warehouses must be active).
2. **Demand Fulfillment:** $\sum_{w \in W} x_{w,f} = \text{Demand}_f, \quad \forall f \in F$ (All facility needs must be met).
3. **Capacity Limitation:** $\sum_{f \in F} x_{w,f} \leq \text{Cap}_w \cdot y_w, \quad \forall w \in W$ (Shipments cannot exceed hub capacity).
4. **Financial Constraint:** $Z \leq 1,500,000$ (The solution must be within the $1.5M budget).

3. **Methodology:**

This problem is formulated as a Mixed Integer Linear Programming (MILP) model.

Algorithm Used: Linear Programming with Binary Decision Variables

* The objective function and constraints are linear.

* Warehouse selection is a binary decision.

* Transportation quantities are continuous variables.

* MILP guarantees a globally optimal solution.

* Efficient solvers (e.g., PuLP, CBC, Gurobi) can solve the problem within reasonable time.

The model was implemented programmatically using optimization libraries, where:

1. Input data is read from CSV files (warehouse, demand, cost).

2. Decision variables are defined.

3. Objective function and constraints are applied.

4. Solver computes the optimal solution.

4. Results and Output Analysis:

4.1 Optimal Warehouse Selection:

The model selects the following warehouses:

{WH_NORTH, WH_SOUTH}

These warehouses provide sufficient combined capacity while maintaining lower fixed and operational costs compared to alternative combinations.

4.2 Cost Analysis:

Total Annual Cost: $959,466.05

Fixed Costs:$605,500

Transportation Costs: $353,966.05

Remaining Budget:$540,533.95

The solution satisfies all constraints and stays well within the allocated annual budget.

4.3 Demand Fulfillment:

* Total daily demand of 270 units is fully satisfied.

* High-priority facilities such as hospitals and community centers receive adequate allocation.

* No warehouse exceeds its capacity.

4.4 Interpretation of Optimal Solution:

The results demonstrate that:

* Operating exactly two warehouses is sufficient for reliable emergency supply distribution.

* Cost savings are achieved without compromising demand satisfaction.

* The optimization model provides a scalable and robust decision-making framework for logistics planning.

5. Conclusion:

This project successfully demonstrates how optimization techniques can be applied to real-world logistics problems. By modeling the campus emergency supply distribution system as a MILP problem, an optimal warehouse selection and supply allocation strategy was obtained.The proposed solution ensures cost efficiency, operational feasibility, and reliability, making it suitable for emergency planning and future scalability.