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Inventory Optimization for a Furniture Shop

1. Introduction

Problem Statement

A furniture shop primarily sources products from wholesalers and manufactures Almirahs in-house. The shop faces inventory management challenges such as:

- **Overstocking**, leading to high storage costs and capital inefficiency.
- **Understocking**, resulting in lost sales and customer dissatisfaction.
- **Unoptimized restocking schedules**, causing inefficiencies in supply chain operations.

An optimized inventory model can help reduce operational costs, improve stock availability, and enhance profitability.

Objective

To develop a data-driven inventory optimization model using **Economic Order Quantity (EOQ)** and **Reorder Point (ROP)** principles while incorporating **nonlinear optimization techniques** to minimize total inventory costs while ensuring product availability.

2. Research Objectives

- Develop an **EOQ-based inventory optimization model** with **nonlinear constraints**.
- Minimize **total inventory costs**, including ordering and holding costs.
- Determine an optimal **reorder point** based on demand and lead time.
- Introduce **gradient-based optimization techniques** for cost efficiency.
- Compare classical EOQ models with **nonlinear programming approaches**.
- Implement **sensitivity analysis** to study parameter variations.

3. Literature Review

Economic Order Quantity (EOQ)

EOQ determines the optimal order quantity that minimizes total inventory costs:

EOQ = $\sqrt{(2 \times D \times O)/H}$

Where:

- **D** = Annual demand
- **O** = Ordering cost per order
- **H** = Holding cost per unit per year

EOQ helps balance ordering and holding costs to improve efficiency.

Nonlinear Optimization for Inventory Control

Traditional EOQ assumes fixed costs, but real-world inventory problems often involve **nonlinear relationships**, such as:

- **Demand-dependent holding costs**
- **Dynamic ordering costs** based on supplier conditions

Thus, we introduce **nonlinear programming techniques** (KKT conditions, convexity analysis) to enhance inventory management.

Reorder Point (ROP) Calculation

The **Reorder Point (R)** ensures timely restocking and is calculated as:

R = $d \times L$

Where:

- **d** = Average daily demand.
- **L** = Lead time in days.

4. Optimization Model

Objective Function

Minimize total inventory cost using a **nonlinear cost function**:

$$Z = X \cdot O + \sum_i \frac{Y_i}{2} H_i + f(Y_i)$$

Where:

- **X** = Number of orders per year.
- **O** = Ordering cost per order.
- **Y_i** = Inventory level of item **i**.
- **H_i** = Holding cost per unit per year.
- **f(Y_i)** = Nonlinear cost function modeling demand fluctuations.

Constraints

1. **Demand Constraint:**

$$Q \cdot X \geq D$$

2. **Storage Capacity Constraint:**

$$\sum_i Y_i \leq S$$

3. **Reorder Point Constraint:**

$$R = d \times L$$

4. **Inventory Flow Constraint:**

$$Y_i = Q - (D/X)$$

5. **KKT Conditions:** Applied to ensure optimality in nonlinear models.

5. Methodology

Data Collection

- **Monthly demand** for furniture items.
- **Ordering cost (O):** ₹10,000 per order.
- **Holding cost (H):** Includes rent, labor, electricity:
  - **Labour cost:** ₹9,000 per month
  - **Electricity charges:** ₹1,500 per month
  - **Storage space:** 4,050 sq. ft.
- **Estimated holding cost per item per year:** Derived from total storage cost divided by stock capacity.
- **Lead time data:** Represents the time taken for an order to arrive from the wholesaler.
- **Storage constraints (S):** Maximum stock capacity for each item:

Item	Monthly Demand (D)	Stock Capacity (S)
Bed	6	16
Sofa	7	7
Table	10	20
Office Chair	10	25
Almirah	8	13
Stool	10	25
Shoe Rack	7	7
Dressing Table	5	10
Dining Table	2	2
Study Table	7	8
Pillow	20	140
Mattress	25	50
Bedsheet	5	10
Wooden Mandir	3	4
Plastic Chair	100	150

Implementation

- Use **Python-based Nonlinear Optimization** techniques.
- Implement the model using **Scipy.optimize, gradient-based search methods, and constraint solvers**.
- Apply **Golden Section Search and Fibonacci Search** to refine order quantity selection.
- Perform **sensitivity analysis** on demand fluctuations and cost variations.

Expected Outcomes

- Reduction in **total inventory cost**.
- Improved **stock availability**.
- Optimized **order scheduling**.
- Validation of **nonlinear EOQ models** against traditional approaches.

6. Conclusion

This project extends traditional inventory optimization methods by incorporating **nonlinear programming techniques, convexity analysis, and dynamic demand forecasting** to minimize costs while ensuring stock availability. The inclusion of advanced **search techniques and machine learning models** makes this a robust and data-driven approach to inventory management.