INVENTORY SIMULATION AND OPTIMIZATION USING PYTHON FOR A U.S. MANUFACTURING PLANT

1. Background

A Tier-2 automotive parts manufacturer based in Michigan faced consistent challenges in balancing raw material availability with production schedules. The operations team struggled to align procurement with variable customer demand, leading to frequent overstocking of certain inputs and last-minute shortages for others.

We were commissioned to build a Python-based inventory simulation model that integrates demand forecasting and production planning to optimize procurement schedules. The goal was to reduce waste, improve delivery compliance, and lower inventory holding costs.

2. Objective

- To simulate raw material inventory dynamics based on forecasted production demand
- To integrate lead time, MOQ (Minimum Order Quantity), and production frequency into the model
- To reduce inventory holding costs and avoid production delays from material shortages
- To deliver a reusable Python model with adjustable parameters for ongoing planning

3. Data Used

Source: Internal ERP + Production Planning System

Data Fields:

- Material_ID, Monthly_Production_Volume, Bill_of_Materials, Supplier_Lead_Time
- Material_Cost, MOQ, Storage_Capacity, Inventory_Holding_Cost_Per_Unit
- Past 18 months of actual production and usage logs
- Forecasted demand for next 6 months (per part number)

4. Methodology

4.1 Forecasting Demand

- Applied linear regression and exponential smoothing (statsmodels)

- Forecasted part-level monthly production needs
- Converted forecast into raw material quantities via Bill of Materials (BoM)

4.2 Inventory Simulation Logic

- Simulated monthly material consumption using forecast data
- Modeled:
    - Reorder points using dynamic lead time and consumption rates
    - Safety stock buffer using historical volatility (95% service level)
    - Constraints: MOQ, max storage per material, supplier delivery patterns

4.3 Optimization Features

- Used SciPy.optimize to minimize holding cost while ensuring 100% fulfillment
- Modeled 6-month rolling window scenario (forecast + inventory + procurement)

5. Optimization Results

- **Holding Cost Reduction**: 17.4% compared to previous 6-month average
- **Raw Material Stockouts**: Dropped from 11 per month to 2 (82% reduction)
- **On-time production orders**: Improved from 87% to 96%
- **MOQ and warehouse capacity** respected in all simulated months

6. Insights and Recommendations

- Identified materials with **long lead times but low turnover**—replaced monthly procurement with quarterly bulk ordering
- Recommended **supplier switch for 2 items** due to repeated lead time violation risk
- Created **reorder timing dashboard** by material group to simplify procurement scheduling
- Proposed integration with Power BI for visualizing future stock risk based on simulation

7. Reporting Output

- **Python Simulation Script (.py)**:
    - Accepts demand forecast and BoM file

    - Simulates month-by-month stock, reorder, and delivery flow
    - Outputs procurement plan with timestamps and quantities
- **PDF Report (14 pages)**:
    - Inventory cost comparison before vs after
    - Material-specific risk summaries
    - Simulation plots: stock trajectory, reorder triggers, supplier delays
- **Excel Dashboard**:
    - Forecasted consumption vs purchase plan
    - Reorder schedule by part
    - Visual material flow calendar

8. Operational Impact

- Reduced inventory planning cycle from 8 days/month to 2 days
- Operations team used simulation output to prepare monthly procurement calendar
- Reduced material wastage from expired/unused stock (esp. adhesives and coatings)
- Model now runs monthly with new forecasts and drives procurement meetings