SEASONAL SALES FORECASTING AND INVENTORY OPTIMIZATION FOR AN ONLINE APPAREL STORE

1. Background and Problem Statement:

An online apparel retailer specializing in seasonal collections (summer and winter wear) experienced recurring issues with overstocking during off-peak seasons and frequent stockouts during high-demand periods. The absence of a structured demand forecasting model led to reactive inventory planning, high holding costs, and missed sales opportunities. The retailer engaged in a project to apply **seasonal sales forecasting and inventory optimization techniques** to align stock levels with actual customer demand across seasons.

2. Objectives:

- To forecast SKU-level demand for two seasonal collections using time series techniques
- To analyze historical sales patterns and seasonal peaks
- To recommend optimal inventory quantities using EOQ and safety stock models
- To reduce stockouts during peak season and minimize overstock during slow periods

3. Methodology:

Data Description:

- Historical sales data (24 months) for 120 SKUs across two major categories: summer wear and winter wear
- Data included: SKU ID, date of sale, units sold, stock level, lead time, and product category

Tools and Libraries Used:

- Python: Prophet, statsmodels, pandas, matplotlib
- Excel: for EOQ and reorder point calculations
- Visualization: Time series decomposition plots, moving averages, heatmaps

Forecasting Approach:

1. **Data Preparation:**
    - Missing value imputation

- Weekly aggregation of unit sales

2. **Seasonal Decomposition:**
    - Trend and seasonality separated using moving averages and STL decomposition
3. **Modeling:**
    - Facebook Prophet model used for seasonality-driven forecasting
    - Cross-validation applied to assess accuracy (MAE, RMSE)
4. **Inventory Planning:**
    - EOQ calculated using: $EOQ = \sqrt{\frac{2DS}{H}}$ where: D = demand per year, S = order cost, H = holding cost per unit
    - Safety stock: $Safety\ Stock = Z \times \sigma_{L}$ (Z = z-score for service level, σL = std. deviation of demand during lead time)
    - Reorder Point (ROP): $ROP = (Average\ daily\ demand \times Lead\ time) + Safety\ stock$

4. Results:

- **Forecast Accuracy:**
    - Average MAE = 14.7 units per SKU
    - RMSE improvement of 27% over previous naïve forecasting methods
- **Inventory Insights:**
    - Summer SKUs: Peak in May–July, demand ~4x higher than off-season
    - Winter SKUs: Demand surged in Nov–Jan, with sharp drop afterward
- **Overstock Reduction Potential:**
    - 18% reduction in slow-moving SKU inventory forecasted over a 6-month period
- **Stockout Prevention:**
    - Safety stock implementation projected to reduce out-of-stock days by 35%

5. Interpretation and Insights:

- Seasonality in fashion was clear and predictable—Prophet effectively captured monthly fluctuations

- EOQ helped avoid bulk ordering of items with declining seasonal demand
- Implementing separate reorder points for seasonal categories was more effective than a unified model
- Lead time variability had a significant impact on required safety stock levels, particularly for imported winter goods

6. Recommendations:

- Shift from reactive inventory replenishment to **forecast-driven ordering**
- Maintain separate EOQ and reorder point models for each seasonal category
- Conduct quarterly model retraining to incorporate the latest trend shifts
- Combine forecasting model output with **supplier performance data** to refine lead time buffers
- Use forecast visualizations and heatmaps to guide warehouse layout and staff allocation

7. Future Work:

- Integrate promotional campaign data into forecast models to improve spike prediction
- Use clustering to group similar SKUs for easier model maintenance
- Introduce dashboard-based alerting system for SKU understock or overstock based on live sales

8. Stakeholder Relevance:

Academic:

- Demonstrates practical application of time series forecasting in retail inventory management
- Useful for teaching EOQ, safety stock, and seasonality modeling in operations courses

Corporate:

- Equips e-commerce managers with actionable forecasting and inventory planning methods
- Helps reduce waste, improve cash flow, and enhance customer satisfaction through stock availability