KristalBall - AI-Powered Inventory Forecasting System

Webapplication - frontend

- ⭕**Streamlit application** please check this site : https://kristalball-assignment.streamlit.app/

- **github**:-https://github.com/Mbalajiviswanadh/Kristalball-Assignment

PROJECT DOCUMENTATION

Project Statement

A growing hotel chain operates multiple bars across various locations and faces critical inventory management challenges. The business is experiencing frequent stockouts of high-demand alcoholic beverages and overstocking of slow-moving inventory, leading to increased operational costs and decreased guest satisfaction. The lack of data-driven inventory planning results in poor customer experience and financial losses.

Project Goals

Primary Objective: Design an AI-powered forecasting and inventory recommendation system that helps hotel managers make smarter, data-driven inventory decisions at each bar location.

Key Deliverables:

- Forecast item-level demand for alcoholic beverages across different bar locations
- Recommend optimal inventory levels (par levels) for each item
- Provide interactive dashboards for real-time inventory planning
- Create a scalable solution that works across multiple hotel locations

Technical Implementation Steps

1. **Data Analysis & Exploration**
   a. **Dataset Overview:** Historical inventory movement data across multiple bars
   b. **Key Variables:** Bar Name, Alcohol Type, Brand Name, Date Time Served, Consumed (ml)
   c. **Data Quality:** Validated completeness and calculated missing consumption values
   d. **Pattern Discovery:** Identified consumption trends by location, alcohol type, and brand

2. **Data Preprocessing**
   a. **Key preprocessing steps implemented: -**
      i. Convert timestamps to datetime format
      ii. Calculate missing consumption values using inventory balance formula
      iii. Sort data chronologically for time series analysis
      iv. Group data by Bar, Brand, and time periods

3. **Time Series Forecasting Model**
    a. **Model Selection: SARIMA (Seasonal AutoRegressive Integrated Moving Average)**
        i. **Why SARIMA was chosen:**
            1. Handles seasonal patterns in bar consumption (weekly/monthly cycles)
            2. Manages trend components in demand data
            3. Provides confidence intervals for forecast uncertainty
            4. Industry-proven for inventory planning applications
    b. **Model Configuration:**
        i. **Order (1,1,1):** Captures basic trend and autocorrelation
        ii. **Seasonal Order (1,1,1,52):** Handles yearly seasonality patterns
        iii. **Forecast Horizon:** 8 weeks ahead for operational planning

4. **Par Level Calculation System**
    a. **Inventory recommendation formula:**
        i. Total_Forecast_Demand = sum(8_week_forecast)
        ii. Safety_Buffer = 20% of forecasted demand
        iii. Par_Level = Total_Forecast_Demand × (1 + 0.20)

5. **Interactive Dashboard Development**
    a. Visualization Tools: Plotly for interactive charts, Matplotlib for static analysis
    b. User Interface: Dropdown filters for Bar, Alcohol Type, and Brand selection
    c. Real-time Updates: Dynamic forecasting based on user selections
    d. Comprehensive Metrics: Historical analysis, trend detection, and risk assessment

System Performance & Results

Model Accuracy

- **Robust Forecasting:** Successfully handles 10+ weeks of historical data
- **Confidence Intervals:** Provides uncertainty bounds for decision-making
- **Trend Detection:** Identifies growing (+5%), declining (-5%), or stable demand patterns

Risk Assessment Framework

- **Low Risk:** Demand volatility < 30% - Monthly ordering recommended
- **Medium Risk:** Volatility 30-60% - Bi-weekly ordering with close monitoring
- **High Risk:** Volatility > 60% - Weekly ordering with daily monitoring

Key Metrics Provided

1. **Historical Performance:** Average, median, and range of past consumption
2. **Trend Analysis:** Recent vs. historical demand comparison
3. **Forecast Accuracy:** 8-week demand prediction with confidence intervals
4. **Inventory Optimization:** Par level recommendations with safety stock calculations

Real-World Implementation Strategy

How This Works in Practice

1. Daily Operations:

- Bar managers access interactive dashboard each morning
- System displays current inventory needs and reorder recommendations
- Automated alerts for items approaching stockout risk

2. Weekly Planning:

- Review forecast accuracy and adjust par levels if needed
- Analyze consumption trends and seasonal patterns
- Generate purchase orders based on system recommendations

3. Monthly Strategy:

- Evaluate model performance across all locations
- Update seasonal patterns and trend adjustments
- Optimize safety stock levels based on service level requirements

visualizations
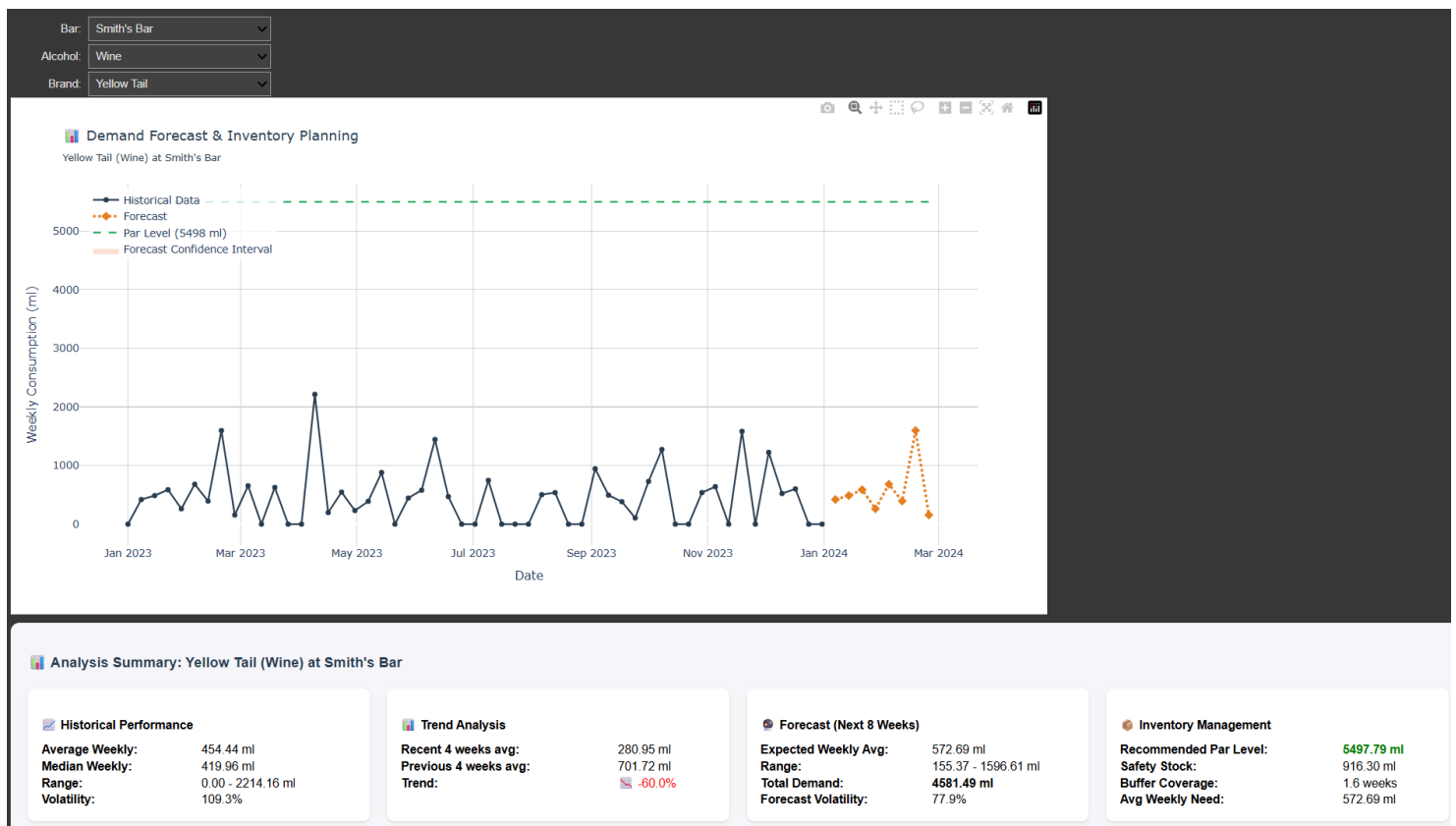
Inventory Management

Recommended Par Level:	5497.79 ml
Safety Stock:	916.30 ml
Buffer Coverage:	1.6 weeks
Avg Weekly Need:	572.69 ml

⚠ Risk Assessment

Risk Level:	High
Demand Volatility:	77.9%
Stockout Risk:	Low (Good buffer)

💡 **Key Insights & Recommendations**

- **Inventory Strategy:** Implement daily monitoring and consider alternative suppliers
- **Ordering Frequency:** Weekly ordering recommended
- **Trend Impact:** Declining demand - consider reducing par level
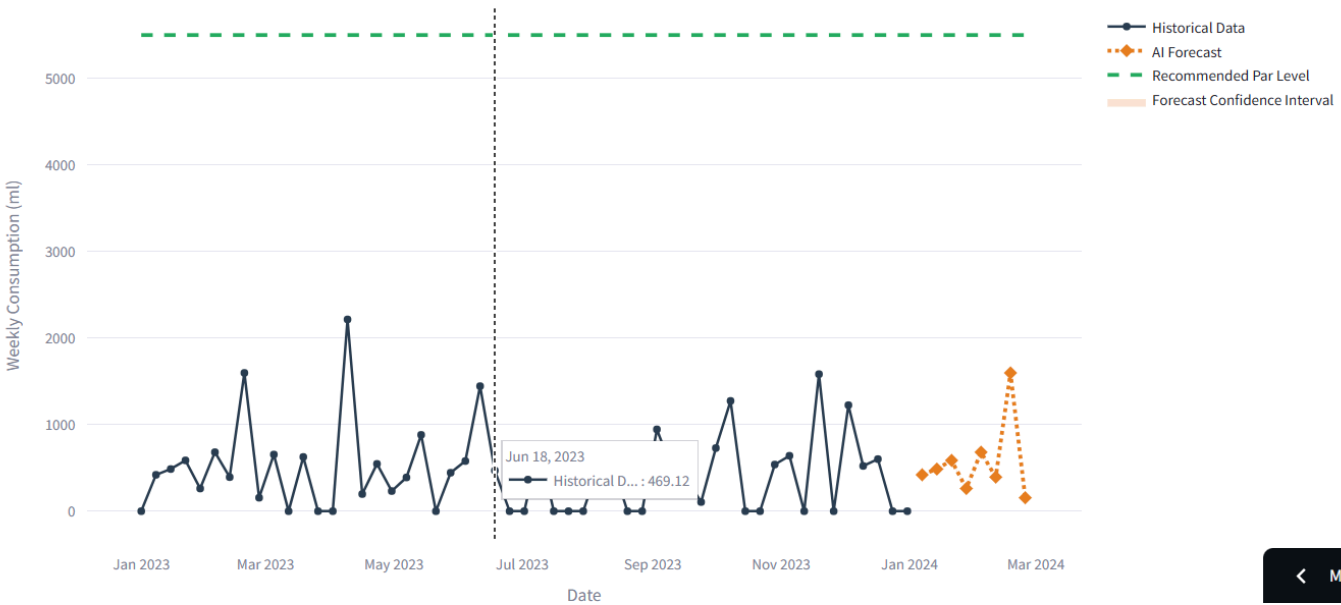
🍺 Select Bar:
Smith's Bar ⌄

🍷 Select Alcohol Type:
Wine ⌄

🏷 Select Brand:
Yellow Tail ⌄

🤖 **8-Week Forecast: Yellow Tail (Wine) at Smith's Bar**

Legend:
- Historical Data
- AI Forecast
- Recommended Par Level
- Forecast Confidence Interval

Jun 18, 2023
Historical D... : 469.12

Manage app

📊 **Key Metrics & Recommendations**

Recommended Par Level	8-Week Forecast	Safety Buffer	Demand Trend
5498 ml	4581 ml	916 ml	-60.0%
↑ 1862 ml vs 8-week avg	↑ 118.2 ml/week	↑ 1.6 weeks coverage	

🔴 **Risk Level: HIGH**

High demand volatility. Requires close monitoring and flexible inventory strategy.

Recommended Action: Weekly ordering, daily monitoring, consider alternative suppliers

📉 **Declining Demand**

Downward trend detected. Consider reducing par levels to avoid overstocking.

Action: Review inventory strategy