Bar Inventory Forecasting and Recommendation System Report

1. Core Business Problem and Its Impact

The central business challenge facing the hotel chain is the optimization of inventory capital across multiple decentralized bar locations. This problem manifests through two costly outcomes:

- **Stockouts:** Running out of high-demand items (e.g., Captain Morgan on a Friday night). This leads to **immediate lost revenue** and causes significant **guest dissatisfaction**, negatively impacting service reviews.
- **Overstocking:** Holding excessive quantities of slow-moving items (niche foreign beer). This **ties up working capital** that could be used elsewhere, increases physical **holding costs** (storage, insurance), and carries the risk of spoilage or obsolescence.

The system's goal is to transition the hotel chain from reactive, intuition-based ordering to a proactive, data-driven approach, maximizing the customer **Service Level** while minimizing inventory **Holding Costs**.

2. Key Assumptions, Supply Chain Logic, and Rationale

The following assumptions and standard supply chain formulas were used to bridge the demand forecast with actionable inventory targets.

Metric / Formula	Supply Chain Logic	Rationale & Code Assumption
Lead Time (LT) & DDLT	**DDLT** (Demand During Lead Time) is the demand expected during the replenishment period. The forecast horizon *must* match the Lead Time.	**LT = 3 Days** (based on business input). We forecast the expected demand over a **3-day period** to cover the inventory exposure window until the next replenishment arrives. This

		ensures the bar maintains sufficient stock during the lead time and avoids stockouts.
Safety Stock (SS)	SS acts as a protective buffer against demand variability or unexpected lead time delays. SS is the primary tool to achieve the Service Level.	**SL = 95%** (Z = 1.65). We target a **95% Service Level**, which corresponds to a **Z-value of 1.65** under the assumption that daily demand variation follows a normal distribution. This means the Safety Stock is sized to cover approximately **95% of potential demand spikes** during the lead time.
Par Level	The **Par Level** is the target inventory position, calculated to meet both predicted consumption and risk coverage.	Par Level = Demand During Lead Time (DDLT) + Safety Stock
EOQ	The **Economic Order Quantity** formula is the standard solution to minimize the *total cost* of inventory (Holding Cost + Ordering Cost).	**Assumptions:** A fixed order cost of **$25 per purchase order** is used, along with a calculated **holding cost per milliliter** based on the product's value and standard storage/handling cost rates.
Minimum History	The quality of the prediction is constrained by the quantity of historical data available.	**Min History = 60 Days.** We require two months of history to reliably train complex models (XGBoost/Prophet) and capture consistent weekly

		patterns, reducing reliance on noisy, sparse data.

3. Model Used and Selection Rationale

The system employs a **Dual-Model Ensemble Strategy with a Fallback Mechanism** to ensure the most accurate and financially appropriate forecast for every single item.

A. Model Selection (Prophet vs. XGBoost)

The system trains both a specialized time series model and a robust machine learning model for each item and selects the one with the lowest validation error (MAE).

Model Type	Primary Use Case	Advantage Over Others
Prophet (Meta)	High-Volume, Highly Seasonal Items	Excels at modeling time series with strong **weekly and yearly seasonality** and provides a mathematically sound forecast uncertainty (sigma) for Safety Stock calculation.
XGBoost Regressor	Items with Complex Features (e.g., promotions, irregular shifts)	A powerful non-linear predictor that captures intricate relationships between **engineered features** (like lag_7, weekend flags) and demand spikes, often providing superior accuracy when features are rich.

B. The Fallback Strategy

For items that have fewer than 60 days of sales history, we classify them as **sparse/intermittent sellers** and use a Fallback Model:

- **Model:** Simple **Historical Mean Demand** and **Historical Standard Deviation** (with a reduced Service Z of 1.0).
- **Rationale:** The business objective for these items shifts from maximizing service to **minimizing holding cost**. The Fallback provides a safe, conservative average, avoiding excessive stock for products that rarely sell.

4. System Performance and Improvements

Performance Summary

The system's performance is evaluated based on its practical usefulness. It successfully calculates the **Recommended Par Level** by correctly balancing the **3-day Demand During Lead Time (DDLT)** with the required **95% Safety Stock buffer**. The final output provides **100% inventory coverage** by using a Fallback Strategy, ensuring that every product receives a clear and actionable recommendation.

Key Improvements for Production

1. **Exogenous Regressors (External Data):** Integrate external data (e.g., **Hotel Occupancy Rate**, local event calendars) as extra regressors in both the Prophet and XGBoost models. This would significantly boost forecasting accuracy for major, unpredictable demand shifts.
2. **Dynamic Service Levels:** Currently, all items are assigned a **95% Service Level**. In a production environment, the system should allow managers to adjust the Service Level dynamically — for example, applying a **higher Service Level (98% or above)** to high-profit or high-demand items, and a **lower Service Level (around 90%)** to slower-moving items. This allows more strategic allocation of working capital while still protecting service quality where it matters most.

5. How This Solution Works in a Real Hotel

This system provides a practical, automated inventory control loop:

1. **Daily Trigger:** An automated job runs the script every morning, pulling the latest `consumed_ml` and `current_stock_ml` from the hotel's Inventory database.
2. **Intelligence Layer:** The script calculates the optimal **Par Level** for every item based on its unique demand history and assigned model.
3. **Actionable Output:** The bar manager receives the **Final Recommendation Report**.
4. **Order Execution:** Items flagged **ORDER NOW** are immediately added to the purchase order. Items flagged **OVERSTOCK / TRANSFER** are reviewed by management to address the capital surplus. This system transforms the manager's role from manual inventory calculation to efficient order approval.

Key Insights from Final Inventory Recommendations

- Several **high-demand items** (*Smirnoff, Bacardi, Grey Goose, Jack Daniels*) across **Brown's Bar, Anderson's Bar, and Smith's Bar** are showing **immediate stock risk**, triggering **ORDER NOW** actions of **1–3 bottles** to prevent stockouts during the 3-day lead time.

- Multiple items, particularly at **Anderson's Bar and Johnson's Bar**, show **closing stock far above the recommended par level**, resulting in **OVERSTOCK / TRANSFER** recommendations. This indicates **excess capital tied up in slow-moving products**.

- The system effectively **distinguishes high vs. low velocity items**: fast-moving items are replenished proactively, while slow sellers are flagged for **inventory balancing**, reducing unnecessary holding cost.

- Overall, this recommendation set guides managers toward **preventing stockouts where demand is strong**, while **reducing waste and freeing capital** where inventory is excessive — directly improving both **service reliability** and **operational cost efficiency**.