Hotel Bar Demand Forecasting & Inventory Recommendation System

1. Core Business Problem

Objective: To accurately forecast daily alcohol consumption at a hotel bar and recommend optimal inventory (par) levels that prevent both stockouts and overstocking.

Why it matters: Poor inventory planning leads to:

- **Lost revenue** when customer demand can't be fulfilled.
- **Excess storage costs** and potential **waste** from unused stock.
- **Operational inefficiency** and poor customer satisfaction.

A data-driven forecasting and inventory system enables **better financial planning**, **efficient operations**, and **improved guest experience** — all critical for hospitality profitability.

---

2. Assumptions

- **Historical consumption** is a reliable proxy for future demand trends.
- **Seasonality effects** (e.g., weekend spikes, holidays) may not be strong or available in the data; Prophet automatically disabled them.
- Inventory needs to be **buffered** (e.g., +15%) to account for demand variability and delivery delays.
- Daily granularity is sufficient for planning; hourly forecasting is out of scope.

These assumptions reflect real-world limitations — such as limited historical data and unpredictable guest behavior — while still allowing for actionable insight.

---

3. Models Used and Rationale

Regression Models:

Multiple models were evaluated on historical data to predict daily consumption:

- **LightGBM**
- **CatBoost**
- **Gradient Boosting**
- **Random Forest**
- **XGBoost**
- **Linear Regression**
- **Decision Tree**
- **Ensemble (GB + CatBoost + LightGBM)**

The **Ensemble model** performed the best with:

- **Lowest MAE (152.99)** and **RMSE (184.27)**
- **Highest R^2 (0.072)** — indicating modest predictive power

Ensembling leveraged the strengths of multiple gradient boosting techniques for more robust predictions.

Prophet (Time Series Forecasting):

Used to predict future consumption trends based on historical daily data. Prophet is suited for time series with missing data and irregular trends. Though seasonality was disabled automatically, the model still generated meaningful forecasts with confidence intervals.

---

4. System Performance and Improvement Areas

Model Performance Summary:

- The **ensemble model** yielded the best results among regression approaches.
- **Prophet** provided forecast intervals for planning purposes, though intervals were wide due to uncertainty.

What's working:

- Accurate enough predictions to inform day-to-day operations.
- Simple, interpretable inventory recommendations (e.g., par level = predicted + 15%).

Areas for Improvement:

- **Enable or engineer seasonal signals** (e.g., holidays, weekends, events) in Prophet.
- **Improve R^2** via more features (e.g., occupancy rates, event schedules, weather).
- **Refine par level buffer** based on service-level optimization, not fixed percentage.
- **Visual dashboards** for forecast trends and real-time inventory tracking.

---

5. Real-World Implementation in a Hotel

Workflow:

1. **Daily predictions** are generated using the trained model or Prophet.
2. **Inventory par levels** are calculated with buffer.
3. Hotel bar managers receive automated **daily restock recommendations**.
4. System integrates with **POS and procurement systems** to monitor usage vs forecast.

This setup ensures **proactive inventory control**, avoiding costly last-minute orders or unsatisfied guests.