Functional Requirements Document (FRD)

Retail Sales Forecasting & Inventory Optimization System

1. Document Control and Introduction

1.1 Document History

Version	Date	Description of Change	Author
1.0	2025-11-17	Initial Draft - Outlining functional modules and requirements.	Harsh Vijay Jha

1.2 Purpose of the Document

This Functional Requirements Document (FRD) specifies the detailed functional and non-functional requirements for the **Retail Sales Forecasting & Inventory Optimization System**. It defines how the system will operate, its component modules, data flows, and required user interactions necessary to fulfill the business needs defined in the Business Requirements Document (BRD) (v1.1).

1.3 Intended Users

This document is intended for the following audiences:

- **Project Team:** Developers, Data Scientists, and Business Analysts (for implementation guidance).
- **Quality Assurance (QA):** To develop comprehensive test cases and acceptance criteria.
- **BI/Visualization Team:** To design and deploy the interactive dashboards.
- **Stakeholders:** To validate that the detailed functional design meets their expectations.

2. System Overview

The system is a unified analytical solution that integrates and analyzes historical **retail sales, inventory, pricing, promotions, holiday, and weather data**. Its core purpose is to generate accurate demand forecasts, provide insights for strategic pricing, and recommend optimal inventory levels through codified business logic (ABC/XYZ classification, safety stock, and reorder point calculation). The system will function primarily in a batch processing mode.

3. Functional Modules

The system is decomposed into the following six core functional modules, designed to operate sequentially:

1. **Data Ingestion & Processing**
2. **Exploratory Data Analysis Engine (EDA)**
3. **Forecasting Engine**
4. **Inventory Optimization Engine**
5. **Pricing & Promotion Analytics**
6. **Reporting & Dashboard Module**

4. Detailed Functional Requirements

4.1 Module 1: Data Ingestion & Processing (FR-1.x)

This module handles the loading, validation, and cleaning of all raw input data.

ID	Requirement Description	Validation/Logic
FR-1.1	The system **shall** support the batch loading of new data via CSV files for Sales, Inventory, and Pricing/External Factors (Weather, Promotions).	Input files must be validated for size (max 500MB), correct delimiter (comma), and mandatory column presence (e.g., Date, StoreID, ProductID).
FR-1.2	The system **shall** apply validation rules to ensure data integrity before cleaning.	**Missing Values:** Flag and report columns with $>10\%$ missing values. **Outliers:** Detect outliers in units_sold, price, and inventory_level using the **Interquartile Range (IQR) method** (1.5x IQR).

		Constraints: Ensure units_sold is not greater than the corresponding inventory_level record.
FR-1.3	The system **shall** apply specific cleaning and imputation logic for missing data.	**Weather:** Missing values must be filled using a **forward-fill/back-fill** approach. **Price/Promotion:** Missing values must be imputed using the **7-day rolling average** of the respective variable. Duplicate rows must be removed, and text fields standardized (case and naming).

4.2 Module 2: Exploratory Data Analysis Engine (FR-2.x)

This module conducts in-depth analysis to understand underlying data characteristics and relationships.

ID	Requirement Description	Output Format / Visuals
FR-2.1	The EDA engine **must** generate analyses to capture temporal patterns.	**Outputs:** Daily, weekly, and monthly trends and seasonality indexes. **Visuals:** Line charts for units_sold, inventory_level, and price over time.
FR-2.2	The EDA engine **shall** calculate and visualize correlations between key variables.	**Calculation:** Pearson correlation coefficient between Price, Weather, Promotion binary indicators, and Units Sold. **Visuals:** Correlation matrix heatmap and a

		corresponding numeric table.
FR-2.3	The system **must** compute aggregate performance metrics across different dimensions.	**Metrics:** Top 10 and Bottom 10 products by sales value; sales contribution percentage by region and category. **Visuals:** Bar charts and a TreeMap for category share.
FR-2.4	The system **shall** compute and display inventory movement KPIs.	**KPIs:** Inventory turnover, Days of Inventory (DOI), and stock aging reports. **Zones:** Clearly define and display inventory risk zones (e.g., Low, Optimal, Excess).

4.3 Module 3: Forecasting Engine (FR-3.x)

This module prepares data for, trains, and executes the demand forecasting models.

ID	Requirement Description	Logic / Criteria
FR-3.1	The system **must** prepare time series data at the Store $\times$ Product level.	**Feature Engineering:** Creation of binary indicators for promotions/holidays, 7/30-day moving averages, seasonality indexes, and lag variables (lag1, lag7, lag30). Missing days must be imputed (zero-fill).
FR-3.2	The system **shall** include a selection of models for demand forecasting.	**Models:** ARIMA, Prophet, XGBoost, and LSTM are available. The final

		deployed model must be selected based on the lowest **MAPE** and demonstrated **stability** across multiple validation windows.
FR-3.3	The system **must** generate a daily forecast output.	**Output:** Daily demand forecasts for the **next 30 days** for *every* unique Store $\times$ Product combination. **Fields:** Date, Store ID, Product ID, and Forecasted Units.
FR-3.4	The system **shall** compute and store mandatory model accuracy metrics.	**Metrics:** Mean Absolute Percentage Error (MAPE), Root Mean Square Error (RMSE), Bias Percentage, and Forecast Accuracy Percentage on a held-out validation set.

4.4 Module 4: Inventory Optimization Engine (FR-4.x)

This module applies specialized logic to recommend optimal stock levels.

ID	Requirement Description	Logic / Criteria
FR-4.1	The system **must** classify inventory items using two dimensions.	**ABC Classification:** Based on annual sales *value* (A: High value, C: Low value). **XYZ Classification:** Based on demand *variability* (X: Stable, Z: Volatile, using Coefficient of Variation).
FR-4.2	The system **shall** calculate the required safety stock	**Formula:** $\text{Safety Stock} = \text{Z-score}

	level.	\times \text{Demand Std Dev} \times \sqrt{(\text{Lead Time})}$ (Z-score to be user-configurable, defaulting to 1.64 for 95% service level).
FR-4.3	The system **shall** compute the Reorder Point.	**Formula:** $\text{Reorder Point} = (\text{Avg Daily Demand} \times \text{Lead Time}) + \text{Safety Stock}$.
FR-4.4	The system **must** generate inventory risk alerts.	**Alerts:** Flag items where (Current Inventory $<$ Safety Stock) as **Stockout Risk**. Flag items where (Current Inventory $>$ 3 $\times$ Safety Stock) as **Overstock Risk**.
FR-4.5	The system **shall** generate a final recommendation table for ordering.	**Fields:** Current Inventory, 30-day Forecasted Demand, Safety Stock, Reorder Point, and Recommended Order Quantity (Calculated as: Reorder Point + 30-day Forecast - Current Inventory, $\text{min}=0$).

4.5 Module 5: Pricing & Promotion Analytics (FR-5.x)

This module provides insights for strategic revenue and margin management.

ID	Requirement Description	Logic / Criteria
FR-5.1	The system **must** calculate	**Formula:** $\text{Elasticity}

	the Price Elasticity of Demand.	= \frac{\% \text{ Change in Demand}}{\% \text{ Change in Price}}$. The calculation must utilize a statistically valid model (e.g., regression-based approach).
FR-5.2	The system **must** quantify the impact of a promotion.	**Formula:** $\text{Promotion Lift } \% = \frac{(\text{Promo Sales} - \text{Baseline Sales})}{\text{Baseline Sales}} \times 100$. Baseline sales must be calculated using the average demand from the 4 weeks preceding the promotion.
FR-5.3	The system **shall** determine cross-elasticity if competitor price data is available.	**Output:** An analysis showing how competitor pricing changes influence the demand for the subject product.
FR-5.4	The system **must** recommend pricing strategy zones based on elasticity.	**Zones: Elastic** (>1 - recommendation to lower price to increase revenue); **Inelastic** (<1 - recommendation to increase price to improve margin); **Neutral** (recommend stable pricing).

4.6 Module 6: Reporting & Dashboard Module (FR-6.x)

This module provides the user interface for consuming all system outputs (Power BI platform).

ID	Requirement Description	Details / Content
FR-6.1	The Dashboard **shall** consist of the following dedicated pages.	Sales Overview, Forecast vs. Actual, Inventory Health & Alerts, Pricing & Promotion Analytics, and Store/Product Performance.
FR-6.2	The Dashboard **must** support a standard set of interactive features.	**Filters:** Mandatory filters for Date Range, Store ID, Product ID, Region, and Category. **Features:** Drill-down capability from Category $\to$ Store $\to$ Product; export functionality to Excel/PDF.
FR-6.3	The Dashboard **must** include the following mandatory visuals.	Line chart for sales trend, Bar chart for product performance, Heatmap for correlation (from FR-2.2), KPI cards (for stockout rate, forecast accuracy), Forecast vs Actual plot, and a TreeMap for category contributions.

5. Non-Functional Requirements (NFRs)

These requirements define the quality attributes of the system.

ID	Category	Requirement Description	Acceptance Standard
NFR-1	Performance	The main dashboards and reports **must** load	Load Time ≤ 5 seconds.

		within 5 seconds upon user login and filter application.	
NFR-2	Performance	The forecasting engine **must** complete the full batch run and generate all 30-day forecasts within 4 hours.	Batch run time ≤ 4 hours.
NFR-3	Accuracy	The final deployed forecasting model (BR-2) **must** maintain a minimum Forecast Accuracy of 80% across the validation period.	Accuracy $\ge 80\%$.
NFR-4	Usability	The user interface (Power BI dashboard) **shall** be simple, clean, and intuitive, requiring minimal training for Inventory and Category Managers.	User satisfaction rating $\ge 4/5$ (via post-deployment survey).
NFR-5	Security	Access to the data and reporting environment **must** be restricted to authenticated users within the local business environment.	Local access only; no PII involved.

6. User Roles & Permissions

Role	Access Level / Permissions
Inventory Manager	View Inventory Health, Stockout/Overstock Alerts, Export reports, View Forecasting Engine outputs.
Category Manager	View Pricing & Promotion Analytics, Sales Overview, Forecast vs. Actual, Export reports.
Data Analyst/Scientist	Full access to data, model code, EDA outputs, and all configuration settings.
Admin/IT	All features, system configuration, user management, and infrastructure monitoring.

7. System Inputs & Outputs

Category	Item	Description
Inputs	Historical sales data	Date, Store ID, Product ID, Units Sold, Price.
	Inventory data	Date, Store ID, Product ID, Inventory Level.
	External data	Date, Holiday Indicator, Promotion Indicator, Weather (e.g., Max Temp).
Outputs	Forecasted demand	30-day product-level demand figures.
	Inventory Recommendations	Safety Stock, Reorder Point, Recommended Order Quantity.

	Analytical Reports	Price Elasticity, Promotion Lift, Correlation heatmaps.
	Dashboards	Interactive visualizations and KPI scorecards.

8. Acceptance Criteria (AC)

The project will be considered complete and successful when all the following criteria are met and validated by the QA team and stakeholders:

- **AC-1:** Daily demand forecasts are generated successfully for **all** unique Store $\times$ Product combinations.
- **AC-2:** The Inventory Optimization Engine correctly calculates and assigns ABC/XYZ classifications, Safety Stock, and Reorder Points.
- **AC-3:** The Pricing & Promotion module accurately computes Price Elasticity and Promotion Lift, providing the recommended pricing zones (FR-5.4).
- **AC-4:** All Power BI Dashboards are fully interactive, responsive, and provide accurate data mirroring the model outputs (FR-6.2).
- **AC-5:** The deployed model meets the minimum performance benchmark (NFR-3: Forecast Accuracy $\ge 80\%$).
- **AC-6:** The system provides clear, actionable alerts for Stockout and Overstock Risk (FR-4.4).

9. Deliverables

Deliverable	**Description**
Documentation	Final BRD and FRD documents, EDA Summary Report, Final Project Report.
Data Pipelines	Python or equivalent scripts for cleaning, validation, and feature engineering.
Forecasting Engine	Fully trained and validated predictive model code (ARIMA / Prophet / ML / LSTM).
Optimization Module	Codified logic for ABC/XYZ, Safety Stock, and Reorder Point calculations.

Analytics Module	Code for Price Elasticity and Promotion Impact analysis.
Visualization	Complete Power BI Dashboard package.
Testing	Comprehensive Test Cases and Validation Report.

10. Approval and Sign-Off

The signatures below signify acceptance of all requirements specified in this document.

Role	Name	Signature	Date
Project Sponsor	Head of Supply Chain		
Business Lead	Category Manager		
Technical Lead	Data/BA Team Lead		
QA Sign-Off	QA/Testing Lead		