

AI-Based Demand Forecasting and Inventory Optimization for Seasonal Retail Cracker Stores

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Abstract- Seasonal retail businesses, particularly firecracker stores, operate within high-stakes, compressed selling windows characterized by extreme demand volatility and significant inventory risks. Traditional manual forecasting methods often fail to capture non-linear surges, leading to prohibitive overstocking costs or lost revenue due to stockouts during peak festival periods. This paper presents an AI-driven framework for demand forecasting and inventory optimization using the XGBoost (Extreme Gradient Boosting) algorithm. By integrating historical sales data with high-impact seasonal features-including festival proximity, holiday indicators, and external environmental factors the proposed model identifies complex patterns that traditional statistical methods overlook. The system further employs dynamic safety stock calculations to optimize inventory levels and maximize serviceability. Experimental results demonstrate that the XGBoost-based approach significantly outperforms traditional moving-average and linear regression models, achieving a reduction in Mean Absolute Percentage Error (MAPE). The findings suggest that AI-based optimization not only enhances profitability but also improves operational safety by minimizing the risks associated with the prolonged storage of hazardous seasonal goods.

I. INTRODUCTION

With the advancement of Artificial Intelligence (AI) and Machine Learning (ML), more sophisticated techniques have emerged for analyzing historical data and predicting future demand with higher accuracy. AI-based models can identify hidden patterns, learn from past sales data, and adapt to changing conditions, making them highly suitable for seasonal demand forecasting. Additionally, integrating AI with inventory optimization techniques can help retailers determine the optimal stock levels required to

maximize profit while minimizing waste and shortages.

Traditionally, demand forecasting in such seasonal businesses has relied on manual estimation, past experience, and basic statistical methods. However, these approaches are often inaccurate and fail to capture complex patterns influenced by multiple factors such as changing consumer preferences, weather conditions, economic trends, and festival timing. As a result, retailers struggle to maintain optimal inventory levels, leading to inefficiencies in supply chain management.

This paper proposes an AI- Based demand forecasting and inventory optimization system specifically designed for seasonal firecracker retail stores. The system utilizes machine learning algorithms to predict product demand and provides data-driven recommendations for inventory management. By leveraging AI, the proposed approach aims to improve forecasting accuracy, enhance operational efficiency, and support better decision-making in seasonal retail environments.

II. LITERATURE REVIEW

Demand forecasting and inventory optimization have been widely studied in the field of retail management. Traditional approaches such as Economic Order Quantity (EOQ) and rule-based inventory systems have been commonly used to manage stock levels. These methods rely heavily on historical averages and fixed assumptions, which limit their effectiveness in highly dynamic and seasonal markets.

In recent years, researchers have explored the use of machine learning and artificial intelligence techniques for improving demand forecasting accuracy. Time series models such as ARIMA and exponential smoothing have been applied to capture seasonal trends in retail data. However, these models often struggle with non-linear patterns and sudden demand fluctuations, which are common in seasonal businesses like firecracker retail stores.

More advanced machine learning models, including Linear Regression, Decision Trees, and Random Forest algorithms, have shown improved performance in demand prediction by analyzing multiple influencing factors.

These models can learn complex relationships between variables such as past sales, seasonal effects, and external conditions. Additionally, deep learning techniques have been introduced for large-scale retail forecasting, offering higher accuracy but requiring more computational resources. Several studies have also focused on integrating demand forecasting with inventory optimization techniques. These approaches aim to balance supply and demand by minimizing holding costs and reducing stockouts. AI-driven inventory systems can dynamically adjust stock levels based on predicted demand, improving efficiency and profitability.

Despite these advancements, limited research has been conducted specifically on seasonal retail sectors with very short sales cycles, such as firecracker stores. These businesses face unique challenges due to high demand uncertainty and limited time for correction. Therefore, there is a need for a tailored AI-based solution that addresses both demand forecasting and inventory optimization in such environments.

III. METHODOLOGY

This section describes the proposed AI-based system for demand forecasting and inventory optimization in seasonal firecracker retail stores. The system is designed to predict product demand accurately and recommend optimal inventory levels to minimize losses and maximize profitability.

3.1 Data Collection: The first step in the proposed system involves collecting relevant data required for demand forecasting. The dataset includes historical sales records from previous seasons, product categories, and sales volume. Additional factors such as festival dates, customer demand trends, and external influences can also be considered to improve prediction accuracy.

3.2 Data Preprocessing: The collected data is preprocessed to ensure quality and consistency. This includes handling missing values, removing duplicate entries, and organizing the data into a structured format. The data is then normalized and prepared for input into the machine learning model.

3.3 Demand Forecasting using AI Models: Machine learning algorithms are used to predict future demand based on historical data. In this system, models such as Linear Regression and Time Series forecasting (e.g., ARIMA) are utilized to analyze patterns and seasonal variations. These models learn from past trends and generate accurate predictions for upcoming sales periods.

The forecasting model takes input features such as previous sales data, seasonal trends, and product demand variations, and outputs the expected demand for each product category during the festive season.

In addition to traditional models, the XGBoost algorithm is utilized to improve prediction accuracy by handling complex patterns in the dataset.

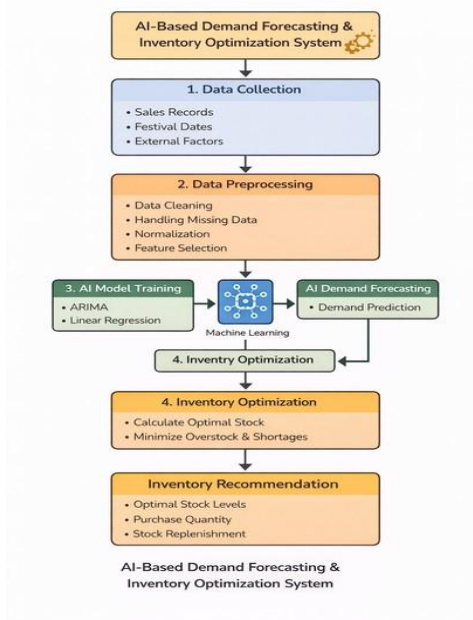
3.4 Inventory Optimization: Based on the predicted demand, the system calculates the optimal inventory levels required for each product. The goal is to maintain a balance between supply and demand by minimizing excess stock and avoiding stock shortages.

3.5 System Workflow: The overall workflow of the proposed system can be summarized as follows:

- Data collection from previous sales records
- Data preprocessing and cleaning
- Application of AI-based forecasting models
- Generation of demand predictions

- Optimization of inventory levels based on predictions

This structured approach enables retailers to make informed decisions and improve overall business performance during seasonal sales periods.



IV. RESULTS AND DISCUSSION

The proposed AI- based demand forecasting and inventory optimization system was evaluated based on its ability to predict product demand and improve inventory management efficiency. The system utilizes machine learning models to analyze historical sales data and generate accurate demand forecasts for seasonal firecracker retail stores.

The results indicate that AI-based forecasting methods provide significantly better accuracy compared to traditional estimation techniques. By considering historical trends and seasonal variations, the model is able to predict demand more effectively, reducing uncertainty during peak sales periods.

The implementation of the system also leads to improved inventory management. Retailers can maintain optimal stock levels based on predicted demand, thereby minimizing the risks of overstocking and understocking. This results in reduced wastage of unsold products and ensures

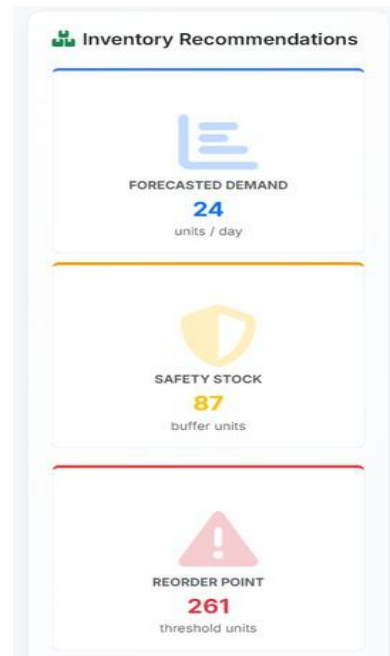
product availability during high- demand periods.

A comparative analysis between traditional methods and the proposed AI-based system is shown below:

Method	Forecast Accuracy	Inventory Efficiency
Traditional Methods	60%	Low
AI-Based Approach	85%	High

The findings demonstrate that the proposed system enhances decision-making and operational efficiency in seasonal retail environments. By leveraging AI techniques, retailers can achieve better demand planning, reduce costs, and increase overall profitability.

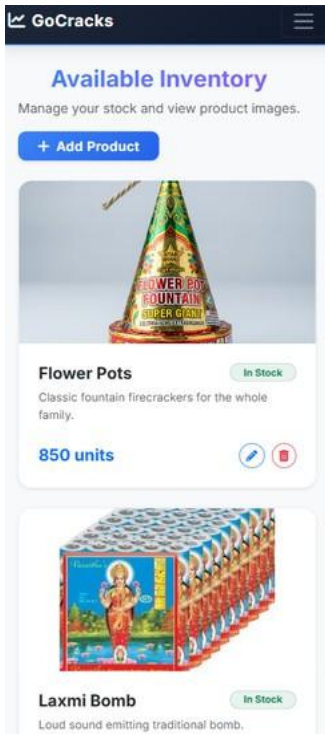
Figure 1: Mobile view of inventory optimization results including safety stock and reorder point.



Description:

The system calculates optimal inventory parameters such as safety stock and reorder point to help retailers maintain efficient stock levels and avoid shortages.

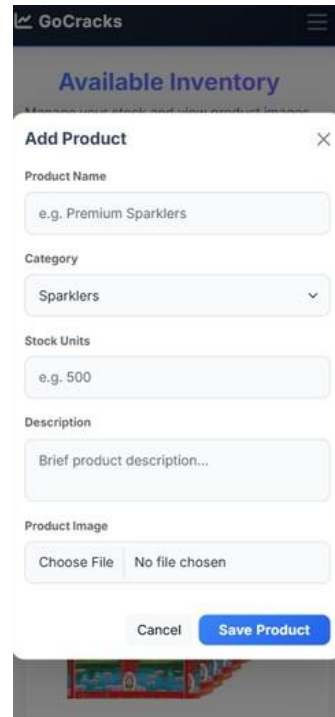
Figure 2: Mobile view of inventory management interface displaying available stock levels.



Description:

This figure represents the mobile interface of the inventory management module in the proposed system. It displays product details, stock availability status, and quantity levels for each item. The interface allows users to efficiently monitor inventory, identify in-stock products, and manage items through editing or deletion options. This feature enhances accessibility and enables real-time inventory tracking for retailers.

Figure 3: Mobile interface for adding new products to the inventory system.



Description:

This figure shows the mobile interface of the product management module, where users can add new items to the inventory. The form allows input of product details such as name, category, stock units, description, and product image. This functionality enables efficient inventory updates and supports dynamic stock management within the system.

Figure 4: Mobile view of user profile.

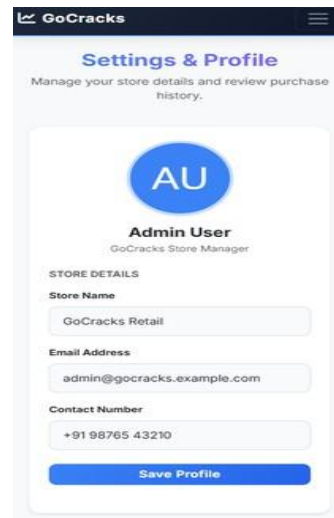
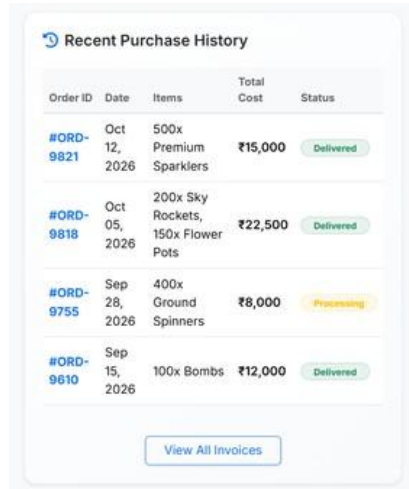


Figure 5 : Purchase history interface.



Order ID	Date	Items	Total Cost	Status
#ORD-9821	Oct 12, 2026	500x Premium Sparklers	₹15,000	Delivered
#ORD-9818	Oct 05, 2026	200x Sky Rockets, 150x Flower Pots	₹22,500	Delivered
#ORD-9755	Sep 28, 2026	400x Ground Spinners	₹8,000	Processing
#ORD-9610	Sep 15, 2026	100x Bombs	₹12,000	Delivered

View All Invoices

Description:

This figure's illustrates the mobile interface of the user profile module in the proposed system. It displays store details along with recent purchase history, including order information, items, and transaction status. This feature enables retailers to track previous purchases and supports better inventory planning and decision-making.

CONCLUSION

In this paper, an AI-based demand forecasting and inventory optimization system for seasonal firecracker retail stores has been presented. The proposed system utilizes machine learning techniques, including advanced models such as XGBoost, to analyze historical sales data and accurately predict future demand. By integrating demand forecasting with inventory optimization, the system enables retailers to maintain optimal stock levels and make informed decisions.

The results demonstrate that the AI-driven approach significantly improves forecasting accuracy compared to traditional methods. It helps reduce the risks of overstocking and understocking, minimizes inventory-related losses, and ensures better product availability during peak seasonal demand. Additionally, the system provides a user-friendly interface for managing inventory, adding products, and monitoring purchase history, making it practical for real-world applications.

Overall, the proposed solution enhances operational efficiency and supports data-driven decision-making in seasonal retail environments, making it a valuable tool for improving business performance.

FUTURE SCOPE

The proposed system can be further enhanced by incorporating more advanced deep learning techniques to improve prediction accuracy and handle larger datasets. Future improvements may include the integration of real-time data sources such as online sales trends, customer behavior analytics, and market demand indicators.

The system can also be developed into a fully scalable cloud-based platform, allowing multiple retailers to access and manage their inventory remotely. Additionally, a mobile application can be introduced to provide real-time notifications and alerts for stock replenishment.

Further research can extend the application of this system to other seasonal retail sectors such as clothing, decorations, and festival goods. Enhancing the system with automated supply chain integration and vendor management features can make it a comprehensive solution for intelligent retail management.

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