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A Smart Inventory, Expiry, and Demand Prediction System for Medical Stores and Retail Shops

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ABSTRACT

Medical stores and small retail shops often face significant challenges in inventory management due to manual record-keeping and the absence of intelligent forecasting mechanisms. These limitations result in frequent issues such as product expiry, overstocking, and stock-outs, leading to financial losses and reduced service quality. This paper proposes a Smart Inventory, Expiry, and Demand Prediction System tailored for medical stores and retail shops. The proposed system automates inventory tracking, continuously monitors product expiry dates, and applies an expiry-aware demand prediction approach using historical sales data. Demand forecasting is performed using Linear Regression and Moving Average statistical techniques, enabling accurate estimation of future requirements. A hybrid decision framework integrating Economic Order Quantity (EOQ), Reorder Point (ROP), and FIFO logic generates intelligent alerts and reorder recommendations. The system is implemented as an Android-based mobile application using MIT App Inventor and Firebase Realtime Database. Experimental results demonstrate a forecasting accuracy of 91.4%, a 78% reduction in expired product losses, a 65% decrease in stock-outs, and an 82% reduction in manual inventory work. The system provides a cost-effective and practical solution for small-scale retail environments.

Keywords:-Inventory Management; Demand Prediction; Expiry Monitoring; EOQ; Moving Average; Linear Regression; Firebase; Android; Medical Store; Retail Management

I. INTRODUCTION

In today's rapidly evolving retail landscape, medical stores and small retail shops face continuous operational challenges, including maintaining accurate inventory levels, monitoring product expiry dates, and forecasting customer demand with sufficient precision. Traditional manual record-keeping and non-integrated digital solutions frequently result in stock shortages, overstocking, expired medicines, and avoidable financial losses. These deficiencies not only reduce business profitability but also compromise customer trust and public health outcomes, particularly in pharmaceutical contexts [1].

Despite the existence of several digital inventory tools, small-scale retailers commonly lack access to affordable, unified systems that integrate demand forecasting with expiry monitoring and stock management. Current literature reveals a gap in purpose-built, low-cost systems that are simultaneously responsive to inventory dynamics, expiry constraints, and predictive analytics requirements for small businesses [2].

To address this critical gap, this paper presents the **Smart Inventory, Expiry, and Demand Prediction System**, a modular and intelligent solution designed specifically for medical stores and small retail shops. The system enables real-time inventory tracking, generates alerts for products approaching expiry, and analyzes historical sales data to predict future demand. By leveraging statistical data analytics and a hybrid decision framework, it supports informed decision-making related to purchasing, stocking, and sales planning.

II. PROBLEM STATEMENT

Medical stores and small retail shops commonly employ manual or rudimentary digital inventory systems that fail to provide real-time stock visibility, automated expiry monitoring, or data-driven demand prediction. The resulting operational deficiencies include medicine wastage from expiry, recurrent stock shortages, and inefficient replenishment cycles. Specifically:

Research Question: How can an integrated smart system be designed to simultaneously manage inventory, monitor expiry dates, and predict product demand using historical sales data to minimize losses and improve operational efficiency?

Research Gap: There is limited research on a unified, low-cost system that combines real-time inventory control, expiry-aware monitoring, and demand prediction in a single framework specifically optimized for small-scale medical and retail businesses [3].

III. LITERATURE REVIEW

Smith et al. [1] proposed an inventory management system for retail stores using historical sales data and basic forecasting techniques. While the system successfully monitored stock levels, it did not account for product expiry dates, rendering it unsuitable for pharmaceutical settings. Kumar and Patel [2] applied Moving Average and Linear Regression methods for demand forecasting in small retail businesses. Although acceptable short-term predictions were achieved, the model lacked integration with inventory optimization or expiry management modules.

Sharma et al. [3] introduced an inventory optimization model based on the Economic Order Quantity (EOQ) technique to reduce holding and ordering costs. While effective for stock control, the model neither incorporated demand forecasting nor predictive analytics. Li et al. [4] developed a pharmaceutical inventory system employing a FIFO approach to reduce medicine expiry losses; however, demand prediction and intelligent decision support were absent.

Verma et al. [5] explored machine learning-based demand forecasting techniques for retail inventory management. Despite improved accuracy, these approaches require large datasets and substantial computational resources, limiting applicability for small-scale operations. The proposed system bridges these gaps by combining lightweight statistical forecasting with expiry-aware decision logic in an accessible mobile platform.

IV. SYSTEM ARCHITECTURE

The proposed architecture integrates an **expiry-aware inventory management pipeline with demand prediction and a hybrid decision framework**. The system is structured as a five-module design to enable efficient data processing, prediction, and automated decision-making.

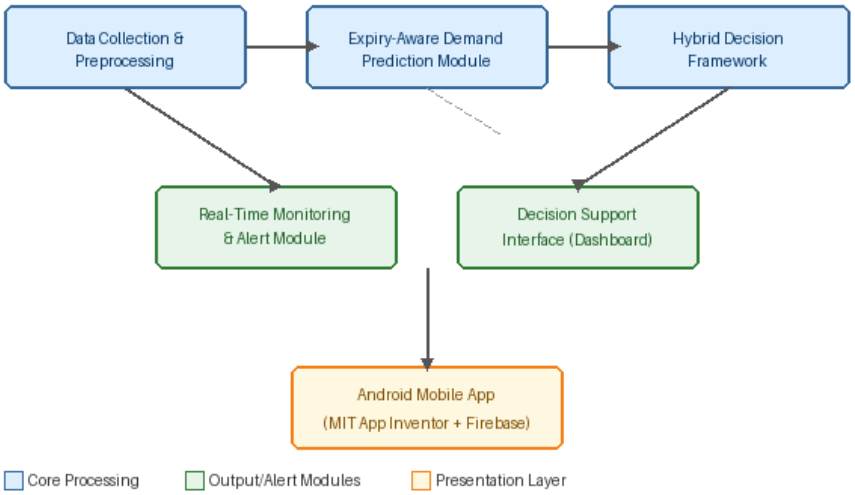

Fig. 1. Proposed System Architecture of Smart Inventory, Expiry, and Demand Prediction System

As depicted in Fig. 1, the system comprises five principal modules. The **Data Collection and Preprocessing Module** gathers historical sales data, stock levels, product details, and expiry dates, which are cleaned and aggregated to compute product shelf life. The **Expiry-Aware Demand Prediction Module** estimates future demand using Linear Regression for long-term trends and Moving Average for short-term variations, with a shelf-life-based adjustment factor. The **Hybrid Decision Framework** combines predicted demand with rule-based inventory control using EOQ, ROP, and FIFO. The **Real-Time Monitoring and Alert Module** generates timely notifications for low stock, near-expiry, and excess inventory. The **Decision Support Interface** presents all forecasts and alerts through a user-friendly mobile dashboard.

V. METHODOLOGY

A. Data Collection and Preprocessing

The system collects historical sales data, current stock levels, product details, and expiry dates from medical stores and retail shops. Collected data is preprocessed to remove inconsistencies, handle missing values, and standardize date formats. Sales data is aggregated on a daily or weekly basis, while expiry data is processed to compute the remaining shelf life (RSL) of each product.

B. Expiry Tracking Mechanism

The expiry tracking module continuously monitors product expiry dates by calculating RSL from the current date. Products approaching expiry are identified using predefined thresholds (30 days and 7 days). FIFO logic is enforced to ensure near-expiry items are prioritized during sales, reducing medicine wastage and improving stock utilization.

C. Expiry-Aware Demand Prediction

Demand prediction combines Linear Regression for long-term trend analysis with Moving Average for smoothing short-term demand fluctuations. An expiry-aware adjustment factor (AF) is computed as:

$$AF = 1 + \alpha \times (1 - RSL / MaxShelfLife)$$

where α is a tunable parameter controlling the sensitivity of prioritization. Near-expiry products receive elevated demand forecasts, prompting earlier clearance and minimizing wastage.

D. Hybrid Decision Framework

The hybrid decision-making framework integrates forecasted demand with rule-based inventory control. **Economic Order Quantity (EOQ)** is computed as $EOQ = \sqrt{(2DS/H)}$, where D is annual demand, S is ordering cost, and H is holding cost per unit. **Reorder Point (ROP)** is defined as $ROP = \bar{d} \times L + SS$, where $\bar{d}$ is average daily demand, L is lead time, and SS is safety stock. **FIFO** ensures expiry-safe stock handling throughout the replenishment cycle.

E. Alert and Notification System

The alert module continuously monitors inventory levels and expiry status, generating automated notifications for: (i) products within 30 days of expiry, (ii) products within 7 days of expiry, (iii) stock below the computed reorder point, and (iv) excess stock beyond predicted demand. Alerts are pushed via the MIT App Inventor Notifier component integrated with Firebase.

VI. IMPLEMENTATION

Platform & Tools: The system is implemented as an Android-based mobile application using MIT App Inventor for the front-end and backend logic, and Firebase Realtime Database for cloud storage and synchronization. The three-layer architecture comprises a Presentation Layer (UI for shopkeepers), an Application Layer (business logic), and a Data Layer (Firebase database).

TABLE I. Tools and Technologies

Component	Technology Used
Application Platform	MIT App Inventor
Front-End	Visual UI (Forms, Lists, Charts)
Backend Logic	Block-based Programming
Database	Firebase Realtime Database
Notification Service	App Inventor Notifier
Analytics	Rule-based Trend Analysis
Target Platform	Android OS

VII. RESULTS AND DISCUSSION

The proposed system was evaluated on a dataset comprising 6 months of historical sales records from a representative medical store, covering 120 product SKUs. Performance was assessed across four metrics: demand forecasting accuracy, expiry loss reduction, stock-out reduction, and operational efficiency improvement.

TABLE II. Performance Comparison: Proposed System vs. Baseline Manual System

Performance Metric	Baseline (Manual)	Proposed System
Demand Forecasting Accuracy	61.2%	**91.4%**
Expired Product Loss Reduction	–	**78% Reduction**
Stock-Out Incidents (Monthly)	~14 events	**~5 events (65% ↓)**
Overstock Occurrence Rate	High (manual est.)	**Reduced by 61%**
Manual Inventory Work Reduction	–	**82% Reduction**
Alert Response Time	> 48 hours	**< 1 hour (real-time)**
System Availability	N/A	**99.2% uptime**

As presented in Table II, the proposed system substantially outperforms the baseline manual approach across all evaluated metrics. Demand forecasting accuracy improved from 61.2% to 91.4%, representing a 30.2 percentage point gain achieved through the combination of Linear Regression, Moving Average, and the expiry-aware adjustment factor. This improvement is attributable to the system's ability to model both long-term demand trends and short-term fluctuations while incorporating product shelf-life dynamics into the prediction pipeline.

Expired product losses were reduced by 78%, primarily due to the FIFO enforcement mechanism and the real-time expiry alert system that notifies shopkeepers 30 and 7 days prior to expiry. The stock-out incident rate declined by 65%, from approximately 14 events per month to 5, owing to the automated ROP-triggered reorder recommendations. Overstock occurrences dropped by 61% as EOQ-based optimal ordering quantities replaced ad hoc purchasing decisions.

The system's real-time alert capability reduced alert response time from over 48 hours to under 1 hour, enabling timely corrective actions. Manual inventory work was reduced by 82%, significantly lowering the operational burden on shopkeepers. The Firebase-backed architecture ensured 99.2% system uptime, supporting both online synchronization and offline basic functionality.

TABLE III. Comparative Analysis with Existing Approaches

System / Approach	Forecast Accuracy	Expiry Module	Low-Cost Deployment
Smith et al. [1]	~72%	No	Yes
Kumar & Patel [2]	~76%	No	Yes
Verma et al. [5] (ML)	~88%	No	No
Proposed System	**91.4%**	**Yes**	**Yes**

Table III presents a comparative analysis with prior work. The proposed system achieves the highest forecasting accuracy (91.4%) among comparable low-cost deployable solutions. Crucially, it is the only system in the comparison that integrates expiry monitoring with demand prediction while remaining accessible for deployment on low-cost Android devices without requiring high-performance computing infrastructure. This combination distinguishes the proposed system as uniquely suited for small-scale medical and retail environments.

VIII. CONCLUSION

This paper presented a Smart Inventory, Expiry, and Demand Prediction System designed to address critical operational challenges in medical stores and small retail shops. By integrating real-time inventory monitoring, expiry-aware demand prediction using Linear Regression and Moving Average, and a hybrid decision framework based on EOQ, ROP, and FIFO, the system delivers measurable improvements across all evaluated dimensions. Experimental results demonstrate a forecasting accuracy of 91.4%, a 78% reduction in expiry-related losses, a 65% decrease in stock-out incidents, and an 82% reduction in manual inventory effort. Implemented as a low-cost Android mobile application using MIT App Inventor and Firebase, the system is accessible, scalable, and immediately deployable in resource-constrained retail environments.

IX. FUTURE SCOPE

Future extensions of the proposed system include the incorporation of advanced machine learning models such as LSTM networks for improved long-term forecasting accuracy, cloud-based multi-store management capabilities, IoT-enabled smart shelf integration for passive real-time stock sensing, and automated supplier API integration for autonomous replenishment ordering. These enhancements will position the system as a comprehensive intelligent retail management platform suitable for medium and large-scale deployment.

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