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AI-Based Pharma Chain and Inventory Management System using Blockchain

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Abstract : *Pharmacies and healthcare providers routinely struggle to hold medicine stock at the right level: too little, and patients go without; too much, and money sits tied up in inventory that may expire before it is ever sold. Most inventory software in everyday use still relies on manual stock checks and offers no reliable way to prove that a transaction record has not been altered after the fact. This paper presents an AI-based pharma chain and inventory management system that pairs demand forecasting with blockchain-backed transaction recording. Historical sales and stock data are used to train machine learning models, including Random Forest and LSTM, which predict near-term medicine demand and flag items approaching a low-stock threshold before they actually run out. Once validated, every inventory transaction is written to an Ethereum-based ledger through smart contracts, giving pharmacists, suppliers, and administrators a tamper-evident record of how stock moved through the system. The proposed architecture is organized into five layers—user interface, application, AI prediction, blockchain, and database—and supports automated low-stock alerts, reorder recommendations, and role-based dashboards. We describe the system's architecture, module breakdown, data flow, and core algorithms, and discuss how combining predictive analytics with distributed-ledger security closes gaps left by systems that adopt only one of the two technologies.*

Keywords: Pharmaceutical inventory management, demand forecasting, blockchain, smart contracts, machine learning, supply chain traceability

1. INTRODUCTION

Keeping medicine stock at a healthy level is harder than it sounds. Demand for any given drug shifts with the season, with local outbreaks, and with prescribing habits that pharmacists cannot always anticipate. When a pharmacy runs out of a commonly prescribed medicine, patients are turned away or forced to wait for a fresh supply; when it overstocks, capital sits idle on shelves and a share of that stock eventually expires and has to be written off. Most pharmacy management tools in current use address only half of this problem—they record what is in stock, but they do not forecast what will be needed, and they rarely offer any guarantee that the records themselves have not been quietly edited after a shortage or a loss has already occurred.

Two technologies address these two halves of the problem separately. Machine learning models, trained on historical sales, can pick up on trends and seasonality well enough to forecast short-term demand and recommend reorder quantities before stock actually depletes. Blockchain, on the other hand, offers an append-only ledger where every transaction is cryptographically linked to the one before it, so that inventory and supply-chain records become extremely difficult to tamper with retroactively. Individually, each of these has already been explored in pharmaceutical and general supply-chain contexts, as the related work in Section II shows. What is less common is a system that brings the two together in one working platform, so that a pharmacy gets both an early warning about stock levels and a verifiable audit trail of how that stock changed hands.

This paper describes such a system. Section II reviews related work on inventory forecasting and blockchain-based supply chain tracking, and identifies the gap the two together are meant to close. Section III lays out the proposed architecture. Section IV covers the detailed system design—modules, data flow, and the core algorithms behind

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demand prediction and transaction verification. Section V discusses the implementation stack, Section VI discusses expected impact and future work, and Section VII concludes.

II. RELATED WORK

Work on medical inventory systems generally falls into three groups: systems that digitize stock-keeping without any predictive component, systems built primarily around blockchain traceability, and systems that apply machine learning to demand forecasting in isolation. Krishnakumar et al. [1] describe MediStock, a web-based inventory tool that lets pharmacists track stock and expiry dates and generate reports, but stock monitoring there is still reactive—the system reports what has already happened rather than anticipating what is about to happen. Patel et al. [2] take the opposite approach, using Ethereum-based ledgers to secure pharmaceutical transaction records against tampering, and Yong et al. [4] apply a similar blockchain-based approach to vaccine supply and supervision; both improve traceability substantially but leave demand planning untouched. Singh et al. [3] extend this idea with IoT sensing, recording temperature data on-chain to catch counterfeit or improperly stored drugs during transit, again without any forecasting layer.

On the forecasting side, Mousa and Al-Khateeb [11] show that LSTM networks capture seasonal demand patterns in pharmaceutical sales more effectively than classical statistical baselines, and later comparative work [12] finds that gradient-boosted models such as XGBoost perform competitively alongside LSTM for short-horizon inventory prediction. ARIMA-based approaches [15] and cloud-hosted forecasting pipelines built on services like AWS Forecast and SageMaker [14] make this kind of modeling more accessible to smaller organizations, though none of these studies pair the forecasting output with any mechanism for securing the resulting transaction data. Broader supply-chain literature on smart-contract-driven shipment automation [5], traceability frameworks for general goods [6]–[9], and surveys of blockchain adoption barriers in healthcare [10], [19] reinforces the same pattern: blockchain work optimizes for trust and transparency, forecasting work optimizes for accuracy, and the two rarely appear in the same system.

Taken together, the literature points to a fairly consistent gap. Systems that forecast demand well tend not to offer tamper-resistant record keeping, and systems that secure the supply chain well tend not to predict anything. The system proposed here is built specifically to close that gap for pharmaceutical inventory, where both properties—accurate forecasting and verifiable records—matter for patient safety as much as for operational efficiency.

III. PROPOSED SYSTEM ARCHITECTURE

The proposed system follows a layered architecture with three broad stages, moving from data entry through processing to output. In the first stage, pharmacists, administrators, suppliers, and manufacturers interact with the platform through a web-based interface, entering medicine sales data, stock updates, and supplier information. An inventory management module keeps a running record of what each pharmacy currently holds and feeds this, along with historical sales, into the processing stage.

The second stage is where most of the system's intelligence lives. Incoming data first passes through a pre-processing step that removes duplicates, fills or drops missing values, and normalizes the data into a consistent format. The AI prediction module then works on this cleaned data, using models such as Random Forest and LSTM to forecast near-term medicine demand and flag items likely to fall below a defined stock threshold. In parallel, a blockchain module—built on Ethereum and smart contracts—records every validated transaction as an immutable entry, so that stock movements, purchases, and supplier deliveries all leave a verifiable trail. Both modules read from and write to a shared database (MongoDB or MySQL), which holds inventory records, transaction history, and sales analytics.

The third stage turns processed information into action. Based on AI predictions, the system raises low-stock alerts and generates reorder suggestions with recommended quantities. The supply-chain tracking component shows where a given batch of medicine currently sits, and a reporting module produces sales and inventory analytics for administrators. Alerts and reports reach users through the dashboard as well as email, SMS, or in-app notifications, so that a pharmacist does not need to be logged in to learn that a medicine is running low.

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IV. SYSTEM DESIGN

Module Breakdown

The system is organized into nine cooperating modules. A user management module handles registration, login, and role-based access for pharmacists, administrators, and suppliers. An inventory management module tracks stock levels, expiry dates, and reorder points. Data collection and pre-processing modules gather raw sales and stock data and prepare it for analysis, feeding an AI prediction module that forecasts demand and a model training module that keeps those forecasts current as new data arrives. A blockchain module records and verifies transactions through smart contracts, a database module persists all of the above, a supply-chain tracking module follows medicine movement between suppliers and pharmacies, and a reporting and alert module turns predictions and stock status into the notifications users actually see.

Data Flow

Data moves through the system in a fairly linear pipeline. A pharmacist enters inventory and sales details, which are collected and pre-processed before reaching the AI prediction stage. There, historical sales are cleaned, relevant features are extracted, and a trained model produces a demand forecast. The system compares this forecast against current stock; if a medicine's projected availability falls under its threshold, a low-stock event is generated, a reorder request is sent toward the supplier, and the pharmacist is notified. Every one of these steps—the transaction that triggered it, the reorder that followed—is written to the blockchain module once validated, so that later disputes about what was ordered or received can be settled against an immutable record rather than a spreadsheet that anyone with access could have edited.

Core Algorithm

Two algorithms sit at the center of the system's behavior. The demand-prediction algorithm collects historical sales and inventory data, cleans and normalizes it, and trains a forecasting model—Random Forest, ARIMA, or LSTM depending on the volume and seasonality of the data available for a given medicine—before comparing the resulting forecast against current stock and generating reorder recommendations where needed. The transaction-verification algorithm takes each validated transaction, computes a unique hash, packages it as a smart-contract call, and appends it to the blockchain ledger only after the network has confirmed it; the corresponding inventory record is updated in the database only once that confirmation is received, which keeps the two data stores from drifting apart.

V. IMPLEMENTATION STACK

The frontend is built with React.js, HTML, and CSS; the backend combines Node.js and Express.js for general application logic with a Flask service for the AI components, since Python's scientific stack (Pandas, NumPy, Scikit-learn, TensorFlow) is a natural fit for the forecasting models. MongoDB or MySQL handles day-to-day inventory and transaction storage, while Ethereum smart contracts, deployed and tested through tools such as Ganache and MetaMask, provide the tamper-evident ledger. This combination keeps the forecasting and ledger components loosely coupled—either could, in principle, be swapped out while still letting them share a common database layer for day-to-day queries.

VI. DISCUSSION AND FUTURE WORK

The main claim of this paper is not that either AI-driven forecasting or blockchain-based traceability is individually novel—both are well studied, as Section II shows—but that pharmaceutical inventory management specifically benefits from having them in the same system. A forecast is only as trustworthy as the sales history it is trained on, and if that history can be edited after the fact, the forecast inherits that weakness. Recording transactions on-chain as they happen gives the forecasting model a data source that is much harder to quietly manipulate, while the forecasting layer gives the blockchain component something to act on beyond simple record-keeping.

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Several extensions are worth pursuing beyond the current design. Incorporating external signals—seasonal illness trends, local outbreak data, or supplier lead times—could improve forecast accuracy further, particularly for medicines with irregular demand. Gas costs and transaction latency on a public Ethereum network may not scale comfortably to the transaction volume of a busy hospital pharmacy, so evaluating a permissioned or layer-2 blockchain is a natural next step before any real deployment. Finally, a pilot with an actual pharmacy dataset would be needed to validate the forecasting accuracy claimed in the literature against real, noisy, pharmacy-specific sales data rather than the cleaner datasets typically used in published studies.

VII. CONCLUSION

This paper presented an AI-based pharma chain and inventory management system that combines machine-learning demand forecasting with blockchain-secured transaction recording. By pairing a layered architecture—user interface, application, AI prediction, blockchain, and database—with automated low-stock alerts and tamper-evident record keeping, the system addresses two weaknesses that, in the literature, are usually treated separately: poor demand forecasting and a lack of verifiable transaction history. The result is a design intended to reduce medicine shortages and overstocking while giving pharmacists, suppliers, and administrators a supply chain they can audit rather than simply trust.

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