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# Pharmachain: Blockchain-Based Drug Traceability System

B Madhu Sudhan<sup>1</sup>, K Sai Charan<sup>2</sup>, Dr.M. Mamatha<sup>3</sup>, G.Naga Sujini<sup>4</sup>

Dr. V. Subbaramaiah<sup>5</sup>, Dr.K. Rajitha<sup>6</sup>

Student, Department of Computer Science and Engineering, Mahatma Gandhi Institute of Technology,  
Gandipet, India<sup>1,2</sup>

Assistant Professor, Department of Computer Science and Engineering, Mahatma Gandhi Institute of Technology,  
Gandipet, India<sup>3,4,5,6</sup>

**ABSTRACT:** PharmaChain is a blockchain-powered drug traceability and verification system addressing critical challenges in the pharmaceutical industry, where counterfeit and substandard medicines threaten patient safety and undermine trust in healthcare systems. Traditional supply chain systems lack transparency, are vulnerable to tampering, and fail to provide end-to-end verification of drug authenticity. The proposed system overcomes these limitations by leveraging the immutable and decentralized nature of blockchain to securely record every transaction—from manufacturing and distribution to retail and consumer validation—in a tamper-proof digital ledger. Each drug batch is assigned a unique QR code, enabling real-time tracking and authenticity verification across the supply chain. Smart contracts automate compliance checks and transaction validation, while IoT sensors continuously monitor environmental conditions during storage and transport to maintain product quality. The system employs a multi-layered architecture integrating blockchain, IoT, and smart contracts to ensure security, transparency, and efficiency. In short, PharmaChain aims to eliminate counterfeit drugs, enhance traceability

**KEYWORDS:** Blockchain, IoT, Smart Contracts, Traceability, Drug Verification, Supply Chain, Transparency, Security

## I. INTRODUCTION

The pharmaceutical industry plays a vital role in global healthcare by ensuring the production and distribution of safe and effective medicines. However, the increasing prevalence of counterfeit and substandard drugs has become a major concern, leading to severe health risks, economic losses, and reduced trust in healthcare systems. According to the World Health Organization (WHO). Traditional supply chain systems rely on centralized databases, manual documentation, and limited visibility across multiple stakeholders such as manufacturers, distributors, wholesalers, and retailers. These systems are vulnerable to data manipulation, lack real-time tracking, and fail to provide verifiable proof of authenticity. As a result, counterfeit drugs often enter the market undetected, posing a direct threat to patient safety. PharmaChain is designed to address these challenges .

## II. LITERATURE SURVEY

The increasing problem of counterfeit drugs in the pharmaceutical supply chain has attracted significant attention from researchers, as it directly impacts public health and safety. [1] R. Menon et al. proposed a blockchain-integrated drug authentication framework that assigns unique cryptographic identifiers to each drug batch and records every transaction in an immutable ledger. The system also incorporates IoT and cost. A blockchain-based drug traceability system was presented by A. Sharma and R. Kulkarni [2], focusing on overcoming the limitations of centralized databases. Their system uses QR codes and decentralized ledgers to enable real-time verification of drug authenticity by stakeholders.



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Although the system enhances transparency and reduces counterfeit risks, it requires widespread adoption and technical infrastructure for effective implementation.

Khanna and Liu Cheng [3] introduced a hybrid blockchain architecture combining public and private blockchains to balance scalability and transparency. The system efficiently manages large-scale data while maintaining public verifiability of drug authenticity. However, the complexity of managing hybrid networks poses challenges in practical deployment. M. Rakesh and Eliza Thomas [4] proposed an IoT-enhanced blockchain framework to ensure safe drug transportation. The system continuously monitors environmental conditions using sensors and stores data on a blockchain to prevent tampering. While it improves drug quality assurance, the requirement of IoT infrastructure increases the overall cost of the system.

S. Ahmed and T. Nakamura [5] developed an integrated IoT-blockchain system for real-time pharmaceutical logistics tracking. Their model records environmental parameters and uses smart alerts to notify stakeholders of unsafe conditions. The system demonstrated significant improvements in reducing spoilage and fraud, but it depends heavily on IoT device availability and maintenance. K. Srivastava and Daniela Costa [6] introduced a blockchain-based trust model that eliminates reliance on centralized authorities. The system uses consensus mechanisms and smart contracts to validate transactions among stakeholders. Although it enhances supply chain integrity, it introduces computational overhead due to consensus operations. Martinez and Sharma [7] proposed a distributed ledger system combined with smart serialization techniques to prevent duplication and unauthorized drug entry. Each drug is assigned a secure serial number verified at multiple checkpoints. While the system improves authentication, it adds complexity to implementation and management.

T. Alharbi and Megan Douglas [8] presented a blockchain-based framework incorporating role-based access control and audit logs to enhance transparency and accountability.

### III. PROBLEM DEFINITION

The pharmaceutical industry faces several critical challenges that compromise patient safety and the integrity of the healthcare system. Counterfeit and substandard drugs have become a serious global issue, leading to harmful health effects, economic losses, and a decline in public trust. The traditional pharmaceutical supply chain relies heavily on centralized databases, manual record-keeping, and limited coordination among manufacturers, distributors, pharmacies, and consumers. This fragmented structure makes it difficult to trace drug origins, verify authenticity, or detect tampering at any stage.

Lack of transparency and real-time visibility allows counterfeit drugs to infiltrate legitimate supply chains, where malicious actors can replicate packaging or alter product details to deceive consumers. Traditional verification systems often depend on static labels or barcodes, which can be easily forged or replaced. Moreover, data stored in centralized systems is vulnerable to manipulation, unauthorized access, and single points of failure, raising concerns about data security and reliability.

#### 3.1 Disadvantages of Previous Systems

Traditional pharmaceutical supply chain systems suffer from several limitations that affect the security, transparency, and efficiency of drug distribution. Most existing systems rely on centralized databases, which are vulnerable to data tampering, unauthorized access, and single points of failure. This makes it easier for counterfeit drugs to enter the supply chain without detection. Another major drawback is the lack of end-to-end visibility. In many systems, stakeholders such as manufacturers, distributors, and pharmacies operate independently with limited data sharing. This results in poor traceability and difficulty in tracking the origin and movement of drug batches.

Manual record-keeping and paper-based processes are still widely used, which increases the chances of human error, delays, and data inconsistencies. These methods also make auditing and verification time-consuming and unreliable. Existing systems often lack real-time monitoring capabilities. There is no efficient mechanism to instantly verify drug authenticity, which makes it difficult for consumers and pharmacies to detect counterfeit medicines.



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### IV. PROPOSED SYSTEM

The proposed system introduces PharmaChain, a blockchain-based framework designed to overcome the limitations of traditional pharmaceutical supply chain systems. It ensures end-to-end transparency, authenticity, and security in the movement of drugs from manufacturing to the consumer level. By integrating blockchain technology with smart contracts and QR code-based verification, the system provides a tamper-proof, decentralized, and automated mechanism for drug traceability and verification.

PharmaChain utilizes the immutable nature of blockchain to record every transaction across the supply chain in a secure and distributed ledger. Each participant, including manufacturers, distributors, pharmacies, and consumers, interacts with the system through blockchain-based transactions. This approach eliminates the risk of data manipulation and removes the single point of failure commonly found in centralized systems.

The system assigns a unique QR code to each drug batch, enabling stakeholders to verify the authenticity of medicines by scanning the code. This unique identification supports real-time tracking of drug movement and ensures that no unauthorized entity can modify or replace the product. Consumers can easily check the origin, manufacturer details, and supply chain history of the drug through a simple scan.

#### 4.1 Advantages of Proposed System

The proposed PharmaChain system offers several advantages over traditional pharmaceutical supply chain systems by ensuring improved security, transparency, and efficiency. One of the major advantages is enhanced transparency. All transactions related to drug movement are recorded on the blockchain, allowing every stakeholder to view and verify the data. This ensures complete visibility across the supply chain. The system provides high security through the use of blockchain technology. Since the data stored on the blockchain is immutable, it cannot be altered or tampered with, which helps in preventing counterfeit drugs from entering the system. PharmaChain enables real-time drug traceability. Each drug batch is assigned a unique QR code that can be scanned at any stage to track its origin, movement, and status. This helps in quickly identifying and verifying genuine medicines. Another key advantage is the implementation of role-based access control. Only authorized users such as manufacturers, distributors, and pharmacies can perform specific actions, ensuring controlled and secure system operations. The integration of smart contracts automates validation and transaction.

### V. DESIGN AND METHODOLOGY

#### 5.1 Process flow Diagram:

The diagram shows the PharmaChain workflow for tracking drugs from manufacturer to consumer. Each stage updates drug data on the blockchain and uses QR codes for identification. Finally, the system verifies authenticity and identifies whether the drug is genuine or counterfeit.

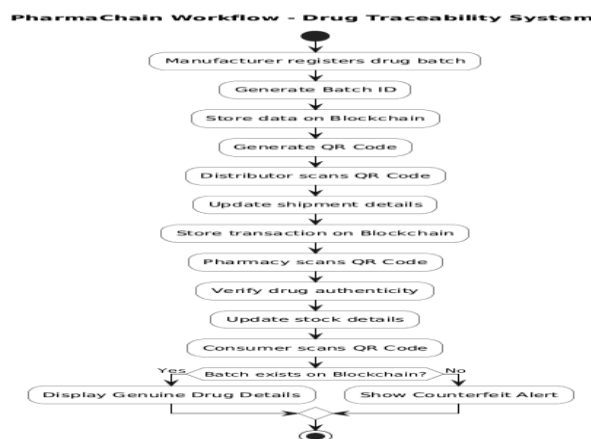


Figure :1 Process flow diagram of Drug Traceability System



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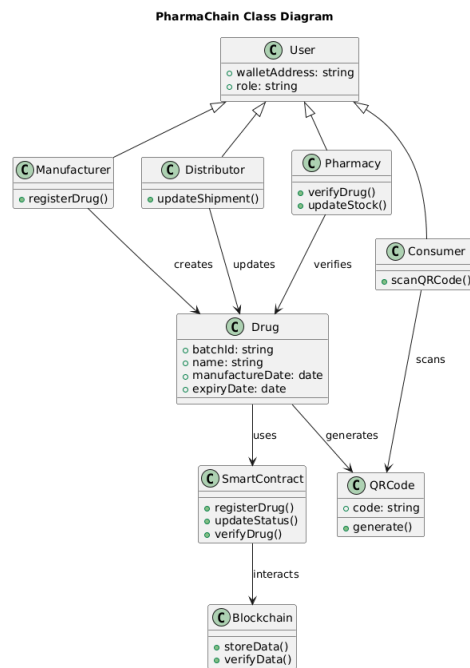
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Figure 5.1 above illustrates the layered architecture of the Drug Traceability System and the flow of data across these functional components.

## 5.2 Class Diagram:

The use case diagram of PharmaChain represents the interaction between different users and the system functionalities. The main actors in the system are Manufacturer, Distributor, Pharmacy, and Consumer. Each actor performs specific actions based on their role within the pharmaceutical supply chain. The Manufacturer is responsible for registering new drug batches and generating QR codes.

Figure 2: Class Diagram of Drug Traceability System



## VI. IMPLEMENTATION

### 6.1 User Interface:

As seen in Figure, the PharmaChain home page provides an overview of the system and its purpose. It allows users to access features like drug registration and verification easily.

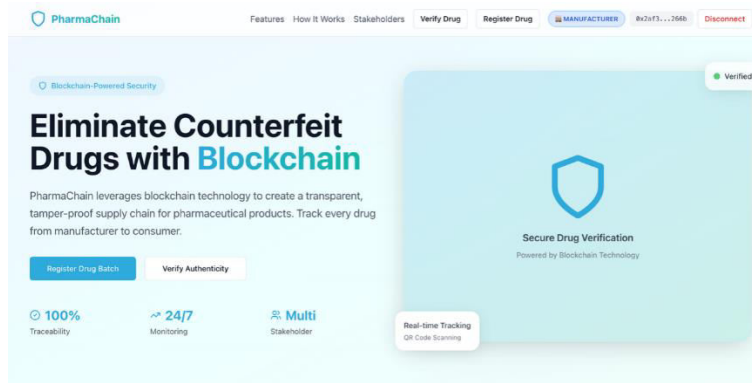


Figure 3 User Interface of Drug Traceability System



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### 6.2 Manufacturer Dashboard:

As seen in Figure 5.2, the Manufacturer Dashboard allows users to register new drug batches and generate QR codes. It helps manage batch details and track their status in the system.

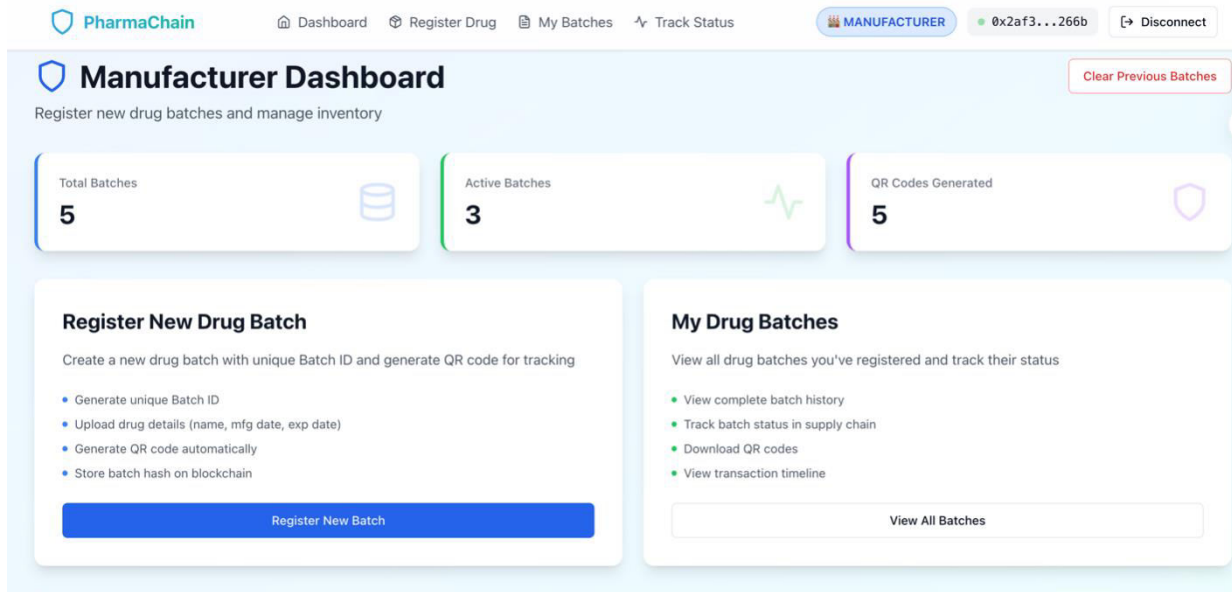


Figure: 3 Manufacturer Dashboard of Drug Traceability System  
Figure: 4 : Live feed monitoring window

### 6.3 Distributor Dashboard:

the Distributor Dashboard is used to update shipment status and track drug movement. It ensures proper monitoring of drugs during transportation. The role-based access control mechanism worked as expected, preventing unauthorized users from performing restricted actions such as drug registration.

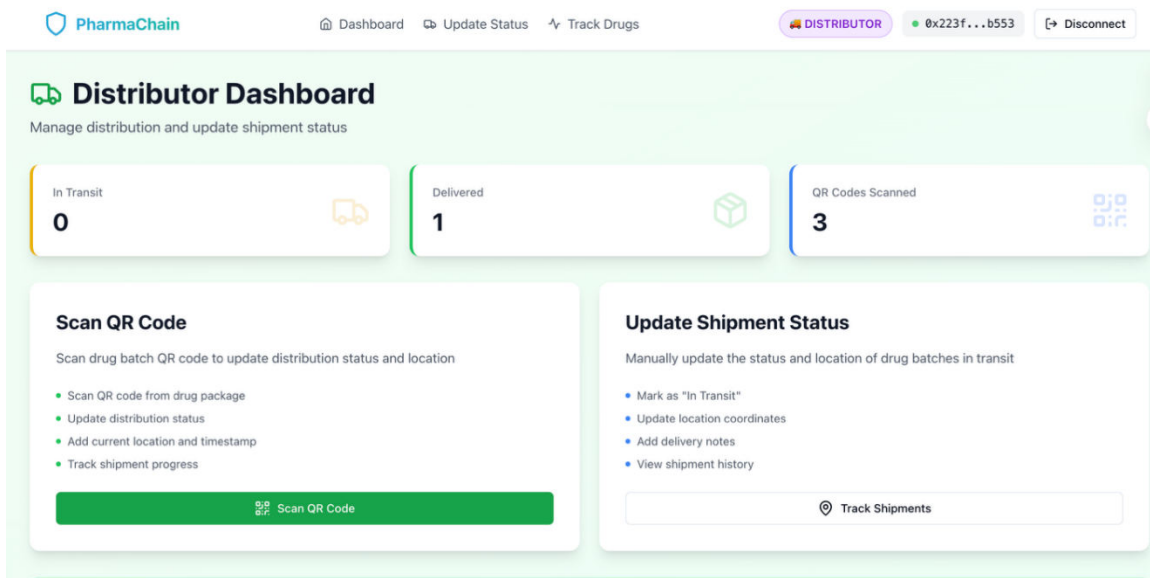


Figure: 5 Distributor Dashboard of Drug Traceability System



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### 6.4 Pharmacy Dashboard:

the Pharmacy Dashboard helps verify drug authenticity and manage inventory. It allows pharmacies to confirm stock and identify any suspicious drugs.

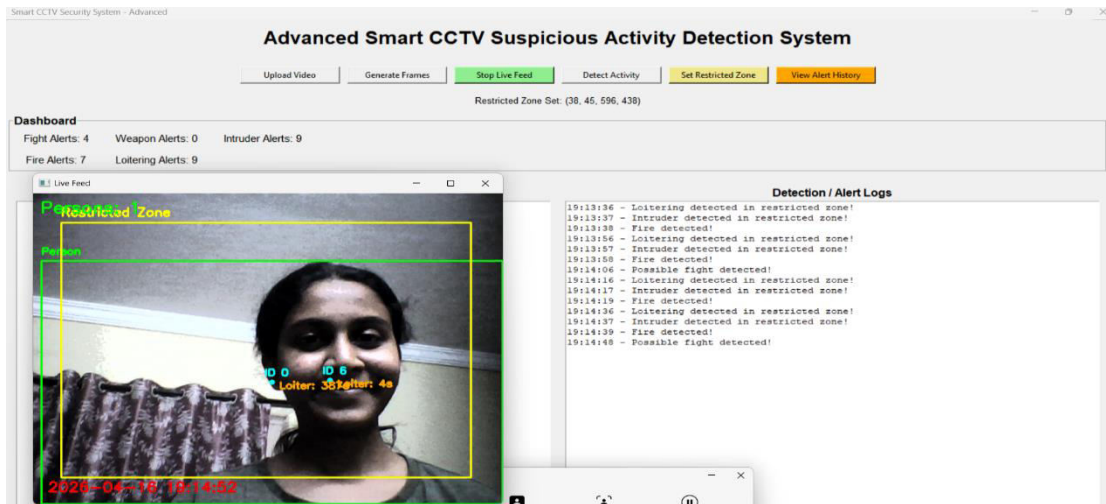


Figure: 6 Intruder and loitering detection in restricted zone

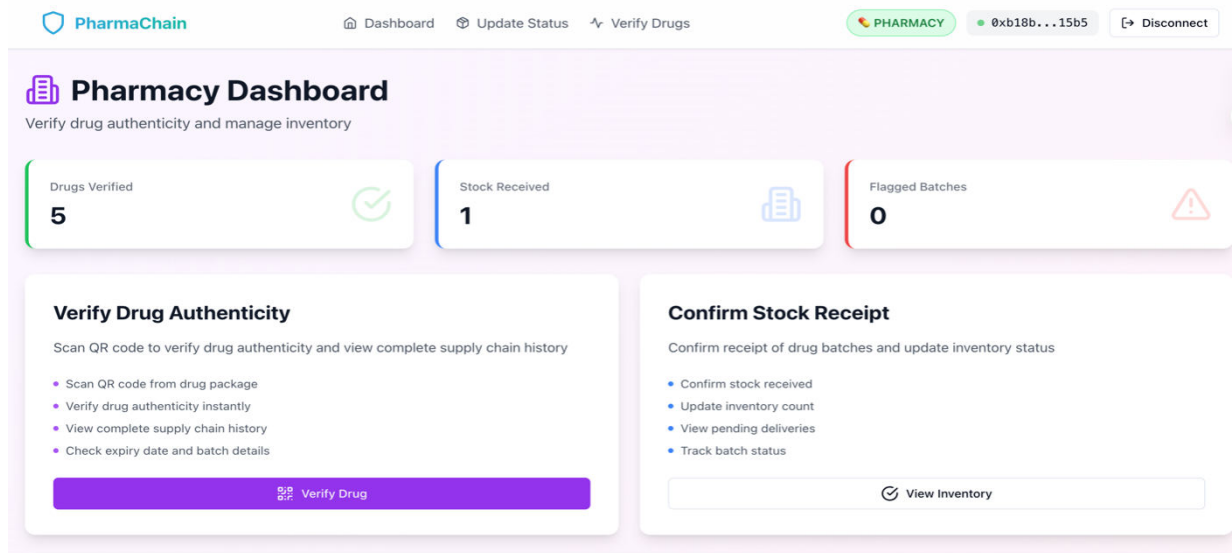


Figure: 6 Pharmacy Dashboard of Drug Traceability System

### 6.5 Consumer Dashboard:

the Consumer Dashboard allows users to scan QR codes and verify drug authenticity. It provides details like manufacturer, expiry date, and supply chain history



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Figure 7: Fire detection result

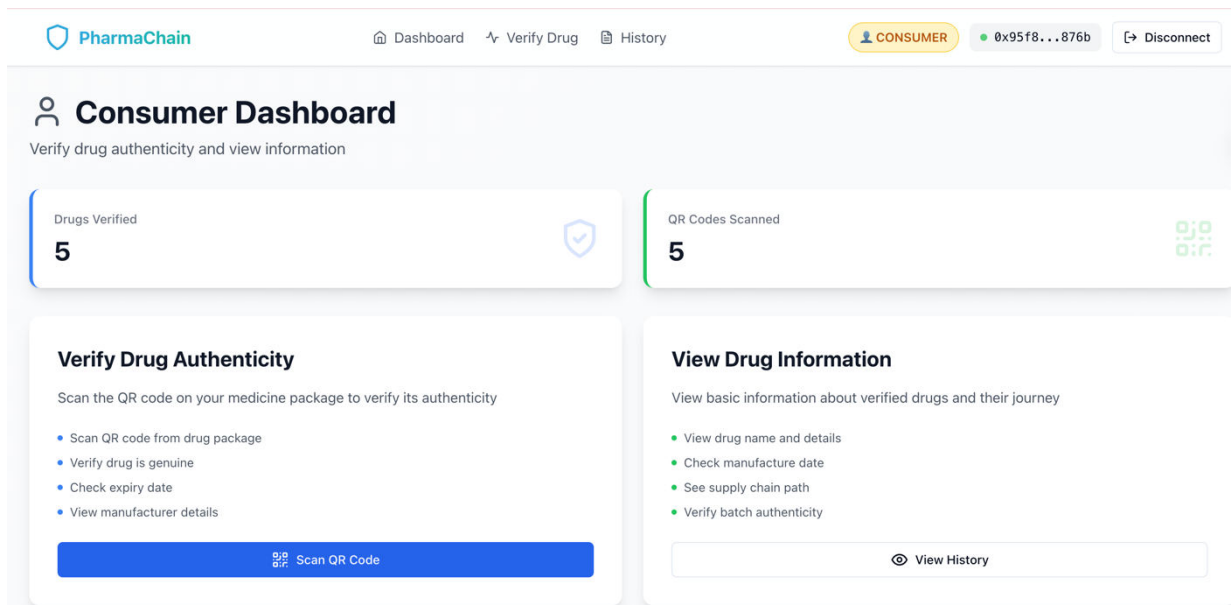


Figure:7 Pharmacy Dashboard of Drug Traceability System

## VII. CONCLUSION AND FUTURE SCOPE

The PharmaChain project successfully demonstrates the application of blockchain technology in improving transparency and security in the pharmaceutical supply chain. The system provides a reliable solution for tracking drug movement from manufacturers to consumers, ensuring that all transactions are securely recorded and cannot be altered. The PharmaChain system can be further enhanced with several advanced features to improve its functionality, scalability, and real-world applicability. One of the major future improvements is the integration of Internet of Things devices to enable real-time tracking of drug conditions such as temperature and humidity during transportation. This ensures that medicines are stored and transported under proper conditions. The system can also be extended by integrating with government and regulatory databases to enable large-scale adoption across pharmaceutical industries. This would help in maintaining a unified and standardized drug verification system at a national or global level.



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