

# Blockchain-Driven Transparency and Traceability in Pharmaceutical Supply Chain Management

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**Abstract** – The integration of QR codes on pharmaceutical packaging facilitates instant access to crucial drug details, including its name, batch number, expiry date, and manufacturing information. By incorporating blockchain technology, the system ensures both security and transparency of data. This approach aims to provide a user-friendly solution that enhances accessibility while safeguarding drug authenticity. The blockchain-backed QR system strengthens the pharmaceutical supply chain, enabling real-time tracking from production to distribution. By ensuring tamper-proof data through cryptographic hashing, consumers can confidently verify the legitimacy of medicines, fostering greater transparency and accountability in the industry. collaboration among stakeholders, and overcoming scalability challenges. Finally, it highlights ongoing projects and regulatory frameworks such as the Drug Supply Chain Security Act (DSCSA), which support blockchain integration. This research demonstrates that blockchain-driven supply chains can provide a secure, efficient, and transparent solution to the evolving needs of the pharmaceutical industry.

**Keywords-** Block chain Technology, pharmaceutical supply, chain, Supply chain management, Smart Contract, traceability, transparency.

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## I- INTRODUCTION

The pharmaceutical industry faces significant challenges regarding drug authenticity and patient safety. Counterfeit medicines, particularly in regions with weak supply chain oversight, result in thousands of deaths annually. Existing supply chain models struggle with inefficiencies due to multiple ownership transfers and the absence of a reliable traceability mechanism. Regulatory bodies find it challenging to implement real-time tracking systems without incurring high costs. To address these concerns, blockchain technology presents a robust solution by offering an immutable, transparent, and decentralized system.

Blockchain, when integrated with IoT and QR codes, enhances security and trust by providing a seamless

tracking mechanism. This study explores the adoption of blockchain-based drug packaging solutions to improve the safety and traceability of pharmaceutical products. With blockchain, each stage of the supply chain is recorded in a tamper-resistant ledger, reducing the risk of counterfeit drugs entering the market. The implementation of these technologies aims to enhance drug authenticity, reduce fraudulent activities, and ensure patient safety.

### Literature Review :

The World Health Organization (WHO) reports that counterfeit medications lead to over 100,000 deaths annually due to incorrect dosages and unsafe substances. The inefficiency of traditional supply chains in linking physical product movement with digital records further

complicates traceability. Researchers highlight that blockchain technology, combined with smart contracts and IoT, can significantly enhance the security of drug supply chains by automating verification processes and ensuring end-to-end visibility.

Previous studies emphasize the importance of integrating blockchain for improved authentication and fraud prevention. The adoption of smart contracts eliminates the need for intermediaries, thereby reducing costs and ensuring transparency. Moreover, data analytics and machine learning techniques can help detect anomalies in supply chain activities, enabling proactive measures against counterfeit distribution. The literature underscores the potential of blockchain in revolutionizing pharmaceutical logistics by creating a secure and efficient tracking system.

### **Proposed System :**

#### **Blockchain-Based Track and Trace System**

A blockchain-powered track and trace system would be designed specifically for the pharmaceutical supply chain. Every transaction, from drug manufacturing to distribution at various points of sale, would be recorded as an immutable block within the blockchain. These blocks would be chronologically linked, creating a transparent and auditable record of the entire supply chain process. With this system in place, stakeholders could efficiently track pharmaceutical products, verify their authenticity, and identify any discrepancies or anomalies in the supply chain.

#### **QR Code Integration**

Pharmaceutical packaging would feature embedded QR codes containing encrypted details such as the drug's name, batch number, expiration date, and manufacturing data. These QR codes could be scanned via smartphones or dedicated scanning devices at each stage of the supply chain, providing quick and easy access to crucial product information. This approach ensures that stakeholders can verify medication authenticity and adhere to regulatory requirements.

#### **Blockchain Authentication Protocol**

A blockchain-based authentication protocol would be implemented to enable real-time verification of pharmaceutical products. Utilizing cryptographic techniques, each drug batch would have a unique digital

signature securely stored and verifiable on the blockchain. Integrating this protocol into supply chain management systems would allow instant authentication of pharmaceutical products, effectively identifying counterfeit or tampered items.

#### **Smart Contracts for Supply Chain Transactions**

Smart contracts—self-executing agreements with predefined terms encoded into blockchain-based protocols—could be employed to automate and secure transactions within the pharmaceutical supply chain. These contracts would facilitate agreements between manufacturers, distributors, and retailers, ensuring efficient processes for payment settlements, product recalls, and compliance checks. By reducing manual intervention, smart contracts minimize errors and fraud, thereby increasing supply chain reliability.

#### **Data Analytics for Supply Chain Optimization**

Advanced data analytics tools would be leveraged to analyze extensive supply chain data and detect patterns indicating counterfeit drug distribution. Machine learning algorithms could identify anomalies and deviations from normal operations, enabling stakeholders to proactively mitigate risks and vulnerabilities. Utilizing data analytics would provide valuable insights into supply chain performance, enhancing decision-making and overall supply chain resilience.

#### **Collaborative Supply Chain Platform**

A centralized, secure platform would be developed to foster communication and information sharing among pharmaceutical supply chain stakeholders. This collaborative system would enable real-time data exchange, coordination, and rapid response to supply chain disruptions. By promoting transparency and cooperation, the platform would help combat counterfeit drugs and maintain the integrity of pharmaceutical products.

#### **Mobile Applications for Consumer Authentication**

Dedicated mobile applications would allow consumers to verify the authenticity of pharmaceutical products directly from their smartphones. By scanning QR codes or blockchain-based digital signatures on packaging, consumers could instantly access information about a product's origin, authenticity, and regulatory

compliance. This transparency would empower consumers to make informed purchasing decisions, reducing the risk of counterfeit drug exposure.

### System Architecture

The proposed system follows a structured workflow:

1. **Manufacturing Stage:** Unique QR codes are generated for each batch, containing drug details such as ingredients, production date, and expiry.
2. **Distribution & Supply Chain:** Smart contracts authenticate and record transactions, ensuring secure handling at every stage.
3. **Retail & Consumer Access:** Consumers can scan QR codes via mobile applications to retrieve verified drug information.
4. **Regulatory Monitoring:** Authorities can audit blockchain records to identify discrepancies and prevent counterfeit activities.

By implementing these mechanisms, the system enhances transparency, minimizes fraud, and promotes a safer pharmaceutical supply chain.

This pharmaceutical supply chain system involves multiple stakeholders. It begins with the manufacturer assigning a unique code to each capsule wrapper, embedding essential details such as the manufacturing and expiry dates. The distributor then packages the medicine, oversees its distribution, and ensures transparency by generating a hash value. Additionally, the tracking path is made visible to consumers using the Tuna Fish Algorithm, allowing them to trace the product's journey. The pharmacist, as the next stakeholder, receives the medicine from the distributor and supplies it to a local store or hospital, where it is then sold to the end user. Throughout each stage, the medicine is tracked via a QR code, ensuring both transparency and security. Consumers can scan this QR code to obtain product details, including manufacturer information, a product description, and tracking history.

The system also incorporates a wholesale stage, facilitating bulk purchases for pharmacies and hospitals. Additionally, consumers have the option to buy medicines directly from the manufacturer or distributor, bypassing intermediaries such as local shops. In conclusion, this supply chain system, strengthened by the Tuna Fish Algorithm, guarantees security, transparency, and seamless tracking from production to

the consumer. The integration of QR codes and hash values further enhances security and transparency, allowing users to retrieve product details effortlessly with a simple scan.

## II-METHODOLOGY

### TUNA FISH Algorithm:

The Tuna Fish Algorithm is an innovative blockchain-based approach aimed at enhancing supply chain transparency, particularly in the seafood industry. By utilizing blockchain's decentralized structure, it helps prevent illegal fishing activities and supports sustainable sourcing.

- **Blockchain Implementation:** Ensures an immutable and secure record of the product's journey from its origin to the end consumer.
- **Automated Smart Contracts:** Enforces sustainability guidelines and ethical industry practices through self-executing agreements.
- **Live Data Tracking:** Integrates IoT-enabled monitoring systems to provide real-time updates on product movement and authenticity.

### Application in the Pharmaceutical Supply Chain:

#### 1. Production Phase:

- **Utilizing the Tuna Fish Algorithm:** Establishes authenticity from the moment a pharmaceutical product is manufactured.
- **Blockchain-Based Documentation:** Securely stores details related to production, enhancing traceability and preventing counterfeiting.

#### 2. Distribution Network:

- **Enforcement of Smart Contracts:** Ensures adherence to ethical procurement and transparent distribution policies.
- **Source Verification:** Provides distributors with a means to verify product origins, preventing fraud.

#### 3. Supply to Retailers:

- **Decentralized Authentication:** Pharmacies and retailers can validate the authenticity of medicines through blockchain verification.
- **Consumer Information Accessibility:** Enables buyers to access supply chain details, promoting informed decision-making.

#### 4. Retailers to End Consumers:

- **QR Code Integration:** Customers can scan a product’s packaging to retrieve authenticated blockchain records.
- **Clear and Verifiable Information:** Assists consumers in verifying the authenticity and ethical sourcing of pharmaceutical products.

**Key Advantages:**

- **Fraud Prevention:** Reduces the risk of counterfeit medicines by providing a secure verification system.
- **Greater Transparency:** Strengthens trust by allowing stakeholders to access verified supply chain data.
- **Informed Consumers:** Empowers buyers with real-time insights into a product’s journey, fostering ethical purchasing choices.

**III - RESULT**

- **QR Code Generation and Scanning Process**
- Once the QR code has been successfully generated, users can scan it using an Android device equipped with either a built-in camera or a third-party scanning application.



Fig 1: QR Code of the Product

Figure4 showcases the QR code created by the manufacturing company. When a user scans this QR or manually enters the Product ID, the following key product details will be displayed:

- **Product ID:** A unique alphanumeric identifier assigned to each product to facilitate traceability.
- **Product Name:** A clearly defined name that allows consumers to recognize the product easily.
- **Manufacturer Details:** Information about the company responsible for producing the product.
- **Distributor Information:** Identifies the organization managing the distribution of the product to retailers and suppliers.

- **Supplier Name:** Specifies the entity that supplies raw materials or components used in manufacturing.
- **Manufacturing Data:** This section provides crucial details such as:
  - **Company Name:** Ensures accountability by identifying the manufacturer.
  - **Ingredient List:** Offers transparency by displaying all components used in the product.
  - **Storage Guidelines:** Details optimal storage conditions to maintain quality.
  - **Pricing Information:** Helps consumers make informed purchasing decisions.
  - **Warnings & Instructions:** Ensures safe usage and minimizes potential risks.

This comprehensive dataset enhances transparency while fostering consumer trust in the product lifecycle.

**User Interaction with the QR Code**



**Client Interaction with the QR Code**



Fig 2:Checking the QR Code on a Versatile Gadget

Once all essential subtle elements are compiled, the producer implants the QR code on item bundling, such as tablet sheets. These sheets are at that point disseminated to providers through authorized merchants. When a client filters the QR code or physically enters the Item ID, they are coordinated to an official site containing nitty gritty item data, as portrayed in Figure 5. This consistent handle improves proficiency, giving clients with real-time get to to confirmed subtle elements almost their buys.

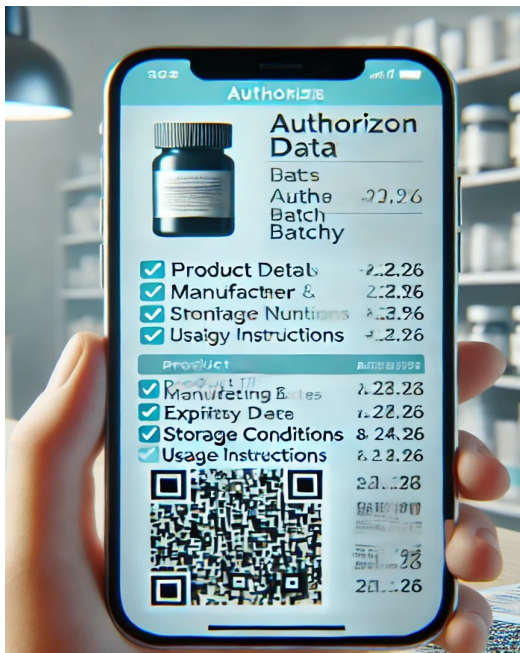


Fig. 3:Item Data Shown on the Authorized Site

Upon checking the QR code, buyers are allowed get to basic item points of interest, counting:

- Item Title and Producer Data
- Fabricating & Expiry Dates
- Group Number for Traceability
- Total Fixing List
- Capacity Conditions & Utilization Informational
- Security Notices & Estimating Points of interest (on the off chance that accessible)

By advertising a riches of confirmed data, this framework advances straightforwardness and engages customers to create educated choices with respect to the security and realness of the item.

Elective Item Confirmation Strategy



Fig 4:Confirming Item Points of interest Utilizing the Item ID

Aside from QR checking, clients can too recover item subtle elements by entering the interesting Item ID. This double confirmation strategy guarantees more prominent availability and comfort for clients, obliging distinctive innovative inclinations. Whether through filtering or manual passage, buyers can quickly confirm the realness of their buy, fortifying believe within the supply chain.



Fig. 5: Invalid Item ID or QR Code Alarms

### Notice for Invalid Item Points of interest

**In the event that a client endeavors to check an unregistered QR code or enters an invalid Item ID, the framework will show a caution expressing:**

"No item subtle elements accessible. If it's not too much trouble check a enlisted QR code or enter a substantial Item ID."

This message advises clients that the provided data does not coordinate any enlisted items within the database. It empowers them to confirm the exactness of their input or guarantee they are utilizing an authorized item identifier. By actualizing this protect, the framework viably avoids deception and upgrades customer certainty in genuine items.

### IV - CONCLUSION

The PharmaTrace and Transparency system, inspired by the Tuna Fish Algorithm, transforms pharmaceutical supply chain management through the integration of Blockchain, QR codes, and IoT technology. This advanced solution guarantees the authenticity and safety of medicines from manufacturing to distribution. By applying the Tuna Fish Algorithm principles to tablet production, the system fosters transparency and ethical practices throughout the supply chain.

The implementation of Blockchain technology establishes a secure, tamper-proof record-keeping system that enhances traceability and accountability. Smart contracts ensure compliance with ethical standards, ensuring responsible sourcing and distribution of pharmaceuticals. Additionally, real-time tracking enabled by IoT devices enhances accuracy and visibility throughout the entire process.

Consumers greatly benefit from this system by simply scanning QR codes on tablet packaging, which provides instant access to crucial details regarding the tablet's origin, authenticity, and ethical compliance. This user-friendly feature empowers consumers to make informed and responsible purchasing decisions. The Pharma Trace system, guided by the Tuna Fish Algorithm, serves as a deterrent to illicit activities in the pharmaceutical supply chain. Beyond improving transparency and consumer confidence, it sets the foundation for a safer and more accountable pharmaceutical industry. By integrating these cutting-edge technologies, the system ensures medicine safety remains a priority while offering stakeholders seamless access to essential information through an efficient scanning process.

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