BLOCKCHAIN-BASED SUPPLY CHAIN TRANSPARENCY FOR AGRICULTURAL PRODUCE

Prof. Monika Sonmale
Assistant Professor
KBPCOES, Satara

Mr. Parth Patil
B.Tech CSE
KBPCOES, Satara

Mr. Sujal Jadhav
B.Tech CSE
KBPCOES, Satara

Mr. Aditya Jagadale
B.Tech CSE
KBPCOES, Satara

Crossref DOI - https://doi.org/10.63665/rh.v7i2.107

Abstract :

Traditional paper-based or centralised systems cannot ensure transparency, traceability, and trust in agriculture because agricultural supply chains are complex and interconnected. Without reliable tracking methods, issues like food fraud, quality loss, price manipulation, delayed accountability, and regulatory violations often emerge. This research presents a blockchain-based supply chain transparency framework that seeks to offer a secure, tamper-proof, and traceable view of agricultural product movement from grower to consumer. The proposed system uses a permissioned blockchain network to record and verify essential supply chain events, including harvesting, grading, transportation, storage, processing, and sale. Each transaction is secured using cryptography, time-stamped, and linked to previous records to ensure strong data integrity and protection against tampering. To handle scalability and storage challenges, large and non-essential data are kept off-chain, while their cryptographic hashes are stored safely on the blockchain. A web or mobile-based interface allows stakeholders such as farmers, logistics providers, and retailers to access role-specific information. At the same time, consumers and regulatory authorities can verify the source, handling conditions, and quality information through read-only access. The proposed framework improves traceability, accountability, and trust among stakeholders, promotes fair trading practices, and boosts consumer confidence in agricultural supply chains.

Keywords : Blockchain, Agricultural Supply Chain, Supply Chain Transparency, Traceability, Permissioned Blockchain, Ethereum, Food Safety, Smart Contracts.

Introduction :

In today's world, agriculture is more connected than ever. Keeping the supply chain open, efficient, trustworthy, and secure has become a major challenge. Farmers often get unfair prices, and consumers are not always sure where their food comes from or how good it is. Even with new technology, the agricultural industry still has issues with growing, transporting, pricing, and providing clear information about products. The main problem is the lack of visibility about how food moves from the farmer to the customer. Everyone involved, including farmers, middlemen, distributors, and stores, plays a role in the supply chain. However, communication among them is often lacking. As a result, farmers earn much less than the final selling price, while consumers pay significantly more. For instance, a fruit that a farmer sells for ₹20 per kg might cost customers ₹70 per kg due to added costs and many layers of middlemen. Furthermore, consumers usually do not have enough information about where their food comes from, its quality, or whether it is safe to eat. These issues highlight the clear need for a solution that is secure, clear, and unchangeable, and that is what blockchain can offer. Blockchain is a new way to track, record, and protect data at every stage of the supply chain. It uses a type of digital record called a blockchain. Information is stored in connected blocks. Each block keeps a record of events, and once something is added to the chain, it cannot be changed or deleted. This ensures that the data remains secure and tamper-proof. It is a type of digital record that is shared across many computers, so no one can change the information once it's added. This record tracks every transaction in a safe and clear way. Each step in the supply chain, from the farmer to the person who moves the goods, to the wholesaler and the store, can be added to the blockchain. This creates a permanent and reliable record of the product's journey. With blockchain, everyone involved can see the same information at the same time. This builds trust and helps prevent dishonest behaviour or unfair practices. Additionally, blockchain can use smart contracts, which are like computer programs that automatically take actions when certain conditions are met. This makes the process quicker and more reliable. Consumers can use a QR code to find out where their food came from, how it was grown, stored, and sold. This system helps track food from the farm to the table, ensuring it's safe to eat. For farmers, blockchain helps them avoid relying too much on middlemen and receive a fair price for their products.

Literature review :

1. Title: Blockchain-Driven Food Supply Chains : A Systematic Review for Unexplored Opportunities

Summary : This study gives a full overview of how blockchain is used in food supply chains. It points out areas that are not yet well explored and talks about both the advantages and the difficulties. The paper shows how blockchain can improve transparency, trust, and the ability to track food products, and also suggests where more research is needed to make food supply chains work better.

2.Title: A Review on Blockchain Applications in Operational Technology for Food and Agriculture Critical Infrastructure.

Summary : This review looks at how blockchain can be used in operational technologies for food and agricultural systems. It explains how blockchain can improve the security, reliability, and effectiveness of important agricultural systems. The paper also talks about the difficulties in integrating blockchain, like making sure different systems work together, handling large amounts of data, and dealing with rules and regulations. It provides ideas for how to use blockchain better in the future.

3.Title : Blockchain Technology: Improving Agricultural Supply Chain Efficiency and

Transparency.

Summary : This paper focuses on agricultural supply chains in Sub-Saharan Africa and explores how blockchain technology can help increase transparency, efficiency, and traceability. It covers real-world uses of blockchain, the obstacles that may stop its adoption, and how it can build trust between different groups involved. The study also offers advice on dealing with logistics and technology issues in developing markets.

4. Title : Impact of Blockchain Technology in Agriculture Supply Chain: A Comprehensive Review of Applications, Challenges, and Future Directions.

Summary : This review looks at how blockchain is actually being used in agricultural supply chains. It talks about the tech challenges and how people are adopting it, and also covers new trends such as digital tokens, smart contracts, and combining blockchain with analytics. The paper shows how blockchain can help make operations more efficient, ensure product quality, and meet regulations better.

Existing system :

1. IBM Food Trust :

A blockchain platform that enables participants (farmers, processors, retailers) to record product provenance, storage conditions, and shipment events to improve traceability and food safety.

Limitation : Enterprise-focused and can be costly for smallholders requires onboarding and integration effort for legacy systems.

Objectives :

a. Analyze current agricultural supply chains and their shortcomings :

Examine existing supply chain structures, processes, and technologies. Identify main issues such as lack of transparency, poor record-keeping, data manipulation, and limited traceability. Evaluate why current digital solutions do not provide secure and reliable information sharing.

b. Explore blockchain's potential for increasing supply chain transparency :

Study how blockchain features, including decentralization, immutability, consensus mechanisms, and smart contracts, can improve transparency. Investigate how blockchain can enable secure recording, verification, and sharing of data among farmers, traders, processors, and retailers.

c. Design a conceptual blockchain framework for traceable supply chains :

Develop a model that uses blockchain to boost transparency and trust. Define participant roles, data recording structures, and methods to ensure accuracy and prevent tampering. Explain how stakeholders can access verified information in real-time.

d. Develop a prototype for tracking agricultural products :

Create a working system or simulation to show how blockchain can track products from farm to market. Record essential supply chain data, such as product origin, changes in ownership, processing steps, and delivery records. Validate how this prototype can improve transparency, accountability, and efficiency.

e. Assess the social and economic effects of using blockchain :

Look at how blockchain-based transparency affects fairness, trust, and market participation. Explore issues related to regulations, ethics, and governance, such as data privacy and standardization. Provide recommendations for wider use of blockchain in agriculture.

f. Develop practical guidelines for sustainable blockchain implementation :

Create a roadmap for large-scale blockchain adoption in agriculture. Include best practices for integration, training, cost management, and collaboration to ensure lasting benefits for all stakeholders.

Proposed System :

A. System Overview :

The suggested approach presents a decentralized supply chain model for agriculture, which seeks to establish trustworthiness, transparency, and traceability among all individuals involved in the production process. Using distributed ledger principles, automated validation logic and hybrid data storage, the system produces a "tamper-proof" record of supply chain activities. Why? A digital identity is assigned to every product batch that remains the same throughout its lifecycle, enabling real-time monitoring and verification of transactions.

B. Layered Architecture Design :

The system consists of five layers that ensure modular design, scalability, and secure communication.

1) User Interaction Layer :

This layer provides the interface for stakeholders such as producers, transporters, retailers, regulators, and consumers to submit transactions, update product status, and view traceability data through dashboards and forms. Access is restricted to authenticated users.

Technology Used : Implemented using Flutter developed by Google for cross-platform interfaces. Firebase Authentication verifies users and assigns roles, while inputs are securely transmitted to backend APIs.

2) Application Processing Layer :

This layer validates inputs, enforces permissions, checks consistency, and converts verified data into structured blockchain transactions, preventing invalid entries from reaching the ledger.

Technology Used : Implemented using Firebase backend services. Cloud Firestore stores temporary transaction states and security rules enforce authorization. Serverless architecture enables automatic scaling.

3) Smart Contract Execution Layer :

This layer automates supply-chain operations using programmable logic for batch registration, ownership transfer, and compliance verification, ensuring transactions execute only when predefined conditions are met.

Technology Used : Smart contracts are deployed on the Ethereum platform maintained by the Ethereum Foundation and are triggered through application-layer requests to record validated events.

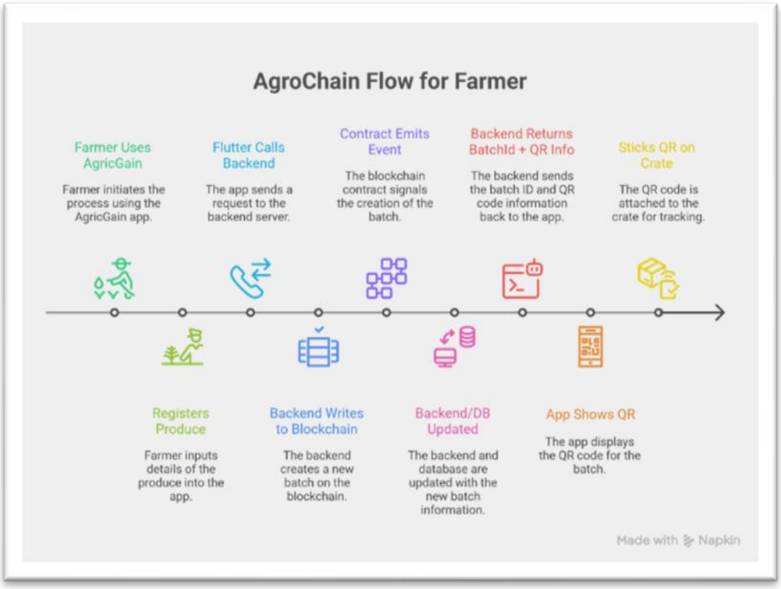
4) Distributed Ledger Layer :

This layer stores immutable transaction records linked cryptographically in chronological order. Distributed node validation ensures integrity, fault tolerance, and resistance to tampering.

Technology Used : Built on the Ethereum network. Transactions are signed using wallets such as WalletConnect or MetaMask from Consensys to provide authentication, non-repudiation, and secure blockchain communication.

5) Off-Chain Data Management Layer :

This layer stores large files externally to reduce blockchain load. Only hash values are recorded on-chain, enabling integrity verification without storing raw data.



Technology Used : Cloud Firestore and cloud storage services store external data. Generated file hashes are written to blockchain and later recomputed for verification.

Algorithm / Techniques :

a. AgroChain Frontend Overview :

- Frontend built using Flutter (cross-platform for Android, iOS & Web).
- Provides user-friendly interfaces for Farmer, Distributor, Retailer & Consumer.
- Uses Firebase Authentication for secure login & signup.
- Uses Cloud Firestore for storing user profiles, crops, product batches, and tracking states.
- Integrates with WalletConnect for blockchain interactions.
- Clean, responsive UI built with Material Design.

b. Frontend Technology Stack Primary Technologies :

- Flutter (Dart) – App development
- Material UI + Custom Widgets
- Firebase Authentication – Login / Signup
- Firestore Database – Real-time data
- Firebase Storage – Storing QR CodesWallet
- Connect v2 Or Metamask – Blockchain wallet connection.

c. Backend Technologies :

Firebase(Backend-as-a-Service)Why Firebase?

- Serverless architecture eliminates server management.
- Real-time synchronization across all devices.
- Built-in authentication with multiple providers.
- Global CDN for fast content delivery
- Automatic scaling handles traffic spikes Security rules for data protection.

d. Blockchain Technologies :

Ethereum & Smart Contracts

Why Ethereum?

- Immutable ledger ensures data integrity.
- Decentralized network eliminates single points of failure.
- Smart contracts for automated business logic.
- Transparency with all transactions publicly verifiable.
- Trust-minimized system reduces reliance on intermediaries.

e. Firebase Services Used :

- Firebase Authentication
- Firestore Database

System WorkFlow :

Login : User logs into the system and is authenticated based on role.

Batch Entry : Producer enters product details such as crop type, quantity, and origin.

Validation : System verifies input data and user permissions.

Transaction Creation : Verified data is sent to the smart contract on the Ethereum platform maintained by Ethereum Foundation.

Digital Signature : Transaction is approved using a secure wallet such as WalletConnect or MetaMask from Consensys.

Blockchain Storage : Transaction is validated by network nodes and stored permanently on the blockchain.

Supply Chain Updates : Authorized participants update shipment or ownership status.

Data Storage : Large files are stored off-chain while hash references are stored on-chain.

Traceability Check : Consumers or regulators scan QR code or enter batch ID to view product history.

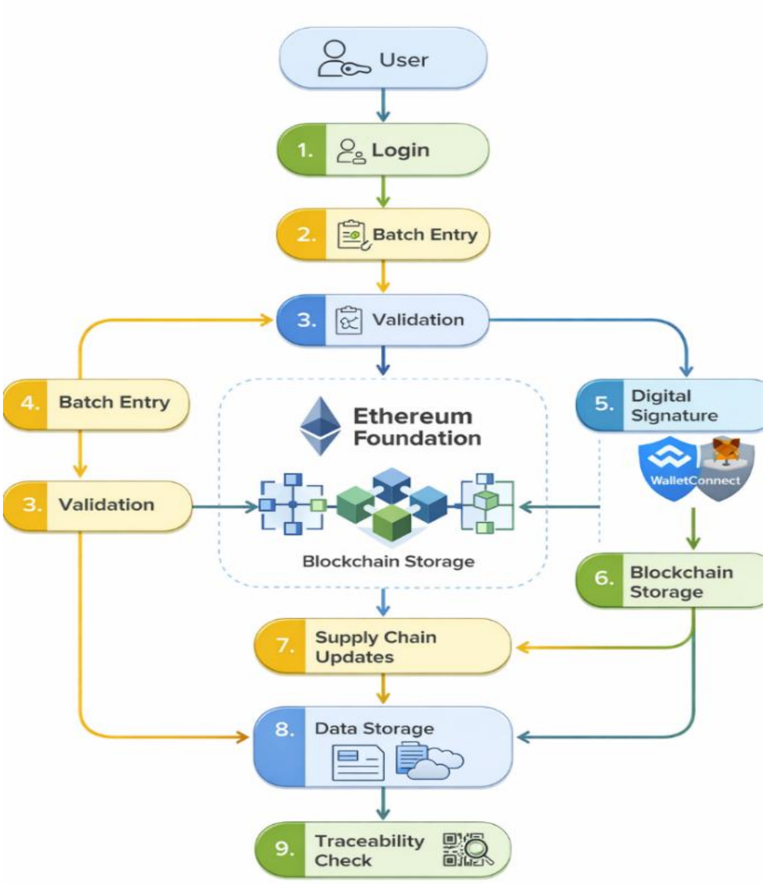


Fig. System WorkFlow

System Modeling Diagram :

Activity Diagram :

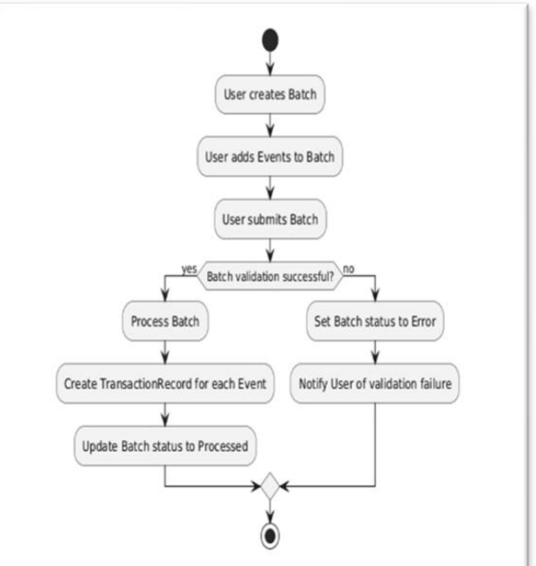


Figure 5.4: Activity Diagram for Produce Lifecycle

Advantages :

The system maintains the integrity of data, preventing records from being altered without user permission. It offers a way to track agricultural products from one end of the supply chain to the other. Automation of smart contract implementation reduces manual intervention and delays. The use of role-based authentication enhances security and limits unauthorized access. The decentralized architecture eliminates single points of failure and enhances system reliability.eu. Scalability is boosted by hybrid storage, which allows for off-chain storage of large files. Integrity and detection of attempted tampering are ensured by cryptographic hashing. How is this achieved? Real-time updates on the transaction make it easier for everyone involved to see Trust is fostered among producers, distributors, retailers and consumers through the transparent recording. It also reduces fraud and data manipulation risks.). » Automated validation enhances the accuracy and reliability of records. In general, the framework boosts efficiency, transparency, security, and accountability in supply chain operations.

Limitations :

The system depends on internet connectivity, which may be unreliable in rural areas. Initial deployment cost can be high due to blockchain integration and setup. Users require basic technical knowledge to interact with digital platforms. Blockchain transactions may introduce latency compared to traditional databases. Scalability can be affected if transaction volume increases significantly. Smart contract errors may be difficult to modify once deployed. Integration with existing legacy systems can be complex. Data privacy concerns may arise if sensitive information is improperly handled. Transaction fees on blockchain networks may increase operational cost. System maintenance and updates require technical expertise. Regulatory and legal acceptance of blockchain records may vary across regions. Overall, adoption barriers and infrastructure limitations can affect large-scale implementation.

Future Scope :

IoT sensors can be integrated to monitor storage and transportation conditions in real time. This system is also possible.? For anomaly detection and predictive analytics, artificial intelligence is a potential solution. The inclusion of multi-blockchain support could result in scalable features and lower transaction costs. Offline functionality can be advantageous for users in rural areas with limited connectivity. Advanced encryption techniques can enhance both data protection and security. Automatic compliance verification can be achieved through the integration with government certification systems. The platform can be utilized for meeting international supply chain criteria. Businesses and regulators have the ability to access insights through analytical dashboards.

Conclusion :

Integrating decentralized ledger technology, automated smart contracts, and hybrid data storage (see also Chain Metrics) makes the proposed system a secure, transparent solution for managing the agricultural supply chain. By reducing the need for manual processes and limiting the risk of fraud, it ensures data integrity, traceability, and trust among all parties. This layered architecture is more scalable and reliable, making it ideal for real-world applications. It also enables real-time tracking and verifiable records, which increases overall system accountability throughout the product lifecycle. The framework demonstrates how modern decentralized technologies can convert traditional supply chain systems into effective, secure, and reliable digital ecosystems.

Reference :

- Kumar, N., et al., "Blockchain-Based Traceability in Agriculture Supply Chain," Interna tional Journal of Advanced Computer Science, 2021.
- Blockchain-Based Traceability and Transparency in Agricultural Supply Chains: Liang, X., Shetty, S., Tosh, D., & Kamhoua, C. (2018). Enhancing supply chain transparency and traceability using blockchain and smart contracts. IEEE International Conference on Smart Computing, 248-253.
- Bockchain and agricultural supply chains traceability: research trends and future challenges Mirabelli, G., & Solina, V. (2020). Blockchain and agricultural supply chains traceability: research trends and future challenges. Procedia Manufacturing, 42, 414–421.
- Blockchain Applications in Agricultural Supply Chain Traceability: A Literature Review Mirabelli, G., & Solina, V. (2020). Blockchain and agricultural supply chains traceability: research trends and future challenges. Procedia Manufacturing, 42, 414–421. https://doi.org/10.1016/j.promfg.2020.02.054.
- Trisha Juneja, "Enhancing Supply Chain Transparency in Agriculture with Blockchain Technology: A Case Study of AgriDigital", Scientific Journal of

Metaverse and Blockchain Technologies, 2(2), 72–82, 2024.

- Ankita K. Tiwari & Seema Mahajan, "An Automated Framework Blockchain-Based Agriculture Supply Chain", Communications on Applied Nonlinear Analysis, Vol. 32 No. 9s, 2025.