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Smart Supply Chain Inventory Management Using Blockchain Technology

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Abstract

This study examines the significant potential of blockchain technology in enhancing smart supply chain inventory management. It tackles ongoing issues like inconsistent inventory records, data update delays, and high operational costs due to manual processes and the involvement of intermediaries. Blockchain uses a decentralized and immutable ledger to provide all participants in the supply chain with real-time access to accurate data, promoting transparency and reducing discrepancies. The research emphasizes the importance of smart contracts in automating key supply chain tasks such as order placement, shipment verification, and inventory updates. The study presents a thorough approach to implementing blockchain technology, covering aspects from data collection and network setup to smart contract design, testing, deployment, and ongoing improvement. Blending theoretical insights with analysis, the research highlights the significant benefits of blockchain in creating more efficient and cost-effective supply chains, advocating for broader adoption of this technology in supply chain management.

Keywords: Blockchain technology, economic order quantity (EOQ) inventory management, supply chain management, logistic management, sharding, soft fork

INTRODUCTION

In the constantly changing field of supply chain management (SCM), adopting advanced technologies is essential for companies to maintain their competitiveness and improve efficiency. Among these innovations, blockchain technology is proving to be a game-changer, offering unmatched levels of transparency, security, and operational effectiveness. This study investigates the application of blockchain technology for smart supply chain inventory management, focusing on its potential to revolutionize inventory tracking, reduce costs, and enhance overall supply chain performance. Historically, supply chains have faced challenges such as inconsistent inventory records, delayed data updates, and high operational costs due to manual processes and middlemen as shown in Figure 1.

Blockchain tackles these challenges by offering a decentralized and permanent ledger that logs every transaction instantly, ensuring all participants in the supply chain have access to accurate and current data. This minimizes inconsistencies and improves transparency. Moreover, smart contracts—automated agreements with predefined terms coded directly into the system—streamline various supply chain functions. By integrating blockchain technology, businesses can achieve notable improvements in metrics such as order processing time, shipment accuracy, inventory accuracy, and overall operational efficiency. This research outlines a systematic approach to deploying blockchain in supply chain inventory management,

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detailing steps from data collection to full-scale deployment and continuous improvement. The ultimate objective is to underscore blockchain's transformative potential and encourage its broader adoption in supply chain management.

LITERATURE REVIEW

Blockchain technology has become a game-changer in SCM, providing greater security, transparency, and the ability to track goods more effectively. The integration of blockchain in SCM facilitates real-time tracking of inventory, reduces fraud, and improves overall efficiency. Research indicates that blockchain technology can greatly improve supply chain management by offering permanent transaction records and minimizing the reliance on middlemen.

One notable study by Sharabati and Jreisat [1] highlights the benefits of blockchain technology in SCM, including increased security, confidentiality, and efficiency. The study also recognizes obstacles, including significant implementation costs and issues with interoperability. Another systematic review by Paliwal et al. [2] emphasizes the role of blockchain in sustainable SCM, noting its potential to improve traceability and transparency.

Blockchain offers a secure, decentralized ledger that ensures all transactions are recorded permanently and can be traced with ease. This capability greatly minimizes the chances of fraud and mistakes in managing inventory. According to Tian [3], blockchain can enhance transparency and traceability in the agricultural supply chain, thereby ensuring the integrity of inventory records and improving stakeholder trust.

Blockchain technology enhances transparency in the supply chain by creating a unified record accessible to all participants. This shared ledger offers real-time insight into inventory status and movements, improving coordination and enabling more informed decision-making.

Kouhizadeh and Sarkis [4] discuss the role of blockchain in improving transparency and trust in green supply chains, highlighting its potential to enhance sustainability practices [4].

Blockchain can lower operational expenses and enhance efficiency by removing middlemen and automating various processes. According to Saberi et al. [5], blockchain has the potential to optimize supply chain operations, cut transaction costs, and boost overall efficiency by automating repetitive tasks and minimizing the reliance on manual record-keeping [5].

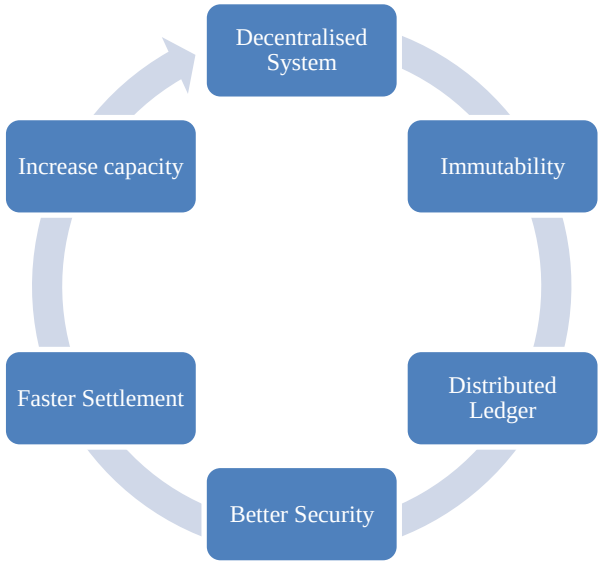

Figure 1. Features of blockchain technology.

Challenges Without Internet of Things (IoT) and Machine Learning (ML): While blockchain offers significant advantages, its effectiveness in inventory management is limited without IoT and ML. IoT devices enable real-time data gathering and monitoring, which is crucial for precise inventory management. Similarly, ML algorithms can predict demand and optimize inventory levels, which blockchain alone cannot achieve. Casado-Vara et al. [6] highlight that integrating blockchain with IoT and ML can lead to smarter and more efficient supply chain management.

Potential Solutions: To overcome these limitations, future research should explore hybrid approaches that combine blockchain with IoT and ML. These integrated systems can leverage real-time data and advanced analytics to enhance inventory management, thereby achieving greater efficiency and accuracy.

Blockchain technology provides secure, unchangeable records of transactions, ensuring that all data is accurately logged and cannot be tampered with. This boosts both security and transparency in supply chain processes, minimizing the chances of fraud and mistakes in inventory management. According to Zhang et al. [7], blockchain improves data integrity and transparency, enabling better coordination among supply chain partners [7].

Real-Time Tracking and Traceability: The decentralized nature of blockchain allows for real-time tracking of inventory and goods movement. This feature guarantees that all members of the supply chain have access to the same information, enabling informed and timely decision-making. Treiblmaier [8] highlights how blockchain technology enhances traceability, helping to prevent counterfeiting and ensuring product authenticity.

Cost Reduction and Efficiency: Blockchain can greatly cut down operational expenses and enhance efficiency in SCM by removing the need for intermediaries and automating various processes [8]. Azzi et al. [9] discuss the potential of blockchain to streamline supply chain operations, reduce transaction costs, and enhance efficiency through smart contracts that automate routine tasks.

METHODOLOGY

This methodology outlines the detailed steps for implementing blockchain technology in e-commerce supply chain inventory management, aiming to enhance transparency, security, and efficiency without relying on IoT and ML algorithms. The research problem is to identify the core issues in the current inventory management system, such as inconsistent records, lack of real-time visibility, and high operational costs [10].

Our entities are central warehouse (CW), regional distribution centers (RDCs), and retail stores (RSs). The processes are order processing, shipment verification, and inventory updates. We have the following approach for the smart chin supply inventory management using blockchain.

Data Collection

Data Requirements

- Inventory data: Current stock levels, product details, shipment histories.
- Transaction data: Order details, shipment records, inventory adjustments.

Data Sources

- Internal databases from CW, RDCs, and RSs.
- Historical transaction logs and inventory records.

Blockchain Network Setup

- Select an appropriate blockchain platform, such as Hyperledger Fabric or Ethereum, considering factors like scalability, security, and ease of integration.

- Network Configuration:
  - *Define nodes:* CW, RDCs, and RSs as nodes in the blockchain network.
  - *Establish consensus mechanism:* Determine the protocol for validating transactions (e.g., proof-of-stake, proof-of-authority).

Smart Contract Design

- *Order Processing:* Develop smart contracts to automate the order placement process:
  - When an order is placed, the smart contract records the order details (e.g., item IDs, quantities, delivery dates) on the blockchain. Trigger notifications for relevant nodes (CW, RDCs) to prepare for shipment.
- *Shipment Verification:* Create smart contracts to handle shipment verification:
  - Upon shipment departure from CW, a smart contract records the shipment details (e.g., items shipped, departure time) on the blockchain. Notify the receiving RDC or RS about the incoming shipment.
- *Inventory Updates:* Implement smart contracts for automatic inventory updates:
  - As shipments are received at RDCs and RSs, smart contracts update inventory levels on the blockchain in real-time. Make sure that all nodes are able to access the most recent inventory information.

Data Integrity and Security

- Make sure that all transactions, including orders, shipments, and inventory updates, are securely logged on the blockchain, establishing a permanent record that cannot be changed or tampered with.
- *Access Control:* Implement access control measures to ensure only authorized personnel can view or update specific data on the blockchain.

Testing and Validation

- *Simulation:* Conduct a simulation of the blockchain network to test the smart contracts and ensure they function as expected:
  Simulate the placement of orders, shipments, and updates to inventory, ensuring that all transactions are properly documented on the blockchain.
- *Pilot Implementation:* Run a pilot implementation with a subset of nodes (e.g., one CW, one RDC, and a few RSs) to test the system in a real-world scenario.
- Collect input from stakeholders during the pilot phase and make required changes to the smart contracts and blockchain network setup.

Full-Scale Deployment

- *Rollout Plan:* Develop a rollout plan for deploying the blockchain network across all nodes (CW, RDCs, RSs) in the e-commerce supply chain.
- *Training:* Provide training for all stakeholders on using the new blockchain system, including how to place orders, verify shipments, and access inventory data.
- Set up a monitoring system to regularly assess the blockchain network's performance and resolve any problems that come up.

Continuous Improvement

- *Performance Metrics:* Define key performance metrics (e.g., order processing time, shipment accuracy, inventory levels) to evaluate the success of the blockchain implementation.
- *Ongoing Optimization:* Regularly review the blockchain system and smart contracts, making improvements as needed to enhance efficiency and address emerging challenges.

RESULT ANALYSIS

By implementing the above methodology, companies can streamline their inventory management systems, reduce operational costs, and achieve a transparent, tamper-proof supply chain inventory management as shown in Table 1.

Table 1. Analysis methodology.

Step	Key Activities	Benefits	Challenges
Problem definition	Identify core issues	Clear understanding of challenges	Comprehensive problem identification
Data collection	Gather inventory and transaction data	Accurate baseline for implementation	Ensuring data accuracy
Blockchain network setup	Choose platform, configure node and consensus mechanism	Secure, scalable and transparent network setup	Initial network setup
Smart contract design	Automated order, processing, shipment verification, inventory update	Reduce manual processing	Designing automated and robust smart contract
Testing and validation	Simulate and pilot the blockchain system	Identify and resolve the issue before deployment	Comprehensive testing process
Full-scale deployment	Implement across all nodes, train stakeholders	Improve transparency and efficiency	Training and change management
Continuous improvement	Monitor performance, regular review and optimization	Ongoing efficiency and process enhancement	Keeping up with technological advancements

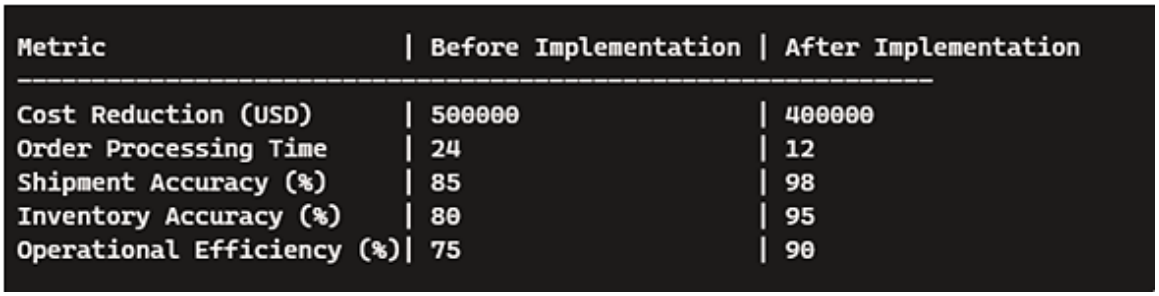

Figure 3. Analysis of cost.

We analyze some different costs after implementing smart supply chain inventory methodology using blockchain technology as shown in Figure 3.

DISCUSSION

Key Metrics and Expected Improvements

- *Cost Reduction:* High costs due to manual processes and intermediaries.
  After Implementation: Reduced operational costs through automation and elimination of intermediaries.
- *Order Processing Time:* Longer processing times due to manual handling.
  After Implementation: Faster order processing with automated smart contracts.
- *Shipment Accuracy:* Inconsistencies and errors in shipment verification.
  After Implementation: Higher accuracy due to blockchain's immutable records and real-time updates.
- *Inventory Accuracy:* Discrepancies in inventory levels across different nodes.
  After Implementation: Improved accuracy with real-time inventory updates on the blockchain.
- *Operational Efficiency:* Inefficiencies due to lack of transparency and coordination.
  After Implementation: Enhanced efficiency with transparent and coordinated blockchain-based operations.

CONCLUSION

To summarize, this research highlights the significant impact of blockchain technology on supply chain inventory management. By addressing key issues such as inconsistent records, data update delays, and high operational costs, blockchain offers a robust solution through its decentralized and unchangeable

ledger. The adoption of smart contracts further automates critical supply chain processes like order placement, shipment verification, and inventory updates. This automation streamlines operations, reduces human error, and minimizes fraud, leading to notable improvements in order processing time, shipment accuracy, inventory accuracy, and overall operational efficiency. The research provides a detailed approach to blockchain implementation, covering data collection, network setup, smart contract design, testing, deployment, and continuous improvement. The results highlight the significant advantages of using blockchain to enhance the efficiency and cost-effectiveness of supply chains. Upcoming research should focus on integrating IoT devices and ML techniques with blockchain technology. This integration will enable real-time data collection, predictive analytics, and more sophisticated automation, leading to even greater accuracy in inventory management and more responsive supply chain operations. This study encourages the broader use of blockchain technology in SCM, emphasizing its ability to transform inventory management and greatly improve operational efficiency.

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