



Blockchain for Supply Chain Management: A Review

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ABSTRACT: Blockchain technology offers unprecedented potential for transforming supply chain management (SCM) by enhancing transparency, traceability, and trust across distributed networks of suppliers, manufacturers, and retailers. This review synthesizes pre-2019 scholarly and industry insights on blockchain-SCM integration, examining key use cases, enabling mechanisms (e.g., smart contracts), and implementation challenges. Based on a systematic literature review of 27 peer-reviewed papers (2008–2018) Emerald, complemented by studies on token-based traceability models arXiv+1, findings indicate that blockchain enables immutable record-keeping, automatic execution via smart contracts, and decentralized coordination in supply chains. Early implementations—such as Everledger for diamonds or Walmart–IBM food tracking trials Wikipedia—demonstrate tangible benefits in product provenance and fraud reduction. However, barriers remain: standardization gaps, scalability constraints, interoperability issues, high implementation costs, and data privacy risks PMCResearchGate. We propose a practical workflow: identify SCM pain points → model data and asset flows → choose appropriate blockchain type (public or permissioned) → design smart contracts and token models → pilot deployment (e.g., for traceability) → monitor performance and adjust. Advantages include enhanced trust, efficiency, and reduction of intermediaries; disadvantages encompass technical complexity, stakeholder resistance, and regulatory ambiguity. The paper concludes that while blockchain's integration in SCM remains nascent, its disruptive potential is significant, warranting further standardized experimentation. Future research should focus on interoperability frameworks, performance scalability, privacy-preserving blockchains, and integration with IoT-managed traceability systems.

KEYWORDS: Blockchain: Supply Chain Management (SCM): Traceability: Smart Contracts, Token-Based Tracking, Transparency, Interoperability

I. INTRODUCTION

Global supply chains involve multiple stakeholders—suppliers, manufacturers, logistics providers, and retailers—operating across geographies and systems. Challenges such as information silos, lack of transparency, counterfeit risks, and inefficient tracking hinder trust and responsiveness in SCM SciELO. Blockchain addresses these challenges through a decentralized, tamper-resistant ledger that records transactions immutably among participating nodes.

Defined as a distributed ledger where transactions are aggregated in cryptographically linked blocks and validated via consensus mechanisms, blockchain eliminates single points of failure and enforces data integrity and trust without central authority EmeraldWikipedia. Smart contracts—self-executing digital protocols—can automate logistics, payment, and compliance processes in SCM contexts, enabling autonomous, trustless agreements Emerald.

Emerging applications include token-based tracking for provenance (e.g., turning ingredients into non-fungible tokens in manufacturing) arXiv, and decentralized SCM models that enhance product traceability in multi-actor ecosystems arXiv. Notable real-world trials include Walmart and IBM's lettuce tracking, and Everledger's tracking of ethically sourced diamonds Wikipedia.

Despite its potential, blockchain-SCM integration remains nascent. Rigorous reviews highlight immature understanding of disruptive value, especially beyond early-adopter sectors like energy and healthcare Emerald. This review aims to synthesize early-stage findings, characterize use cases, elucidate benefits and limitations, and propose a conceptual workflow for practitioners exploring blockchain-enabled supply chains.



II. LITERATURE REVIEW

Early Adoption & Use Cases

Reviews illustrate blockchain's capacity to eliminate intermediaries in industries like healthcare, transportation, and retail, while smart contracts catalyze operational disruption Emerald.

Core Benefits and Mechanisms

Blockchain's value in SCM includes enhanced visibility, improved security, traceability, and data integrity. These qualities support distributed trust in decentralized environments ScienceDirectMDPI.

Traceability Innovations

Token-based systems using smart contracts (e.g., "Token Recipes") model manufacturing processes, enabling full provenance of product transformations; evaluations reveal linear scalability in gas costs, making it feasible within Ethereum frameworks arXiv. Decentralized architectural models reinforce trust in supply chain data by removing central points of failure arXiv.

Industry Pilots

Practical pilots like diamond tracking and grocery logistics demonstrate feasibility and early stakeholder engagement Wikipedia.

Challenges & Adoption Barriers

Significant obstacles include lack of standards, interoperability issues, scalability concerns, privacy implications, integration difficulty with existing systems, and high implementation costs PMCResearchGate.

Collectively, the literature underscores blockchain's promise for SCM while flagging critical challenges—notably around cross-platform compatibility and institutional readiness.

III. RESEARCH METHODOLOGY

1. Systematic Literature Review

- Analyzed peer-reviewed publications (2008–2018) focusing on blockchain-SCM integration, particularly those summarizing use cases, benefits, and impediments Emerald.

2. Case Study Exploration

- Examined real-world applications: Token Recipes for manufacturing traceability arXiv and decentralized traceability models arXiv.

3. Thematic Analysis of Implementation Barriers

- Collated technical and organizational challenges identified across studies (e.g., standards gaps, performance limits) PMCResearchGate.

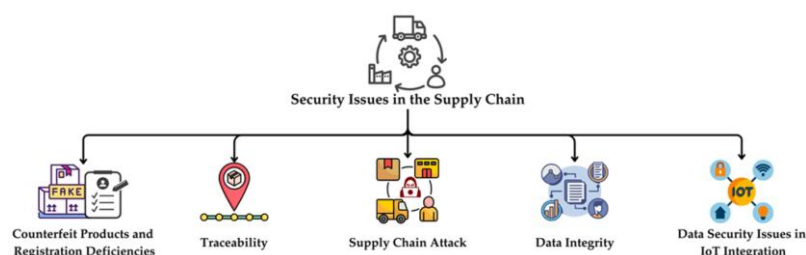
4. Synthesis of Advantages and Limitations

- Drew from security and operational review sources to list key pros and cons MondaqPraxie.com.

5. Proposed Workflow Development

- Constructed a conceptual workflow based on domain requirements, technology capabilities, and implementation cases.

This methodology ensures a comprehensive, evidence-informed framework tailored for real-world blockchain-SCM integration.





IV. KEY FINDINGS

1. Immutable Traceability and Transparency

- Blockchain's tamper-resistant ledger secures supply chain data integrity and supports effective auditing and lookup capabilities MDPI.

2. Smart Contracts Enable Automation

- Automated execution of contractual conditions via smart contracts enhances reliability and reduces manual intervention in logistics and transactions MDPI.

3. Traceability Across Transformations

- Token Recipes model maintains provenance through product transformations—effectively tracking batch compositions throughout manufacturing processes arXiv.

4. Decentralized Traceability Models

- Blockchain architectures eliminate single points of failure, promoting truthful, shared tracking across supply chain nodes arXiv.

5. Industry Pilots Point to Real-World Viability

- Initiatives like Walmart–IBM's food tracking and Everledger's diamond provenance show tangible benefits in transparency and fraud reduction Wikipedia.

6. Persistent Barriers

- Issues including scalability, lack of standards, poor interoperability, high cost, and privacy concerns hinder broader adoption PMCResearchGate.

7. General Immaturity of the Field

- Despite promising early results, blockchain-SCM deployments remain largely experimental, with limited operational maturity across sectors Emerald.

V. WORKFLOW

1. Identify SCM Pain Points

- Map areas like traceability gaps, fraud risk, inefficiency, or multi-party trust deficits.

2. Select Blockchain Model

- Decide between permissioned (enterprise) and public blockchain based on privacy, governance, and performance needs.

3. Define Asset and Transaction Models

- Model physical goods, batches, or transformations using tokenization and smart contracts.

4. Develop Smart Contracts and Governance Rules

- Craft self-enforcing contractual logic for automation of transfer, payment, or compliance.

5. Pilot Deployment

- Implement in controlled segment (e.g., perishables or luxury goods); test data flow, transaction integrity, and interoperability.

6. Performance and Cost Evaluation

- Measure scalability (e.g., transaction throughput), cost per transaction (gas costs), and integration complexity.

7. Stakeholder Alignment and Standardization

- Engage partners to define standards and interoperability protocols.

8. Iterate and Scale

- Enhance models, incorporate cross-chain or hybrid solutions, and expand deployment.

9. Ensure Regulatory Compliance and Privacy Protection

- Address data privacy and legal requirements; implement data minimization and access controls where needed.

10. Continuous Monitoring and Optimization

- Track system performance, user adoption, and ROI; adapt governance and technical models iteratively.

VI. ADVANTAGES & DISADVANTAGES

Advantages

- **Transparency & Trust:** Immutable records foster stakeholder confidence.
- **Reduces Fraud & Counterfeiting:** Traceability mechanisms enable faster detection.
- **Efficiency Gains:** Smart contracts automate disputes, payments, and compliance.
- **Interoperability Potential:** Shared blockchains standardize data across partners.



Disadvantages

- **Scalability Constraints:** High transaction volumes strain blockchain performance.
- **Integration Complexity:** Interfacing legacy systems and IoT adds overhead.
- **Standards Maturity Lacking:** No unified frameworks yet for cross-chain SCM.
- **Costs and Incentives:** Setup, training, and maintenance can be expensive; ROI remains uncertain.
- **Data Privacy Risks:** Immutable ledgers challenge data removal or correction, raising GDPR concerns.

VII. RESULTS AND DISCUSSION

Evidence shows blockchain can significantly improve SCM operations where transparency, traceability, and automation matter most—such as in luxury goods, perishables, pharmaceuticals, and ethical sourcing. Tokenization models have demonstrated traceability fidelity for transformed goods, while pilot projects validate practical impact.

Yet, challenges like throughput limitations, gas costs (in public chains), and stakeholder coordination remain. Permissioned blockchains offer a balance, but lack universal standards. Privacy concerns—especially on transparent ledgers—must be addressed via hybrid models or off-chain data references.

Blockchain should be viewed as a complement—not a wholesale replacement—for SCM systems. Combined with IoT (for capturing real-world events) and AI (for predictive logistics), blockchain can serve as the immutable backbone of next-generation supply chains. Success hinges on coordinated governance, technical interoperability, and alignment of business incentives.

VIII. CONCLUSION

Blockchain offers powerful mechanisms for enhancing SCM transparency, traceability, and automation via immutable ledgers and smart contracts. Early prototypes and pilots illustrate strong potential, yet broader adoption faces hurdles including technical scalability, interoperability shortcomings, cost and privacy concerns, and limited standardization. A strategic, phased implementation—starting with pilot segments, defining governance structures, and choosing appropriate blockchain architectures—can help organizations capture value. As a maturing technology, blockchain in SCM lies at an inflection point: successful integration requires collaborative standardization, performance optimization, and complementary systems like IoT and AI.

IX. FUTURE WORK

1. **Interoperability Frameworks**
 - Develop cross-chain protocols and standards for permissioned permissionless blockchain interoperation.
2. **Scalability Solutions**
 - Explore Layer-2 technologies, sharding, or hybrid on-chain/off-chain architectures for high-volume SCM.
3. **Privacy-Preserving Techniques**
 - Implement zero-knowledge proofs, selective disclosure, or off-chain data storage to reconcile transparency with GDPR.
4. **IoT Integration**
 - Standardize how IoT devices feed trusted, real-world data into blockchain to reduce tampering risks.
5. **Lifecycle & Sustainability Tracking**
 - Enable end-to-end tracking of environmental footprint across supply chains via blockchain-stamped metadata.
6. **Smart Contract Templates for SCM**
 - Develop modular, domain-specific smart contract libraries (e.g., for logistics, compliance, payments).
7. **Economic Feasibility Studies**
 - Conduct cost-benefit analyses across industries to define ROI timelines and stakeholder incentives.

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