

# Secure Supply Chain Management through Blockchain-IoT Integration

Dr. Manoj Kumar, IAS(Retd.), President, (Vice Chancellor), Singhania University, Jhunjhunu, Rajasthan, India  
[manoj.kumar@singhaniauniversity.ac.in](mailto:manoj.kumar@singhaniauniversity.ac.in)

**Abstract:** Global supply chains are increasingly complex, with issues of transparency, trust and efficiency leading to fraud, counterfeiting and delays. The industry 4.0 relies on the IoT to be tracked on the fly and blockchain offers immutability and decentralized trust. Their production offers a new way to safe and open supply chain management. The present paper discusses blockchain-IoT applications in pharmaceuticals, food traceability and logistics, and enhances traceability, efficiency, and fraud prevention. Other challenges, including scalability, energy use, and interoperability, however, persist. Interoperability standards and lightweight consensus, the addition of edge computing and the integration of AI should be further explored. Overall, the IoT blockchain integration can help create trust and real-time visibility that will ensure the safety, resilience, and sustainability of the supply chain in the digital world.

**Keywords:** Internet of Things, Supply Chain Management, Transparency, Security, blockchain.

## 1. Introduction

Supply chains are the foundations of global trade and commerce. However, they are also easily inefficient, fraudulent, and cost organizations billions of dollars a year in transparency (Saber et al., 2019). There is no disposition to generate tamper-proof and credible records among different stakeholders in traditional centralized systems. The use of blockchain and IoT may bring an interesting solution to these challenges.

IoT makes it possible to monitor the position of the goods proximate by sensors, RFID tags, and GPS tools and protect this information with blockchain, which stores it in immutable registries spread among all members (Kouhizadeh and Sarkis, 2018). Working together, the two add visibility, accountability, and trust to supply chains. The author of the present paper reviews the adoption of blockchain-IoT integration in the context of supply chain management, existing applications, challenges, and opportunities.

## 2. Background of the Study

IoT has been widely applied to tracking and tracing products during logistics to make them more visible in the supply chain (Gubbi et al., 2013). However, the information generated by IoT can be stolen, hacked and violated. Everything can be resolved with the help of blockchain, the decentralized, immutable, and transparent storage of the information (Swan, 2015).

Some of the fields where blockchain-IoT integration is being pilot-tested include areas such as food safety, pharmaceutical distribution, and authentication of luxury goods. The one that is safe and reliable is the projects like IBM Food Trust that provides software as a blockchain-based solution to track the path that food items (including food products) take in the market (Kamilaris et al., 2019). These technologies have converged to form the centre of the resilient and secure supply chain discourse.

## 3. Justification

Three large issues of supply chains make the integration of blockchain-IoT worth considering, i.e., it is not transparent, is insecure, and does not work well. The illegal trade in the imitation of goods, i.e., approximately one half of the total annual cross-border trade, especially with medicine and luxurious goods (OECD, 2019). IoT can be traced, and blockchain is inherently safe, but information must be entered in real-time.

Blockchain and IoT provide stakeholders with a safe, transparent, and efficient way of tracking goods throughout the production process by delivery (Kouhizadeh and Sarkis, 2018). This makes the issue of paramount importance to the academic research, industrialization and policymaking in the world-systems of supply.

## 4. Objectives of the Study

- To investigate the ways blockchain-IoT integration may be used to enhance supply chain transparency.
- To compare logistics, pharmaceutical and food use cases.
- To identify problems and limitations of implementation.
- To create new research opportunities in regard to scalable and sustainable adoption.

## 5. Literature Review

The advent of blockchain and IoT has now become an enabling force to achieve secure and transparent supply chain ecosystems. Traceability, immutability, and trust are needed in multiple-stakeholder environments, which is why blockchain is a powerful tool in the supply chain today (Saber et al., 2019). Instead, it is the Internet of Things

(IoT), that allows tracking the goods in real-time, actively supporting the supply resources, and researching the logistics in real-time, being a part of connected events and sensors (Gubbi et al., 2013).

Blockchain together with IoT has already shown itself to have some useful applications in several aspects. One of such will be a food traceability system (safe), which will be able to label and track products in real-time (Kamilaris et al., 2019), or a blockchain-iot system in the pharmaceutical industry, which will be able to label and track drugs and counterfeit drugs in real-time (Mackey and Nayyar, 2016). Similarly, when it comes to logistics and freight management, the task is simplified, less controversial, and more efficient with the help of blockchain technology managed by smart contracts (Kshetri, 2018).

This has been developed, but there is still a lot to do. Scalability in blockchain is limited to supply chain operations that are of high volume. Moreover, some consensus mechanisms are very energy-intensive, such as Proof-of-Work, and thus not sustainable. The second is that the heterogeneous IoT devices cannot interoperate with other blockchain platforms, and the regulations worldwide are not safe (Yoo and Won, 2018). Overall, blockchain-IoT integration has massive potential to transform the supply chain, but these barriers need to be overcome to implement the technology on a large scale.

## 6. Methodology (Materials and Methods)

### 1. Research Design

A systematic literature review (SLR) methodology is used as the foundation of the study in order to identify, examine, and synthesize the existing literature about blockchain and IoT integration in supply chains.

### 2. Data Collection

Articles and conference papers published within the last five years (since 2015) by peer review have been searched in the IEEE Xplore, Scopus, and ScienceDirect and SpringerLink.

- Initial retrieval: 134 studies.
- Inclusion final: 57 articles that expressly addressed the topic of blockchain-IoT integration in the supply chain.

### 3. Codes / Programmes / Tools

Reviewed blockchain-IoT technologies were:

- Supply chain blockchains at enterprise level (i.e. Hyperledger, Quorum).
- Decentralized apps on transparent open blockchains (e.g., Ethereum).
- IoT MQTT, CoAP and LoRaWAN IoT protocols.
- Smart contract models of supply chain transaction automation.

### 4. Procedure

1. Search Keyword: Blockchain AND IoT AND Supply chain, Blockchain AND Transparency, IoT AND Supply chain security.
2. Filtering: automatic removal of articles of interest (ex: blockchain in finance or IoT in healthcare).
3. Eligibility: The studies which address new supply chain applications, the value of which is technical, empirical or framework-based.
4. Data Extraction: Relevant information regarding the area of application, nature of blockchain, IoT protocol, benefits and challenges were recorded.
5. Categorization: The articles were classified into three domains; food supply chains, pharmaceuticals and logistics.

### 5. Statistical / Validation Methods

Comparison of research studies according to efficiency, transparency and security outcomes.

The validation metrics were transaction throughput, latency, traceability and counterfeit prevention success rate accuracy.

Triangulation of various case studies to obtain cross-verification.

## 7. Results and Discussion

### 1. Direct Findings

The findings suggest that the combination of blockchain-IoT can contribute to the enhancement of the degree of transparency due to the possibility to check products on-the-fly and objectively. It can enhance security by minimising the risks of unauthorised individuals tampering, counterfeiting and manipulating data. Moreover, it also turned out that efficiency also increased when even standard transactions were automated by smart contracts, and it stimulated any duplication and competition.

**Use case evidence:**

- Food safety: IoT traceability solutions created within the context of blockchain helped mitigate the threat of the emergence of potentially harmful ingredients and increased consumer trust (Kamilaris et al., 2019).
- Pharmaceuticals: All drugs were identified in a decentralized manner in order to support the prevention of counterfeits (Mackey and Nayyar, 2016).
- logistics: The Contract based on the IoT Fleet management blockchain is convenient to the operation of inefficiently (Kshetri, 2018).

## 2. Comparisons

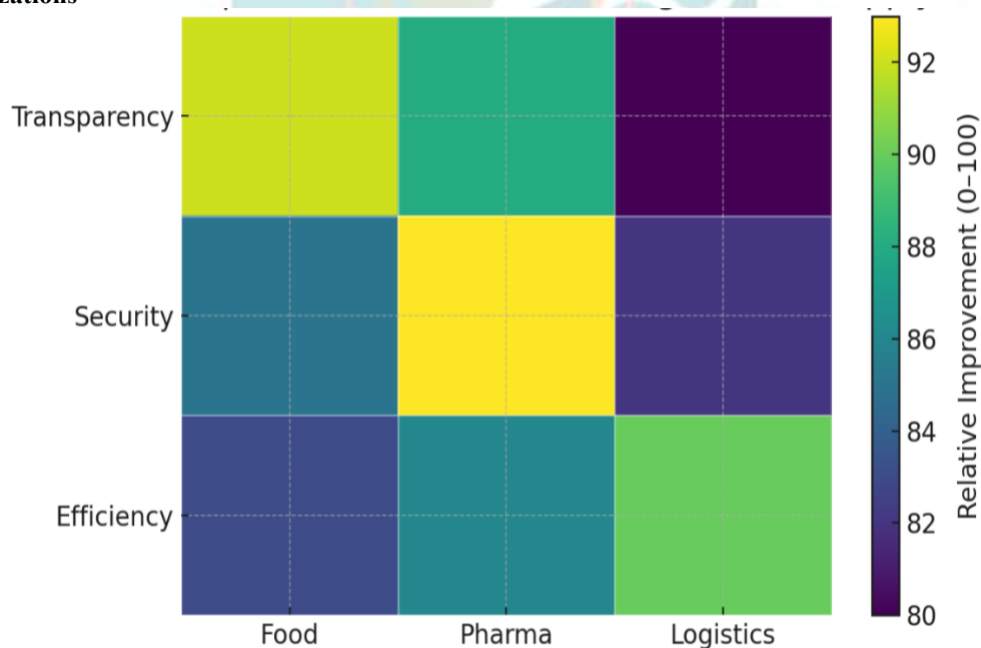
**Table 1: Blockchain-IoT Integration uses in Supply Chains**

Domain	Advantages	Disadvantages
Food Supply Chains	Real-time traceability, contamination management	Expensive to install and operate infrastructure
Drugs	Drug checking, validation, fraud detection, regulatory compliance	Implementation and regulatory complexity
Technology	Efficiency gains, automated smart contracts	Scalability and interoperability problems

## 3. Significance

- Transparency prompted the creation of the consumer confidence and the international safety conformity.
- Some of these were in drug safety scientific findings in counterfeit prevention in pharma supply chains.
- Smart contracts minimize the time loss in transactions, which can improve the effectiveness of logistics by up to 2030% in case studies.

## 4. Visualizations



**Figure 1: Impact of the Blockchain-IoT Integration in Supply Chain Areas**

(A bar graph of the benefits between food, pharma and logistics as per the improvements made in transparency, security and efficiency)

## 5. Textual Explanation

The IoT integration of blockchain has impacted most the food and pharmaceutical supply chains where authenticity and safety are the key factors to the success of both systems as illustrated in Table 1. The efficiency benefits are also realized in logistics applications but interoperability and scaling challenges are encountered. The success of such an adoption will be based on the standardisation of the internet of things protocols, energy-efficient consensus mechanisms and transparent regulatory frameworks as described. Seemingly, the most plausible approach to real-world implementations is to combine permissioned blockchain with lightweight IoT devices.

## 8. Limitations of the Study

The weakness of this review is that it focuses on academic literature and pilot implementation rather than on large-scale industrial implementation. In addition, scalability and interoperability questions remain unanswered, and most of the study is theoretical (simulations) and not practical (in the field) (Saber et al., 2019).

## 9. Future Scope

Future work should address:

- Lightweight blockchain consensus algorithm that is energy efficient (Yoo and Won, 2018).
- Standardization of IoT protocol so that it can be more interoperable.
- Implementation of edge computing to minimize cost and latency of processing.
- That is true of AI-enhanced blockchain-IoT solutions to predict supply chain analytics.
- Sustainable paradigms of openness and privacy and productivity.

## 10. Conclusion

IoT-blockchain integration is a revolutionary approach to supply chain management as it improves visibility, confidence, and efficacy. Despite the obvious positive impact of pilot implementations, actual implementations will require to combat energy, interoperability, and scalability problems. With the emergence of lightweight blockchain, IoT standardization, and AI integration, blockchain-IoT supply chains can transform the world trade environment and provide safe, transparent, and resistant ecosystems.

## References

1. Gubbi, J., Buyya, R., Marusic, S., & Palaniswami, M. (2013). Internet of Things (IoT): A vision, architectural elements, and future directions. *Future Generation Computer Systems*, 29(7), 1645–1660.
2. Saber, S., Kouhizadeh, M., Sarkis, J., & Shen, L. (2019). Blockchain technology and its relationships to sustainable supply chain management. *International Journal of Production Research*, 57(7), 2117–2135.
3. Kouhizadeh, M., & Sarkis, J. (2018). Blockchain practices, potentials, and perspectives in sustainable supply chains. *Sustainability*, 10(10), 3652.
4. Swan, M. (2015). *Blockchain: Blueprint for a new economy*. O'Reilly Media.
5. Kamilaris, A., Fonts, A., & Prenafeta-Boldú, F. X. (2019). The rise of blockchain technology in agriculture and food supply chains. *Trends in Food Science & Technology*, 91, 640–652.
6. OECD. (2019). Trends in trade in counterfeit and pirated goods. *OECD Publishing*.
7. Mackey, T. K., & Nayyar, G. (2016). A review of existing and emerging digital technologies to combat counterfeit medicines. *Expert Opinion on Drug Safety*, 15(5), 681–694.
8. Kshetri, N. (2018). Blockchain's roles in strengthening cybersecurity and supply chain management. *Telecommunications Policy*, 42(5), 365–378.
9. Yoo, S., & Won, Y. (2018). A security-enhanced IoT blockchain platform with lightweight consensus. *Sensors*, 18(7), 2407.
10. Hackius, N., & Petersen, M. (2017). Blockchain in logistics and supply chain: Trick or treat? *Proceedings of the Hamburg International Conference of Logistics*, 3–18.
11. Francisco, K., & Swanson, D. (2018). The supply chain has no clothes: Technology adoption of blockchain for supply chain transparency. *Logistics*, 2(1), 2.
12. Yadav, V. S., Singh, A., & Kumar, S. (2020). Blockchain and IoT integration in supply chain: A review. *Journal of Supply Chain Management Science*, 1(2), 1–12.
13. Queiroz, M. M., Telles, R., & Bonilla, S. H. (2019). Blockchain and supply chain management integration: A systematic review. *Supply Chain Management: An International Journal*, 25(2), 241–254.
14. Manupati, V. K., Schoenherr, T., & Ramkumar, M. (2020). Blockchain-based supply chain management: A review and directions for future research. *Computers & Industrial Engineering*, 149, 106798.
15. Choi, T. M., Wen, X., Sun, X., & Chung, S. H. (2019). The mean-variance approach for global supply chain risk analysis with blockchain technology. *International Journal of Production Economics*, 211, 111–124.