



Original Article

# Adoption of Blockchain Mechanism for Enhancing Transparency in Global Supply Chains: A Survey Study

Krishna Bhardwaj Mylavarapu<sup>1</sup>, Jenitha Pilli<sup>2</sup>, Prathik Kumar Jannu<sup>3</sup>, Javed Ali Mohammad<sup>4</sup>, Sri Harsha Panchali<sup>5</sup>, Usha Mohani kavirayani<sup>6</sup>

<sup>1</sup>MS in Computer Science, University of Illinois Springfield.

<sup>2</sup>MS in Computer Science, University of Louisiana at Lafayette.

<sup>3</sup>Computer Science Engineering, JNTU Hyderabad.

<sup>4</sup>Masters in Data Science, New England College.

<sup>5</sup>Information Systems Engineer, CrowdStrike Inc.

<sup>6</sup>Kent State University, MS in Computer Science.

**Abstract** - Global supply chains are becoming increasingly intricate, dispersed, and vulnerable to problems including fraud, data silos, counterfeit goods, traceability, and lack of transparency. Conventional centralized supply chain models may not offer real-time visibility and credible information exchange between various stakeholders. A decentralized, immutable, transparent, and cryptographically secured system called blockchain has recently emerged as a viable option for circumventing these limitations. The paper provides an overview of blockchain technology as well as its potential applications in international supply chain management to increase trust and transparency. After outlining the fundamental blockchain architecture, key consensus features, and different kinds of blockchains, the paper delves deeply into supply chain transparency-related topics. Several industries, such as the pharmaceutical, food and agricultural, electronics, and luxury goods markets, have benefited from blockchain technology's efficiency, traceability, and fraud prevention capabilities, as noted in the study's brief summary of real-world applications. Lastly, the essay skims over the present state of scalability, interoperability, and data privacy issues, then moves on to potential areas for future study, such as the integration of blockchain with emerging technologies like the IoT and AI. The results show that blockchain-based supply chains should cause a substantial improvement in accountability, data integrity, and sustainability under the condition of proper technical and regulatory frameworks.

**Keywords** - Blockchain Technology, Decentralization, Supply Chain Management, Financial Transactions, Transparency, Security, Scalability, Artificial Intelligence, Fraud Detection, Immutability.

## 1. Introduction

Blockchain technology, which operates as a decentralized "peer-to-peer linked-structure," has the potential to allay concerns about preventing double spending and keeping transaction orders straight. Bitcoin transactions are controlled by assembling them into blocks of limited size, and each block has the same timestamp. Network nodes, also known as "miners," link blocks in what appears to be a sequential order, which is needed for blockchains to function. A hash of the block before it is included in every block [1]. So, a Blockchain's architecture usually manages to keep an auditable and strong register for all the associated transactions. The good and bad aspects of every technology are always present. There are a few drawbacks to Blockchain technologies. Because they rely on consensus, blockchains, for instance, have a tougher time scaling. Blockchain processing speeds might be affected by the number of users on the network.

The blockchain is quickly becoming a game-changing tool in the SCM industry. A digital, decentralized, and distributed ledger system is what the word "blockchain" describes. A "chain of blocks" stores information in an unchangeable, transparent, traceable, and tamper-proof manner. There are a number of pain points in SCM that make it an ideal area for Blockchain deployment [2]. Applications built on the Blockchain have the potential to greatly enhance openness, efficiency, and sustainability. Professionals in many fields, such as food, construction, textiles, and pharmaceuticals, have tried the technology that can improve supply chain management. For them, it represents SCM's upcoming gold rush.

Distributed digital ledger technology known as "blockchain" links together data stored in the form of cryptographically linked blocks. Blockchain technology was conceptualized and defined in 2008 [3], while comparable data structures have been around for quite some time. A piece of digital information, including a timestamp, cryptographic operations, and any transactions that have taken place, is defined by its block. This is the structure that contains the list of transactions and the header of the block. The block header contains metadata such as the nonce, timestamp, hash of the previous block, and the root of the Merkle tree.

A new era of increased openness and responsibility in monetary transactions has begun with the introduction of blockchain technology. The use of blockchain technology to standardize financial report activities, particularly with the help of the extensible Business Reporting Language (XBRL) [4]. In order to make sure that financial reports are trustworthy and transparent, the study suggests using a blockchain-based system. The use of blockchain technology ensures the quality and verifiability of financial data by recording all report analysis processes and findings onto a shared ledger.

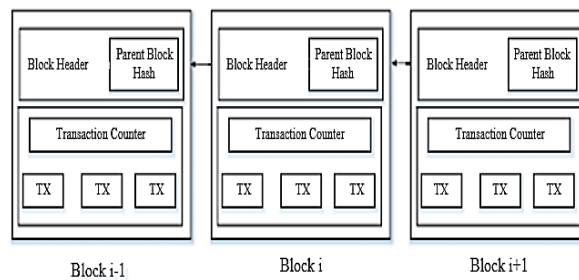
Supply chain management aims to achieve cost savings and increased efficiency through the efficient integration of logistics, money flow, and information flow. Supply chains are complicated due to many factors, including increased globalization, diverse consumer wants, more product lines, and unpredictable supplier performance. Transparency and safety are highly valued by many companies [5]. In conventional supply chains, monitoring the entire network is a major obstacle for contemporary supply chain managers. Supply chain control requires transparency at every stage of the operation, from procuring resources to delivering them to the customer. Accurately tracking and tracing items and products while they are in transit can be a real challenge.

**1.1. Structured of the Paper**

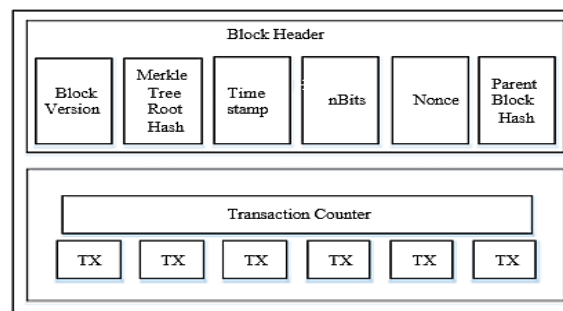
The format of this paper is as follows Section II for a Brief Overview of Blockchain Software, provide global supply chain transparency in Section III and outline the benefits of blockchain technology in Section IV, Section V Literature Readings, and Section VI: Final Thoughts and Future Goal.

**2. Overview of Blockchain Technology**

The blockchain is a distributed ledger system that, similar to a traditional public ledger, records all transactions in an ordered succession of blocks. Put a blockchain on display in Figure 1. There is always one parent block for each given block because the hash of the previous block is always included in the block header [6]. Additionally, the hashes of uncle blocks—the offspring of a block—are documented on the Ethereum blockchain. The initial block of a blockchain that does not have a parent block is called the genesis block. Following that, go into depth into the blockchain's inner workings.



**Fig 1: An Example of Blockchain Which Consists of A Continuous Sequence of Blocks**



**Fig 2: Block Structure**

The body and the header are the two components of a block, as Figure 2 illustrates. According to its design, the block header:

- Version of the block: gives the rules for validating blocks [7].
- The Merkle tree root hash: the value of the hash for each transaction in the block.
- nBits: minimum acceptable level for a legitimate block hash.
- Hash value of the parent block: the 256-bit value of the hash value of the previous block.

**2.1. Key Features of Blockchain Technology**

Blockchain consensus aims to address three critical aspects that define its usefulness and effectiveness:

- Safety: The presence of safety features ensures that undesirable events never transpire. This is in line with the validity and agreement characteristics of the first distributed consensus.

- Liveness: "Liveness" ensures that something positive eventually occur. According to the conventional wisdom in distributed systems, which states that all legitimate processes must settle on a value at some point, this is also called termination.
- Fault Tolerance: The ability of a consensus mechanism to continue functioning properly in the event that certain nodes involved in the consensus experience faults at any one time is what makes it fault-tolerant [8].

**2.2. Types of Blockchain**

Private Blockchain, public Blockchain, and its numerous versions are the main categories into which blockchain technology falls. Blockchain technology, on the other hand, can be called consortium blockchain technology or hybrid blockchain technology based on different sets of criteria and assessments [9]. Remember that a collection of nodes operating on the P2P network design form the foundation of any Blockchain system. Different forms of blockchains are contrasted and compared in Table 1.

- Public Blockchain: Any user can view and add transactions to this Blockchain.
- Private Blockchain: This Blockchain type restricts access to viewing and submitting transactions to a single organization or all subsidiaries within the same group.
- Community/Consortium Blockchain: Multiple organizations work together to form a consortium in this Blockchain model, which allows them to submit transactions and access transaction data.
- Hybrid Blockchain: Any three kinds of blockchains—public, private, or community/consortium—can now work together to facilitate transactions thanks to this new category. The flexibility of a blockchain platform is greatly enhanced by hybrid blockchain technology [10].

**Table 1: Comparisons among Public, Private Blockchain, Consortium Blockchain and Hybrid Blockchain**

Blockchain Type	Access Control	Transaction Permission	Typical Participants	Key Characteristics
Public Blockchain	Open to everyone	Anyone can read and submit transactions	General public, anonymous participants	Fully decentralized, high transparency, lower throughput, trustless environment
Private Blockchain	Restricted	Only a single organization or its subsidiaries can read and submit transactions	Single enterprise or organizational group	High control, better performance, enhanced privacy, limited decentralization
Community / Consortium Blockchain	Partially restricted	Multiple authorized organizations can read and submit transactions	Consortium of enterprises or institutions	Shared governance, moderate decentralization, improved collaboration and trust
Hybrid Blockchain	Mixed (public + restricted)	Configurable based on application needs	Enterprises, consortia, public users	Combines transparency and privacy, flexible architecture, multi-mode operation

**2.3. Key Characteristics of Blockchain Technology**

In short, blockchain has the following important features:

**2.3.1. Decentralization**

A trust less ecosystem is guaranteed by decentralization. shouldn't put faith in anyone on the network. All network nodes are guaranteed to keep a local copy of the data thanks to the distributed ledger. Any change to a node's linked ledger is rejected by the vast majority of network nodes. When data is decentralized, it is easier to recover [11]. Every node may see the same, up-to-the-minute data thanks to a decentralized data store. The distribution of resources is optimized by decentralization, leading to improved performance and consistency. Instead of prioritizing performance, decentralized blockchain focuses on security.

**2.3.2. Immutability**

Immutability is the characteristic of blockchain records that render them highly challenging to modify or destroy when they are authenticated and verified and inserted into the ledger. Each transaction's hash results in a chain of blocks that are cryptographically connected, ensuring the system's security. Any such attempt to update the data would have to update all further blocks of most of the network nodes, computationally infeasible. Immutability in a supply chain application is a property that guarantees the records in terms of product origin, transport and handling are immutable, which improves the integrity and auditability of the data.

**2.3.3. Transparency**

Blockchain system transparency enables authorized stakeholders to access and confirm transactions stored on the distributed ledger within near real-time. All the stakeholders have one, trusted version of information since data is always replicated throughout the network. Such visibility enhances traceability throughout supply chain processes and allows stakeholders to trace product flows, check certifications and observe adherence to regulatory and sustainability regulations. Although transparency leads to increased trust, in permissioned blockchains, it can be selectively regulated to secure sensitive business data.

### 2.3.4. Security and Trustlessness

The blockchain technology offers high levels of security by integrating cryptographic algorithms, consensus algorithms and decentralized verification of transactions. Digital signatures provide assurance against non-repudiation and authentication and consensus algorithms avert frauds like double-spend or unauthorized alterations of data. The term trustlessness implies that agents do not have to trust an authoritative figure or one another, but rather trust is defined by mathematical demonstrations and protocol implementation. This aspect ensures safe interactions between parties having no past trust relationship in the global supply chains lessening the conflict and reliance on third party intermediaries.

## 3. Global Supply Chain Transparency: Concepts and Challenges

The primary goal of logistics and SCM on a global scale has been the enhancement of operational efficiency. Although they are distinct concepts, they share some common ground. SCM is concerned with the integration of tasks to boost operational efficiency, whereas logistics is more concerned with the tasks needed to improve inventory management. The growth of international business has led to enhanced supply chains, capable of using sustainable SC practices. Large supply chain networks today are efficient operations and able to standardize their processes. They are able to use current developments to their advantages and use new forms of technology as new options appear as technology evolves.

### 3.1. Lack of Transparency and Traceability

There are several reasons why supply chain transparency is important. The last decade has seen a lot of bad things happen in the fashion business. Not only is the fashion industry notorious for its hazardous working conditions, but it is also a major contributor to water and air pollution [12]. Sustainable business initiatives like the Fashion Transparency Index are pushing for more transparency in the fashion industry. As a result, companies in this sector are faced with the issue of effectively communicating their positive and bad impacts on people and the world.

The management of agri-food SCs was upgraded with the implementation of a traceability solution. Recently, Walmart and IBM worked together to study the tracing outcomes that blockchain technology produces. A blockchain-based traceability solution based on Hyperledger Fabric could make it possible to track mango origins in three days as opposed to the seven days that were previously required. Constructed a pharmaceutical SC's recording and monitoring system using Ethereum. The SC consists of an Internet of Things (IoT) container, a single sender, and a receiver. A significant obstacle to real-world applications is the large volume of visual tracking that relies on a structure driven by segmentation.

### 3.2. Fraud, Counterfeiting

Scalability, accuracy, and proactive fraud detection are three ways in which artificial intelligence (AI) helps to shore up supply chain weaknesses. Key aspects of supply chain security are being transformed by AI:

- **Supplier Data Analysis:** Artificial intelligence (AI) checks compliance records, supplier certifications, and historical data for irregularities. To avoid using low-quality parts in manufacturing, AI can detect manipulated certifications by comparing supplier data with known fraud trends.
- **Computer Vision for Physical Verification:** Computer vision systems driven by artificial intelligence check replacement parts by comparing their packaging, measurements, and serial numbers to a verified database.
- **Predictive Analytics for Fraud Prevention:** The use of predictive AI models in the detection of inconsistencies between shipping data and supplier behaviors allows for proactive fraud prevention.

### 3.3. Key Challenges in Supply Chain Transparency

There are some important challenges of supply chain transparency discussing below:

#### 3.3.1. Lack of Real-Time Visibility

The inability to track shipments, inventories, and items in real time is a common problem in global supply chains due to the reliance on delayed or irregular data updates. Such non-timely visibility lowers the level of responsiveness to disruptions and influences the level of decision-making on operations.

#### 3.3.2. Data Silos and Information Asymmetry

The data regarding supply chain is distributed among several and independently operated systems which causes lack of data sharing and unreliable information. This causes information asymmetry amongst the stakeholders which results to inefficiencies and lack of trust.

#### 3.3.3. Counterfeiting and Fraud

Poor traceability facilitates fake products and fraud in other industries where pharmaceutical and food sectors are the major ones. Conventional systems do not have effective systems to authenticate product authenticity and tampering with data [13].

#### 3.3.4. Sustainability Issues, Audit, and Compliance

Fragile, manual or unreliable records-keeping pose a challenge to organizations in showing compliance to regulatory measures and sustainability practices. This escalates the complexity of audits, compliance expenses and chances of regulatory and reputational risks.

## 4. Applications of Blockchain in Supply Chains

Blockchain technology has significantly increased supply chain management's efficiency. Blockchain technology, for example, makes it feasible to gather information on products at every stage of their supply chain lifetime and then promptly share that information with all parties [14]. This immutable data ensures that production ends receive correct information about product demand from customers and successfully mitigates the "bullwhip effect" in the supply chain.

### 4.1. Food and Agriculture

There are a lot of moving parts in the global food chain, including farmers, shipping companies, distributors, retailers, wholesalers, and consumers. A generic agri-food supply chain is outlined here, with the main phases defined below:

- **Production:** The production part includes all of the farming activities that happen on the farm. Farmers employ raw and organic materials to grow crops and raise livestock, such as fertilizers, seeds, animal breeds, and feeds.
- **Processing:** This step involves converting a main product into a secondary product or goods, either entirely or partially.
- **Distribution:** The distribution process begins once the product is packaged and labelled [15]. The product in question dictate the delivery timeframe, which may or may not include a storage stage (Storage).
- **Retailing:** Sending products to retailers, who then sell them, is the last step in the distribution process. The last link in the supply chain is the consumer, who buys the goods.
- **Consumption:** The final link in the chain is the customer. This is the person who gets the product and wants to know about quality standards, where it comes from, how it was made, etc.

### 4.2. Pharmaceuticals

The pharmaceutical supply chain involves a wide range of individuals, including manufacturers and raw material suppliers, wholesalers, distributors, pharmacies, and patients. This intricate web operates on a global scale, where drugs are often manufactured in one country, packaged in another, and then distributed worldwide. The stages in this chain are interconnected and require careful coordination to ensure that medicines reach the end-user without any compromise in quality or efficacy.

### 4.3. Electronics and Luxury Goods

The term "electronic SCM" refers to the ways in which the Internet influences the integration of critical business processes, beginning with the procurement of goods and services and ending with the delivery of valuable information to consumers and other stakeholders [16]. Logistics management and online marketplaces are known to have troublesome interactions. Cooperative supply chains strive to reduce supplier numbers by forming long-term strategic partnerships that keep suppliers in and competitors out. This remains true despite the fact that the electronic market promotes competition, assists buyers in identifying suitable suppliers, and maintains affiliations based on transactions.

## 5. Literature Review

The literature on blockchain technology for global supply chains is reviewed extensively in this section. It is presented in Table 2.

Yousuf and Svetinovic (2019) Information processing, transit history, and product lifecycle management are just a few of the SCM issues that still need to be addressed. Since blockchain technology is gaining acceptance among organizations, it is important to analyze the issues at each stage of the supply chain and determine if they can be resolved using it. To create a broad framework, the analysis is carried out with an emphasis on the factors of trust and decentralization [17].

Aich et al. (2019) The IoT integrated blockchain system offers numerous advantages, such as enhancing supply chain network efficiency by linking flows, increasing transparency to decrease code of conduct violations, and facilitating product tracing for stakeholders through immutable properties. This article compares and contrasts conventional supply chains with blockchain-based ones, including examples from the food, retail, pharmaceutical, and automotive industries to demonstrate the advantages of utilizing blockchain technology across various enterprises [18].

Mondragon, Coronado and Coronado (2019) investigating the feasibility of integrating blockchain technology into supply chains for both industrialized and consumable goods. The method suggested in this article is demonstrated through the use of two examples. A composite material supply chain that expedites the certification of carbon fiber parts used in aeroplanes is described in the first example, which makes use of blockchain technology. The second case study investigates the potential for using blockchain technology to track the movement of live fish across the supply chain. In the first, companies in a similar position might use blockchain technology to validate experiments for things like flammability, crashworthiness, and operations [19].

Kaid and Eljazzar (2018) the use of quick response (QR) codes to manage these kinds of situations in the supply chain sector, especially between sellers and buyers. The following stage is to consider blockchain technology's possible applications in this setting. Also, construct and launch a Hyperledger Composer prototype to demonstrate the potential advantages of blockchain technology for a supply chain. The supply chain relationship could benefit from blockchain technology, as this model illustrates, and it has elements that can assist build the required degree of confidence between the two sides [20].

Naidu et al. (2018) The website serves as the sole access point to the consolidated supply chain data, which in turn reduces data availability, increases risk, and creates an inflexible system that must be updated via the hosted system. The aim of combining the traditional supply chain with blockchain technology is to make sure that everyone involved (buyers, sellers, raw material suppliers, assemblers, etc.) has authority over their own data. This includes order details, status updates, tracking information, and more. The decentralization of this data at multiple levels, starting with the raw material manufacturer and concluding with the merchant, results in a more flexible and transparent system [21].

Tse et al. (2017) Indirectly or directly, people's health, quality of life, and safety are threatened by China's increasingly significant food safety problem. Globally, a more extensive societal, political, and economic impact is felt. Traceability systems have been researched, developed, and put into place in many countries and regions as an effective way to manage and monitor product quality and safety. While these technologies have not yet achieved more precise tracking, their findings are not immediately applicable to the Chinese market [22].

Feng Tian (2016) start by summarizing the state of blockchain technology development and implementation as well as RFID (Radio-Frequency Identification). Considering these technologies' benefits and drawbacks in an agri-food supply chain monitoring system is the next stage. Also, please demonstrate the steps to construct this system. Achieving food safety is best accomplished by collecting, transferring, and sharing the initial agri-food data at every stage of the supply chain, including production, processing, warehousing, distribution, and sales. By using reliable data, this ensures traceability throughout the whole agri-food supply chain

**Table 3: Summary of Literature on Blockchain Adoption in Supply Chains**

Author(s)	Year	Key Findings	Challenges Identified	Future Work Directions
Yousuf & Svetinovic	2019	Blockchain enhances trust, decentralization, and transparency across supply-chain stages; suitable for managing product lifecycle and logistics data	Lack of standardized frameworks; scalability concerns; integration with legacy systems	Develop generalized blockchain frameworks; evaluate scalability and real-world deployment across industries
Aich et al.	2019	IoT–blockchain integration improves efficiency, transparency, traceability, and compliance across multiple industries	High implementation cost; interoperability between IoT devices; data privacy issues	Optimization of IoT–blockchain architectures; sector-specific adoption models and cost-efficient solutions
Mondragon, Coronado & Coronado	2019	Blockchain is feasible for certification validation in aerospace materials and traceability in perishable goods	Technical complexity; regulatory constraints; lack of unified standards	Expansion to multi-party industrial ecosystems; regulatory-aligned blockchain frameworks
Kaid & Eljazzar	2018	Blockchain combined with QR codes strengthens trust between distributors and retailers	Limited scalability; computational overhead; dependency on correct data input	Large-scale deployment; integration with IoT sensors; automation via smart contracts
Naidu et al.	2018	Decentralization of supply-chain data improves availability, flexibility, and transparency	Migration from centralized systems; data consistency and governance issues	Hybrid blockchain models; secure data-sharing protocols among stakeholders
Tse et al.	2017	Blockchain-based traceability systems improve food safety and accuracy over traditional methods	Adoption barriers in large markets; system integration challenges	Tailored blockchain traceability models for regional markets like China
Feng Tian	2016	RFID + blockchain enables end-to-end trusted traceability in agri-food supply chains	High infrastructure cost; data volume management; sensor reliability	Lightweight blockchain solutions; enhanced sensor-blockchain integration

## 6. Conclusion and Future Work

Transparency, accountability, and trust in international supply chains can all be enhanced using blockchain technology. Its connected, correct, and auditable registry allows secure documenting of product lifecycle activities and addressing traditional issues, including information asymmetry, fraud, counterfeit items, and the bullwhip effect. The use in food and agriculture, pharmaceutical, electronics, and luxury products shows that blockchain can be used to promote real-time visibility, verify product provenance, simplify logistics, and enhance regulatory adherence. Although these advantages exist, blockchain integration still experiences some limitations associated with scalability, compatibility with legacy systems, performance bottlenecks, and the necessity of effective governance frameworks, which restrict their common usage in complex, globally distributed networks.

In the future, researchers may look into integrating smart contracts, the IoT, and AI with blockchain to create supply chain networks that can verify themselves, self-fold, and predict what's going to happen next. The current performance and compatibility shortcomings require lightweight and scalable consensus and Layer-2 solutions along with standardized interoperability frameworks. Also, the privacy-saving techniques, including zero-knowledge proofs and selective disclosure of data, should be explored to find a balance between transparency and commercial secretiveness. The consistent regulatory and technical system, which is backed with the industry-wide standards, will be necessary to maximize the potential of blockchain and facilitate uninterrupted cooperation among the global supply chain participants.

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