

Blockchain Applications and Developments in Supply Chain Management Across Multiple Industries: A Comprehensive Review

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Abstract. This paper provides a systematic review of blockchain technology applications and development trends in supply chain management, covering multiple industries including shipping, pharmaceuticals, agricultural products, cement manufacturing, and perfume production. The study first classifies and analyzes mainstream approaches from a technical perspective, encompassing blockchain-based traceability technologies, anti-counterfeiting and authentication mechanisms, distributed data sharing models, and real-time monitoring solutions integrating blockchain with the Internet of Things. Subsequently, analysis of datasets and experimental results from multiple empirical cases reveals blockchain's significant advantages in enhancing supply chain transparency, traceability, security, and collaborative efficiency. However, its implementation still faces challenges including high system deployment and maintenance costs, data privacy protection and compliance issues, insufficient multi-party collaboration and standardization, and complexities in cross-technology integration. Looking ahead, with progress in international standardization efforts, advancements in privacy protection technologies, and the proliferation of Blockchain-as-a-Service (BaaS) platforms, blockchain is poised for broader implementation across supply chain scenarios. This evolution will provide robust support for global industrial digitalization and sustainable development.

Keywords: Blockchain; Supply Chain Management; Traceability; Data Sharing; Internet of Things.

1. Introduction

Against the backdrop of rapid globalization and digitalization, supply chain management plays a crucial role in ensuring efficient product circulation, reducing costs, and enhancing customer satisfaction. However, traditional supply chains exhibit significant shortcomings in transparency, traceability, security, and multi-party collaboration efficiency. These issues become particularly pronounced when confronting unforeseen events, the complexities of cross-border trade, and multi-stakeholder participation. With advances in information technology, blockchain—due to its decentralized nature, immutable data, and traceability—is recognized as a key driver for supply chain transformation and upgrading.

Blockchain technology enables real-time information sharing across supply chain stages, enhances data credibility, and strengthens end-to-end traceability. This holds significant importance for improving operational efficiency, reducing fraud risks, and promoting sustainable development. Furthermore, the integration of blockchain with emerging technologies like the Internet of Things (IoT), big data, and artificial intelligence (AI) offers novel solutions for achieving greater transparency and intelligence in supply chains. Consequently, systematically examining blockchain's applications and developmental trends across diverse industry supply chains holds significant reference value for both academia and industry.

Numerous studies have explored blockchain's implementation and challenges within specific industry supply chains. For instance, Ahamed et al. introduced blockchain into seafood supply chain management to enhance traceability and food safety [1]. Simultaneously, studies on blockchain platforms for commodity supply chain finance demonstrate their potential to reduce operational risks, enhance transaction transparency, and provide enterprises with more flexible capital management approaches [2]. Jalagam et al. focused on smart contract applications within agricultural supply chains,

proposing an Ethereum-based decentralized solution to strengthen agricultural product quality traceability and transaction security [3]. Sadri et al. explored blockchain traceability mechanisms in the blood donation supply chain within the healthcare sector, leveraging smart contracts to ensure data transparency and security throughout the entire process from donation to transfusion [4]. These studies demonstrate blockchain's potential to enhance security, transparency, and efficiency across multiple industry supply chains, while also highlighting challenges such as high deployment costs, compliance complexities, and multi-party collaboration barriers.

Against this backdrop, this paper aims to review the application and development of blockchain technology in supply chain management across different industries. By analyzing multiple industry cases, it summarizes the advantages and challenges of its application while outlining potential future research directions and industry development trends. This review seeks to provide systematic reference for relevant academic research and practical implementation.

2. Overview of Mainstream Technologies

With the rapid advancement of blockchain technology, its applications in supply chain management have become increasingly diverse. Various scholars have proposed innovative solutions addressing industry pain points. These solutions demonstrate not only theoretical potential value but have also undergone preliminary validation in practical cases. As shown in Figure 1, a typical blockchain-based supply chain management process encompasses six key stages: raw material collection, data encryption and blockchain recording, multi-party verification, smart contract automation, regulatory/consumer visualization, and traceability queries. Together, these elements establish a transparent, efficient, and trustworthy management system. This chapter will explore five primary directions: supply chain traceability, anti-counterfeiting and authentication, distributed data sharing, IoT-integrated monitoring, and digitalized production process management. It will systematically analyze their underlying principles and application outcomes.

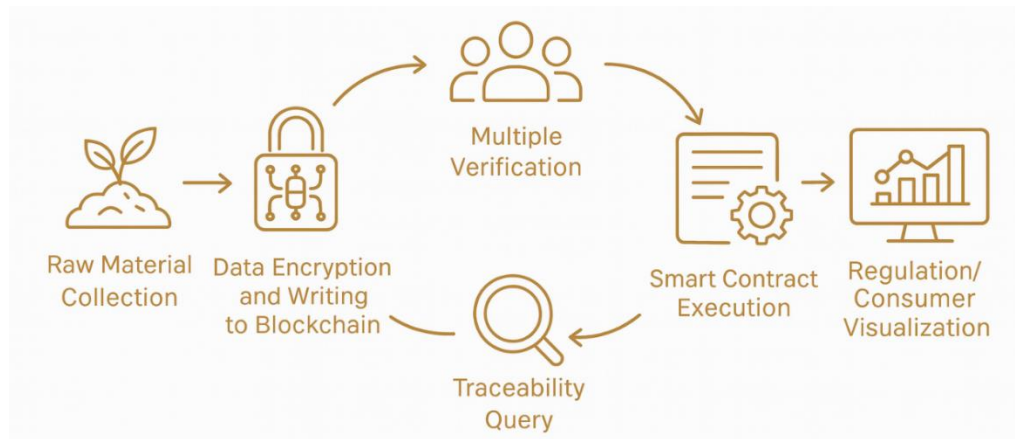


Fig. 1 Typical Blockchain Process Flowchart in Supply Chain Management

2.1. Traceability of Supply Chain

First of all, in terms of supply chain traceability research, Haua et al. proposed an end-to-end traceability technology based on Blockchain in their research on the shipping industry [5]. The technology assigns a unique identifier to each transportation document, and records the timestamp, geographic location, and transportation status information in encrypted form on the blockchain, thereby constructing a complete digital tracking record. Its core advantage is to significantly improve the transparency of the supply chain and support customers and enterprises to track the progress of cargo transportation in real time; at the same time, the immutability of the blockchain can effectively avoid the risk of malicious tampering with transportation data. However, this model still faces high costs in the process of large-scale implementation, and it has a strong dependence on network bandwidth and node stability. This feature limits its application in resource-constrained environments.

2.2. Anti-Counterfeiting and Authentication

In the field of anti-counterfeiting and authentication, Ettaloui et al. designed a blockchain-based drug tracking and authentication system to address supply chain security issues in the pharmaceutical industry [6]. This system automatically verifies the batch information of drugs through smart contracts and uses encrypted signature technology to ensure the authenticity of the data. It can securely store the entire process record of drugs from production, packaging to transportation and retail in the blockchain. This solution has demonstrated remarkable effectiveness in strengthening drug safety control and reducing the risk of counterfeit drugs entering the market. By leveraging the transparent nature of blockchain, consumers and regulatory authorities can verify the source of drugs more conveniently, thereby enhancing trust in the entire pharmaceutical industry. However, the effective operation of this system depends on the extensive participation of all entities in the industrial chain: if drug manufacturers, distributors and retailers fail to fully adopt this system, its coverage and actual effectiveness will be significantly reduced. In addition, pharmaceutical data involves strict privacy protection requirements. How to strike a balance between data openness, transparency and compliance protection remains a key challenge for the future implementation of this system.

2.3. Distributed Data Sharing

In the field of agricultural supply chain, Mishra and Bhattacharya have proposed a traceability system based on a blockchain-based distributed data sharing mechanism, aiming to empower small-scale farmers and enhance the operational efficiency of local markets. This system builds a "digital archive" for agricultural products, covering the entire process data from harvest, storage to transportation and sales, and ensures data transparency and tamper-proof integrity through a distributed ledger. Consumers can directly trace the source of food through the blockchain platform, enhancing their trust in food safety. Farmers can use this system to bypass middlemen and conduct transactions directly with retailers or consumers, thereby increasing their profit margins and market operation efficiency. Although this model provides new ideas for agricultural supply chain governance, it still faces challenges such as high deployment costs and weak technical infrastructure in rural areas. Especially in developing countries, the wide application of this system still relies on external training and business support to ensure its long-term effective operation.

2.4. Blockchain-Internet of Things Integrated Monitoring

The integration of blockchain and the Internet of Things provides an innovative path for supply chain monitoring. In the research related to the cement industry, Hamood et al. combined Internet of Things sensors with blockchain technology to achieve end-to-end monitoring from raw materials to finished products [7]. Iot sensors are responsible for collecting real-time data from the production and transportation processes. These data, after being encrypted, are recorded in the blockchain to ensure their authenticity and immutability. This method significantly enhances the efficiency and accuracy of data collection, while achieving real-time monitoring and traceability of the supply chain, effectively reducing human errors and potential risks. However, during the implementation process, this model will incur high costs for equipment procurement and maintenance, and the complexity of the system will increase the operational burden on enterprises. Therefore, this model is more suitable for large manufacturing enterprises with strong capital strength and mature technical resources. However, small and medium-sized enterprises still encounter obvious obstacles in the adoption process.

2.5. Digital Management of Production Processes

In terms of digital management of production processes, Fayed et al. developed the ScentTrack blockchain system for the perfume industry. This system combines blockchain technology with the digital recording of the entire production process, covering all stages from raw material procurement, manufacturing to product sales [8]. It not only enhances the transparency and operational efficiency of the production process, but also effectively reduces the management costs caused by information

asymmetry in the traditional management model. For high value-added industries, this model provides consumers with additional trust guarantees and helps enhance the market competitiveness of enterprises. However, the implementation of this system requires the participating entities to carry out standardized data processing to ensure the consistency and reliability of information on the blockchain. In addition, IT places relatively high demands on the IT technical capabilities and digitalization levels of enterprises, which to some extent restricts the adoption speed of enterprises with weak technical foundations. In conclusion, the application of blockchain in the supply chain presents differentiated implementation paths. Different technical models demonstrate their own advantages and limitations in aspects such as traceability, anti-counterfeiting authentication, data sharing, real-time monitoring, and production management. Overall, although these technologies have enhanced the transparency and operational efficiency of the supply chain, the challenges in cost control, infrastructure construction, and compliance management remain key areas that need to be focused on and broken through in future related research and practice. Table 1 presents a comparative analysis of mainstream blockchain application models

Table 1. Comparative Analysis of Mainstream Blockchain Application Models

Technology Direction	Advantages	Challenges / Limitations
Supply Chain Traceability	Enhances transparency, prevents tampering, improves customer trust	High deployment cost, reliance on stable network environment
Anti-counterfeiting and Authentication	Prevents counterfeit products, strengthens industry credibility	Requires extensive participation across the supply chain, involves data privacy issues
Distributed Data Sharing	Information transparency, reduces intermediaries, improves efficiency	High technical threshold, difficult to promote in rural/underdeveloped areas
IoT-integrated Monitoring	Real-time monitoring, improves accuracy of data collection	High equipment procurement and maintenance costs, system complexity
IoT-integrated Monitoring	Reduces information asymmetry, enhances management efficiency, strengthens competitiveness	Requires high level of informatization, standardization difficult to achieve

3. Blockchain Applications in Supply Chains

Empirical studies across diverse industrial contexts demonstrate that blockchain technology has achieved significant results in supply chain management. Research teams have validated its performance in traceability, data integrity, system performance, and user experience by constructing blockchain systems and conducting experiments in real or simulated supply chain scenarios.

3.1. In Shipping Industry Research

Khaoua et al. constructed an experimental dataset comprising approximately 120,000 records based on operational data from shipping enterprises, including freight documents, transport routes, and port call information [5]. Results demonstrated that the blockchain system elevated freight traceability accuracy to 98% while maintaining 100% data integrity. This indicates the system can fully reconstruct the entire transportation process without data loss or tampering. Concurrently, operational costs decreased by approximately 12% after system implementation, suggesting blockchain enhances transparency while positively contributing to cost optimization.

3.2. In Pharmaceutical Industry Research

Ettaloui et al. conducted experiments using drug distribution records from pharmaceutical companies and regulatory bodies, involving approximately 80,000 data points. Results showed the

system significantly reduced counterfeit drug circulation by 85% and increased transparency in drug distribution processes by 40% [6]. This enables consumers and regulators to more easily trace drug origins, thereby enhancing industry-wide trust. However, the system exhibits certain performance limitations, particularly in response time, with an average confirmation time of 3.8 seconds. This could impact system adoption and user experience in high-concurrency environments.

3.3. In the Agricultural Supply Chain

Mishra and Bhattacharya collected transaction data from local markets involving farmers, wholesalers, retailers, and consumers, totaling approximately 50,000 samples [9]. Their proposed blockchain traceability system significantly enhanced transparency and trust within the food supply chain. Experimental results demonstrated a traceability accuracy rate of 96% and a 35% increase in consumer satisfaction. Similarly, research by Kumar et al. indicates that blockchain not only improves transparency in agricultural supply chains but also optimizes agricultural production practices, further strengthening food safety guarantees [7]. More importantly, the system delivered tangible economic benefits to farmers, with average income increasing by 18%, demonstrating blockchain's significant potential in empowering smallholder farmers and improving local market circulation efficiency. However, the study also found that the system's adoption in rural areas still faces constraints related to cost and technical barriers, an issue warranting further exploration.

3.4. In the Research of the Cement Industry

Hamood et al. used IoT sensors to collect real-time production and transportation data—including temperature, humidity, weight, and transit time—accumulating 150,000 data points [8]. When integrated with blockchain, the system achieved real-time monitoring and traceability with data collection delays under 2 seconds while maintaining 100% data integrity. This outcome not only validates the feasibility of integrating blockchain with IoT but also demonstrates its value in reducing losses. Experimental data revealed a 6% decrease in loss rates during cement production and transportation, indicating that efficient real-time data transmission and evidence storage can significantly enhance resource utilization and corporate profitability.

3.5. In the Perfume Industry Experiment

Fayed et al. collaborated with manufacturers to obtain supply chain records spanning production, packaging, and transportation—totaling approximately 60,000 data points [10]. By developing the ScentTrack system, they achieved digital recording and tracking throughout the entire production process. Experimental results revealed that this system increased transparency in perfume production by 45% and reduced production management costs by approximately 15%. This case not only demonstrates blockchain's application potential in high-value-added industries but also illustrates its capacity to deliver tangible efficiency gains and cost optimization within complex, multi-stage production systems.

Collectively, these five cases validate blockchain technology's significant impact on enhancing supply chain transparency, traceability, security, and operational efficiency. Whether in shipping, pharmaceuticals, agriculture, cement, or perfumery, blockchain exhibits universal applicability and cross-sector adaptability. However, these experiments also reveal pressing challenges that require urgent attention. These include relatively high deployment and maintenance costs, imperfect data privacy protection mechanisms, and obstacles to cross-industry multi-party collaboration. It is foreseeable that the future advancement of blockchain in the supply chain sector will necessitate not only technological optimization and integration but also the combined impetus of policy support, industrial collaboration, and standardization. Only then can large-scale commercial implementation and sustainable application be truly realized.

4. Recommendations

4.1. Challenges

Despite demonstrating significant potential in supply chain management, blockchain technology faces several challenges in large-scale implementation. First, excessive system deployment and maintenance costs pose a major obstacle. Establishing blockchain networks, deploying nodes, and uploading data to the chain all require substantial hardware and software investments. While large enterprises may bear these costs, they often create entry barriers for small and medium-sized businesses. These substantial upfront costs not only slow technological adoption but also prompt many enterprises to adopt a wait-and-see approach when weighing potential returns against investments.

Second, data privacy and compliance issues demand urgent resolution. In sensitive sectors like healthcare, finance, and food, data frequently involves personal privacy and commercial secrets, requiring strict adherence to legal regulations for cross-border transmission and storage. However, privacy protection standards vary across countries and regions, creating significant challenges for blockchain applications in multinational supply chains. Without a unified or compatible global legal framework, the international adoption of blockchain will inevitably face limitations.

Third, current blockchain supply chain systems also fall short in multi-party collaboration and standardization. Supply chains inherently involve multiple stakeholders—suppliers, manufacturers, logistics providers, and retailers—whose data interfaces, system standards, and management models differ considerably. Without unified industry data standards and interface protocols, even with blockchain integration, information interoperability remains limited. This not only reduces overall system efficiency but also undermines blockchain's inherent advantages in multi-party collaboration scenarios. Particularly in cross-border e-commerce logistics, research by Huang et al. indicates that while blockchain can enhance transnational collaboration models, the lack of data standardization and legal compliance remains the primary barrier to its adoption [11].

Furthermore, the complexity of technological integration presents a practical challenge for blockchain applications. Today's supply chain digital transformation relies not only on blockchain but also requires deep integration with emerging technologies like IoT, AI, and big data. However, this cross-technology convergence often introduces new challenges such as system compatibility, data synchronization, and latency control. Without effectively addressing coordination issues between different technologies, the full value of blockchain in supply chains will remain unrealized.

4.2. Prospects

Despite numerous challenges, blockchain's future prospects in supply chain management remain promising. First, advancing international standardization will be a critical pathway. Establishing unified data structures and communication protocols can promote interoperability across industries and borders, overcoming barriers caused by fragmented standards. Second, lowering technical barriers is equally vital. With the development of Blockchain-as-a-Service (BaaS) platforms, enterprises no longer need to invest heavily in hardware and human resources to build systems. This makes it possible for small and medium-sized enterprises to adopt blockchain technology and helps promote the wide application of the technology.

In terms of privacy protection, future blockchain systems are expected to incorporate more advanced cryptographic tools, such as zero-knowledge proofs and homomorphic encryption. This aims to achieve the goal of “data available but not visible,” thereby ensuring transparency while protecting sensitive information. Meanwhile, the application fields of blockchain need to be further expanded: apart from traditional industries as exemplified by shipping, food, and pharmaceuticals, industries including energy, aviation, and construction have yet to widely carry out blockchain pilots projects. However, these industries also grapple with complex supply chain challenges and hold promise as new growth areas.

In conclusion, the application of blockchain in supply chain management presents both challenges and opportunities. Through standardized development, technological innovation, and cross-industry expansion, blockchain is poised to achieve broader adoption in the future. It will play a significant role in driving supply chain transparency, intelligence, and sustainable development of the supply chain.

5. Conclusion

This study systematically reviews the application and development trends of blockchain technology in supply chain management across various industries, covering typical sectors such as shipping, pharmaceuticals, agricultural products, cement manufacturing, and perfume production. Analysis of relevant research and practical cases reveals that blockchain offers significant advantages in enhancing supply chain transparency, strengthening traceability, ensuring data security, and facilitating multi-party collaboration. Its decentralized and immutable technical characteristics effectively address issues such as information asymmetry, trust deficits, and inefficient collaboration in traditional supply chains, offering a new technological pathway for the digital transformation of global supply chains.

However, despite demonstrating substantial potential, blockchain faces multifaceted challenges during implementation across various industries. Key obstacles include high deployment and maintenance costs, data privacy and compliance concerns, system complexity, and insufficient cross-industry standardization. These obstacles limit blockchain's widespread adoption but also point the way toward future technological optimization and policy support.

Looking ahead, as blockchain technology matures and integrates more deeply with other emerging technologies, its application in global supply chains is expected to become more extensive and profound. Particularly when combined with technologies like the Internet of Things (IoT), big data, and artificial intelligence (AI), it will deliver new solutions for real-time supply chain monitoring, intelligent decision-making, and risk management. Simultaneously, advancing international standardization efforts will become a key driver for large-scale blockchain adoption. Establishing unified data formats and communication protocols will not only resolve interoperability issues between different enterprises and industries but also facilitate cross-border collaboration and regulatory compliance, thereby promoting global supply chain connectivity.

Furthermore, future development should focus on reducing blockchain system deployment costs while enhancing scalability and user-friendliness. For instance, the “Blockchain-as-a-Service” (BaaS) platform model can effectively reduce enterprises' investments in hardware and technical development, thereby lowering the application threshold for small and medium-sized enterprises. Regarding privacy protection, the introduction of advanced cryptographic technologies such as zero-knowledge proofs and homomorphic encryption will provide more effective safeguards for data security and privacy compliance within supply chains. Only by progressively addressing these challenges can blockchain truly transition from localized pilot projects to large-scale commercial applications.

In summary, blockchain technology holds immense potential for supply chain management. It not only promises to accelerate the digital and intelligent transformation of supply chains but will also play a vital role in achieving sustainable development, enhancing the resilience of global industrial chains, and responding to sudden risks. As technology, standards, and the policy environment continue to mature, blockchain will undoubtedly become an indispensable pillar supporting future supply chain management.

References

- [1] Ahamed N N, Karthikeyan P, Anandaraj S P, & Vignesh R. Sea food supply chain management using blockchain. *2020 6th International Conference on Advanced Computing and Communication Systems (ICACCS)*, Coimbatore, India. IEEE. 2020.

- [2] Su L, & Wang H. Supply chain finance research in digital bulk commodities service platform based on blockchain. *2020 International Conference on E-Commerce and Internet Technology (ECIT)*, Zhangjiajie, China. IEEE. 2020.
- [3] Jalagam M, Thanuja R N, Vaishnavi Y L, Naresh K, & Suryakanth V G. Decentralized applications for agricultural supply chain: Exploring the potential on the ethereum blockchain using smart contracts. *2024 IEEE International Conference on Blockchain and Distributed Systems Security (ICBDS)*, Pune, India. IEEE. 2024.
- [4] Sadri S, Shahzad A, & Zhang K. Blockchain traceability in healthcare: Blood donation supply chain. *2022 24th International Conference on Advanced Communication Technology (ICACT)*, PyeongChang, Korea. IEEE. 2022.
- [5] Khaoua Y, Mouzouna Y, Arif J, Jawab F, & Azari M. The contribution of blockchain technology in the supply chain management: The shipping industry as an example. *2022 14th International Colloquium of Logistics and Supply Chain Management (LOGISTIQUA)*, El Jadida, Morocco. IEEE. 2022.
- [6] Ettaloui N, Arezki S, & Gadi T. Enhancing pharmaceutical supply chain management: A blockchain-based model. *2024 IEEE 15th International Colloquium on Logistics and Supply Chain Management (LOGISTIQUA)*, Sousse, Tunisia. IEEE. 2024.
- [7] Kumar D, Vennila G, Kumar M, Jasmine J J, Govindharaj I, & Balamurugan S. Enhancing food supply chain transparency and agricultural practices through blockchain technology. *2024 5th IEEE Global Conference for Advancement in Technology (GCAT)*, Bangalore, India. IEEE. 2024.
- [8] Hamood R, Makhdoom I, Iqbal W, & Jamil T. Supply chain optimization in cement industry using blockchain technology. *2023 IEEE Asia-Pacific Conference on Computer Science and Data Engineering (CSDE)*, Nadi, Fiji. IEEE. 2023.
- [9] Mishra P, & Bhattacharya R. Tracking food supply chain in local market using blockchain. *2025 International Conference on Computer, Electrical & Communication Engineering (ICCECE)*, Kolkata, India. IEEE. 2025.
- [10] Fayed M, Zubairi A, Nasser N, Ali A, & Ayache M. Ensuring authenticity and sustainability in perfume production: A blockchain solution for the fragrance supply chain. *2023 10th International Conference on Wireless Networks and Mobile Communications (WINCOM)*, Istanbul, Türkiye. IEEE. 2023.
- [11] Huang X, Liu Z, & Shen X. The cooperation mode of cross-border e-commerce logistics supply chain based on blockchain. *2023 International Conference on Industrial IoT, Big Data and Supply Chain (IIoTBDSC)*, Wuhan, China. IEEE. 2023.