Published by OTS Canadian Journal
Available at: *https://journal.canadian-ots.ca*
ISSN: 2817-1756
Vol-4, Issue-7; July, 2025
Research Article Open Access

Blockchain Applications in Supply Chain Management: A Review of Transparency and Traceability Solutions

Rakaesh Singh[1], Anna Moler [2]

[1]IIT Bombay, India
[2]Faculty of Engineering, RWTH Aachen University, Germany

Article History
Received: June, 01,2025
Revised: June, 15,2025
Accepted: June 29, 2025

Doi: https://doi.org/10.58840/sp3fkz32

Abstract:

As global supply chains become increasingly complex and susceptible to disruption, the need for transparency, trust, and traceability has never been greater. Blockchain technology has emerged as a promising tool to address these challenges by providing immutable, decentralized, and verifiable data across supply chain networks. This article reviews current applications of blockchain in supply chain management (SCM), with a focus on its role in enhancing transparency and traceability. It explores real-world use cases across various industries—such as food, pharmaceuticals, and luxury goods—and highlights the technological, organizational, and regulatory challenges involved. The paper concludes with future directions for integrating blockchain into mainstream supply chain systems.

Keywords: *Blockchain Technology, Supply Chain Management, Transparency, Traceability, Distributed Ledger Systems, Smart Contracts, Data Integrity, Logistics Innovation.*

1. Introduction

Supply chains today span multiple geographies, involve numerous stakeholders, and are increasingly digital. Despite technological advances, supply chains often lack visibility, leading to inefficiencies, fraud, and a breakdown in consumer trust. The COVID-19 pandemic further exposed the fragility of global supply networks, prompting organizations to seek more resilient and transparent systems. Blockchain, with its ability to securely store and share data among untrusted parties, has gained traction as a transformative technology in supply chain management (SCM).

Blockchain's core characteristics—immutability, decentralization, and transparency—make it ideal for solving long-standing issues in SCM, such as data tampering, counterfeit products, and siloed information. By recording every transaction or movement of goods on a distributed ledger, blockchain can enable end-to-end traceability, thus improving accountability and trust across the supply chain. However, implementing blockchain in supply chain management is not merely a matter of technological integration—it requires a paradigm shift in how organizations share information and collaborate. Traditional supply chains often operate in silos, with each stakeholder maintaining separate records. This fragmentation creates inefficiencies and opportunities for fraud or human error. Blockchain's distributed ledger system addresses these issues by allowing all authorized participants to access a single, tamper-proof version of the truth in real time. For example, manufacturers, suppliers, logistics providers, and retailers can each log and verify transactions on the same platform, reducing disputes and eliminating the need for third-party reconciliation.

In industries such as food, pharmaceuticals, and luxury goods, where authenticity and provenance are critical, blockchain enables verification of the entire lifecycle of a product—from origin to consumer. A notable example is IBM Food Trust, which uses blockchain to trace fresh produce through every stage of the supply chain, enabling retailers and consumers to identify sources of contamination or ensure ethical sourcing practices. Similarly, pharmaceutical companies are leveraging blockchain to combat counterfeit drugs by ensuring that every step in the production and distribution process is verifiable and auditable.

Blockchain also enhances supply chain resilience by improving response times during disruptions. Real-time visibility into inventory, shipping routes, and vendor performance allows organizations to make informed decisions quickly. This was especially relevant during the COVID-19 pandemic, where rapid shifts in demand and transportation bottlenecks required agile, data-driven responses. Smart contracts—self-executing agreements stored on the blockchain—can further streamline operations by automating compliance, payments, and dispute resolution based on predefined rules.

Despite its potential, blockchain adoption in supply chains faces challenges. Technical issues such as scalability, integration with legacy systems, and energy consumption must be addressed. Moreover, widespread implementation requires consensus among multiple stakeholders, including those who may be hesitant to relinquish control over proprietary data. Regulatory uncertainties and the need for common standards also present barriers to adoption. Nonetheless, as organizations seek to future-proof their operations and build consumer trust, the strategic use of blockchain in SCM holds considerable promise. When integrated with other technologies like IoT, AI, and cloud

computing, blockchain can become the backbone of a more transparent, efficient, and resilient global supply network. Its evolution from a niche innovation to a foundational infrastructure may redefine the rules of commerce and accountability in the years to come.

2. Transparency and Traceability in Supply Chains

Transparency refers to the ability of all stakeholders in a supply chain to access relevant, accurate, and real-time data. Traceability, on the other hand, is the ability to track the origin, journey, and handling of a product across its lifecycle. Both are critical for regulatory compliance, ethical sourcing, and risk mitigation. Traditional systems often rely on paper records or isolated digital databases, which are prone to manipulation and inconsistencies. Blockchain replaces these centralized systems with distributed ledgers that are shared across all participants. Each transaction is time-stamped and cryptographically secured, making it nearly impossible to alter without consensus from the network.

By enabling a single version of the truth accessible to all authorized parties, blockchain significantly elevates the standard for both transparency and traceability in supply chain management. In industries such as food and pharmaceuticals, where contamination, counterfeiting, or improper storage can have severe health and legal consequences, the need for granular product-level traceability is particularly urgent. Blockchain allows organizations to document every step—from raw material sourcing and production to warehousing and final delivery—in a permanent, tamper-resistant ledger. For example, in the food industry, blockchain-powered systems can record the time and location of harvesting, transport conditions (such as temperature and humidity), and processing details. This capability allows companies to quickly isolate and recall contaminated products, reducing the risk to consumers and minimizing financial loss. Similarly, in the fashion industry, brands can prove ethical labor practices and sustainability claims by tracking materials from origin to retail, thus enhancing brand integrity and consumer trust.

Moreover, transparency through blockchain helps combat fraud, grey market trading, and supplier non-compliance. Smart contracts—self-executing codes embedded in the blockchain—can automatically enforce quality checks, verify certifications, or release payments only when all conditions are met. This reduces the dependence on manual audits or third-party verifiers, making operations more efficient and secure. In humanitarian supply chains or government procurement, blockchain can also enhance accountability. Every stakeholder, from donor agencies to last-mile distributors, can verify how goods and funds are being used, minimizing corruption and leakage.

Ultimately, the integration of blockchain transforms transparency and traceability from reactive compliance functions into proactive value drivers. As consumer demand for ethical, safe, and sustainable products grows, organizations that adopt blockchain for supply chain visibility will be better positioned to meet expectations, reduce risk, and gain competitive advantage in a data-driven global economy.

3. Industry Applications of Blockchain for SCM

Blockchain technology is rapidly transforming supply chain management across a range of industries by providing immutable records, shared visibility, and real-time tracking capabilities. Below are some of the most impactful applications.

3.1 Food and Agriculture

The food supply chain is complex, involving multiple stakeholders from farms, processors, distributors, and retailers. This makes it highly susceptible to issues such as contamination, mislabeling, and spoilage. Blockchain addresses these concerns by enabling complete traceability from farm to fork. Walmart, in collaboration with IBM's Food Trust, has implemented blockchain to track leafy greens and other produce, cutting traceability times from days to seconds. This not only accelerates response to food safety issues but also improves inventory management, reduces food waste, and builds consumer confidence in product origins. Additionally, smallholder farmers can benefit from increased visibility and fairer trade by having their produce digitally documented and verified on blockchain networks.

3.2 Pharmaceuticals

The pharmaceutical industry faces immense challenges with counterfeit medications, estimated to cause hundreds of thousands of deaths annually worldwide. Blockchain offers a secure way to authenticate every drug batch throughout its lifecycle. Companies like Modum and Chronicled provide blockchain solutions that help pharmaceutical manufacturers meet regulatory standards such as the U.S. Drug Supply Chain Security Act (DSCSA) and the EU's Falsified Medicines Directive. By embedding serialization and tracking into a blockchain system, drugs can be traced from production through distribution, ensuring legitimacy, proper handling, and timely recalls when needed. This improves patient safety and strengthens regulatory compliance.

3.3 Luxury Goods and Fashion

High-end brands are increasingly turning to blockchain to combat counterfeiting and boost consumer trust. LVMH's Aura Blockchain Consortium and De Beers' Tracr platform allow consumers to verify the origin and ownership history of items such as handbags, watches, and diamonds. These solutions document every step of a product's lifecycle—sourcing, manufacturing, shipping, and resale—providing a digital certificate of authenticity. This transparency enhances brand value and allows luxury buyers to make informed, ethical purchases.

3.4 Logistics and Freight

In global trade, documentation errors and delays are costly and frequent. Maersk and IBM's TradeLens platform applies blockchain to streamline shipping and logistics operations. By digitizing bills of lading, customs declarations, and cargo tracking, blockchain reduces processing times and minimizes fraud. The platform improves collaboration among shipping lines, ports, customs agencies, and freight forwarders—resulting in faster clearances, reduced costs, and more resilient logistics networks.

4. Benefits of Blockchain in SCM

The integration of blockchain into supply chain management (SCM) offers a transformative set of benefits that directly address some of the most persistent challenges in global logistics and procurement. From increasing transparency to improving compliance, blockchain's unique capabilities offer both operational and strategic advantages.

Enhanced Trust

One of the most significant contributions of blockchain is its ability to foster trust among stakeholders. Because blockchain records are immutable—once data is entered, it cannot be altered without consensus—participants can rely on the integrity of shared information. This builds confidence between supply chain partners, reduces the need for intermediaries, and facilitates smoother business relationships. In industries with complex vendor networks or third-party logistics providers, blockchain creates a shared, single source of truth.

Real-Time Tracking

Blockchain systems equipped with smart contracts and integrated Internet of Things (IoT) devices enable real-time tracking of goods throughout their lifecycle. Smart contracts can trigger automated alerts when goods arrive at specific checkpoints or if storage conditions deviate from acceptable ranges (e.g., temperature-sensitive vaccines). This real-time visibility empowers decision-makers to respond swiftly to delays, spoilage, or tampering—ultimately reducing losses and enhancing customer satisfaction.

Fraud Prevention

Counterfeit products—particularly in pharmaceuticals, luxury goods, and electronics—pose serious risks to consumers and brand reputations. Blockchain helps verify product authenticity through digital records that trace goods back to their origin. Every transaction, from manufacturing to final sale, is documented and timestamped, making it extremely difficult to introduce fraudulent goods into the supply chain. Consumers can even verify authenticity using QR codes linked to blockchain records.

Operational Efficiency

Manual processes, paper records, and fragmented digital systems often slow down supply chains. Blockchain streamlines operations by digitizing transactions, automating contract execution through smart contracts, and reducing redundant documentation. This leads to faster turnaround times, lower administrative costs, and improved coordination among supply chain actors.

Regulatory Compliance

Global supply chains must adhere to numerous regulations—such as the Food Safety Modernization Act (FSMA) and the Drug Supply Chain Security Act (DSCSA)—which mandate traceability and data integrity. Blockchain simplifies compliance by providing regulators with tamper-proof audit trails and real-time data access. This reduces the burden of manual reporting and improves the speed and accuracy of regulatory audits.

5. Challenges to Implementation

Despite its potential to revolutionize supply chain management, the widespread adoption of blockchain technology remains limited due to several technical, organizational, and regulatory

hurdles. Understanding these challenges is critical for businesses considering blockchain integration into their supply chains.

5.1 Technological Integration

Many supply chains rely on legacy systems like ERP (Enterprise Resource Planning), CRM (Customer Relationship Management), and various IoT platforms. Integrating blockchain into these infrastructures is technically demanding, often requiring significant redesign of existing workflows and data management practices. Furthermore, the lack of universal standards or interoperability protocols among blockchain platforms creates compatibility issues, making it difficult for firms to choose or align on a single solution across the supply chain network.

5.2 Scalability and Speed

Public blockchain networks like Ethereum and Bitcoin are limited in their transaction processing speed due to consensus mechanisms such as Proof of Work. These limitations make them unsuitable for high-volume supply chains requiring real-time data processing. While private or permissioned blockchains like Hyperledger Fabric or R3 Corda offer improved scalability, their adoption requires tailored development and often lacks the global trust of public networks. Striking a balance between scalability, decentralization, and security remains a key technical challenge.

5.3 Data Privacy and Governance

While blockchain is designed for transparency, not all supply chain information is suitable for public visibility. Companies may be reluctant to expose pricing data, supplier contracts, or sourcing information due to competitive concerns. Moreover, data governance issues—such as who owns the data, who can modify it, and how access is controlled—must be clearly defined. Many organizations turn to hybrid models that combine on-chain and off-chain storage to balance transparency with privacy.

5.4 Cost and ROI Uncertainty

Deploying blockchain infrastructure involves considerable costs related to software development, network maintenance, cybersecurity, and staff training. Additionally, the financial benefits of blockchain may not be immediately tangible, particularly for firms with low margins or limited IT budgets. This uncertainty deters investment, especially in the absence of clear, short-term ROI or industry benchmarks.

5.5 Regulatory Uncertainty

Blockchain operates in a fragmented legal landscape. Regulations concerning digital records, smart contracts, and cross-border data sharing vary widely between countries and are evolving rapidly. This regulatory ambiguity poses risks for organizations operating internationally, as legal compliance becomes a moving target. Clearer global standards are needed to foster greater confidence in blockchain adoption.

6. Future Directions

The future of blockchain in supply chain management (SCM) is being shaped by rapid technological advancements and growing demand for transparency, sustainability, and agility. While challenges remain, several emerging trends signal a significant expansion of blockchain applications across global supply networks.

Integration with IoT

The convergence of blockchain with the Internet of Things (IoT) is particularly powerful. Sensors, RFID tags, and GPS trackers can collect real-time data about products in transit, such as temperature, humidity, and location. When this data is logged on a blockchain, it creates an immutable, automated record that can be accessed by all stakeholders. This is especially beneficial in cold chain logistics—such as food and pharmaceuticals—where compliance with storage conditions is critical. Smart sensors combined with blockchain can instantly trigger alerts and automate actions when predefined conditions are breached, enhancing both efficiency and safety.

AI and Predictive Analytics

Blockchain can serve as a trusted data source for artificial intelligence (AI) and machine learning models. Because blockchain ensures data integrity, AI systems can confidently use historical supply chain data to forecast demand, detect anomalies, and make predictive decisions. For instance, AI could analyze blockchain-verified logistics patterns to optimize delivery routes or detect early warning signs of supplier non-compliance or bottlenecks.

Tokenization of Assets

Asset tokenization is another area gaining traction. By representing physical goods or financial instruments as digital tokens on a blockchain, companies can streamline transactions and ownership transfers. This is particularly useful in international trade, where goods often change hands multiple times. Tokenized assets can also facilitate faster, transparent payment settlements using smart contracts, reducing reliance on banks and lowering transaction costs.

Sustainability and ESG Reporting

As ESG (Environmental, Social, and Governance) metrics become central to corporate accountability, blockchain offers a way to verify sustainability claims. It can track the carbon footprint of shipments, prove ethical sourcing of raw materials, and provide verifiable records of labor conditions in supply chains. This level of transparency not only helps meet regulatory requirements but also strengthens brand trust and investor confidence.

Looking ahead, blockchain's widespread adoption in SCM will depend on the development of universal standards, scalable platforms, and collaborative governance models. Industry consortia like the Blockchain in Transport Alliance (BiTA) and the Mobility Open Blockchain Initiative (MOBI) are already fostering ecosystem-level cooperation. As trust and interoperability improve, blockchain is poised to become a foundational technology in next-generation supply chains.

7. Conclusion

Blockchain technology represents a fundamental shift in the architecture of modern supply chain management. Its core attributes—decentralization, immutability, and real-time accessibility—offer transformative solutions to long-standing issues such as data fragmentation, lack of visibility, fraud, and inefficiencies. By enabling transparent, secure, and tamper-proof tracking of goods and transactions, blockchain empowers all supply chain stakeholders to make better-informed decisions, increase accountability, and build trust.

The advantages of blockchain are especially evident in areas requiring high levels of traceability, such as food safety, pharmaceutical authentication, ethical sourcing, and high-value asset tracking. From enabling instant product recalls in agriculture to eliminating counterfeit drugs and verifying ESG compliance in global trade, blockchain's potential to enhance operational integrity is vast and well-documented.

Moreover, the integration of blockchain with other emerging technologies like IoT, AI, and digital tokens is expected to unlock even greater efficiency and agility. These synergies can enable automated compliance monitoring, predictive logistics, real-time quality control, and faster settlements, bringing about a new era of intelligent, autonomous supply chains.

However, realizing this vision is not without obstacles. Implementation challenges—ranging from technological integration and data privacy concerns to scalability limitations and regulatory ambiguity—must be addressed through thoughtful planning and multi-stakeholder collaboration. The cost of deployment, uncertainty over return on investment, and lack of standardized frameworks have slowed adoption, particularly among smaller enterprises and in cross-border contexts.

Nonetheless, momentum is building. Industry consortia, government initiatives, and public-private partnerships are increasingly promoting blockchain pilots and infrastructure sharing. As interoperability standards mature and the ecosystem evolves, the barriers to adoption are likely to diminish.

In conclusion, blockchain is not a cure-all, but when strategically aligned with business objectives and supported by proper governance, it can serve as a foundational layer for secure, transparent, and resilient supply chains. As global supply networks continue to grow in complexity and vulnerability, embracing blockchain may no longer be a matter of competitive advantage—but one of necessity. Future-ready organizations that invest in blockchain today are likely to lead tomorrow's supply chains with greater trust, efficiency, and sustainability.

References

Saberi, 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.

Kamble, S. S., Gunasekaran, A., & Arha, H. (2019). Understanding the blockchain technology adoption in supply chains. *International Journal of Production Research*, 57(7), 2009–2033.

Hackius, N., & Petersen, M. (2017). Blockchain in logistics and supply chain: Trick or treat? *Proceedings of Hamburg International Conference of Logistics (HICL)*, 23, 3–18.

Abeyratne, S. A., & Monfared, R. P. (2016). *Blockchain-ready manufacturing supply chain using distributed ledger*. *International Journal of Research in Engineering and Technology, 5*(1), 1–10.

Kowalskie, A. (2025). The Impact of Outliers on Linear Regression Models: Detection and Correction Strategies. *OTS Canadian Journal*, *4*(6), 108-118.

Chang, S. E., & Chen, Y. (2020). *When blockchain meets supply chain: A systematic literature review on current development and potential applications*. *IEEE Access, 8*, 62478–62494.

Shukur, I. (2025). Biomechanical Considerations in the Use of Temporary Anchorage Devices (TADs) in Complex Orthodontic Cases. *OTS Canadian Journal*, *4*(6), 119-129.

Difrancesco, D., et al. (2021). *Blockchain for sustainable supply chain management: A literature review*. *International Journal of Operations & Production Management*.

Mohamedamin, S. Q. (2025). Aspects Of Digital Identity In E-Commerce. *OTS Canadian Journal*, *4*(6), 1-90.

Durach, C. F., Kurpjuweit, S., & Wagner, S. M. (2020). *Blockchain applications in supply chain transactions*. *Journal of Business Logistics*.

Heese, H. S. (2007). *Building visibility in supply chains*. *Journal unspecified.*

Surchi, A. (2024). Factors Shaping Organizational Contingency Plans: Insights into Risk Management and Preparedness. *OTS Canadian Journal*, *4*(3), 1-10.

Faeq, D.K. Narcissistic leadership, workplace bullying, turnover intention, and creative performance: a study of nurses. *BMC Nurs* 24, 898 (2025). https://doi.org/10.1186/s12912-025-03479-x

Hastig, G. M., & Sodhi, M. S. (2020). *Blockchain for supply chain traceability: Business requirements and critical success factors*. *Production and Operations Management*.

Queiroz, M. M., Telles, R., & Bonilla, S. H. (2020). *Blockchain and supply chain management integration: A systematic literature review of the literature*. *Supply Chain Management: An International Journal*.

Nader, R. A., Saadi, M. B., & Abdulqadir, B. B. (2024). The Impact of High-Performance Works Practice on Employees Job, Life and Career Satisfaction. *OTS Canadian Journal*, *3*(1).

Tönnissen, F., & Teuteberg, F. (2020). *Analysing the impact of blockchain technology for operations and supply chain management: An explanatory model drawn from multiple case studies*. *International Journal of Information Management*.

Toyoda, K., Mathiopoulos, P. T., & Sasase, I. (2021). *Product ownership management system with blockchain to prevent counterfeit goods*. *IEEE Access*.

Mirah, K. (2025). Leadership Evolution: Bridging Foundations to Organizational Impact. *OTS Canadian Journal*, *4*(1), 1-7.

Wamba, S. F., & Queiroz, M. M. (2020). *Blockchain adoption in operations and supply chain management: Benefits, challenges and future research opportunities*. *International Journal of Information Management, 52*, 102064.

John, N. (2025). The Intersection of Performance Management and Legal Termination Practices. *OTS Canadian Journal*, *4*(1), 17-34.

Wamba, S. F., Queiroz, M. M., & Trinchera, L. (2020). *Dynamics between blockchain adoption determinants and supply chain performance: An empirical investigation*. *International Journal of Production Economics, 229*, 107777.

Shan, D. K. (2025). Legal Foundations in Business: Key Factors Influencing Modern Practices. *OTS Canadian Journal*, *4*(1), 8-16.

Yiu, N. C. (2021). *Decentralizing supply chain anti-counterfeiting and traceability systems using blockchain technology*. *Future Internet, 13*, 84.

Queiroz, M. M., & Wamba, S. F. (2019). *Blockchain adoption challenges in supply chain: An empirical investigation of the main drivers in India and the USA*. *International Journal of Information Management, 46*, 70–82.

Macru, K. (2025). Customer Preferences and Advertising Trends: A Symbiotic Connection. *OTS Canadian Journal*, *4*(1), 35-41.

Vincent, N. (2023). *Blockchain for supply chain transparency and logistics optimization*. *Unpublished manuscript*.

Naveuler, K. (2025). What Drives Purchases? A Closer Look at Shopping Determinants. *OTS Canadian Journal*, *4*(1), 42-46.

Vishal Gaur & Gaiha, A. (2020). *Building a transparent supply chain*. *Harvard Business Review, May–June 2020*.

Subramanian, N., Joshi, A., & Bagga, D. (2023). *Transparent and traceable food supply chain management*. *arXiv preprint arXiv:2305.12188*.

Sadiq, G. J., Kanabi, I. S., Tahir, S. R., & Nader, A. S. (2025). The Impact of Marketing Crises on Marketing Recovery. *OTS Canadian Journal*, *4*(1), 47-65.

Sezer, B. B., Topal, S., & Nuriyev, U. (2021). *Auditability, transparency, and privacy-preserving for supply chain traceability based on blockchain*. *arXiv preprint arXiv:2103.10519*.

Sermpinis, T., & Sermpinis, C. (2018). *Traceability decentralization in supply chain management using blockchain technologies*. *arXiv preprint arXiv:1810.09203*.

Bayz, H. Q. (2024). The Role and Impact of the International Criminal Court in Global Justice. *OTS Canadian Journal*, *3*(5).

Patel, A., et al. (2025). *Blockchain-enabled traceability in the jewelry supply chain*. *Scientific Reports, 15*, 3837.

Shukur, I. (2023). Invisalign vs Braces: Which is Right for You? A Guide from an Orthodontist: Case of Blanca Dental Care. *OTS Canadian Journal*, *2*(4).

Chang, Y., Iakovou, E., & Shi, W. (2019). *Blockchain in global supply chains and cross-border trade: A critical synthesis of state-of-the-art, challenges and opportunities*. *arXiv preprint arXiv:1901.02715*.