SCIENTIFIC CULTURE

www.sci-cult.com

SCIENTIFIC CULTURE, Vol. 12, No. 2.1, (2026), pp. 148-159
Open Access. Online & Print

DOI: 10.5281/zenodo. 122.12614

BLOCKCHAIN TECHNOLOGY IN SUPPLY CHAIN MANAGEMENT: A REVIEW OF APPLICATIONS AND BENEFITS

Santanu Roy[1*], Deepak Srivastava[2], Abhimanyu Gupta[3], Basavaraj Mallikarjun Halabhavi[4], Virendra Kumar Verma[5], Sidharth Jain[6], Vipin Kumar[7]

[1]Professor, IILM Institute for Higher Education, New Delhi, India*
rsan58@yahoo.co.uk, https://orcid.org/0000-0003-4566-1040
[2]Associate Professor, PSIT College of Higher Education, Kanpur, India
ds@psit.ac.in, https://orcid.org/0000-0003-1438-4642
[3]Research Scholar, Devi Ahilya University, Indore, India
ecoabhimanyugupta@gmail.com, https://orcid.org/0009-0006-9910-7749
[4]Research Scholar, Department of Computer Applications and IT, University of Technology, Sanganer, Jaipur, India. b06071984@gmail.com
[5]Assistant Professor, Symbiosis Institute of Business Management, Symbiosis International (Deemed University), Bengaluru, India. virendra.verma@sibm.edu.in, https://orcid.org/0000-0002-1115-1221
[6]Professor, Institute of Business Management and Commerce (IBMC), Mangalayatan University, Aligarh, India. siddharth.jain@mangalayatan.edu.in, sjainbsr@gmail.com https://orcid.org/0009-0008-2117-3513
[7]Associate Professor, Teerthanker Mahaveer University, Moradabad, India
drvipink.engineering@tmu.ac.in

Received: 01/12/2025
Accepted: 02/01/2026

Corresponding Author: Santanu Roy (rsan58@yahoo.co.uk)

ABSTRACT

Blockchain technology is a disruptive technology which has the potential to transform supply chain management (SCM) by solving the poor data sharing issues, poor transparency and eliminating fraud. The present paper conducts literature review and industrial case studies to assess the potential and advantages of blockchain in SCM. The results indicate that blockchain provides better traceability, data integrity, automates compliance with smart contracts and trust among stakeholders in supply chains across the world. Commercial applications, like those operated by Walmart, OpenSC, Everledger, and Nestle, show that blockchain is quite useful in enhancing operational efficiency, ethical sourcing, and product authentication. This is evidence of how blockchain technology should not be considered as an abstract phenomenon but a practical option with quantifiable results. Based on these insights, the paper develops a blockchain-based SCM framework that combines data gathering, blockchain architecture, and application capabilities with an effective system of coordinating stakeholders into a coherent framework. In this framework, one will find a systematic manner of including the blockchain to enhance the performance of the supply chain. The discussion points to the technical, organizational and regulatory issues which stall large-scale adoption. It also indicates future possibilities, as

when blockchain can be coupled with IoT and AI, they may be used to raise analytics, real-time decision-making, and sustainability monitoring. Even though it is still at an early stage, blockchain has further potential to transform supply chains globally in a dramatic way. The removal of some of the existing barriers by innovation, standardization and collaboration will enable it to release full potential transformative power.

KEYWORDS: Blockchain, Supply Chain Management, Traceability, Smart Contracts, Transparency.

1. INTRODUCTION

Supply chain management has emerged as a significant activity of the organizations that aspire to become competitive in the more globalizing and diversified marketplace. Nevertheless, the conventional SCM systems still experience the same problems; they are not transparent, problematic in terms of traceability, susceptible to fraud, inefficient in sharing data, and very difficult in terms of ensuring that different stakeholders comply with standards [1]. These issues are also aggravated in cases where safety of the product and ethical sourcing and authenticity is paramount such as in food and drugs and in luxury goods [2]. A radical solution to these problems has been proposed in the form of the technology of blockchain and its decentralized, immutable and transparent ledger system. Blockchain enhances trust within the members of the supply chains since they can conduct safe and verifiable transactions without the involvement of third parties [3]. It has also the most basic features, namely distributed consensus, cryptographic security, and automated smart contracts, and therefore can be effectively used to address the inefficiencies of the current SCM processes. The recent past two years have verified the potential of blockchain in supply chains with effective practical implementations. To illustrate, Walmart in association with IBM Food Trust has already been able to pilot pork and mango traceability in China and the United States of America, respectively, to reduce traceability to a few seconds [4]. On this note, the TradeLens is a blockchain-based platform developed by IBM and Maersk which has also demonstrated increased visibility and efficiency in international shipping activities by sharing shipping information among different parties in a secure way [5]. All these implementations indicate that blockchain can change SCM through the provision of end-to-end visibility, automation of compliance via smart contracts, and the reduction of the costs of operations [6].

Despite such positive trends, the real application of blockchain in SCM is currently at the initial stage, and there are technical, organizational, and regulatory issues. The previous research studies have either been more descriptive in nature of what was actually implemented in a particular case or more literature research studies in general and as such, there has been a gap in bridging the results of what was implemented with a fully laid out analysis of the same. Such paper should feature a review of the existing state of the research into blockchain applications in SCM, as well as condense the knowledge obtained in a formal model that can be used by future adoption and further research work in this domain. It has been assumed in this paper that not only will a review of blockchain and its opportunities in supply chain management, but also a new contribution in developing a blockchain-enabled SCM framework will be carried out. The review provides an overview of the findings of literature as well as industrial case studies and classifies blockchain application, industry-wise, and the benefits of the same. Other than this, all these findings have been summarized in the given framework to present a framework that outlines how blockchain can be used to strengthen supply chain services at various levels.

2. BACKGROUND ON BLOCKCHAIN TECHNOLOGY IN SUPPLY CHAIN

2.1. Fundamentals of Blockchain Technology

Blockchain is a decentralized ledger, that is, a record of transactions that is hosted on a distributed system of nodes. Each and every transaction is cryptographically confirmed and is made up of an irreversible chain of records. The information is valid and could not be changed without any legal actions, and such consensus protocols as Proof of Work (PoW) and Proof of Stake (PoS) are used [7]. Unlike a conventional centralized database, blockchain lacks single points of failure that helps with data security and reliability. Moreover, the process of transactions and enforcement of contractual regulations is also automated as the smart contracts or self-executing agreements are written into the blockchain [8].

Table 1: Core Features of Blockchain Technology and Their Relevance to SCM.

Blockchain Feature	Description	Relevance to SCM
Decentralization	Distributed control with no central authority	Enhances trust among multiple supply chain actors
Immutability	Records cannot be altered once validated	Ensures data integrity and authenticity
Transparency	Shared visibility of transactions across participants	Improves traceability of goods
Smart Contracts	Automated execution of pre-defined conditions	Streamlines processes and reduces manual errors

Security via Cryptography	Data is encrypted and protected from tampering	Reduces fraud risks in supply chain transactions

2.2. Blockchain's Role in Supply Chain Management

Blockchain, within the scope of supply chain management, can resolve the most problematic inefficiencies by providing end-to-end visibility, real time data sharing, and tamper free documentation. Blockchain-enabled solutions are especially enhancing the performance in industries that have high traceability and regulatory needs, including food, pharmaceutical, and maritime logistics [9][10].

Case Insight: Maersk TradeLens, a blockchain-based platform, is enabling sharing of information amongst the stakeholders in the shipping industry, which has minimized paperwork, delays and the risk of fraud. Likewise, the IBM Food Trust blockchain has helped retailers to track and trace contaminated products to their origin, within a short time, and hence be in compliance with food safety regulations [5].

Table 2: Traditional SCM Challenges vs. Blockchain-Enabled Solutions.

SCM Challenge	Impact	Blockchain Solution
Lack of Transparency	Difficulty tracking goods across supply chains	Shared ledger ensures real-time visibility
Counterfeiting	Fake goods infiltrate markets	Immutable records verify authenticity
Data Silos	Inefficient information sharing	Decentralized network breaks data silos
Regulatory Compliance	Complex manual verification processes	Smart contracts automate compliance
High Transaction Costs	Excessive intermediaries and paperwork	Peer-to-peer transactions reduce costs

2.3. Related Technologies Enhancing Blockchain in SCM

Blockchain also has many applications in SCM along with other technologies of Industry 4.0, like the Internet of Things, Artificial Intelligence, and Cloud Computing [11]. Data transmissions through IoT devices and sensors will provide real-time data (e.g. temperature sensors in food logistics) but AI will broaden out predictive opportunity, and cloud solutions will provide a scalable foundation. When such technologies are combined with blockchain, their efficiency, security, and sustainability of the supply chain improve [12].

3. METHODOLOGY

This paper presents a mixed-method approach to review the literature on blockchain in supply chain management, as well as review of industry applications and benefits, based on cases. This method will help cover both theoretical views and applied solutions, which will give a balanced idea of the effects of blockchain.

3.1. Review Approach

This review employs a wide range of resources including peer-reviewed journal articles, conference proceedings and industry reports by experts. The well-known databases, which were used as the sources of literature, were IEEE Xplore, Web of Science, ScienceDirect, and SpringerLink. The studies of high quality were given the priority, and such an approach provided worthwhile information concerning the implementation of blockchain, its advantages, and implementation challenges in SCM. It was not directed to conduct a thorough systematic review but to look at some of the exemplary works that contribute to the notion of the role of blockchain in the context of supply chains.

3.2. Use of Case Studies

Together with scholarly sources, industrial case studies were used to corroborate theoretical results. The reason behind selecting these cases is that they were well documented, were related to the industry, and showed how blockchain could be used in the real-world supply chain situation. Among the most prominent ones are the use of blockchain in the food safety, shipping, and the luxury goods traceability [13]. The incorporation of such cases imparts practical richness to the review, and it is possible to analyze the research and practice intersection.

3.3. Data Integration

The information gathered through literature and case studies was thematically analyzed to determine the blockchain applications, reported benefits and associated implementation challenges. This thematic synthesis acts as the basis of analysis in this research. The analysis is more comprehensive in looking at the potential of blockchain in SCM since it harmonizes academic discoveries with industry experience. Table 3 summarizes the classification of the sources that were utilized in this research, where we can draw a distinction between academic studies and case-based evidence.

Table 3: Classification of Sources Used in This Study.

Source Type	Examples	Purpose in the Study
Academic Literature	Peer-reviewed journals, conference papers [8], [10]	Provides theoretical insights and conceptual understanding of blockchain in SCM
Industry Case Studies	Walmart–IBM Food Trust, Maersk TradeLens, Everledger [9]	Validates academic findings with real-world evidence
Industry Reports	Official reports, technical white papers	Supplements literature with practical perspectives

3.4. Applications of Blockchain in Supply Chain Management

Blockchain technology has been integrated into different areas of the supply chain to enhance the performance of operations, to minimize fraud and to increase transparency. The uses include product traceability to sustainability tracking, and all the above utilizations show that blockchain can help address certain issues within a specific industry.

3.5. Product Traceability and Provenance

Blockchain facilitates end-to-end visibility on products throughout the supply chain. All the transactions, including the supply of raw materials and the final delivery, are recorded on an immutable ledger, so the origins of products can be checked in real-time. Another example, WWF has promoted blockchain-powered traceability to obtain ethically sourced foodstuffs to increase regulatory compliance and consumer confidence [14]. In the same manner, Nestle has adopted blockchain so that customers can trace the origin of products, making food supply chains transparent and safe [15].

3.6. Smart Contracts and Process Automation

One of the major uses of blockchain in SCM is smart contracts, where the agreements can be automatically executed once the predetermined conditions are satisfied. This automation decreases administrative time lag and does not require intermediaries. An example of an open blockchain application is OpenSC, which allows the simplification of verification processes to achieve an increased speed and compliance with sustainability practices [16]. Automated contracts reduce the cases of human errors and enhance the efficiency of operations.

3.7. Counterfeit Prevention and Quality Assurance

Blockchain records are immutable and secure, which aids in the fight against counterfeit goods, especially in the areas where their authenticity matters. Everledger has used blockchain to trace diamonds, and this gives verifiable evidence of origin and quality, so it helps to avoid fraudulent activities [17]. The brand reputation and consumer confidence are also safeguarded under this mechanism.

3.8. Sustainability and Ethical Sourcing

Blockchain can assist with sustainability because it can document and track environmental and ethical compliance in supply chains. The WWF has managed to utilize blockchain in tracking the sustainability of suppliers. Likewise, the implementation of blockchain in Nestle will guarantee that products will be ethically sourced, and companies can enhance their corporate social responsibility initiatives. Table 4 summarizes the main usage of blockchain in SCM, as well as their representatives in the industrial context. Moreover, blockchain interaction with the supply chain stakeholders is depicted in Figure 1.

Table 4: Applications of Blockchain in SCM with Case Examples.

Application	Description	Case Example(s)
Product Traceability	Tracks goods from origin to destination, ensuring safety and compliance	WWF blockchain for food chains; Nestlé transparency initiative
Smart Contracts	Automates transactions and compliance through self-executing digital agreements	OpenSC automated verification processes
Counterfeit Prevention	Secures product data to verify authenticity and prevent fraud	Everledger diamond authentication
Sustainability Monitoring	Verifies ethical sourcing and environmental compliance throughout the supply chain	WWF and Nestlé sustainability programs

Figure 1 below shows a generic blockchain-enabled supply chain management architecture, showing data flow among supply chain actors (suppliers, manufacturers, logistics providers, retailers, and consumers) via blockchain levels including smart contracts and distributed ledgers.

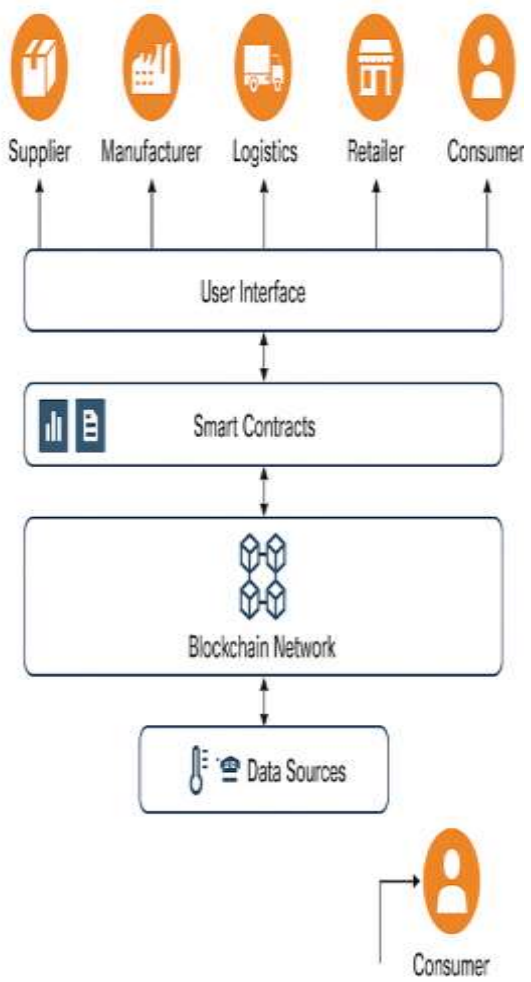

Figure 1: Generic architecture of a blockchain-enabled supply chain.

3.8. Industrial Case Studies Supporting Blockchain Applications

Blockchain technology has a significant role in supply chain management, supported by several industrial case studies. These examples show how the functionalities of blockchain, traceability, smart contracts, anti-counterfeiting, and sustainability tracking have been successfully applied in practice.

3.8.1. Walmart and IBM Food Trust

Walmart, in collaboration with IBM Food Trust, introduced blockchain to improve traceability of food products. The company has saved days of traceability down to few seconds by using IoT sensors and supplier data that is integrated into a blockchain ledger. The innovation enhanced compliance with food safety, minimized the chances of producing contaminated products getting into the market, and enhanced operational efficiency [4].

3.8.2. OpenSC (WWF Sustainability Program)

OpenSC, a project organized by the World Wildlife Fund, implements blockchain with IoT to track sustainable manufacturing within supply chains of food. It is a system to check the environmental and ethical statements in the moment, making businesses transparent to the consumer and maintaining responsible sourcing [14].

3.8.3. Everledger – Diamond Authentication

Everledger uses blockchain to give diamonds unique digital identities so that stakeholders can track the stones through the supply chain. This blocks the influx of counterfeit diamonds, makes sure that ethical sourcing practices are followed, and generates trust within the buyer seller relationships [17].

3.8.4. Nestlé Blockchain Transparency Initiative

Nestle has launched a blockchain-enabled platform where customers can find detailed information regarding the origin and the manufacturing process of such products as coffee and baby food. Such end-to-end traceability enhances brand responsibility, consumer confidence and supply chain openness [15].

These industrial contexts help to confirm the actual impact of blockchain in several industries. As Table 5 demonstrates, the functionalities used are applied to analyze the outcomes of the blockchain applications in these cases.

Table 5: Case Studies Supporting the Proposed Framework.

Case Study	Blockchain Functionality Applied	Outcome Observed
Walmart – IBM Food Trust	Traceability, Smart Contracts	Traceability times reduced; improved food safety compliance
OpenSC (WWF Initiative)	IoT Integration, Traceability, Sustainability Tracking	Verified ethical sourcing; increased consumer trust
Everledger – Diamonds	Anti-Counterfeiting, Immutable Ledger	Prevented counterfeit goods; ensured ethical sourcing
Nestlé Transparency Initiative	Traceability, Sustainability Monitoring	Enabled end-to-end product tracking; enhanced accountability

4. BENEFITS OF BLOCKCHAIN IN SUPPLY

CHAIN MANAGEMENT

The capability to integrate blockchain into the supply chain management has several benefits which do not revolve around process optimization. With the aid of decentralization, transparency, and immutability of blockchain, organizations can gain better trust, less fraud, and easier operations. Such benefits have been witnessed in variety of industries with both academic literature and real-life applications backing it up.

4.1. Transparency and Trust Enhancement

Enhancing transparency is one of the core benefits of blockchain in supply chains. The information on all transactions is captured in a shared ledger, un-destructible and accessible to the authorized stakeholders and it eliminates information asymmetry. This transparency builds trust between suppliers, manufacturers, and customers. Wamba and Queiroz [18] have stressed that greater trust leads to more effective collaboration and enhanced relationships in supply chains, especially in those that are global in nature where intermediaries are prevalent.

4.2. Fraud Reduction and Security Improvement

Blockchain's cryptographic security significantly reduces opportunities for fraudulent activities. By using immutable records, it is not possible to alter them, and decentralized storage eliminates any single point of weakness. Evidence of this case indicates that the industries utilizing blockchain encounter the lowest frequencies of counterfeit items, unapproved alterations, and information breaches [19]. In high value supply chains e.g. the pharmaceutical industry and luxury goods, this feature is very useful.

4.3. Cost Efficiency and Process Optimization

Deployment of smart contract transactions cut down administration costs, and dependence on intermediaries. Research has revealed that the implementation of blockchain reduces the processing time, the number of disputes, and saves costs at different levels of the supply chain [20]. Also, the goods are moved and inventories handled are made faster by doing away with unnecessary checks.

4.4. Stakeholder Collaboration and Data Integrity

Blockchain also helps to improve multi-party collaboration by establishing a single source of truth among the participants. This common exposure allows us to make decisions in unison and minimizes the disputes of stakeholders. Habib et al. [21] discovered that the data integrity offered by blockchain allowed effective coordination between the suppliers, manufacturers, logistic providers, and the retailers, and the supply chain resilience in general. The list of the above-defined benefits is summarized and, furthermore, divided based on the areas of impact as can be observed at Table 6.

Table 6: Key Benefits of Blockchain in SCM and Their Impact Areas.

Benefit	Impact Area
Transparency and Trust	Enhanced supplier–buyer relationships; improved consumer confidence
Fraud Reduction and Security	Lower counterfeit risks; improved data security
Cost Efficiency	Reduced administrative costs; optimized transaction processing
Collaboration and Data Integrity	Better multi-stakeholder coordination; resilient supply networks

4.5. Original Contribution: Proposed Blockchain-Enabled SCM Framework

The present paper introduces a proposed blockchain-enabled supply chain management framework that takes both the benefits of blockchain technology and in-real life supply chain activities into consideration. This framework will be developed subscribing to the synthesized knowledge of academic literature and the validated instance in the industry that can obviously deliver a structured manner of understanding how blockchain technology can be effectively incorporated into the SCM operations.

4.6. Framework Overview

There are four layers that are inter-related to form the framework namely Data Sources, Blockchain Layer, Application Layer and Stakeholders. The information is received by sensors, RFID tags, and available databases, which are fed into the blockchain layer and are secured and validated using distributed ledgers and smart contracts. This is developed in the application layer which allows traceability, anti-counterfeiting, automated contract performance, and sustainability tracking. Finally, the functions themselves enable exchanges between the stakeholders including, but not limited to, suppliers,

manufacturers, logistics providers and consumers [22] [23]. Figure 2 shows the architecture and clearly shows how data and functionality moves through the framework.

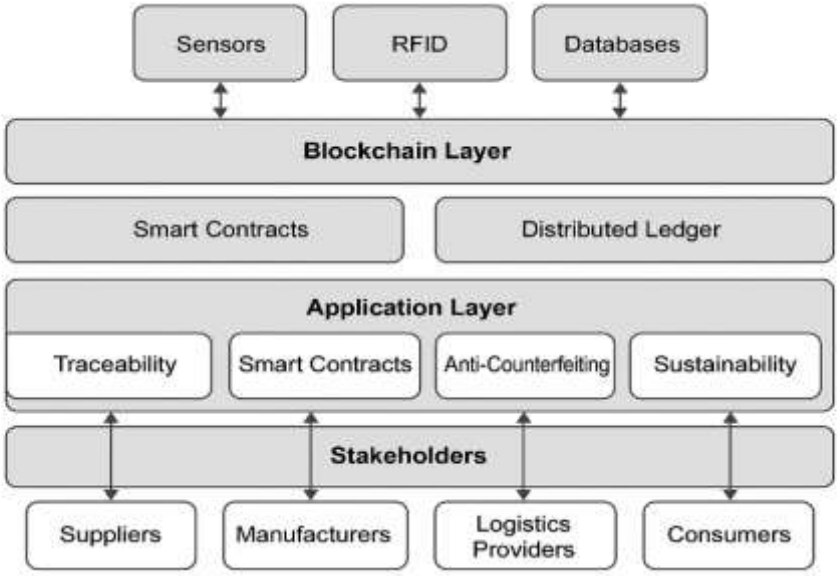

Figure 2: Proposed Blockchain-Enabled SCM Framework.

4.7. Components of the Framework

The proposed framework ensures that blockchain is not an isolated technology but an integrated part of the supply chain ecosystem. Each layer plays a distinct role in achieving operational efficiency and trust among participants:

Data Sources Layer: Comprises IoT devices, RFID systems, and traditional databases that capture real-time information from supply chain operations.

Blockchain Layer: Ensures security and immutability by recording all transactions in a distributed ledger, with smart contracts enabling automated execution.

Application Layer: Provides blockchain-powered functionalities such as product traceability, counterfeit detection, compliance monitoring, and sustainability verification.

Stakeholder Layer: Includes all the parties of the supply chain that engage the system with visibility and trust provided by sharing access to the verified information.

The specifics of those layers and their contributions are outlined in Table 7.

Table 7: Components of the Proposed Blockchain-Enabled SCM Framework.

Layer	Functions	Expected Contribution to SCM
Data Sources	Collects real-time data via IoT sensors, RFID, and databases	Accurate, real-time information flow
Blockchain Layer	Uses smart contracts and distributed ledgers to validate and secure data	Enhances security, reduces fraud, automates verification
Application Layer	Implements traceability, anti-counterfeiting, and sustainability modules	Improves compliance, visibility, and operational efficiency
Stakeholders	Includes suppliers, manufacturers, logistics providers, and consumers	Builds trust and collaboration across the supply chain

This model can be described as an inclusive model of blockchain integration that involves interplay of technology, application and stakeholders. It offers the foundation of questioning how blockchain can help to alleviate the prevailing limitation on supply chain and how to instigate innovation in future SCM practices.

4.8. Discussion

The findings of this review affirm that blockchain technology holds the capability of transforming supply chain management with the potential to massively boost transparency, data security and the efficiency of operation. The latter can be proven by both scholarly research and practical implementations, as both have shown that blockchain can tackle long-term issues of the supply chain, including low traceability, fraud, and data fragmentation. The case study analysis of such spheres as food, luxury products, and sustainability

projects only proves that blockchain is not an abstract idea but rather a practical tool that already has a measurable result in the real environment. Comparing the findings of this study to what has been said in the existing literature, the findings are consistent with those done previously that acknowledge blockchain in supply chains as a disruptive technology [24] [25]. Nevertheless, the review goes beyond the previous efforts to include industrial case studies and frame out a structured SCM based on blockchain implementation. Compared to previous literature where most of the studies have been solely centered on personal rewards or individual use cases, this framework offers a holistic perspective that will explain how the layering aspect of blockchain can be used to systematically resolve supply chain inefficiencies. Furthermore, although there are claims in past studies that blockchain has been leading to some doubts in terms of scalability and economic viability, the facts presented here reveal that the emerging hybrid models, as well as the changing consensus mechanisms, are increasingly addressing these issues [26].

Nevertheless, as the outcomes were encouraging, several constraints still limit the extensive use of blockchain. Implementation costs and the shortage of well-trained personnel are still a major obstacle, especially when it comes to the small and medium-sized businesses. Efficiency in terms of technical issues including network scalability and the usage of energy in certain blockchain systems are obstacles to expansion as well. Other difficulties are the organizational resistance to change and the intricacies of incorporating blockchain with legacy infrastructure [27]. Also, legal risks are created by uncertainty in regulation, particularly in cross-border trade, which deters significant-scale investments [28]. The specified limitations mean that the adoption of blockchain is not as easy as it might seem, and it should be planned and resources dedicated to it.

Blockchain in SCM has a bright future. Future technical developments such as the energy-efficient consensus algorithms and hybrid blockchain structures will likely resolve the existing technical limitations and international efforts to establish standardized regulatory protocols will help blockchain to gain wider adoption [29]. Moreover, the combination of blockchain with the industry 4.0 technologies including the Internet of Things and artificial intelligence is expected to facilitate better predictive analytics, make decisions in real-time and increase sustainability monitoring. The nature of these developments not only enhances the potential of blockchain but also introduces new research front on the topic of multi-technology synergy in the supply chain contexts [30]. These findings have two implications. In theory, the review helps to clarify the role of blockchain in SCM due to synthesizing the available literature with real-life experience and providing a structured framework that can be used as the basis of further academic research. In practice, the framework gives supply chain managers a guide to adoption, explaining how blockchain can be used to achieve transparency, efficiency and trust in a phased manner. The fact that it has been applied in the industrial context and brought success to companies like Walmart, Nestle, and Everledger only supports its applicability. However, even though the usage of blockchain has not been broad enough because of technical, organizational, and regulatory concerns, its potential to change a wide range of industries has been confirmed numerous times. The obstacles could be broken by innovation and policy making and industry collaboration, which would play an essential role in accelerated adoption. The reviewed paper suggests that implementation of blockchain must be gradual and strategic with the framework being the important step in achieving the benefits of blockchain and making it an instrument of transparent, sustainable, and resilient supply chains in the future.

5. CONCLUSIONS

The paper has discussed the application and usefulness of blockchain technology in the management of a supply chain besides the introduction of an original framework of blockchain-enabled SCM. The analysis of literature and industry case studies showed that blockchain can increase the effectiveness of supply chains significantly and can enhance the transparency of the processes, ensure integrity of the data, reduce the fraud level, and facilitate trust in the stakeholders. The fact that real-world solutions are being offered by Walmart, OpenSC, Everledger, and Nestle is a good indication of the potential that blockchain has in solving endemic inefficiencies in different industries. The suggested structure summarizes academic research and industrial experience and underlines the way that blockchain becomes a part of the supply chain processes by using layered elements: data sources, blockchain infrastructure, application functionalities, and stakeholder interactions. This systematic review paves a way of learning and adopting blockchain in SCM setups. Although the implementation of blockchain promises to be transformative, its

implementation is not devoid of challenges. A major barrier to widespread implementation is technical issues, cost, regulatory uncertainties and organizational readiness. Nevertheless, innovations like scalable blockchain architectures and energy-efficient consensus algorithms and continued regulatory initiatives show that a good portion of these difficulties are being tackled. The synthesis of blockchain and other technologies (IoT and AI) results in the emergence of new angles of innovation and operation optimization in supply chains as well. In conclusion, blockchain is a strong catalyst in the development of supply chains but its success heavily depends on its future ability to transcend its current weaknesses through research, policy development and collaboration between industries. Technological innovation should be aligned with the organizational and regulatory plans as this will enable blockchain to be an agent of efficient, modern, and transparent supply chain networks.

REFERENCES

A. A. A. Sharabati and E. R. Jreisat, "Blockchain technology implementation in supply chain management: A literature review," Sustainability, vol. 16, no. 7, p. 2823, 2024.

A. A. Khanfar, M. Iranmanesh, M. Ghobakhloo, M. G. Senali, and M. Fathi, "Applications of blockchain technology in sustainable manufacturing and supply chain management: A systematic review," Sustainability, vol. 13, no. 14, p. 7870, 2021.

A. Gurtu and J. Johny, "Potential of blockchain technology in supply chain management: a literature review," International Journal of Physical Distribution & Logistics Management, vol. 49, no. 9, pp. 881–900, 2019.

A. Iftekhar, X. Cui, M. Hassan, and W. Afzal, "Application of blockchain and Internet of Things to ensure tamper-proof data availability for food safety," Journal of Food Quality, vol. 2020, no. 1, p. 5385207, 2020.

A. Kaur, G. Singh, V. Kukreja, S. Sharma, S. Singh, and B. Yoon, "Adaptation of IoT with blockchain in Food Supply Chain Management: An analysis-based review in development, benefits and potential applications," Sensors, vol. 22, no. 21, p. 8174, 2022.

A. P. De Barros, C. S. Ishikiriyama, R. C. Peres, and C. F. S. Gomes, "Processes and benefits of the application of information technology in supply chain management: an analysis of the literature," Procedia Computer Science, vol. 55, pp. 698–705, 2015.

C. Gutierrez and A. Khizhniak, "A Close Look at Everledger—How Blockchain Secures Luxury Goods," Everledger-Blockchain-Diamonds-HyperLedger-Fabric-IBM-v2, Apr. 27, 2017. https://www.altoros.com/blog/a-close-look-at-everledger-how-blockchain-secures-luxury-goods

E. Chhabra, "The WWF backs blockchain to unpick messy food supply chains," Business, Jan. 31, 2019. https://www.wired.com/story/food-supply-chains-blockchain-wwf

E. Rodrigues, W. Lourenzani, and E. Satolo, "Blockchain in supply chain management: Characteristics and benefits," BAR-Brazilian Administration Review, vol. 18, no. spe, p. e200065, 2021.

F. Yiannas, "Walmart's food safety solution using IBM Food Trust built on the IBM Blockchain Platform," IBM Media Center, 2019. https://mediacenter.ibm.com/media/Walmart%27s+food+safety+solution+using+IBM+Food+Trust+built+on+the+IBM+Blockchain+Platform/1_zwsrls30

G. Blossey, J. Eisenhardt, and G. Hahn, "Blockchain technology in supply chain management: An application perspective," 2019.

G. Habib, S. Sharma, S. Ibrahim, I. Ahmad, S. Qureshi, and M. Ishfaq, "Blockchain technology: benefits, challenges, applications, and integration of blockchain technology with cloud computing," Future Internet, vol. 14, no. 11, p. 341, 2022.

H. Feng, X. Wang, Y. Duan, J. Zhang, and X. Zhang, "Applying blockchain technology to improve agri-food traceability: A review of development methods, benefits and challenges," Journal of Cleaner Production, vol. 260, p. 121031, 2020.

I. Abu-Elezz, A. Hassan, A. Nazeemudeen, M. Househ, and A. Abd-Alrazaq, "The benefits and threats of blockchain technology in healthcare: A scoping review," International Journal of Medical Informatics, vol. 142, p. 104246, 2020.

IBM and Maersk, "TradeLens: blockchain powered platform for supply chain innovation," IBM Documentation, 2018. https://www.ibm.com/docs/en/announcement_archive/ENUS218-524/ENUS218-524.PDF

J. Louw-Reimer, J. L. M. Nielsen, N. Bjørn-Andersen, and N. Kouwenhoven, "Boosting the effectiveness of containerised supply chains: A case study of TradeLens," in Maritime Informatics: Additional Perspectives and Applications, Cham: Springer International Publishing, 2021, pp. 95–115.

K. Almutairi, S. J. Hosseini Dehshiri, S. S. Hosseini Dehshiri, A. X. Hoa, J. A. Dhanraj, A. Mostafaeipour, and K. Techato, "Blockchain technology application challenges in renewable energy supply chain management," Environmental Science and Pollution Research, vol. 30, no. 28, pp. 72041–72058, 2023.

L. I. Malyavkina, A. G. Savina, and I. G. Parshutina, "Blockchain technology as the basis for digital transformation of the supply chain management system: benefits and implementation challenges," in Proc. 1st Int. Sci. Conf. Modern Management Trends and the Digital Economy: From Regional Development to Global Economic Growth (MTDE 2019), May 2019, pp. 10–15.

M. Berneis, D. Bartsch, and H. Winkler, "Applications of blockchain technology in logistics and supply chain management—insights from a systematic literature review," Logistics, vol. 5, no. 3, p. 43, 2021.

M. Jovanovic, N. Kostić, I. M. Sebastian, and T. Sedej, "Managing a blockchain-based platform ecosystem for industry-wide adoption: The case of TradeLens," Technological Forecasting and Social Change, vol. 184, p. 121981, 2022.

M. M. Queiroz, R. Telles, and S. H. Bonilla, "Blockchain and supply chain management integration: a systematic review of the literature," Supply Chain Management: An International Journal, vol. 25, no. 2, pp. 241–254, 2020.

N. C. K. Yiu, "Decentralizing supply chain anti-counterfeiting systems using blockchain technology," arXiv preprint, arXiv:2102.01456, 2021.

R. Cole, M. Stevenson, and J. Aitken, "Blockchain technology: implications for operations and supply chain management," Supply Chain Management: An International Journal, vol. 24, no. 4, pp. 469–483, 2019.

R. Kamath, "Food traceability on blockchain: Walmart's pork and mango pilots with IBM," The Journal of the British Blockchain Association, vol. 1, no. 1, 2018.

Rishan Digital, "Case Study 1: IBM Food Trust – Enhancing Food Traceability," RishanDigital.com, May 2025. https://rishandigital.com/blockchain/blockchain-case-studies-ibm-food-trust-maersk-etc/

S. Aich, S. Chakraborty, M. Sain, H. I. Lee, and H. C. Kim, "A review on benefits of IoT integrated blockchain based supply chain management implementations across different sectors with case study," in Proc. 21st Int. Conf. Advanced Communication Technology (ICACT), Feb. 2019, pp. 138–141.

S. F. Wamba and M. M. Queiroz, "Blockchain in the operations and supply chain management: Benefits, challenges and future research opportunities," International Journal of Information Management, vol. 52, p. 102064, 2020.

U. Kishnani, S. Madabhushi, and S. Das, "Blockchain in oil and gas supply chain: a literature review from user security and privacy perspective," in Proc. Int. Symp. Human Aspects of Information Security and Assurance, Cham: Springer, Jul. 2023, pp. 296–309.

V. Shrimangale, "Nestle's Blockchain Revolution: A Deep Dive into Supply Chain Transparency," Medium, Dec. 28, 2024. https://medium.com/@shrimangalevallabh789/nestles-blockchain-revolution-a-deep-dive-into-supply-chain-transparency-08c17c0ec097

W. A. Ahmed and A. Rios, "Digitalization of the international shipping and maritime logistics industry: a case study of TradeLens," in The Digital Supply Chain, Elsevier, 2022, pp. 309–323.