Sinergi International Journal of Logistics
E-ISSN: 2988-6244
Volume. 2, Issue 1, February 2024
Page No: 45-61

Unlocking the Potential of Blockchain for Secure and Efficient Global Supply Chains

Intan Tenisia Prawita Sari[1], Mohamad Iqbal Abdul Rauf[2], Agung Zulfikri[3]
[1]Universitas Pendidikan Indonesia, Indonesia
[2]Universitas Garut, Indonesia
[3]Universitas Telkom, Indonesia
Correspondent : intantenisia@upi.edu [1]

Received : January 4, 2024
Accepted : February 13, 2024
Published : February 29, 2024

Citation: Sari, I, T, P., Rauf, M, I, A,. & Zulfikri, A. (2024). Unlocking the Potential of Blockchain for Secure and Efficient Global Supply Chains. Sinergi International Journal of Logistics, 2(1), 45-61.

ABSTRACT: Blockchain technology is rapidly transforming global supply chain management by introducing new levels of transparency, traceability, and operational efficiency. This narrative review aims to evaluate the impact of blockchain integration on supply chain transparency across various sectors. Using a literature-based approach, studies were retrieved from leading databases such as Scopus, Google Scholar, and Web of Science, focusing on applications in food, pharmaceuticals, logistics, and sustainability. The results indicate that blockchain enhances traceability and transparency through decentralized ledgers, enabling real-time data access and reducing fraud, errors, and inefficiencies. Case studies show significant improvements in product tracking, cost reduction, and consumer trust, particularly when combined with technologies like IoT and smart contracts. However, challenges persist, including high implementation costs, limited technical skills, and unequal adoption between large firms and SMEs. Systemic issues such as regulatory uncertainty and lack of stakeholder collaboration further hinder implementation. The discussion highlights the role of public policy and data governance in facilitating adoption and calls for collaborative ecosystems that support blockchain deployment. Limitations in geographic scope, methodological design, and long-term impact assessment were identified, suggesting avenues for future research. Ultimately, blockchain holds significant promise for building sustainable, secure, and efficient supply chains, provided that structural barriers are addressed through targeted policy and inclusive innovation strategies.

Keywords: Blockchain Technology, Supply Chain Transparency, Traceability, Smart Contracts, Sustainable Supply Chains, Data Security, Adoption Challenges.

INTRODUCTION

Blockchain is a decentralized digital ledger technology that enables secure and transparent record-keeping across multiple participants in a network. Each transaction or data entry is recorded in a "block" and linked chronologically to previous blocks, forming a tamper-proof "chain" of information. This distributed nature ensures that no single party controls the data, increasing trust

and transparency. Transactions are validated by consensus mechanisms, such as proof-of-work or proof-of-stake, which ensure data integrity across the network. These features make blockchain particularly relevant for global supply chains, where complex networks of suppliers, manufacturers, and distributors require accurate, real-time data sharing across borders and entities.

The relevance of blockchain to supply chains lies in its ability to overcome common challenges such as data silos, fraud, counterfeiting, and traceability gaps. By offering a shared, immutable system of record, blockchain facilitates better coordination, compliance, and risk management among supply chain stakeholders.

Blockchain technology is rapidly transforming the landscape of global supply chain management (SCM), introducing an unprecedented level of transparency, trust, and efficiency. In contrast to traditional centralized models of supply chain operations that are often characterized by limited visibility, inefficiencies, and fragmented data systems, blockchain offers a decentralized infrastructure that ensures data immutability, traceability, and security across all stages of the supply chain. As digital transformation accelerates globally, blockchain has emerged as a core innovation enabling the modernization of SCM processes by allowing real-time, tamper-proof tracking of goods and transactions (Chowdhury et al., 2022; Khan et al., 2022).

The adoption of blockchain in supply chains is primarily motivated by its unique capability to facilitate trust among stakeholders. This trust is anchored in the decentralized and transparent nature of the technology, which mitigates information asymmetry and enhances collaboration. Each entity involved in the supply chain can access a unified, immutable ledger, ensuring consistent and verified data sharing. This enables stakeholders to track product provenance, verify compliance with safety and quality standards, and respond swiftly to issues such as product recalls or fraud (Rejeb et al., 2023; Rejeb et al., 2021; Melendez et al., 2024). Furthermore, the implementation of smart contracts within blockchain platforms automates agreements and streamlines processes, reducing administrative delays and manual errors (Khan et al., 2022).

Alongside these operational advantages, blockchain contributes significantly to advancing sustainability within supply chains. Its integration with the Internet of Things (IoT) enables comprehensive tracking of products from source to end-consumer, offering insights into resource utilization and environmental impact. Companies that adopt blockchain are better positioned to meet rising demands for sustainable practices and ethical sourcing. Studies have shown that transparency enabled by blockchain leads to higher levels of customer trust and improved brand reputation, especially in sectors where consumer consciousness around sustainability and ethics is growing (Wünsche & Fernqvist, 2022; Niesya & Sayeed, 2024; Ebinger & Omondi, 2020).

The urgency of increasing transparency in supply chains has been amplified by global disruptions such as the COVID-19 pandemic, which exposed deep vulnerabilities in existing SCM models. These events prompted organizations and governments alike to rethink traditional logistics systems and emphasize supply chain resilience. Heightened scrutiny of supply chain operations, particularly for critical sectors like pharmaceuticals and food, reflects a broader shift towards transparency and accountability. In response, blockchain has gained traction as a promising

solution to restore stakeholder confidence and improve systemic robustness (Ng et al., 2021; Rejeb et al., 2023; Alabaddi et al., 2023).

Current regulatory frameworks and market dynamics further underscore the relevance of blockchain in achieving compliance and operational excellence. The growing emphasis on environmental, social, and governance (ESG) performance has driven regulators to demand clearer disclosures regarding supply chain practices. Blockchain addresses these demands by providing real-time, verifiable data that enhances corporate accountability. Studies highlight that organizations investing in transparency tend to outperform their peers in customer satisfaction and market competitiveness (Li & Kassem, 2021; Jimenez-Castillo et al., 2023). Regulatory pressure in industries such as healthcare and food has particularly spurred blockchain adoption to meet traceability requirements.

The adoption of blockchain is also consistent with the principles of Industry 4.0, which prioritizes digital interconnectivity, automation, and data-driven decision-making. Blockchain enables seamless data integration across supply chain networks, allowing for predictive analytics and proactive risk management. For instance, the deployment of blockchain with AI and IoT can automate inventory management, demand forecasting, and logistics planning, thereby minimizing waste and improving responsiveness (Chang & Chen, 2020; Munir et al., 2022). These capabilities collectively position blockchain as a pivotal enabler of agile and intelligent supply chains.

Despite these promising developments, the implementation of blockchain within supply chain systems is not without challenges. One of the most prominent obstacles is the integration of blockchain with legacy IT systems. Many organizations operate on outdated digital infrastructure, making it difficult to incorporate blockchain without incurring significant transition costs. This challenge is compounded by resistance from internal stakeholders who may be wary of disruptions to established processes (Alabaddi et al., 2023; Chowdhury et al., 2022; Hauschild & Coll, 2023). Furthermore, while blockchain is known for its robust security, integrated systems can still be vulnerable to cyberattacks if not properly configured (Alharthi et al., 2020; Long et al., 2022).

Another pressing issue is the high cost of blockchain implementation. Although long-term gains in efficiency and transparency are anticipated, the initial investment required for technology acquisition, infrastructure setup, and personnel training can be prohibitive, particularly for small and medium-sized enterprises (SMEs) (Abdelaziz & Munawaroh, 2024; Cai et al., 2023). Research reveals that while SMEs have much to gain from blockchain transparency, they often lack the financial capacity to pursue such digital transformations (Faasolo & Sumarliah, 2021). In addition, complex legal and regulatory landscapes pose further barriers to implementation. Concerns related to data privacy laws, such as the European Union's General Data Protection Regulation (GDPR), can hinder the sharing and storage of transactional data on blockchain platforms (Wünsche & Fernqvist, 2022).

Moreover, the successful deployment of blockchain systems requires collective participation across the supply chain. However, the lack of trust among stakeholders remains a significant impediment to widespread adoption. Not all partners may be willing to share data transparently, even if the technology allows for secure and controlled access (Chowdhury et al., 2022; Wan et al., 2020; Dutta

et al., 2020). Addressing these behavioral and institutional barriers is essential for fostering an environment conducive to blockchain-enabled transparency (Alsmadi et al., 2023; Chang & Chen, 2020; Rejeb et al., 2023).

Existing literature on blockchain-enabled transparency in supply chains reveals several important gaps. While theoretical discussions are abundant, there is a lack of empirical studies demonstrating real-world applications of blockchain in diverse SCM contexts. Many articles discuss the potential of blockchain without providing concrete case studies or performance metrics that validate its practical effectiveness (Tayal et al., 2020; Ebinger & Omondi, 2020). Additionally, there is insufficient focus on the social and economic impacts of blockchain adoption, especially in developing economies where infrastructure and digital literacy remain limited (Ng et al., 2021; Bosco et al., 2024; Amirova et al., 2024).

This review aims to bridge these gaps by critically examining how blockchain technology can enhance transparency, accountability, and operational performance in supply chains. Specifically, the paper investigates blockchain's role in enabling traceability, automating transactions through smart contracts, improving compliance with regulatory frameworks, and promoting sustainability. By synthesizing findings from multidisciplinary sources, the study provides a comprehensive understanding of the enablers, barriers, and implications of blockchain integration in SCM (Philsoophian et al., 2021; Tran & Nguyen, 2021; Rejeb et al., 2021).

Furthermore, the study emphasizes the significance of blockchain adoption in sectors where transparency is particularly critical, such as agriculture, healthcare, and food. It explores the relationship between blockchain-driven information accuracy and consumer trust, as well as its implications for resource efficiency and environmental sustainability (Chandan et al., 2023; Zhou et al., 2024). This literature review also aims to offer practical insights for supply chain managers, policymakers, and stakeholders on leveraging blockchain to gain competitive advantage through enhanced supply chain transparency (Chowdhury et al., 2022; Wang et al., 2021).

The geographic scope of existing studies on blockchain in supply chain transparency is broad and varied, encompassing both developed and developing regions. Asia, particularly India and China, has received considerable attention due to its large agricultural and manufacturing sectors. Studies in India illustrate blockchain’s potential in enhancing traceability in food supply chains, while research in China explores its application in logistics and environmental monitoring (Wünsche & Fernqvist, 2022; Kumar & Kavuri, 2024; Niesya & Sayeed, 2024). In the United Kingdom, blockchain has been studied extensively in the pharmaceutical sector, where regulatory compliance and drug authenticity are top priorities (Ebinger & Omondi, 2020; Ding et al., 2024; Hauschild & Coll, 2023).

European countries such as Germany and France have explored blockchain applications in the fashion and textile industries, focusing on combating counterfeit goods and promoting ethical sourcing (Alsmadi et al., 2023). In Africa, emerging studies are evaluating blockchain’s role in palm oil and resource-based supply chains, highlighting its potential for promoting environmental stewardship and social equity (Archana & Gloth, 2024; Paul et al., 2021). Meanwhile, research in

North America and Western Europe has focused on blockchain in the healthcare sector, especially for managing vaccine distribution during public health emergencies (Kamble et al., 2018).

Collectively, these regional insights reveal a growing interest in blockchain as a transformative tool for supply chain transparency. However, the variation in technological readiness, regulatory environments, and stakeholder engagement across regions underscores the need for context-specific strategies for implementation. This paper aims to contribute to this evolving discourse by offering an integrative view of the current state of research and identifying pathways for future exploration in the adoption of blockchain in global supply chains.

METHOD

This study adopts a narrative review methodology to collect, synthesize, and interpret academic literature on the impact of blockchain technology on supply chain transparency. A narrative review is particularly suitable for examining complex and evolving topics such as blockchain applications in supply chain management (SCM), as it allows for flexible exploration of diverse research findings while providing a coherent interpretation of themes and insights. Unlike systematic reviews that strictly follow predefined protocols, narrative reviews are more interpretive and holistic, focusing on understanding the breadth and depth of existing knowledge and identifying conceptual patterns, theoretical developments, and contextual nuances.

To initiate the review, the authors formulated guiding research questions centered on how blockchain contributes to enhancing transparency in supply chains, what challenges arise during its implementation, and how different industries and regions have adopted this technology. Using these guiding questions, the literature search was conducted in major academic databases, including Scopus, Google Scholar, and Web of Science. These platforms were selected due to their comprehensive indexing of peer-reviewed journals, conference proceedings, and relevant scholarly literature across various disciplines. The review encompassed studies from multiple industry contexts such as agriculture, healthcare, logistics, and e-commerce, providing a wide lens through which the applications and implications of blockchain technology could be understood (Benabdellah et al., 2023; Chandan et al., 2023).

Keywords and Boolean operators were carefully chosen to ensure the breadth and relevance of the literature retrieved. Common search terms included combinations such as "Blockchain AND Supply Chain," "Transparency AND Blockchain AND Supply Chain," and "Traceability AND Blockchain." Other Boolean phrases like "Blockchain AND Transparency AND Risk Management" and "Sustainability AND Blockchain AND Supply Chain" were also employed to uncover studies related to risk mitigation, traceability, and environmental sustainability in supply chain systems (Avinash & Joseph, 2024; Rejeb et al., 2023).

The inclusion criteria for this narrative review were designed to capture relevant literature that provided meaningful insights into the integration of blockchain in supply chains. Eligible sources included peer-reviewed articles, case studies, and empirical research published in English between

2018 and 2024. Studies were selected based on their relevance to the research questions, the clarity of their findings, and their contribution to the broader discourse on transparency in supply chains. Articles that focused solely on the technical development of blockchain without discussing its supply chain implications or that lacked empirical or theoretical grounding were excluded.

After collecting the literature, the review process involved thematically organizing the studies to identify recurring themes, gaps in knowledge, and sector-specific applications. Thematic categories included blockchain characteristics (e.g., decentralization, immutability), benefits to supply chains (e.g., transparency, traceability, efficiency), implementation challenges (e.g., cost, integration, regulation), and industry-specific use cases. This process enabled the identification of key insights and patterns across a diverse array of studies (Li & Kassem, 2021; Wang et al., 2021).

Some reviewed articles utilized bibliometric methods to map the development of the research field and highlight influential publications, trends, and contributors. While the present study did not conduct a bibliometric analysis itself, insights from these articles enriched the contextual understanding of how blockchain research has evolved and where it is heading (Rejeb et al., 2021; Bosco et al., 2024).

Throughout the review, an interpretive approach was maintained to connect findings across disciplines and contexts. Studies were analyzed not just in terms of their findings, but also for how they framed the role of blockchain within broader supply chain challenges. Special attention was paid to regional differences in adoption, technological readiness, and regulatory environments, as these factors influence the practical feasibility and strategic benefits of blockchain integration (Munir et al., 2022; Ding et al., 2024; Alabaddi et al., 2023).

In conclusion, the narrative review methodology enabled a comprehensive and integrative examination of blockchain's potential to enhance transparency in supply chain systems. This approach allowed for an in-depth exploration of conceptual, empirical, and practical dimensions of blockchain adoption, providing a rich foundation for future research, policy development, and practical implementation strategies (Khan et al., 2022; Long et al., 2022).

RESULT AND DISCUSSION

Transparency and Traceability in Supply Chains

The reviewed literature consistently underscores the transformative role of blockchain technology in enhancing transparency and traceability within supply chains. Blockchain functions through a distributed ledger mechanism that records every transaction in a tamper-proof and chronologically ordered block. This technology allows all stakeholders within the supply chain to access identical, real-time data, thereby reducing the risks of fraud and data manipulation (Munir et al., 2022; Khan et al., 2022; Chowdhury et al., 2022). The real-time visibility afforded by blockchain not only increases trust among supply chain partners but also streamlines auditing and compliance processes. The digital trace created by blockchain facilitates the verification of product origin, movements, and handling conditions throughout the supply chain.

In the food industry, for instance, blockchain enables end-to-end product traceability from farm to table. Consumers can verify the origin, processing, and transportation of food products, thereby enhancing confidence in food safety and quality (Munir et al., 2022; Almasarweh et al., 2023). The integration of Internet of Things (IoT) devices further enriches blockchain records by feeding real-time data on temperature, humidity, and location into the ledger (Rejeb et al., 2019; Khan et al., 2022). This capability is critical for perishable goods, pharmaceuticals, and other time-sensitive products. Moreover, traceability through blockchain supports adherence to industry standards and regulatory frameworks, thus strengthening supply chain governance (Li et al., 2021).

Empirical studies have provided substantial evidence supporting the transparency benefits of blockchain. Companies that implemented blockchain reported significant improvements in product traceability and stakeholder access to relevant supply chain information (Aslam et al., 2023; Alabaddi et al., 2023). In the healthcare sector, blockchain deployment during the COVID-19 pandemic proved instrumental in authenticating vaccine distribution, mitigating counterfeit risks, and reinforcing public trust in healthcare systems (Ng et al., 2021; Niesya & Sayeed, 2024). Similarly, food industry case studies revealed that blockchain adoption enhanced brand reputation, reduced product recalls, and improved customer satisfaction (Melendez et al., 2024; Paul et al., 2021). Data from food and beverage companies suggest that transparency achieved through blockchain positively correlates with customer loyalty and financial performance (Wang et al., 2021; Almasarweh et al., 2023).

Overall, the transparency and traceability enabled by blockchain are not only critical for quality assurance but also for fostering trust among consumers, suppliers, and regulators. This transparency serves as a key competitive advantage in building sustainable and resilient supply chains (Khan et al., 2022; Chandan et al., 2023).

Operational Efficiency and Cost Reduction

Blockchain's contribution to operational efficiency and cost savings in supply chain management has emerged as a prominent theme in the literature. By automating processes, eliminating intermediaries, and improving data accuracy, blockchain significantly streamlines operations. Organizations utilizing blockchain report reduced transaction times and decreased reliance on manual documentation, leading to lower administrative costs (Philsoophian et al., 2021; Rejeb et al., 2021). One study documented that blockchain implementation in supply chains resulted in approximately 30% cost savings and a 40% increase in shipping process speed (Rejeb et al., 2021).

Access to real-time, accurate data enables all supply chain participants to coordinate more effectively, reducing verification time and enabling faster decision-making. The reduction in documentation errors and redundancies also enhances operational flow (Rejeb et al., 2023; Chandan et al., 2023). Organizations can better align supply and demand, optimize inventory levels, and respond swiftly to market fluctuations, thereby improving overall supply chain agility and resilience (Benabdellah et al., 2023; Wang et al., 2021).

Case studies highlight the effective use of smart contracts in automating logistics operations. In the shipping and logistics industry, smart contracts facilitate automated payments and goods release upon fulfillment of predefined conditions (Hauschild & Coll, 2023; Khan et al., 2022). In a documented case involving two leading logistics firms, blockchain was employed to automate

tracking and payment for shipments. When goods arrived at the port, the smart contract verified compliance and triggered payment without manual intervention, reducing processing time and error potential (Khan et al., 2022; Gomes et al., 2022).

In the travel industry, blockchain-enabled platforms have used smart contracts to manage ticketing transactions. These platforms automate ticket booking, validation, and refund processing, thereby improving customer experience and reducing back-office costs (Aslam et al., 2022). These successful implementations underscore blockchain's potential to enhance operational efficiency and reduce costs across a wide range of industries (Cao et al., 2023; Stranieri et al., 2021).

Data Security and Anti-Counterfeiting

The security features of blockchain technology offer substantial advantages for protecting data integrity in supply chains. Each transaction is encrypted and stored in a block that is linked to previous blocks through cryptographic hashes. Altering any part of the chain requires consensus across the entire network, making unauthorized data manipulation highly improbable (Chandan et al., 2023; Wang et al., 2021). These properties provide a robust framework for ensuring the authenticity of supply chain data and mitigating the risks of data breaches and fraud.

With blockchain, all supply chain participants share access to the same ledger, ensuring consistent and verifiable data across the network. Every modification is timestamped and logged, enabling audit trails that can quickly identify the origin of discrepancies or fraudulent activities (Rejeb et al., 2021; Stranieri et al., 2021). This level of transparency is especially crucial in industries where accuracy and accountability are paramount, such as food safety and pharmaceuticals.

Several studies have documented blockchain's effectiveness in combating counterfeit products. In the food industry, major corporations like Walmart and Nestlé have deployed blockchain systems to trace food origins from farm to shelf. Walmart reduced the time required to verify product origin from several days to mere seconds, thereby significantly enhancing consumer safety and trust (Chandan et al., 2023; Wang et al., 2021). Consumers now have the ability to verify product authenticity through blockchain-enabled QR codes, decreasing the likelihood of counterfeit items entering the supply chain.

The pharmaceutical industry has also seen notable success with blockchain adoption. Blockchain-enabled systems have been used to secure drug distribution channels and document every transaction in a tamper-proof manner (Paul et al., 2021; Rejeb et al., 2023). Smart contracts are deployed to ensure that medications are only transferred through authorized entities. Pharmaceutical companies report a marked reduction in counterfeit drug cases after integrating blockchain into their supply chains (Paul et al., 2021; Avinash & Joseph, 2024).

Moreover, the application of blockchain in electronic waste management and other sensitive sectors has further demonstrated its utility in enhancing product security and traceability. These cases affirm the critical role of blockchain in safeguarding supply chains against fraud and ensuring product authenticity, particularly in high-risk industries (Tayal et al., 2020; Stranieri et al., 2021).

Sustainability and Carbon Footprint

Blockchain has emerged as a powerful tool for supporting environmental sustainability efforts in supply chains, particularly by enabling detailed tracking and reduction of carbon emissions. Its

decentralized ledger system allows all parties within a supply chain to log and view emissions data, ensuring that environmental impacts are documented transparently and immutably. Studies have indicated that blockchain can support real-time carbon footprint accounting, allowing organizations to identify and address high-emission processes with precision (Al-Okaily et al., 2024).

Through blockchain-based systems, companies can monitor emissions at each stage of the product lifecycle—from raw material extraction to final delivery. This level of granularity enhances corporate accountability and supports compliance with increasingly stringent environmental regulations (Philsoophian et al., 2021; Rejeb et al., 2021). Several pilot projects have integrated blockchain with IoT-based sensors to capture real-time emissions data, providing companies with actionable insights to reduce their carbon footprint (Chandan et al., 2023).

Empirical evidence supports the effectiveness of blockchain in this domain. Firms adopting blockchain to monitor emissions have reported significant improvements in their sustainability metrics, facilitated by the ability to pinpoint emission sources and apply targeted interventions (Stranieri et al., 2021; Rejeb et al., 2023). In addition to internal benefits, this transparency enhances credibility with stakeholders and aligns with global carbon reduction initiatives.

Blockchain has also been effectively employed to support circular economy models and waste management. By tracking products throughout their lifecycle, blockchain systems ensure that materials designated for reuse or recycling are properly documented. This enhances the transparency of recycling processes and promotes compliance with environmental standards (Benabdellah et al., 2023; Long et al., 2022). In the fashion industry, for example, blockchain has been used to trace textile recycling, verifying that sustainable practices are followed at each stage (Aslam et al., 2022).

Moreover, blockchain facilitates electronic waste tracking, enabling secure and responsible disposal and recycling. In one initiative, blockchain technology was used to monitor discarded electronics, ensuring that they were processed by certified facilities and not diverted into illegal waste channels (Jimenez-Castillo et al., 2023; Wang et al., 2021). This transparency is particularly important for meeting international environmental protocols and protecting brand reputation.

A broader application lies in the carbon credit market, where blockchain enhances the integrity and efficiency of carbon trading systems. Smart contracts can automate the validation and execution of carbon offset transactions, ensuring that credits are issued and exchanged only when verifiable emissions reductions are achieved (Paul et al., 2021; Song et al., 2022). This contributes to a more reliable and scalable mechanism for incentivizing sustainable behavior across supply chains.

Technology Adoption and Implementation Challenges

Despite its numerous benefits, blockchain adoption in supply chains faces several barriers. Literature highlights both enabling and constraining factors influencing the technology's implementation. One of the most significant enablers is the increased transparency and accountability blockchain provides. A decentralized ledger accessible to all stakeholders builds trust and facilitates accurate decision-making, with over half of supply chain managers affirming

blockchain's potential to enhance operational efficiency (Philsoophian et al., 2021; Rejeb et al., 2023; Ng et al., 2021; Nabipour & Ülkü, 2021).

However, adoption is often impeded by high upfront costs, limited stakeholder understanding, and technical integration challenges. Establishing blockchain infrastructure and training personnel requires significant investment, which may be beyond the reach of many small and medium-sized enterprises (SMEs) (Balcıoğlu et al., 2024; Benabdellah et al., 2023). Transitioning from traditional systems to blockchain requires complex change management and may encounter resistance due to uncertainty and perceived risk (Aslam et al., 2022; Jimenez-Castillo et al., 2023).

Studies specifically addressing the adoption gap between large corporations and SMEs indicate that while the former can leverage abundant resources and IT expertise, the latter often struggle with access to capital and technical know-how. Prados-Castillo et al. (2023) found that SMEs typically face higher barriers due to financial constraints and lower digital readiness. Similar observations were made by Nabipour and Ülkü (2021), who noted that knowledge gaps and unclear cost-benefit expectations hinder technology uptake among smaller firms.

Addressing these disparities requires targeted support strategies, including training programs, stakeholder engagement, and financial incentives. Educational initiatives and collaborative platforms can play a pivotal role in improving awareness and fostering a culture of innovation. Khan et al. (2022) and Govindan (2022) argue that policy frameworks should prioritize inclusion, enabling SMEs to adopt blockchain without bearing disproportionate burdens.

Ultimately, bridging the adoption gap is critical for equitable and widespread blockchain integration. Without inclusive strategies, the transformative potential of blockchain for enhancing transparency and efficiency across global supply chains may remain limited to resource-rich entities. Future research and policy development must therefore consider the varied capacities of different actors within the supply chain ecosystem (Rejeb et al., 2023; Song et al., 2022).

The findings of this review illustrate a growing consensus in the literature regarding the role of blockchain in enhancing supply chain transparency and operational resilience. Yet, this technological potential cannot be separated from the larger institutional and systemic factors that either facilitate or hinder its implementation. One of the key linkages highlighted is between blockchain adoption and the existing regulatory landscape. Tran and Nguyen (2021) as well as Rejeb et al. (2021) argue that without supportive public policies and clear regulatory frameworks, the adoption of blockchain may remain fragmented or limited to a few large firms. Particularly in critical sectors such as food and pharmaceuticals, regulatory guidance is vital to standardize the implementation of blockchain for traceability and quality assurance. Governments can accelerate adoption by introducing fiscal incentives, such as tax breaks or subsidies, aimed at reducing the entry barriers for companies adopting blockchain solutions (Bosco et al., 2024).

A supportive regulatory environment must also address data privacy and cybersecurity. Trust in blockchain systems hinges not only on technological reliability but also on legal assurances regarding data ownership, storage, and protection. Philsoophian et al. (2021) and Benabdellah et al. (2023) emphasize that stricter rules on data usage in blockchain platforms can mitigate stakeholder concerns and encourage broader adoption. This is especially important in jurisdictions

governed by data protection laws such as GDPR, where non-compliance can have serious legal and financial repercussions.

While regulatory support is essential, literature also draws attention to systemic inequalities in blockchain adoption, particularly between large corporations and small-to-medium enterprises (SMEs). Wang et al. (2021) and Chandan et al. (2023) found that larger firms often possess the capital, infrastructure, and technical expertise to seamlessly adopt blockchain, while SMEs are constrained by limited financial resources and a lack of technological know-how. Bosco et al. (2024) further argue that this digital divide may worsen if policies and capacity-building programs do not specifically target SME participation.

Li and Kassem (2021) confirm that larger enterprises are typically better equipped to respond to technological change, which enables them to experiment with and scale up blockchain applications more rapidly. This creates a potential risk of monopolization of blockchain benefits unless smaller firms are supported through subsidized access to blockchain platforms and dedicated training programs. To address these disparities, researchers such as Nabipour and Ülkü (2021) and Rejeb et al. (2023) recommend national and regional initiatives that build awareness and technical capacity among SMEs. Training in digital skills and regulatory compliance, coupled with collaborative infrastructure such as blockchain consortia, can help reduce these barriers.

Collaboration among stakeholders is another vital systemic factor influencing the success of blockchain adoption. The technology's distributed nature inherently relies on the participation and coordination of multiple actors across the supply chain. Rejeb et al. (2021) point out that blockchain implementation requires a shared commitment from all stakeholders, as it demands transparency, data sharing, and a reconfiguration of traditional workflows. When collaboration is weak or fragmented, it can create resistance to change and limit the system-wide benefits of blockchain.

Stranieri et al. (2021) support this by emphasizing the importance of cross-sector partnerships, particularly between public and private institutions, in facilitating blockchain integration. Government involvement can provide a regulatory sandbox for testing blockchain solutions and foster an innovation-friendly environment. These partnerships are especially valuable in high-stakes sectors such as healthcare, where Ng et al. (2021) documented how multi-stakeholder collaboration during the COVID-19 pandemic enabled efficient and secure vaccine distribution through blockchain platforms.

Chandan et al. (2023) further underscore the role of stakeholder collaboration in the food industry. Their study revealed that shared platforms between producers, distributors, and consumers significantly enhanced supply chain visibility, sustainability reporting, and consumer trust. Active participation from all nodes in the supply chain enabled real-time verification of product origin and compliance with environmental standards, demonstrating how blockchain and collaboration together foster more transparent and ethical business practices.

To strengthen collaborative efforts, Aslam et al. (2022) recommend policy instruments such as cross-sectoral incentives and public-private partnerships that encourage blockchain experimentation and knowledge-sharing. Initiatives such as industry consortia, joint ventures, and

innovation hubs can help harmonize blockchain architectures across firms, reducing fragmentation and lowering the cost of implementation.

In analyzing existing literature, several limitations become apparent. One of the most prominent is the geographical concentration of research. Studies tend to be heavily skewed toward developed countries in North America and Europe, while there is a paucity of research on blockchain adoption in developing economies. Al-Okaily et al. (2024) and Chandan et al. (2023) caution that this restricts our understanding of the unique infrastructural, regulatory, and cultural barriers faced by firms in emerging markets. Without inclusive geographical representation, blockchain research risks offering solutions that are misaligned with the needs of diverse global supply chain actors.

Methodologically, most studies reviewed employed qualitative approaches based on small sample sizes, limiting the generalizability of findings. While interviews and case studies offer valuable insights, they often lack the statistical robustness needed for large-scale policy decisions. Ng et al. (2021) and Philsoophian et al. (2021) argue that a reliance on qualitative data may underrepresent the full complexity of blockchain adoption drivers. Future research could benefit from employing mixed-methods designs, integrating survey-based quantitative data with in-depth qualitative case studies to yield more comprehensive insights.

Another significant gap lies in the short-term orientation of much existing research. While numerous studies document immediate benefits of blockchain adoption, such as reduced costs and increased process efficiency, few investigate its long-term implications for economic sustainability, environmental impact, or social equity. Rejeb et al. (2021) and Stranieri et al. (2021) note the lack of longitudinal studies tracking blockchain's performance over time, especially in the context of evolving supply chain dynamics and regulatory landscapes.

To bridge these gaps, future research should focus on cross-regional comparative studies, particularly in regions like Southeast Asia, Latin America, and Africa, where supply chains are rapidly evolving. Long et al. (2022) and Chandan et al. (2023) advocate for research that accounts for local institutional contexts and tailors blockchain applications accordingly. Furthermore, collaborative research efforts involving academia, industry, and government can help generate actionable insights and practical guidelines for blockchain deployment.

There is also a need for research that explores blockchain's compatibility with broader sustainability goals. Paul et al. (2021) and Wang et al. (2021) suggest that blockchain could be a catalyst for achieving circular economy objectives, yet empirical evaluations of this potential remain limited. Studies should investigate how blockchain systems can be designed to support not just economic efficiency but also environmental stewardship and social inclusion. In sectors such as agriculture and energy, Ketbi et al. (2021) and Aslam et al. (2022) argue that blockchain could enable transparent resource tracking and equitable access, but these claims must be tested through rigorous empirical analysis.

Finally, Sharma et al. (2023) and Benabdellah et al. (2023) highlight the importance of interdisciplinary research that integrates insights from supply chain management, information systems, public policy, and sustainability science. As blockchain technology evolves, it will intersect with emerging domains such as artificial intelligence, IoT, and big data analytics. Future studies

must anticipate and examine these intersections to provide forward-looking guidance for blockchain governance and innovation within supply chains.

CONCLUSION

This review highlights the transformative potential of blockchain technology in addressing long-standing challenges within supply chain management, particularly in enhancing transparency, improving operational efficiency, ensuring data security, and supporting sustainability goals. The integration of blockchain significantly improves traceability and accountability across supply chain networks by enabling real-time, immutable data sharing among stakeholders. These improvements are not only instrumental in reducing fraud and operational delays but also play a critical role in promoting consumer trust and regulatory compliance.

Despite its potential, blockchain adoption remains uneven, with significant gaps between large corporations and SMEs. Barriers such as high implementation costs, limited technical expertise, and regulatory uncertainty hinder widespread uptake. Furthermore, successful adoption is often contingent upon cross-sector collaboration and supportive public policies. This underscores the urgent need for targeted interventions, including capacity-building programs for SMEs, fiscal incentives, and robust data governance frameworks to foster inclusive blockchain integration.

Future research should address current limitations in the literature by incorporating geographically diverse case studies, adopting mixed-method approaches, and exploring long-term sustainability impacts. In particular, studies that evaluate blockchain's role in circular economy initiatives and equitable supply chain governance are critical for advancing the field.

In summary, this review underscores the transformative power of blockchain in enhancing supply chain transparency, efficiency, and resilience. The technology’s core attributes—decentralization, immutability, and real-time data access—enable secure product tracking, automated compliance, and reduced operational friction. However, implementation gaps remain, especially in developing regions and small enterprises. Addressing these disparities through inclusive policies, technical support, and collaborative frameworks will be essential to fully realize blockchain’s potential.

Looking ahead, blockchain is expected to evolve beyond traceability into broader applications, such as AI-driven predictive analytics, dynamic pricing models, and real-time carbon footprint tracking. As blockchain ecosystems mature, integration with emerging technologies like quantum computing and edge AI could further optimize global supply chain performance. Future developments will depend not only on technological innovation but also on institutional trust, governance maturity, and the willingness of global actors to embrace transparency as a competitive asset.

REFERENCE

Abdelaziz, R., & Munawaroh, H. (2024). *Blockchain for transparency: A study of adoption readiness in SMEs*. Journal of Supply Chain Innovation, 12(1), 33–48.

Alabaddi, A., Rejeb, A., & Keogh, J. (2023). Blockchain technology for supply chain resilience: A post-pandemic assessment. *International Journal of Logistics Management*, 34(1), 21–43.

Alharthi, A., Alrashed, S., & Alfarraj, O. (2020). Blockchain-based supply chain for digital transformation: A cyber risk perspective. *Journal of Cyber Security Technology*, 4(4), 227–242.

Almasarweh, A., Omar, A., & Khan, S. (2023). Enhancing food safety through blockchain-enabled traceability. *Food Supply Chain Journal*, 15(2), 88–102.

Al-Okaily, M., Obeidat, A., & Harasis, A. (2024). Real-time carbon accounting with blockchain: Evidence from emerging markets. *Sustainability Accounting Review*, 9(1), 12–30.

Alsmadi, I., & Gebauer, H. (2023). Ethical sourcing through blockchain: The fashion industry perspective. *Journal of Business Ethics and Technology*, 6(3), 201–219.

Amirova, M., Zhukova, E., & Idrisova, L. (2024). Blockchain and transparency in developing economies: An assessment framework. *Global Economic Review*, 49(2), 165–180.

Archana, R., & Gloth, F. (2024). Blockchain for sustainability in palm oil supply chains. *African Journal of Environmental Economics*, 7(1), 44–59.

Aslam, J., Khan, M., & Thomas, M. (2022). Smart contracts in tourism supply chains: Efficiency and customer satisfaction. *Tourism Innovation Journal*, 8(4), 213–225.

Aslam, J., Wang, Y., & Lee, H. (2023). Blockchain implementation in healthcare: Challenges and opportunities. *International Journal of Health Management*, 11(2), 87–101.

Avinash, V., & Joseph, M. (2024). Blockchain and data governance: Supply chain perspectives. *Journal of Digital Policy & Governance*, 10(1), 23–37.

Balcıoğlu, B., & Karaca, S. (2024). Barriers to blockchain adoption in SMEs: A case study approach. *Small Business and Technology Journal*, 9(2), 62–78.

Benabdellah, A., Faizi, R., & El Afia, A. (2023). The integration of blockchain and sustainability metrics in supply chains. *Journal of Green Logistics*, 14(1), 51–65.

Bosco, S., Malik, A., & Zheng, F. (2024). Blockchain and the circular economy: A systematic mapping review. *Journal of Sustainable Supply Chain Management*, 16(1), 103–119.

Cai, H., Xu, L., & Zhang, Y. (2023). Blockchain-based logistics platform: Challenges for SMEs. *Journal of Transportation and Logistics*, 19(3), 99–112.

Chandan, R., Goh, M., & Soh, K. (2023). Blockchain-enabled transparency in agri-food supply chains: A review. *Journal of Agribusiness and Technology*, 12(2), 67–85.

Chang, V., & Chen, H. (2020). Intelligent logistics through blockchain and AI integration. *Future Internet*, 12(11), 176. https://doi.org/10.3390/fi12110176

Chowdhury, M., Paul, A., & Ali, M. (2022). Blockchain for modern SCM: A review. *International Journal of Information Management*, 62, 102439.

Ding, Y., Zhang, L., & Li, X. (2024). Blockchain adoption in the UK pharma sector: Regulatory and trust factors. *European Journal of Pharmaceutical Policy*, 5(2), 130–145.

Dutta, P., Choi, T. M., & Bilsel, R. (2020). Blockchain applications in global supply chains: A framework. *Annals of Operations Research*, 290(1), 77–99.

Ebinger, F., & Omondi, J. (2020). Enhancing public sector transparency through blockchain. *Journal of Public Administration and Digital Innovation*, 3(1), 22–39.

Faasolo, H., & Sumarliah, E. (2021). The digital divide and blockchain adoption in developing countries. *Journal of Innovation and Development Studies*, 7(3), 44–59.

Gomes, R., Patel, D., & Wong, J. (2022). Blockchain automation in logistics payments. *Logistics & Tech Review*, 9(2), 119–132.

Hauschild, M., & Coll, P. (2023). Smart contracts and process automation in European logistics. *Journal of Operational Technologies*, 18(2), 78–93.

Jimenez-Castillo, D., Ruiz-Mafe, C., & Sanz-Blas, S. (2023). Blockchain for sustainable brands: Customer perspectives. *Journal of Brand Sustainability*, 5(1), 101–115.

Kamble, S., Gunasekaran, A., & Dhone, N. (2018). Blockchain and IoT integration in vaccine supply chains. *Computers in Industry*, 105, 48–63.

Ketbi, S., Al Falasi, S., & Khan, S. (2021). Blockchain and renewable energy supply chains. *Energy Economics Journal*, 13(2), 122–136.

Khan, S. A., Loukil, F., & Yousaf, A. (2022). Blockchain applications in SCM: A systematic review. *Technological Forecasting and Social Change*, 176, 121469.

Kumar, R., & Kavuri, M. (2024). Blockchain for food safety: The India experience. *Asian Journal of Food Regulation*, 9(1), 56–72.

Li, C., & Kassem, M. (2021). Drivers of blockchain adoption in construction supply chains. *Automation in Construction*, 125, 103653.

Long, X., Wang, J., & Zhang, T. (2022). Blockchain integration with IoT for sustainable logistics. *International Journal of Production Economics*, 247, 108424.

Melendez, P., Garcia, M., & Hasan, M. (2024). Enhancing brand trust through blockchain: Food sector applications. *Consumer Behavior and Tech Journal*, 11(3), 45–63.

Mohammad, W. (2023). The role of AI Waifu characters in supporting Weaboos with Post-Traumatic Relationship Syndrome (PTRS). *Sinergi International Journal of Education*, 1(2), 77–96.

Munir, M., Azam, A., & Hassan, S. (2022). Blockchain and IoT convergence in SCM. *Sensors*, 22(5), 1901. https://doi.org/10.3390/s22051901

Nabipour, M., & Ülkü, M. A. (2021). Blockchain adoption by SMEs: Institutional perspectives. *International Journal of Innovation Management*, 25(3), 2150021.

Ng, I. C., Wakenshaw, S. Y. L., & Wei, J. (2021). Blockchain in vaccine supply chains: Case insights. *Health Information Science and Systems*, 9(1), 34.

Niesya, R., & Sayeed, A. (2024). Sustainable traceability through blockchain in food systems. *Journal of Sustainability in Agriculture*, 8(2), 70–88.

Paul, J., Zhang, X., & Choi, J. (2021). Anti-counterfeiting via blockchain in pharma and food. *Technovation*, 102, 102213.

Philsoophian, M., Razi, M., & Navid, A. (2021). Blockchain and supply chain efficiency: A conceptual review. *Journal of Logistics Research*, 13(4), 89–107.

Prados-Castillo, J., Moreno, P., & Lopez, D. (2023). Barriers to blockchain adoption in small firms: A survey study. *Journal of Emerging Technologies*, 17(1), 33–49.

Rejeb, A., Simske, S., Keogh, J. G., & Zailani, S. (2019). Blockchain for traceability in Industry 4.0: A review. *International Journal of Production Research*, 57(7), 2117–2135.

Rejeb, A., Simske, S., Keogh, J. G., & Treiblmaier, H. (2021). Blockchain technology in the smart city: A bibliometric review. *Cities*, 113, 103228.

Rejeb, A., Keogh, J. G., & Zailani, S. (2023). Blockchain and sustainable SCM: A literature review. *Journal of Cleaner Production*, 362, 132403.

Sharma, M., Devi, S., & Kumar, V. (2023). The interdisciplinary future of blockchain research. *Technological Innovations Review*, 9(2), 150–170.

Song, Y., Gao, Y., & Li, X. (2022). Blockchain for carbon trading systems: Smart contracts and validation. *Environmental Economics and Policy Studies*, 24(3), 513–528.

Stranieri, S., Riccardi, F., & Mele, E. (2021). Blockchain applications for circular economy: Case studies. *Sustainability*, 13(4), 2264.

Tayal, S., Yadav, S., & Kataria, A. (2020). Blockchain in global trade compliance: A conceptual framework. *Journal of International Trade Law and Policy*, 19(2), 123–137.

Tran, D. T., & Nguyen, H. T. (2021). Regulatory issues in blockchain-based supply chains. *Asian Journal of Law and Technology*, 6(1), 44–59.

Wang, Y., Han, J. H., & Beynon-Davies, P. (2021). Understanding blockchain for future SCM. *International Journal of Operations & Production Management*, 41(3), 163–183.

Wünsche, S., & Fernqvist, F. (2022). Blockchain and consumer trust in ethical sourcing. *Journal of Retail and Consumer Services*, 65, 102870.