

Blockchain-Based Innovations in Logistics and Supply Chain Management

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Abstract

Abstract—Blockchain technology has emerged as a transformative force in logistics and supply chain management, enhancing transparency, security, and efficiency. This survey explores eight recent research papers focusing on various blockchain applications in logistics, including container tracking, real-time monitoring, IoT integration, smart contracts, artificial intelligence-driven logistics, and security improvements. By analyzing methodologies, key findings, advantages, and limitations, this paper provides an in-depth review of blockchain's impact on modern supply chains. The survey also presents a comparative analysis of these studies, highlighting existing challenges and future research opportunities.

1 Introduction

Logistics and supply chain management are critical components of modern economies, ensuring seamless transportation and delivery across industries. However, traditional systems face challenges such as inefficiencies, fraud, lack of transparency, and high operational costs. Blockchain technology, with its decentralized, tamper-proof, and transparent nature, has been proposed as a solution to address these issues. This paper surveys eight research studies that explore blockchain-based innovations in logistics and supply chain management.

The studies explore various aspects, including container tracking, logistics optimization, fraud prevention, real-time monitoring, smart contracts, decentralized IoT platforms, and high-value shipment security. Each paper contributes unique insights into how blockchain enhances traceability, improves operational efficiency, and mitigates risks such as fraud, data tampering, and inefficient manual processes.

1.1 Key themes in Blockchain-Based Supply Chain Management:

Recent research has explored the adoption of blockchain in various supply chain domains, including maritime logistics, perishable goods tracking, product authentication, and high-value shipment management. These studies highlight blockchain's ability to automate processes, improve traceability, and reduce inefficiencies. Despite its potential, blockchain adoption still faces challenges such as high implementation costs, scalability limitations, and regulatory uncertainties.

- **Transparency and Security:** Blockchain ensures immutable, decentralized records, reducing fraud and improving accountability in logistics.
- **Integration with IoT & AI:** IoT sensors provide real-time tracking, while AI optimizes route planning and predictive logistics.
- **Smart Contracts:** Automated contracts streamline operations by enforcing agreements

without intermediaries.

- Scalability and Challenges: High computational costs, network latency, and integration complexity remain key hurdles in large-scale blockchain applications.
- Operational Efficiency: Blockchain enhances tracking, reduces delays, and improves resource allocation across supply chains.

The increasing complexity of global supply chain networks has necessitated the adoption of advanced technologies to ensure transparency, security, and efficiency. Blockchain technology has emerged as a transformative force in logistics, enabling secure, decentralized, and tamper-proof data sharing among stakeholders. With the integration of the Internet of Things (IoT), artificial intelligence (AI), and machine learning (ML), blockchain-based supply chain management systems are revolutionizing industries such as shipping, food distribution, retail, and smart city logistics.

2 Literature review

The impact of blockchain and RFID technology on clothing logistics is another area of research. This study explores how blockchain can improve product traceability, reduce counterfeit goods, and streamline inventory management. By integrating smart contracts, retailers can automate transactions and minimize manual intervention. RFID tags enable real-time tracking of garments, ensuring that supply chain participants have accurate inventory data. Despite these benefits, the study highlights challenges related to data privacy and RFID adoption costs, which may deter smaller retailers from implementing the technology.

A decentralized IoT-based logistics tracking system utilizing blockchain is proposed in another study. The research presents a multi-sensor approach where IoT devices capture data on product movement, environmental conditions, and handling procedures. This information is stored on a blockchain network, ensuring data transparency and security. The findings

reveal that such systems enhance logistics efficiency, reduce human errors, and prevent data tampering. However, the study also points out the limitations of blockchain scalability and the energy consumption of IoT devices, which can impact long-term feasibility.

Finally, blockchain's potential in managing high-value shipments within smart cities is explored in a study that examines privacy-focused and scalable logistics solutions. The research presents a blockchain-based model that enhances shipment security, ensures data confidentiality, and improves operational efficiency. The findings suggest that blockchain can significantly reduce supply chain fraud, improve regulatory compliance, and enhance trust among logistics participants. However, the study identifies integration costs and complex data management as key barriers to adoption, particularly for urban logistics networks.

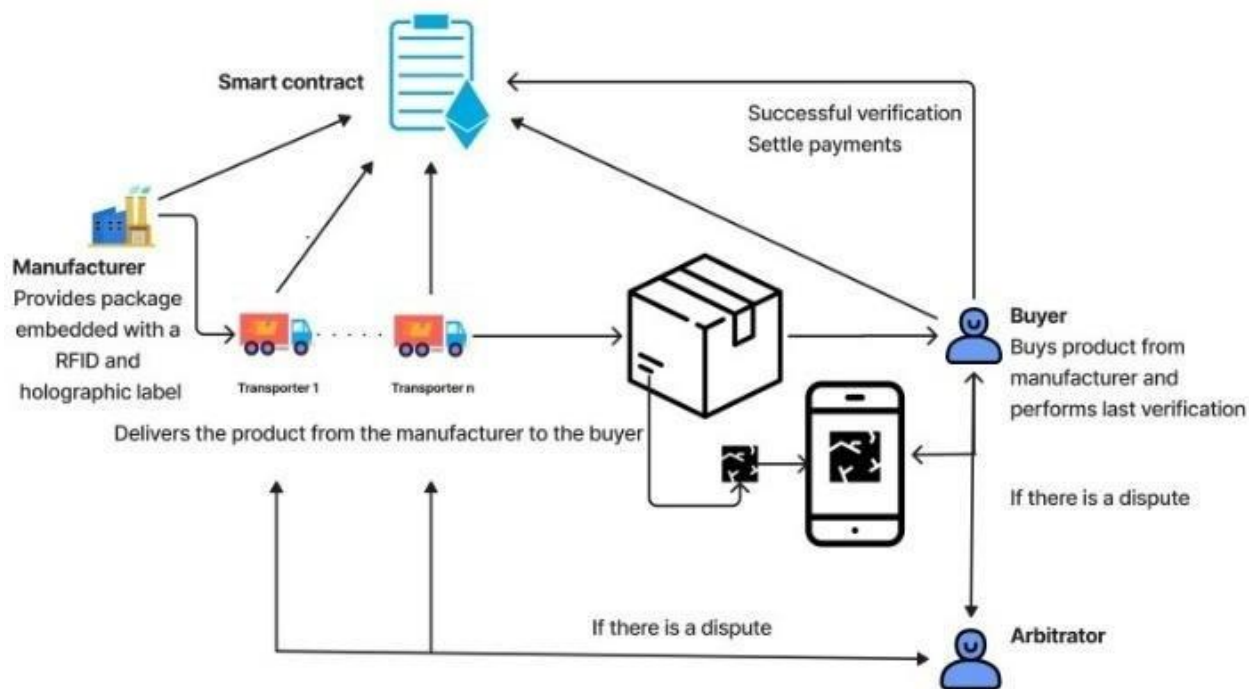


Figure 1: 1: Blockchain-Based Supply Chain Verification Using Smart Contracts

These studies collectively demonstrate the transformative potential of blockchain in supply chain management. While blockchain enhances transparency, security, and efficiency, its adoption is hindered by technical challenges, scalability issues, and regulatory constraints.

Future research should focus on addressing these limitations by developing scalable blockchain solutions, integrating AI for enhanced decision-

making, and establishing regulatory frameworks to facilitate widespread adoption across industries. The integration of blockchain technology into supply chain management has been explored extensively, focusing on its role in enhancing transparency, security, and efficiency. Various studies have demonstrated blockchain's capability to address critical challenges in logistics, including fraud, inefficiencies, and lack of traceability. One study at the CASA Port terminal showcases how blockchain, combined with IoT and smart contracts, improves container tracking, reduces fraud, and enhances coordination between stakeholders. The research highlights how blockchain's immutable ledger ensures data integrity but also points out the complexity of integration and regulatory challenges. Another study focuses on optimizing logistics using blockchain and AI, employing CNN and ACO algorithms for predictive route planning. Results indicate significant efficiency gains, including a 15% improvement in delivery speed and a 25% reduction in security breaches. However, computational costs and scalability remain concerns for smaller enterprises. The role of blockchain in product authentication and fraud prevention is another critical area of research. By linking physical assets to blockchain records, companies can ensure product authenticity, preventing counterfeiting. While blockchain enhances trust, high implementation costs and the absence of regulatory standards hinder widespread adoption. A study on perishable goods logistics explores blockchain's potential in real-time monitoring of food storage conditions. By integrating IoT sensors, the study finds improved food safety and reduced spoilage. However, challenges related to large data storage and blockchain's processing limitations necessitate hybrid solutions. Blockchain's application in the fashion industry has also been studied, with a focus on improving inventory management and anti-counterfeiting efforts through RFID and smart contracts.

Blockchain technology has revolutionized supply chain management by introducing transparency, security, and efficiency in various logistics and tracking systems. Several

studies have explored its implementation across different domains, including container tracking, perishable goods logistics, smart contracts, and IoT-based supply chains. This section critically reviews and analyses the key contributions of previous research, highlighting their methodologies, findings, and limitations.

2.1 Blockchain-Based Container Tracking in Port Logistics

Nasih et al. (2024) conducted an extensive study on blockchain-based container tracking at the CASA Port terminal, addressing inefficiencies in container storage, reception, and delivery. The study revealed that maritime operators faced significant challenges in coordinating logistics due to a lack of transparency and real-time tracking. The researchers proposed an IoT-integrated blockchain model that enabled stakeholders to access immutable data related to container movements, reducing fraud, errors, and operational delays. While the implementation of blockchain ensured secure data sharing, the study acknowledged potential scalability issues, especially in integrating IoT with decentralized systems. The findings aligned with earlier research on blockchain's role in port security but emphasized the need for policy reforms to streamline blockchain adoption in large-scale logistics.

2.2 Optimization of Logistics Using Blockchain and AI

Balfaqih et al. (2023) explored the integration of Convolutional Neural Networks (CNN) and Ant Colony Optimization (ACO) algorithms with blockchain technology to optimize logistics operations. Their model improved delivery efficiency by 15% and reduced inventory management errors by 12%. The study highlighted that blockchain enhances supply chain transparency, but its computational overhead when combined with AI-driven route optimization poses a challenge. Despite its advantages, the study pointed out that high-performance computing infrastructure is essential for real-time AI-based logistics, making large-scale deployment difficult. However, the research effectively demonstrated how AI and blockchain together can minimize costs and delays in logistics, setting the foundation for

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future AI-driven supply chain models.

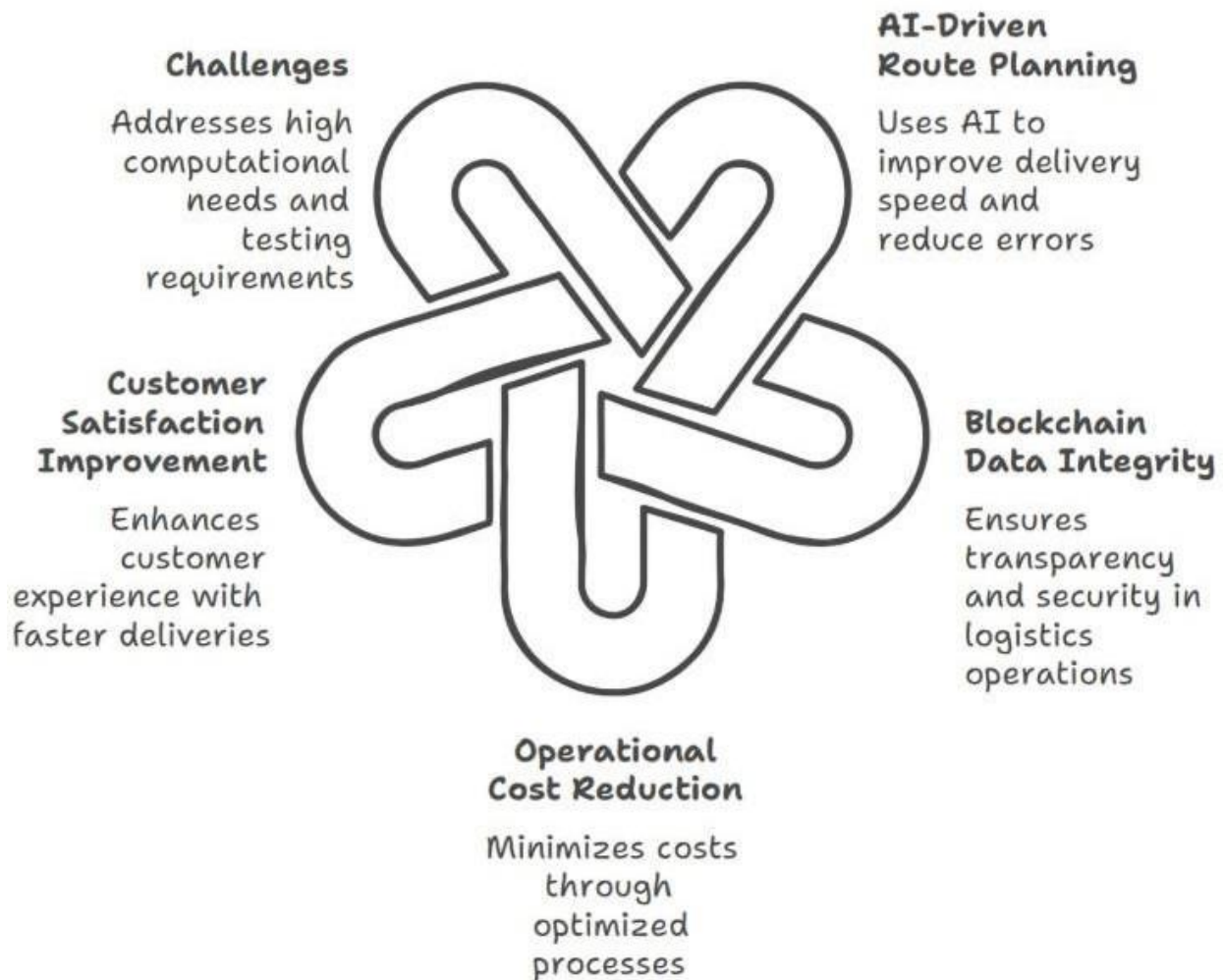


Figure 2: e 2: Enhancing Logistics with Blockchain and AI

2.3 Blockchain Implementation in Product Circulation and Supply Chains

Islam et al. (2024) provided a systematic review of blockchain's application in product circulation, particularly focusing on fraud prevention, property registration, and verification. The paper discussed how traditional tracking methods were vulnerable to manipulation, whereas blockchain's decentralized architecture ensured data immutability. The researchers underscored the importance of linking digital tokens to physical assets, enabling secure

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and verifiable transactions. Despite its transformative potential, the study noted adoption barriers, such as the complexity of integrating blockchain with legacy supply chain management systems. This work built upon existing RFID-based tracking systems, proposing blockchain as an enhancement to existing verification models rather than a replacement.

2.4 Real-Time Tracking and Secure Identification in Perishable Goods Logistics

Bhutta et al. (2021) proposed a blockchain and IoT-based framework for tracking perishable goods, integrating machine learning algorithms such as Support Vector Machines (SVM) and Random Forest (RF) to predict backorder cases. The study showed that blockchain could preserve food safety by maintaining immutable records of temperature, humidity, and storage conditions, thus preventing food spoilage.

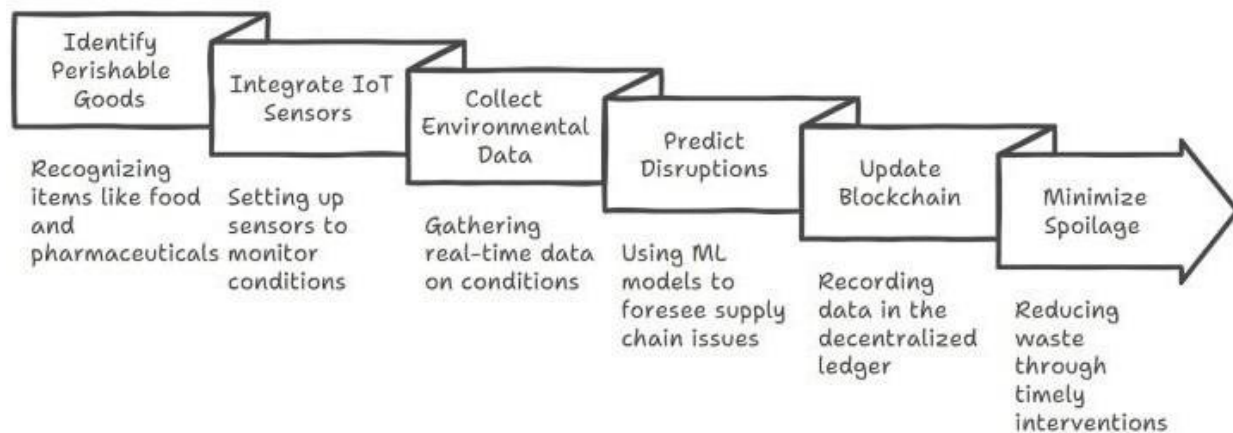


Figure 3: Blockchain-Based Perishable Goods Tracking
However, the research pointed out the energy-intensive

nature of IoT devices and the challenges of ensuring uninterrupted network coverage. The model effectively addressed supply chain bottlenecks but required further optimization to scale efficiently across different regions with varying infrastructure capabilities. Compared to prior research, this study uniquely combined predictive analytics with blockchain, ISBN:97881-19905-39-3

demonstrating its potential in preventing supply chain disruptions.

2.5 RFID and Blockchain Integration in Clothing Logistics

Tsai et al. (2017) examined how blockchain and RFID technology could be leveraged to improve logistics in the fashion industry. Their study focused on automating product tracking using smart contracts, ensuring that transactions and inventory updates were conducted without manual intervention.

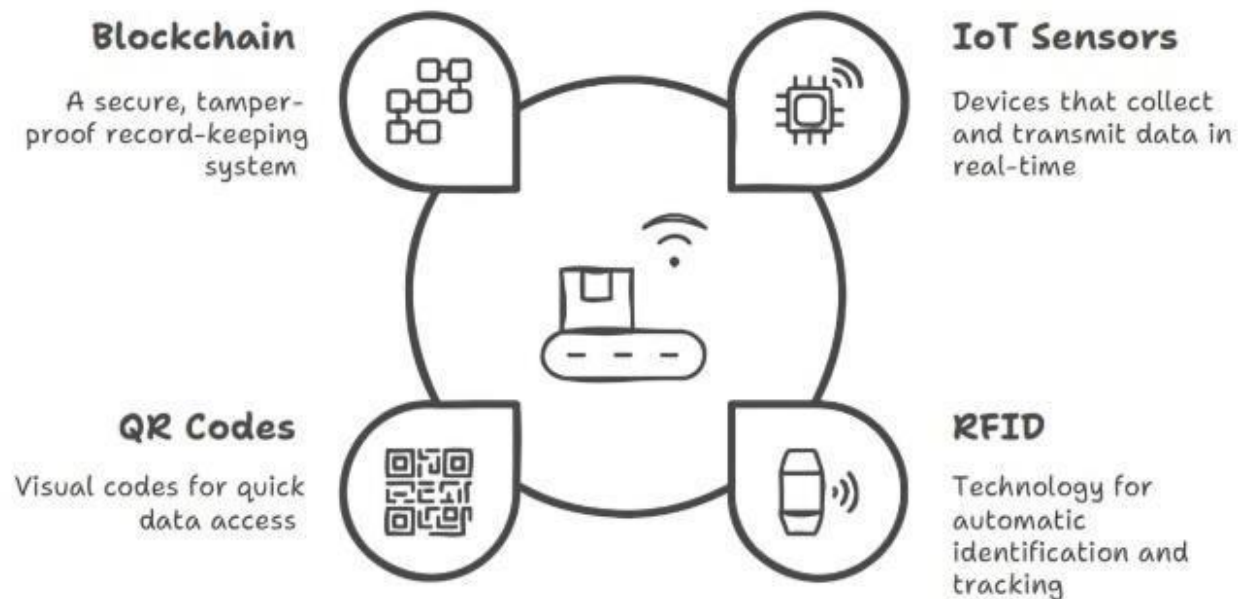


Figure 4: 4: Integration of Technologies for Enhanced Logistics

The research highlighted that blockchain reduced counterfeit goods by enabling consumers to verify product authenticity through immutable transaction records. However, a key limitation was the high cost of RFID adoption, which prevented small retailers from implementing the technology. The paper also emphasized data privacy concerns, as RFID tracking could potentially expose sensitive supply chain data. This study reinforced earlier findings on RFID's benefits but provided new insights into how blockchain could mitigate fraud in luxury goods markets.

2.6 IoT and Blockchain-Based Logistics Tracking System

El Midaoui et al. (2021) introduced a decentralized IoT and blockchain-based logistics tracking system incorporating multi-sensors, QR codes, and RFID technology. Their model aimed to enhance supply chain visibility by collecting real-time data on environmental conditions such as temperature, light, humidity, and vibration. The study found that blockchain significantly improved product traceability in industries like pharmaceuticals and cold chain logistics, preventing counterfeit and substandard products from

entering the supply chain. However, the researchers acknowledged scalability challenges, particularly concerning blockchain's storage limitations and high energy

consumption. Despite these concerns, their model demonstrated practical applications in logistics where real-time monitoring and data integrity were critical.

3 Comparative Analysis

Comparative Analysis of Blockchain-Based Logistics and Supply Chain Solutions :

4 Discussions

The integration of blockchain into logistics and supply chain management has demonstrated transformative benefits, particularly in enhancing security, traceability, and operational efficiency. The reviewed studies indicate that blockchain, when combined with IoT, AI, and smart contracts, optimizes logistics operations and enhances supply chain security. Blockchain ensures immutability, thereby preventing data tampering and fraudulent activities, while smart contracts facilitate automation by executing agreements without intermediaries.

Despite these advantages, blockchain adoption in logistics still faces numerous challenges. Scalability remains a major concern, as blockchain networks must process a high volume of

Table 1:

Pap- er No.	Title	Fo- cus Area	Method- ology	Techno- logies Used	Key Find- ings	Con- clusi- on	Draw- back s	Limita- tion s	Existing Works
1	Blockchain- Based Container Tracking	Supply Chain, Port Logis- tics	Case Study at CASA Port Termi- nal	Blockchain, IoT, Smart Contracts	Im- proved con- tainer track- ing, re- duced fraud & errors	Blockchain ensures in- tegrity, secu- rity, and effi- ciency	Integra- tion chal- lenges, high initial costs	Limited scalabil- ity due to IoT con- straints	CASA Port operation s study, Blockchain in in supply chain transpare ncy
2	Logis- tics Opti- mizat ion with Blockchain & AI	Logis- tics Ef- ficien- cy	CNN & ACO Algo- rith ms for route opti- mizati on	Blockchain, CNN, ACO	15% faster deliv- eries, 25% lower data breaches	Blockchain im- proves effi- ciency , secu- rity, and trans- pare ncy	High compu- tatio nal cost of CNN & ACO	Requires more real- world imple- ment ation and scalabil- ity tests	AI in logistics, CNN for route predictio n
3	Blockchain in Prod- uct Circu- latio & Supply Chains	Supply Chain Trans- pare ncy	Liter- ature Re- view & Case Analy- sis	Blockchain, Smart Contracts	Im- proved fraud pre- ventio n, asset secu- rity	Decen- tral ized nature of blockchai n en- hances trust	Adop- tion barri- ers, com- plex imple- ment ation	Not all indus- tries have stan- dardize d tracking methods	Blockchain- based product tracking, RFID in logistics
4	Secure Identi- fica tion & Real- Time Track- ing	Per- ish- abl e Goods Lo- gis- tics	Ma- chine Learn- ing Pre- dic- tion s	Blockchain, IoT, Smart Contracts , SVM, RF	Pre- dicts backo- rder cases, en- hances food secu- rity	Can be scaled to other indus- tries with digital IDs	High data storage require- men ts, IoT battery dependenc-	Limited by IoT device network coverage	IoT in food supply chains, ML for backorde- r predictio -n
5	RFID & Blockchain	Cloth- ing Sup-	Smart Con- tracts	Blockchain, RFID,	Im- proved trace-	Smart con- tracts	RFID adop- tion	Not all retailers have	RFID in retail, smart

Table 2:

6	IoT & Blockchain in Logistics Tracking	Decentralized IoT Platform	Multi-sensor Tracking with RFID	Blockchain, IoT, QR Codes, Multi-Sensors	Improves quality control, product safety	Enhances supply chain monitoring, prevents data falsification	Scalability issues, high energy consumption	Limited by lack of interoperability between IoT and blockchain	IoT-based tracking, QR codes in logistics
7	Blockchain for Ports Operations	Port Container Management	CASA Port Study & Blockchain Adoption	Blockchain, IoT, Smart Contracts	Transparency in port operations, better tracking	IoT + Blockchain enhances trust & efficiency in logistics	Security risks, lack of blockchain regulations	Policy updates in blockchain are slow and costly	Port-based tracking using IoT, blockchain for logistics
8	Blockchain for Smart City Logistics	High-Value Shipments Tracking	Empirical Study in Smart Cities	Blockchain, IoT, Privacy-Focused Smart Contracts	Improves shipment transparency & operational efficiency	Blockchain adoption ensures security, privacy, and trust	Data management complexity, high integration cost	Not yet tested for large-scale urban logistics	Blockchain in smart cities, logistics security

transactions efficiently. Public blockchains, while offering decentralization, can experience slow processing speeds, making them less viable for large-scale logistics operations. Conversely, private and consortium blockchains provide better performance but may compromise decentralization.

High implementation costs also present a significant barrier. Deploying blockchain-based solutions requires investment in infrastructure, software development, and staff training. Many companies are hesitant to adopt blockchain due to concerns about return

on investment and integration with legacy systems. Additionally, interoperability between different blockchain platforms and existing logistics software is still a technical challenge that requires standardized solutions.

Regulatory compliance is another critical issue. Blockchain-based supply chains operate across different jurisdictions, each with unique legal frameworks regarding data privacy, security, and contract enforceability. The lack of global standards for blockchain adoption creates uncertainty for businesses and delays widespread implementation. Additionally, while blockchain ensures transparency, certain stakeholders may be reluctant to share data on a distributed ledger due to competitive and confidentiality concerns.

Security risks also need further consideration. While blockchain itself is highly secure, vulnerabilities can emerge from external factors, such as weak IoT device security, compromised private keys, and smart contract bugs. Ensuring robust cybersecurity practices and incorporating advanced encryption mechanisms will be essential for securing blockchain-based logistics networks.

To overcome these challenges, future research should focus on developing scalable blockchain architectures, such as sharding and layer-2 solutions, to improve transaction processing speeds. Enhanced interoperability protocols, such as cross-chain bridges, will enable seamless data exchange between different blockchain networks and legacy systems. Additionally, regulatory bodies must work towards establishing standardized frameworks to ensure compliance and facilitate blockchain adoption on a global scale.

4.1 Conclusion

This survey paper analysed eight research studies focusing on blockchain applications in logistics and supply chain management. The findings highlight blockchain's potential to enhance security, traceability, and operational efficiency across various sectors. By integrating blockchain with IoT, AI, and smart contracts, logistics processes can become more transparent, automated, and resistant to fraudulent activities.

Despite its promising benefits, blockchain implementation in logistics faces several hurdles, including scalability issues, high costs, regulatory uncertainties, and interoperability challenges. Addressing these barriers requires ongoing research and technological advancements. Scalable blockchain frameworks, combined with optimized consensus algorithms, can improve transaction throughput while maintaining security. Additionally, industry-wide collaboration will be essential to developing common standards that ensure smooth integration and regulatory compliance.

Future research should explore hybrid blockchain models that combine the advantages of public and private blockchains to balance decentralization and performance. The integration of AI-driven predictive analytics can further optimize supply chain operations by anticipating demand fluctuations and detecting anomalies in real-time. Moreover, the deployment of 5G-enabled IoT networks can enhance data collection accuracy, leading to more reliable blockchain-based tracking systems.

In conclusion, blockchain technology has the potential to revolutionize logistics and supply chain management. However, realizing this potential requires addressing key technical and regulatory challenges. With continued advancements in blockchain scalability, security, and interoperability, along with supportive regulatory frameworks, blockchain can become a cornerstone of future global logistics networks, driving efficiency, trust, and resilience in supply chains.