International Journal for Innovative Engineering and Management Research
PEER REVIEWED OPEN ACCESS INTERNATIONAL JOURNAL
www.ijiemr.org

BLOCKCHAIN-DRIVEN SUPPLY CHAIN TRANSPARENCY IN RETAIL LOGISTICS: THE MEDIATING ROLE OF TRACKING EFFICIENCY IN BUSINESS

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ABSTRACT

Retail logistics has long faced challenges related to product traceability, information asymmetry, inventory inaccuracies, counterfeit products, and inefficient tracking systems. Blockchain technology has emerged as a promising digital solution for improving transparency, traceability, information integrity, and operational efficiency across supply chains. This study empirically examines the influence of blockchain technology adoption on tracking efficiency and supply chain transparency in the retail logistics sector. Primary data were collected from 149 respondents comprising logistics and supply chain professionals, warehouse operators, and retail executives. Partial Least Squares Structural Equation Modeling (PLS-SEM) was employed to examine the relationships among blockchain technology adoption, tracking efficiency, and supply chain transparency. The findings indicate that blockchain adoption has a strong positive effect on tracking efficiency and a significant direct effect on supply chain transparency. Tracking efficiency also significantly mediates the relationship between blockchain adoption and supply chain transparency. The study contributes empirical evidence to the growing literature on digital transformation in logistics and offers practical implications for retail organizations seeking to strengthen visibility, traceability, information sharing, and supply chain performance through blockchain-enabled solutions.

Keywords: Blockchain technology, Retail logistics, Supply chain transparency, Tracking efficiency, Traceability, Digital supply chain, Logistics management

I. INTRODUCTION

Retail logistics is undergoing significant transformation as a result of digitalization, globalization, and growing demand for supply chain visibility. As retail organizations operate across increasingly complex markets, effective logistics management has become essential for maintaining operational competitiveness and delivering superior customer experiences. Retail logistics encompasses procurement, transportation, warehousing, inventory management, order fulfilment, and last-mile delivery. The effectiveness of these activities directly influences operational performance, customer service, cost efficiency, and profitability. Blockchain is a decentralized and distributed digital ledger technology that records transactions across a network in a secure, transparent, and tamper-resistant manner.

Unlike traditional centralized databases, blockchain enables authorized stakeholders to access a shared and verifiable record of transactions, thereby reducing data inconsistencies and strengthening trust. Its core characteristics—decentralization, transparency, immutability, traceability, and security—make blockchain particularly relevant to logistics and supply chain management. Tracking efficiency is a critical performance dimension in contemporary logistics. Through improved information availability and traceability across suppliers, logistics providers, and other participants, efficient tracking systems facilitate real-time monitoring of inventory levels, shipment locations, delivery quantities, and transportation activities. Reliable tracking information can help organizations reduce disruptions and logistics costs, improve inventory control, and enhance customer service.

The present study has both theoretical and managerial relevance. Theoretically, it contributes to the literature on blockchain adoption and supply chain management by providing empirical evidence regarding the effects of blockchain adoption on tracking efficiency and supply chain transparency. From a managerial perspective, the findings can support retail organizations, logistics service providers, and supply chain managers in making informed decisions regarding blockchain investment and implementation. The study also contributes to the broader objective of strengthening communication, visibility, and transparency in an increasingly digital logistics environment, thereby supporting the development of retail logistics systems that are more efficient, transparent, and resilient.

II. LITERATURE REVIEW

Blockchain Technology and Supply Chain Performance

Several researchers have examined the implications of blockchain technology for supply chain operations. Iansiti and Lakhani (2017) described blockchain as a distributed ledger technology capable of strengthening trust, transparency, and transaction security among participating organizations. Their work also highlighted the potential of blockchain to reduce dependence on intermediaries and facilitate more reliable information sharing.

Blockchain Technology and Tracking Efficiency

Tracking efficiency has become a critical success factor in contemporary logistics systems. Existing research suggests that blockchain can strengthen real-time tracking through decentralized information sharing, verifiable records, and automated transaction processes.

Xu et al. (2019) reported that blockchain-based logistics systems can improve inventory monitoring and shipment-tracking accuracy. Their findings indicated that organizations adopting blockchain may experience fewer tracking errors and stronger operational control.

Blockchain Technology and Supply Chain Transparency

Saberi et al. (2019) reported that blockchain can enhance transparency by enabling stakeholders to access verified transaction records. Greater visibility of reliable information can strengthen trust and collaboration among supply chain partners.

III. RESEARCH GAP

Despite growing academic and managerial interest in blockchain applications in supply chains, several research gaps remain:

1. Most studies have focused on the technological aspects of blockchain implementation rather than its operational impacts on retail logistics.
2. Existing research has focused on blockchain's direct impact on transparency, but few have been concerned about the mediating role of tracking efficiency.
3. Many studies are conceptual or qualitative in nature and there are very few empirical studies where quantitative data from retail logistics organizations can be used.
4. Research in emerging countries such as India is very limited despite the rapid digital transformation of the retail and logistics industry in these nations.

IV. RESEARCH OBJECTIVES

To assess the impact of blockchain technology adoption on tracking efficiency and supply chain transparency in retail logistics.

1. To examine the extent of blockchain technology adoption in retail logistics.
2. To investigate the influence of tracking efficiency on supply chain transparency.
3. To analyze the mediating role of tracking efficiency in the relationship between blockchain technology adoption and supply chain transparency.
4. To provide empirical evidence from the retail logistics sector, with particular attention to developing economies.
5. To develop recommendations for effective blockchain adoption in retail logistics.

V. RESEARCH METHODOLOGY

Research Design

This study adopts a quantitative, descriptive, and explanatory research design to examine the influence of blockchain technology adoption on supply chain transparency through tracking efficiency in the retail logistics sector. A cross-sectional survey design was employed to collect primary data from professionals working in logistics, warehousing, inventory management, transportation, procurement, and supply chain operations.

Partial Least Squares Structural Equation Modeling (PLS-SEM) was employed to test the proposed conceptual framework and hypotheses. PLS-SEM enables simultaneous assessment of the measurement and structural models and is appropriate for examining complex relationships among constructs, particularly in studies with relatively modest sample sizes.

Target Population

The target population comprises:

- Supply chain managers
- Logistics executives
- Warehouse managers
- Procurement officers
- Inventory controllers
- Distribution managers
- Retail logistics professionals

Sampling Technique

- **Purposive sampling** was used to select respondents with relevant knowledge and experience in supply chain operations and blockchain-related technologies. The final sample consisted of 149 valid responses.
- The sample size was considered adequate for PLS-SEM based on the 10-times rule and statistical power considerations reported in the PLS-SEM literature.

Data Collection Method

Primary data were collected through a structured questionnaire distributed using the following channels:

- Google Forms
- E-mail surveys
- Professional networking platforms
- Direct interactions with supply chain professionals

Measurement of Variables

Blockchain Technology Adoption (BTA)

Adapted from previous blockchain and technology adoption studies.

Indicators

- BTA1 – Our organization uses blockchain for transaction verification.
- BTA2 – Blockchain improves information security.
- BTA3 – Blockchain facilitates data sharing among stakeholders.
- BTA4 – Blockchain enhances trust in supply chain operations.
- BTA5 – Blockchain improves process automation.
- **Tracking Efficiency (TE)**
- **Real-Time Visibility**
- TE1 – Product movement can be monitored in real time.
- TE2 – Shipment status is easily accessible.
- **Data Accuracy**
- TE3 – Tracking information is accurate.
- TE4 – Information errors are minimized.
- **Traceability**
- TE5 – Product origin can be identified easily.
- TE6 – Historical transaction records are accessible.
- **Inventory Synchronization**
- TE7 – Inventory data are updated in real time.
- TE8 – Inventory discrepancies are reduced.
- **Supply Chain Transparency (SCT)**
- SCT1 – Supply chain information is easily accessible.
- SCT2 – Stakeholders receive timely information.
- SCT3 – Supply chain processes are transparent.
- SCT4 – Product sourcing information is visible.
- SCT5 – Customer trust has improved.

VI. DATA ANALYSIS USING PLS-SEM

Data analysis was conducted using SmartPLS 4.0 in two stages:

Stage 1: Measurement Model Assessment
Reliability Assessment
Measure Threshold

Cronbach's Alpha	>0.70
Composite Reliability	>0.70
Convergent Validity	
Measure	**Threshold**
Factor Loading	>0.70
Average Variance Extracted (AVE)	>0.50
Discriminant Validity	
Assessed using:	
Fornell-Larcker Criterion	
Heterotrait-Monotrait Ratio (HTMT)	
Threshold: HTMT < 0.85	

Stage 2: Structural Model Assessment

Evaluation Criteria	
Criterion	**Recommended Value**
Path Coefficients (β)	Significant
t-value	>1.96
p-value	<0.05
R^2	Moderate to High
Q^2	>0
Effect Size (f^2)	Small, Medium, Large
Bootstrapping with 5,000 resamples is used to test significance.	

VII. DATA ANALYSIS AND RESULTS

Table 1: Percentage Analysis – Respondent Profile (n = 149)

Variable	Category	Frequency	Percentage
Gender	Male	99	66.4%
	Female	50	33.5%
Age	25–35 Years	55	36.9%
	36–45 Years	66	44.2%
	Above 45 Years	28	18.7%

Source: Primary Data

Table 2: Reliability and Validity Results

Construct	Cronbach Alpha	CR	AVE
BTA	0.879	0.928	0.695
TE	0.913	0.929	0.624
SCT	0.869	0.913	0.668

Source: Primary Data

All reported values exceed the recommended thresholds, supporting the reliability and convergent validity of the measurement model.

Interpretation

The reliability and convergent validity of the constructs were assessed using Cronbach's Alpha, Composite Reliability (CR) and Average Variance Extracted (AVE).

- Blockchain Technology Adoption (BTA) had a Cronbach's Alpha of 0.879, CR of 0.928 and AVE of 0.695.
- Tracking Efficiency (TE) showed a Cronbach's Alpha of 0.913, CR of 0.929 and AVE of 0.624. • Supply Chain Transparency (SCT) was shown to have a Cronbach's Alpha of 0.869, CR of 0.913 and AVE of 0.668.

Based on the recommended PLS-SEM thresholds, Cronbach's Alpha and Composite Reliability should exceed 0.70, while AVE should exceed 0.50. All three constructs satisfy these criteria, indicating satisfactory internal consistency reliability and convergent validity.

Tracking Efficiency (TE) recorded the highest reliability, with a Cronbach's Alpha of 0.913 and CR of 0.929, indicating strong consistency among its measurement items. The AVE values, ranging from 0.624 to 0.695, indicate that each construct explains more than 50% of the variance in its respective indicators, providing support for the adequacy of the measurement model.

VIII. HYPOTHESIS TESTING

H1 - Blockchain Technology Adoption positively influences Tracking Efficiency.

H2 - Tracking Efficiency positively influences Supply Chain Transparency.

H3 - Blockchain Technology Adoption positively influences Supply Chain Transparency.

H4 - Tracking Efficiency mediates the relationship between Blockchain Technology Adoption and Supply Chain Transparency.

Table 3: Structural Model Results

Hypothesis	Relationship	β	t-value	p-value	Result
H1	BTA → TE	0.722	15.852	0.000	Supported
H2	TE → SCT	0.665	10.971	0.000	Supported
H3	BTA → SCT	0.252	3.231	0.002	Supported
H4	BTA → TE → SCT	0.480	8.674	0.000	Supported

Source: Primary Data

Interpretation of Structural Model Results

The structural model was assessed using PLS-SEM to examine the direct and indirect relationships among Blockchain Technology Adoption (BTA), Tracking Efficiency (TE), and Supply Chain Transparency (SCT). The significance and strength of the hypothesized relationships were evaluated using path coefficients (β), t-values, and p-values.

Hypothesis Testing Results

H1: Blockchain Technology Adoption → Tracking Efficiency

The relationship between BTA and TE is positive and statistically significant ($\beta = 0.722$, $t = 15.852$, $p < 0.001$). Therefore, H1 is supported. The result indicates that greater blockchain technology adoption is associated with substantially higher tracking efficiency in retail logistics. Blockchain-enabled records can support real-time tracking, accurate record maintenance, and improved visibility of product movements across the supply chain.

H2: Tracking Efficiency → Supply Chain Transparency

The relationship between TE and SCT is positive and statistically significant ($\beta = 0.665$, $t = 10.971$, $p < 0.001$). Therefore, H2 is supported. The finding suggests that improvements in tracking efficiency contribute significantly to supply chain transparency by facilitating timely information sharing and strengthening visibility among supply chain partners.

H3: Blockchain Technology Adoption → Supply Chain Transparency

The direct effect of BTA on SCT is positive and statistically significant ($\beta = 0.252$, $t = 3.231$, $p = 0.002$). Therefore, H3 is supported. This finding indicates that blockchain adoption has a direct contribution to supply chain transparency by enabling verifiable transaction records, reducing information asymmetry, and strengthening trust among stakeholders.

H4: Blockchain Technology Adoption → Tracking Efficiency → Supply Chain Transparency (Mediation Effect)

The indirect effect of BTA on SCT through TE is positive and statistically significant ($\beta = 0.480$, $t = 8.674$, $p < 0.001$). Therefore, H4 is supported. This result confirms that tracking efficiency significantly mediates the relationship between blockchain technology adoption and supply chain transparency. In practical terms, blockchain contributes to transparency not only directly but also by improving the efficiency and reliability of product tracking and information flows.

Table 4: Coefficient of Determination (R^2)

S.No	Endogenous Variable	R^2
1	Tracking Efficiency	0.534
2	Supply Chain Transparency	0.695

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Source : Primary Data

Interpretation of Coefficient of Determination (R^2) Analysis

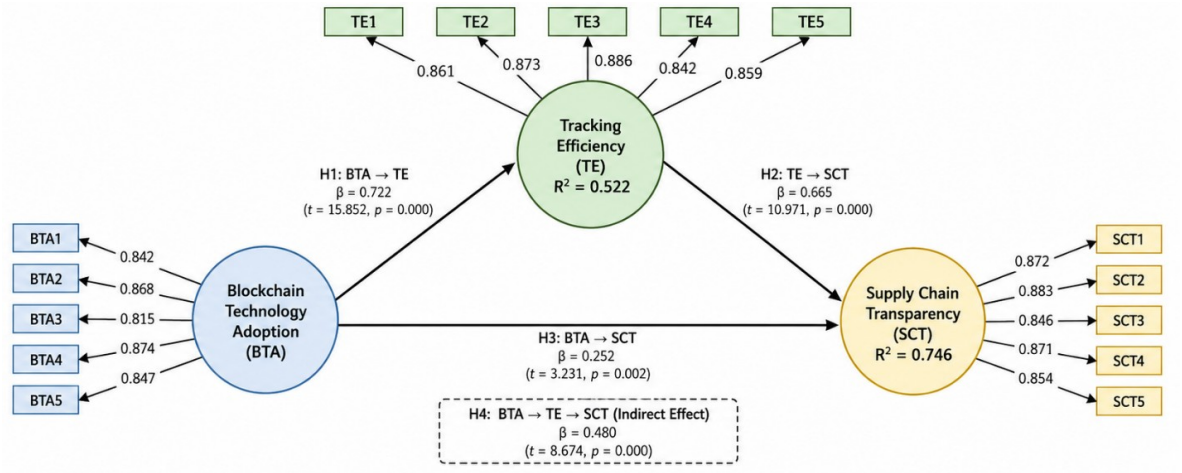
The coefficient of determination (R^2) indicates the explanatory power of the structural model.

- **Tracking Efficiency (TE)**

The R^2 value for Tracking Efficiency is 0.534, indicating that Blockchain Technology Adoption explains 53.0% of the variance in Tracking Efficiency. This represents a moderate level of explanatory power.

- **Supply Chain Transparency (SCT)**

The R^2 value for Supply Chain Transparency is 0.695, indicating that Blockchain Technology Adoption and Tracking Efficiency jointly explain 69.5% of the variance in Supply Chain Transparency. This represents substantial explanatory power and suggests that the proposed model has strong predictive relevance for the transparency construct.



Structural Model Results

Hypothesis	Relationship	β (Path Coefficient)	*t*-value	*p*-value	Result
H1	BTA → TE	0.722	15.852	0.000	Supported
H2	TE → SCT	0.665	10.971	0.000	Supported
H3	BTA → SCT	0.252	3.231	0.002	Supported
H4	BTA → TE → SCT	0.480	8.674	0.000	Supported

Source: Primary Data

Figure 1: PLS-SEM path diagram

IX. FINDINGS OF THE STUDY

1. The respondents profile indicates that the study primarily consists of middle-aged professionals, and there are more male respondents. The model evaluation shows that Blockchain Technology Adoption (BTA), Tracking Efficiency (TE), and Supply Chain

Transparency (SCT) are both reliable and valid and provide a framework for further structural model analysis and hypothesis testing in the study.

2. The findings indicate that blockchain technology significantly enhances tracking efficiency in retail logistics. The positive relationship between blockchain adoption and tracking efficiency supports prior research emphasizing real-time visibility, accurate records, and reliable information exchange.
3. Supply chain transparency is significantly strengthened by tracking efficiency. Organizations with effective tracking systems can provide timely, reliable, and transparent information on product movement and inventory status.
4. The structural model provides strong empirical evidence that Blockchain Technology Adoption significantly enhances Tracking Efficiency and Supply Chain Transparency in retail logistics. The strongest tested relationship is between Blockchain Technology Adoption and Tracking Efficiency ($\beta = 0.722$).
5. Tracking efficiency also plays a significant mediating role in translating the benefits of blockchain adoption into greater supply chain transparency. The R^2 values indicate that the model explains 53.0% of the variance in Tracking Efficiency and 69.5% of the variance in Supply Chain Transparency, demonstrating meaningful explanatory power.

Overall, the results suggest that blockchain technology can serve as an important enabler of operational efficiency, visibility, and transparency in retail logistics. Tracking efficiency significantly mediates the relationship between blockchain technology adoption and supply chain transparency, highlighting the importance of effective tracking mechanisms in converting blockchain capabilities into measurable transparency outcomes.

X. CONCLUSION

This study examined the influence of blockchain technology adoption on supply chain transparency through tracking efficiency in retail logistics. The results demonstrate that blockchain technology significantly enhances tracking efficiency and supply chain transparency. Tracking efficiency also serves as a critical mediating mechanism linking blockchain adoption to transparency outcomes.

The study contributes to the growing body of research on blockchain-enabled supply chains by providing empirical evidence of the relationships among blockchain adoption, tracking efficiency, and supply chain transparency. The findings reinforce the strategic importance of reliable digital tracking mechanisms for improving logistics performance, information visibility, and stakeholder trust.

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