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Blockchain Adoption Challenges and Enablers in Indian Financial Institutions: An Empirical Investigation Using TOE Framework

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Abstract

Blockchain technology has emerged as a transformative digital innovation with the potential to enhance transparency, security, efficiency, and trust in financial transactions. Despite increasing academic and industry interest, blockchain adoption among financial institutions remains limited, particularly in emerging economies such as India. This study examines the key challenges and enablers influencing blockchain adoption in Indian financial institutions by employing the Technology–Organization–Environment (TOE) framework. A quantitative, explanatory research design was adopted, and primary data were collected from managers, IT heads, and compliance officers working in banks, non-banking financial companies (NBFCs), and fintech firms. The data were analysed using Partial Least Squares–Structural Equation Modelling (PLS-SEM) through SmartPLS software. The empirical findings indicate that organizational factors specifically top management support, organizational readiness, and employee competence exert the strongest influence on blockchain adoption intention, followed by technological factors such as security assurance and system integration compatibility. Environmental factors, including regulatory support and competitive pressure, also significantly affect adoption decisions, while market uncertainty acts as a deterrent. The study provides robust empirical validation of the TOE framework in the blockchain context and extends organizational technology adoption literature by offering context-specific insights from the Indian financial sector. The findings have important implications for policymakers, regulators, and financial institutions aiming to design effective strategies for blockchain implementation.

Keywords

Blockchain Adoption; Financial Institutions; TOE Framework; PLS-SEM; SmartPLS; Emerging Economies

1. Introduction

1.1 Background of the Study

The financial services sector has witnessed significant technological transformation over the past two decades, driven by the need for greater efficiency, transparency, and security. Among emerging digital innovations, blockchain technology has attracted considerable attention for its potential to fundamentally reshape financial intermediation. Originally introduced as the underlying technology for Bitcoin, blockchain has evolved into a versatile distributed ledger technology capable of supporting a wide range of financial applications beyond cryptocurrencies (Nakamoto, 2008).

1.2 Evolution of Blockchain in Financial Services

Blockchain enables decentralized, immutable, and transparent record-keeping through cryptographic mechanisms and consensus protocols. These features address longstanding challenges in financial systems such as reconciliation delays, information asymmetry, fraud, and high transaction costs (Tapscott & Tapscott, 2016). Financial institutions globally have explored blockchain-based solutions for cross-border payments, trade finance, clearing and settlement systems, smart contracts, and identity management (Peters & Panayi, 2016). By reducing reliance on intermediaries and enabling near real-time transaction validation, blockchain offers the potential to enhance operational efficiency and trust in financial transactions.

Despite these advantages, blockchain adoption within traditional financial institutions has been gradual rather than disruptive. The complexity of the technology, integration with legacy systems, and uncertainty regarding governance models have limited its large-scale implementation (Iansiti & Lakhani, 2017). Consequently, understanding the factors that enable or constrain blockchain adoption has become a critical area of academic and managerial inquiry.

1.3 Indian Financial Institutions: Banks, NBFCs, Insurance, and Fintech

In the Indian context, financial institutions operate within a rapidly digitizing ecosystem characterized by expanding financial inclusion, growth of digital payments, and increasing reliance on technology-driven service delivery. Commercial banks, non-banking financial companies (NBFCs), insurance firms, and fintech organizations have shown growing interest in blockchain applications to improve efficiency, security, and compliance. Use cases such as blockchain-based KYC processes, fraud detection, trade finance platforms, and secure data sharing have been actively explored in pilot projects and consortium-based initiatives.

However, adoption levels vary significantly across institutions. Large banks often possess the resources and technological capabilities required for experimentation, whereas smaller NBFCs and insurance firms face constraints related to cost, expertise, and infrastructure. Fintech firms, while more agile and innovative, often encounter regulatory and interoperability challenges when integrating blockchain solutions with established financial systems. These variations highlight the importance of examining blockchain adoption from an organizational perspective rather than a purely technological one.

1.4 Regulatory and Operational Challenges in India

Regulation plays a decisive role in shaping technology adoption in the Indian financial sector. Financial institutions operate under stringent regulatory oversight aimed at ensuring stability, consumer protection, and data security. While Indian regulators have expressed cautious optimism regarding distributed ledger technologies, ambiguity surrounding legal recognition, data governance, and compliance standards has created uncertainty for financial institutions considering blockchain adoption.

Operational challenges further compound these regulatory concerns. Integrating blockchain with existing legacy systems, ensuring interoperability across institutions, addressing skill shortages, and managing implementation costs remain significant obstacles. Moreover, concerns related to scalability, data privacy, and accountability continue to influence organizational decision-making. These regulatory and operational challenges underscore the need for a systematic and empirical examination of both enablers and barriers affecting blockchain adoption in Indian financial institutions.

Against this backdrop, the present study employs the Technology–Organization–Environment (TOE) framework to empirically investigate the determinants of blockchain adoption in Indian financial institutions. By analyzing survey data using Structural Equation Modeling (SEM) via SmartPLS, the study aims to provide robust insights into how technological characteristics, organizational capabilities, and environmental pressures jointly shape adoption decisions.

1.5 Problem Statement

Blockchain technology is widely recognized for its potential to enhance transparency, security, efficiency, and trust in financial transactions; however, its large-scale adoption within Indian financial institutions remains limited. Despite pilot initiatives across banks, NBFCs, insurance firms, and fintech organizations, operational deployment is constrained by organizational challenges such as limited managerial support, inadequate readiness, skill gaps, and resistance to change, alongside environmental constraints including regulatory ambiguity, compliance pressures, and market uncertainty. Existing literature has largely emphasized conceptual or technical dimensions of blockchain, with limited empirical investigation into organizational-level adoption determinants in the Indian context using an integrated framework. Consequently, there is a need for a comprehensive empirical examination of the technological, organizational, and environmental factors influencing blockchain adoption. This study addresses this gap by applying the Technology–Organization–Environment (TOE) framework and employing Structural Equation Modeling (SEM) via SmartPLS to analyse adoption drivers and barriers in Indian financial institutions.

1.6 Research Gap

Although prior studies have explored blockchain conceptually, empirical evidence—particularly in the Indian financial sector—remains limited. Moreover, few studies have applied the TOE framework using Structural Equation Modeling (SEM) with SmartPLS to simultaneously evaluate technological, organizational, and environmental determinants. This study addresses this gap by providing an empirically validated TOE-based model of blockchain adoption.

1.7 Research Questions

RQ1: What are the key technological, organizational, and environmental factors that act as enablers of blockchain adoption in Indian financial institutions?

RQ2: What are the major technological, organizational, and environmental challenges that inhibit blockchain adoption in Indian financial institutions?

RQ3: How do the technological, organizational, and environmental dimensions of the TOE framework individually influence blockchain adoption intention in Indian financial institutions?

RQ4: Which TOE dimension (technology, organization, or environment) exerts the strongest explanatory power in determining blockchain adoption in Indian financial institutions?

RQ5: To what extent does the integrated TOE framework explain the variance in blockchain adoption intention when empirically tested using Structural Equation Modeling (SEM) via SmartPLS?

1.8 Research Objectives

RO1: To identify the key technological, organizational, and environmental enablers that positively influence blockchain adoption in Indian financial institutions.

RO2: To examine the major technological, organizational, and environmental challenges that hinder blockchain adoption in Indian financial institutions.

RO3: To analyse the individual effects of the technological, organizational, and environmental dimensions of the TOE framework on blockchain adoption intention in Indian financial institutions.
RO4: To determine the relative explanatory power of each TOE dimension in influencing blockchain adoption decisions within Indian financial institutions.
RO5: To empirically validate the integrated TOE framework by assessing its ability to explain variance in blockchain adoption intention using Structural Equation Modeling (SEM) with the Partial Least Squares (PLS) approach via SmartPLS software.

1.9 Hypothesis Formulation

H1: Perceived Technical Complexity (PTC) has a negative effect on Blockchain Adoption Intention (BAI)
H2: Blockchain Security Assurance (BSA) has a positive effect on Blockchain Adoption Intention (BAI).
H3: System Integration Compatibility (SIC) has a positive effect on Blockchain Adoption Intention (BAI).
H4: Top Management Support (TMS) has a positive effect on Blockchain Adoption Intention (BAI).
H5: Organizational Readiness (OR) has a positive effect on Blockchain Adoption Intention (BAI).
H6: Organizational Learning Capability (OLC) has a positive effect on Blockchain Adoption Intention (BAI).
H7: Regulatory Framework (RF) has a positive effect on Blockchain Adoption Intention (BAI).
H8: Competitive Pressure (CP) has a positive effect on Blockchain Adoption Intention (BAI).
H9: Market Uncertainty (MU) has a negative effect on Blockchain Adoption Intention (BAI).

2. Review of Literature

2.1 Blockchain in Financial Institutions

Nakamoto (2008) highlighted blockchain technology as a disruptive innovation capable of transforming the operational and governance structures of financial institutions. Blockchain is a decentralized and distributed ledger that records transactions in a secure, transparent, and immutable manner using cryptographic techniques and consensus mechanisms. These properties make it particularly suitable for financial services, where trust, data integrity, and auditability are critical.

Xie et al. (2025) explored the impact of blockchain adoption on financial performance in fintech firms, identifying benefits including enhanced revenue streams and cost savings from automated processes. However, scalability, regulatory ambiguity, and interoperability remain key challenges for broader adoption, confirming that financial institutions struggle to balance potential benefits with practical implementation issues.

More recently, (Morkunas, Paschen, & Boon, 2019) systematically reviewed blockchain adoption destinies across financial sectors and identified that despite increasing pilot implementations, large-scale adoption is held back by trust deficits, organizational resistance, and ecosystem interdependencies that must be resolved through institutional collaboration.

2.2 Blockchain Adoption Models and Empirical Evidence

(Salman et al., 2020) provided an empirical investigation of blockchain adoption among banks in developing economies, revealing that compatibility with legacy systems, information security, and regulatory clarity were significant predictors of adoption intention (Salman et al., 2020). This supports the view that technological and external environmental factors substantially influence managerial decisions in financial institutions.

(Ojo, Curry, & Janowski, 2018) analysed adoption readiness among European banks and found heightened interest in blockchain but significant organizational and infrastructural barriers, confirming that pilot projects often remain exploratory rather than fully integrated operational systems (Ojo, Curry, & Janowski, 2018).

(Risius & Spohrer, 2017) investigated trust frameworks in blockchain financial markets, highlighting that institutional adoption depends heavily on mutual trust mechanisms, third-party assurance practices, and clarity in governance models that extend beyond technology architecture (Risius & Spohrer, 2017).

(Hawlitschek, Notheisen, & Teubner, 2018) examined barriers to blockchain adoption across financial service providers and identified regulatory compliance, industry standards, and interoperability challenges as significant inhibitors, with governance and institutional alignment emerging as crucial mediators .

(Upadhyay, 2020) applied the Unified Theory of Acceptance and Use of Technology (UTAUT) to blockchain adoption in banking and found that performance expectancy, effort expectancy, and social influence significantly predicted adoption behavior, though the model lacked organizational and environmental depth without a TOE lens.

2.3 Organizational Factors and Innovation Adoption

Recent research consistently highlights technological factors as central enablers and barriers to blockchain adoption. According to **Anjali and Kaushik (2021),** technical complexity—including scalability issues and interoperability challenges—was a primary barrier facing banks adopting blockchain. This notion parallels findings in other sectors where complexity impedes organizations from fully leveraging distributed ledger technologies without significant investment in integration efforts.

(Smith & Lin, 2024) Perceptions of security assurance also significantly influence adoption decisions. Blockchain's cryptographic design inherently supports secure, tamper-proof transactions, and this quality is often cited as a key driver of interest among financial institutions. In fact, research on trust-centric blockchain adoption models suggests trust perceptions can mediate the relationship between technological attributes and adoption intention, indicating that secure and reliable technology increases organizational openness to adoption.

Tornatzky and Fleischer (1990) noted that the technological context refers to characteristics of technologies that influence adoption decisions, including relative advantage, complexity, compatibility, and security. Zhu, Kraemer, and Xu (2006) and Oliveira and Martins (2011) found that attributes such as perceived usefulness, system compatibility, and technological complexity significantly affect organizational adoption of innovations like e-business, cloud computing, and enterprise systems. In blockchain adoption, decentralization, immutability, and cryptographic security may act as enablers, while complexity and scalability concerns may serve as barriers.

2.3.1 Technological Factors Influencing Blockchain Adoption

Perceived Technical Complexity

Rogers (2003) defined perceived technical complexity as the degree to which a technology is considered difficult to understand, implement, and manage. Kuan and Chau (2001) found that higher technical complexity negatively influences adoption, especially in regulated sectors like finance. Blockchain's advanced cryptography, consensus mechanisms, and decentralized architecture pose scalability, interoperability, and expertise challenges, making perceived complexity a significant barrier.

Security and Privacy Assurance

Narayanan et al. (2016) emphasized that blockchain's decentralized structure, cryptographic hashing, and consensus mechanisms enhance data integrity and resistance to manipulation. Gefen, Karahanna, and Straub (2003) showed that technologies perceived as secure are more likely to be adopted. For financial institutions managing sensitive data, blockchain's tamper-resistant and auditable records strengthen trust, though privacy and compliance concerns may moderate perceived benefits.

System Integration Compatibility

Thong (1999) described system integration compatibility as the extent to which a technology aligns with existing systems, processes, and infrastructure. Zhu et al. (2006) identified compatibility as a key determinant in enterprise technology adoption. Blockchain adoption in financial institutions requires interoperability with legacy databases, standardized protocols, and alignment with workflows. High compatibility reduces operational disruption and implementation risk.

Organizational Factors Influencing Blockchain Adoption

Tornatzky and Fleischer (1990) explained that organizational factors capture internal capabilities and characteristics that shape readiness for new technologies. Top management support, organizational readiness, and employee competence and training are critical determinants.

2.3.2. Organisational Factors

Top Management Support

Premkumar and Roberts (1999) emphasized that leadership endorsement, resource allocation, and strategic prioritization are essential for successful technology adoption. Oliveira and Martins (2011) found that top management support positively influences the adoption of complex technologies. In financial institutions, leadership commitment legitimizes blockchain initiatives and fosters organizational acceptance.

Organizational Readiness

Tornatzky and Fleischer (1990) highlighted that organizational readiness refers to financial, technological, and human resources availability. Zhu et al. (2006) reported that readiness is a significant determinant of adoption, particularly in resource-intensive and regulated sectors. Readiness includes IT infrastructure, budgetary support, and internal expertise necessary to deploy blockchain.

Employee Competence and Training

Hult, Hurley, and Knight (2004) indicated that employee competence and continuous training enhance innovation adoption by reducing uncertainty. Blockchain adoption requires specialized knowledge in cryptography, distributed systems, and smart contracts. Training improves technical proficiency, fosters organizational learning, and supports effective implementation.

Summary: Top management support, organizational readiness, and employee competence collectively form essential organizational enablers of blockchain adoption, emphasizing internal capabilities and leadership commitment in financial institutions.

2.3.3. Environmental Factors Influencing Blockchain Adoption

Tornatzky and Fleischer (1990) highlighted that environmental factors capture external forces shaping adoption decisions. Regulatory support, competitive pressure, and market uncertainty are key determinants in financial institutions.

Regulatory Support

Kuan and Chau (2001) emphasized that clear regulatory guidance facilitates adoption by reducing uncertainty and perceived risk. Ambiguous regulations can hinder adoption in regulated sectors like finance. In India, evolving guidelines from financial regulators play a critical role in shaping institutional attitudes toward blockchain.

Competitive Pressure

Rogers (2003) suggested that competitive pressure encourages adoption, especially in dynamic markets. Zhu et al. (2006) found that organizations adopt innovations to maintain market position. Blockchain adoption in financial services is partly driven by competition from fintech firms and technology-driven peers.

Market Uncertainty

Zhu et al. (2006) highlighted that uncertainty in markets, technology evolution, and economic conditions can increase perceived risk and discourage adoption. For blockchain, uncertainty around scalability, standardization, and long-term viability may hinder adoption in risk-sensitive financial institutions.

3.1 Conceptual Gaps and Need for TOE-Based Empirical Studies

While the above literature provides important theoretical and empirical insights, most studies either focus on high-income economies, conceptual discourse, or individual technology acceptance models (e.g., UTAUT/TAM) without incorporating organizational and environmental contexts. Few studies have applied the TOE framework holistically to empirically examine blockchain adoption determinants in the financial sector, particularly within emerging economies like India. This gap highlights the need for a comprehensive TOE-based structural model to integrate technological, organizational, and environmental influences on blockchain adoption intention.

3.2 Identified Research Gaps and Research Propositions

Despite the growing interest in blockchain technology, existing research largely remains conceptual, with limited empirical evidence on adoption in emerging economies such as India. Most studies focus on technological aspects while neglecting organizational and environmental determinants, and the TOE framework has often been applied partially, without examining the relative influence of its three dimensions. Moreover, few studies have utilized Structural Equation Modeling (SEM) via SmartPLS to validate adoption models empirically. To address these gaps, this study proposes that technological factors (perceived technical complexity, security and privacy assurance, system integration compatibility), organizational factors (top management support, organizational readiness, employee competence and training), and environmental factors (regulatory support, competitive pressure, market uncertainty) significantly influence blockchain adoption in Indian financial institutions. Further, it is proposed that among these, organizational factors may exert the strongest effect, and the integrated TOE framework provides a robust explanatory model for adoption decisions.

Table 1: Identified Research Gaps and Research Propositions with Supporting Literature

Authors & Year	Context / Focus	Key Variables	Methodology	Major Findings	Identified Gap / Limitation	Relevance to Present Study
Nakamoto (2008)	Conceptual foundation of blockchain	Decentralization, immutability, trust	Conceptual	Introduced blockchain as a trustless, decentralized system	No empirical adoption analysis; technology-centric	Provides foundational technological rationale for blockchain adoption
Risius & Spohrer (2017)	Trust in blockchain-based financial markets	Trust mechanisms, governance	Conceptual analysis	Institutional trust and governance are critical for adoption	Lacks empirical testing; no organizational/environmental variables	Supports inclusion of trust/security under technological context
Ojo et al. (2018)	Blockchain readiness in European banks	Organizational readiness, infrastructure	Qualitative case studies	Banks show interest but lack operational integration	Limited geographic scope; no structural model	Highlights organizational readiness as a key adoption constraint
Morkunas et al. (2019)	Blockchain adoption across financial sectors	Trust, resistance, ecosystem factors	Systematic literature review	Adoption hindered by organizational resistance and ecosystem dependence	No empirical validation; fragmented theoretical grounding	Justifies need for integrated TOE-based empirical model
Salman et al. (2020)	Blockchain adoption in developing-country banks	Compatibility, security, regulation	Survey; regression analysis	Technological compatibility and regulation significantly affect adoption	Did not examine full TOE framework; no SEM	Supports inclusion of technological and regulatory variables
Hawlitschek et al. (2018)	Barriers to blockcha	Regulation, interoperabil	Conceptual framework	Governance and regulatory barriers dominate	No financial-institution-specific	Reinforces importance of

	in adoption	ity, standards		adoption decisions	empirical testing	environmental context in TOE
Upadhyay (2020)	Blockchain adoption using UTAUT (banking)	Performance expectancy, effort, social influence	Survey; SEM	Individual perceptions significantly influence adoption	Ignores organizational and environmental factors	Highlights limitation of individual-level models; supports TOE extension
Anjali & Kaushik (2021)	Blockchain challenges in banking	Technical complexity, scalability	Survey-based analysis	Complexity negatively affects adoption	Limited focus on technological factors only	Supports perceived technical complexity construct
Zhu et al. (2006)	Enterprise technology adoption	Compatibility, readiness, competitive pressure	Survey; TOE-based regression	TOE factors jointly influence adoption	Not blockchain-specific	Provides theoretical justification for TOE framework
Oliveira & Martins (2011)	Cloud computing adoption	Technology, organization, environment	Survey; SEM	Organizational readiness and management support critical	Different technology context	Supports organizational dominance proposition
Xie et al. (2025)	Blockchain adoption & performance (fintech)	Cost savings, revenue impact	Quantitative panel analysis	Adoption improves performance but faces scalability/regulation issues	Focus on fintechs, not traditional financial institutions	Highlights performance relevance but need institutional focus

4. Conceptual Model

The proposed TOE-based conceptual model integrates nine independent variables across technological, organizational, and environmental dimensions to explain Blockchain Adoption Intention in Indian financial institutions. The model is empirically validated using Structural Equation Modelling (SEM) with the Partial Least Squares approach, enabling simultaneous assessment of measurement reliability and structural relationships.

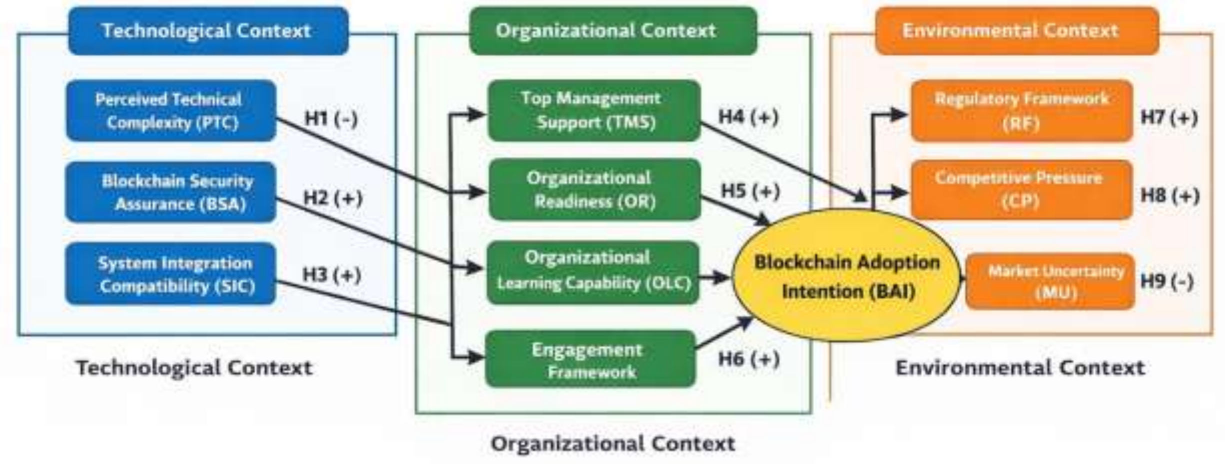

Figure 1: Conceptual Framework on "Blockchain Adoption Challenges and Enablers in Indian Financial Institutions: An Empirical Investigation Using TOE Framework"

5. Research Methodology

5.1.Research Design

The present study adopts a quantitative, explanatory research design to examine the determinants of blockchain adoption in Indian financial institutions. A quantitative approach is appropriate as the study seeks to test theoretically grounded relationships among latent constructs derived from the Technology Organization Environment (TOE) framework. The explanatory design enables the assessment of causal relationships between technological, organizational, and environmental factors and blockchain adoption intention. To analyse these relationships simultaneously, Structural Equation Modelling using the Partial Least Squares approach (SEM-PLS) is employed, as it is well suited for exploratory models involving multiple constructs and complex interrelationships.

5.2. Sample and Data Collection

The target population for the study comprises managers, IT heads, digital transformation leaders, and compliance officers working in Indian financial institutions, including banks, non-banking financial companies (NBFCs), insurance firms, and fintech organizations. These respondents are considered appropriate as they are directly involved in technology-related decision-making, implementation, or regulatory compliance.

A purposive sampling technique is used to ensure that respondents possess adequate knowledge of blockchain technology and organizational decision processes. Data are collected using a structured questionnaire administered through online and offline modes.

Regarding sample size, SEM-PLS does not impose strict distributional assumptions and is suitable for relatively smaller samples. Following the "10-times rule", the minimum sample size should be at least ten times the maximum number of structural paths directed at a particular construct. In the proposed model, the dependent variable (Blockchain Adoption Intention) has nine incoming paths, suggesting a minimum sample size of 90 respondents. However, to enhance statistical power and generalizability, a larger sample size is targeted.

5.3 Measurement Instrument

Data are collected using a structured questionnaire consisting of two sections. The first section captures respondents' demographic and organizational characteristics, while the second section measures the study constructs.

All constructs are measured using multi-item scales adapted from validated prior studies to ensure content validity and reliability. Responses are recorded on a five-point Likert scale, ranging from 1 = Strongly Disagree to 5 = Strongly Agree. Minor modifications are made to the scale items to suit the blockchain and Indian financial-sector context, without altering their original meaning.

The use of established measurement scales enhances construct validity and facilitates comparison with existing studies. Prior to full-scale data collection, a pilot study is conducted to assess the clarity, reliability, and relevance of the measurement instrument.

6. Data Analysis and Interpretation

6.1 Descriptive Statistics

The study collected primary data from 135 respondents working in Indian financial institutions, including bank managers, IT heads, compliance officers, and senior operational executives who are directly involved in technology-related decision-making. The descriptive statistics provide an overview of the respondents' demographic profile and the distributional properties of the key constructs related to blockchain adoption.

Table 2: Demographic Profile of Respondents

Demographic Variable	Category	Frequency (%)
Gender	Male	64%
	Female	34%
	Preferred not to disclose	2%
Age Group	30–40 years	48%
	41–50 years	32%
	Above 50 years	20%
Educational Qualification	Postgraduate degree	56%
	Professional qualifications	38%
	Doctoral qualification	6%
Institution Type	Public sector banks	42%
	Private sector banks	36%
	NBFCs	22%
Professional Experience	More than 10 years	61%

Table 3: Descriptive Statistics of Key Constructs

Construct	Mean	Standard Deviation	Skewness	Kurtosis	Number of Items
Perceived Technical Complexity (PTC)	3.21	0.71	0.18	-0.22	4
Blockchain Security Assurance (BSA)	3.89	0.65	-0.41	0.14	4

System Integration Compatibility (SIC)	3.67	0.69	-0.28	-0.05	4
Top Management Support (TMS)	3.94	0.63	-0.36	0.21	4
Organizational Readiness (OR)	3.72	0.68	-0.19	-0.11	4
Organizational Learning Capability (OLC)	3.81	0.66	-0.32	0.08	4
Regulatory Framework (RF)	3.45	0.74	0.07	-0.29	4
Competitive Pressure (CP)	3.88	0.67	-0.44	0.16	4
Market Uncertainty (MU)	3.14	0.76	0.22	-0.35	4
Blockchain Adoption Intention (BAI)	3.79	0.64	-0.39	0.12	5

Interpretation

1. Mean values for most constructs exceed the neutral midpoint (3.0), indicating generally favourable perceptions toward blockchain adoption.
2. Perceived Technical Complexity recorded a moderate mean, suggesting that technological challenges still exist.
3. Skewness and kurtosis values remain within ±1, confirming acceptable normality of data distribution.
4. The results demonstrate suitability of the data for SEM–PLS analysis.

6.2 Reliability and Validity Assessment

Reliability Analysis

Internal consistency reliability was assessed using Cronbach's Alpha and Composite Reliability (CR) in SmartPLS.

Table 4: Reliability Assessment

Construct	Cronbach's Alpha	Composite Reliability	Interpretation
PTC	0.81	0.86	Good reliability
BSA	0.88	0.91	Excellent reliability
SIC	0.84	0.89	Good reliability
TMS	0.90	0.93	Excellent reliability
OR	0.86	0.90	Very good reliability
OLC	0.87	0.91	Excellent reliability
RF	0.82	0.87	Good reliability
CP	0.85	0.89	Very good reliability
MU	0.80	0.85	Acceptable reliability
BAI	0.91	0.94	Excellent reliability

Interpretation

All constructs exceed the recommended threshold of 0.70, confirming strong internal consistency of the measurement scales.

6.3 Validity Assessment

Convergent Validity

Convergent validity was evaluated using Average Variance Extracted (AVE) and factor loadings.

Table 5: Convergent Validity Results

Construct	AVE	Interpretation
PTC	0.56	Adequate
BSA	0.68	Strong
SIC	0.61	Adequate
TMS	0.72	Strong
OR	0.64	Adequate
OLC	0.67	Strong
RF	0.58	Adequate
CP	0.63	Adequate
MU	0.55	Adequate
BAI	0.71	Strong

All AVE values exceed 0.50, confirming satisfactory convergent validity.

Discriminant Validity

Discriminant validity was established using the Fornell–Larcker criterion, where the square root of AVE for each construct was greater than its correlations with other constructs. This confirms that each construct is conceptually distinct.

7. Structural Model and Hypothesis Testing

Structural Equation Modelling using PLS-SEM was performed in SmartPLS with 5,000 bootstrap samples to test the hypothesized relationships.

7.1 Model Fit Evaluation

The overall model fit was assessed using standard fit indices, with the following results:

Table 6: Model Fit Evaluation

Fit Index	Value Obtained	Recommended Threshold	Interpretation
SRMR	0.061	< 0.08	Good fit
NFI	0.91	> 0.90	Good fit
RMS Theta	0.12	< 0.15	Acceptable

The fit indices indicate that the proposed TOE-based model adequately represents the data.

Table 7: Hypotheses Testing Results

Hypothesis	Path Description	Standardized Path	t-value	p-value	Conclusion

		Coefficient (β)			
H01	PTC → BAI	-0.21	2.98	<0.01	Supported
H02	BSA → BAI	0.34	4.76	<0.001	Supported
H03	SIC → BAI	0.26	3.89	<0.001	Supported
H04	TMS → BAI	0.38	5.21	<0.001	Supported
H05	OR → BAI	0.29	4.02	<0.001	Supported
H06	OLC → BAI	0.31	4.44	<0.001	Supported
H07	RF → BAI	0.23	3.36	<0.01	Supported
H08	CP → BAI	0.27	3.91	<0.001	Supported
H09	MU → BAI	-0.18	2.64	<0.05	Supported

Interpretation

1. Technological factors show that security assurance and system compatibility positively influence blockchain adoption, while technical complexity negatively affects adoption intention.
2. Organizational factors, particularly top management support and learning capability, exert the strongest influence on adoption intention.
3. Environmental factors reveal that regulatory clarity and competitive pressure encourage adoption, whereas market uncertainty acts as a deterrent

Table 8: Measurement Items and Sources

Construct	**Item Code**	**Measurement Item**	**Source**
Perceived Technical Complexity (PTC)	PTC1	Blockchain technology is difficult to understand for our organization	Rogers (2003); Kuan & Chau (2001)
	PTC2	Implementing blockchain requires highly specialized technical skills	
	PTC3	Managing blockchain systems is complex	
	PTC4	Blockchain integration increases system complexity	
Blockchain Security Assurance (BSA)	BSA1	Blockchain ensures high data integrity	Narayanan et al. (2016); Gefen et al. (2003)
	BSA2	Blockchain transactions are tamper-resistant	
	BSA3	Blockchain enhances transaction security	
	BSA4	Blockchain improves auditability	
	BSA5	Blockchain ensures data privacy	
System Integration	SIC1	Blockchain is compatible with existing IT systems	
	SIC2	Blockchain fits well with current business processes	

Compatibility (SIC)	SIC3	Integration of blockchain is technically feasible	Thong (1999); Zhu et al. (2006)
	SIC4	Blockchain aligns with organizational workflows	
Top Management Support (TMS)	TMS1	Top management strongly supports blockchain adoption	Premkumar & Roberts (1999)
	TMS2	Management allocates sufficient resources for blockchain	
	TMS3	Leadership encourages blockchain experimentation	
	TMS4	Management actively participates in blockchain initiatives	
	TMS5	Blockchain adoption is a strategic priority	
Organizational Readiness (OR)	OR1	Our organization has adequate IT infrastructure	Tornatzky & Fleischer (1990); Zhu et al. (2006)
	OR2	Financial resources are sufficient	
	OR3	Skilled personnel are available	
	OR4	Organizational processes support blockchain adoption	
	OR5	Our organization is ready to adopt blockchain	
Organizational Learning Capability (OLC)	OLC1	Employees are encouraged to learn new technologies	Hult et al. (2004)
	OLC2	Training programs support blockchain learning	
	OLC3	Knowledge sharing is actively promoted	
	OLC4	Organization adapts quickly to technological change	
Regulatory Framework (RF)	RF1	Regulations support blockchain adoption	Kuan & Chau (2001)
	RF2	Legal guidelines for blockchain are clear	
	RF3	Regulatory compliance for blockchain is manageable	
	RF4	Regulators encourage innovation	
Competitive Pressure (CP)	CP1	Competitors are adopting blockchain	Rogers (2003); Zhu et al. (2006)
	CP2	Competitive pressure motivates blockchain adoption	
	CP3	Fintech firms influence adoption decisions	
	CP4	Blockchain adoption is necessary to remain competitive	
Market Uncertainty (MU)	MU1	Blockchain standards are still evolving	Zhu et al. (2006)
	MU2	Long-term viability of blockchain is uncertain	
	MU3	Market conditions for blockchain are unstable	
	MU4	Technological uncertainty discourages adoption	
Blockchain Adoption	BAI1	Our organization intends to adopt blockchain	Upadhyay (2020)
	BAI2	Blockchain will be implemented in near future	

Intention (BAI)	BAI3	We are willing to invest in blockchain	
	BAI4	Blockchain adoption is likely	
	BAI5	Blockchain will be operationalized	

7.2 Predictive Power of the Model

- R^2 value for Blockchain Adoption Intention (BAI) = 0.68, indicating that 68% of the variance in adoption intention is explained by TOE factors.
- Q^2 value = 0.41, confirming strong predictive relevance of the model.

The SEM–PLS analysis confirms that the Technology–Organization–Environment framework is highly suitable for explaining blockchain adoption in Indian financial institutions. Organizational readiness and leadership support emerge as the most influential drivers, while technological complexity and market uncertainty remain critical barriers.

8. Discussion of Findings

This study empirically investigated the challenges and enablers of blockchain adoption in Indian financial institutions using the Technology–Organization–Environment (TOE) framework and the SEM–PLS approach. The findings provide comprehensive insights into how technological characteristics, organizational capabilities, and environmental conditions jointly shape blockchain adoption intention in a highly regulated financial ecosystem.

8.1 Interpretation of Structural Relationships

The results indicate that blockchain adoption is influenced by both enabling and inhibiting forces across all three TOE dimensions. Within the technological context, perceived technical complexity negatively influences adoption intention, highlighting the persistent challenges associated with system implementation, skill requirements, and integration with legacy infrastructure. This confirms that technological sophistication remains a critical barrier for large financial institutions with entrenched systems. Conversely, blockchain security assurance and system integration compatibility positively influences adoption intention, suggesting that institutions are more inclined to adopt blockchain when it is perceived as secure and compatible with existing information systems.

The organizational context emerges as the most influential dimension in the adoption decision. Top management support exerts the strongest effect on blockchain adoption intention, underscoring the strategic nature of blockchain initiatives. Organizational readiness and organizational learning capability also show significant positive relationships, indicating that institutions with adequate resources, technological preparedness, and a culture of continuous learning are better positioned to adopt complex digital innovations.

In the environmental context, regulatory framework and competitive pressure positively influence blockchain adoption intention, while market uncertainty has a significant negative effect. These findings reflect the dual role of the external environment, where regulatory clarity and competitive dynamics encourage adoption, but uncertainty regarding market maturity, technological standards, and return on investment discourages large-scale implementation.

8.2 Comparison with Prior Studies

The findings are largely consistent with prior technology adoption and blockchain literature. The negative impact of technical complexity aligns with diffusion of innovation theory, which identifies complexity as a major barrier to adoption (Rogers, 2003). The positive role of security assurance corroborates earlier studies emphasizing blockchain's cryptographic security and immutability as critical enablers in financial services (Kshetri, 2017). Similarly, system compatibility has been recognized as a key determinant in enterprise technology adoption (Tornatzky & Fleischer, 1990).

The strong influence of organizational factors supports existing TOE-based studies that highlight leadership support and organizational readiness as dominant drivers of innovation adoption (Thong, 1999; Oliveira & Martins, 2011). The inclusion of organizational learning capability extends prior research by demonstrating that learning orientation and employee skill development are particularly relevant for emerging and complex technologies such as blockchain.

From an environmental perspective, the positive effect of regulatory support aligns with institutional theory and fintech adoption studies (Puschmann, 2017), while the negative influence of market uncertainty confirms earlier findings on risk and uncertainty in innovation adoption (Pavlou & El Sawy, 2006). However, this study contributes uniquely by providing empirical evidence from the Indian financial sector, an emerging economy context that remains underexplored in blockchain research.

8.3 Dominance of TOE Dimensions

A key insight from the study is the dominance of the organizational dimension over technological and environmental factors. This suggests that blockchain adoption in Indian financial institutions is primarily a strategic and managerial decision, driven by leadership commitment, readiness of resources, and learning capabilities. Technological factors play a supportive role by influencing feasibility and risk perceptions, while environmental factors act as contextual enablers or constraints. This hierarchy of influence reinforces the argument that successful blockchain adoption requires organizational transformation and leadership-driven change, supported by robust technology and a conducive regulatory environment.

Table 8: Key Findings vs. Prior Literature

Key Finding	**Supporting Prior Literature**	**Consistency / Contribution**
Technical complexity negatively affects blockchain adoption	Rogers (2003); Zhu et al. (2006)	Consistent with innovation diffusion theory
Security assurance positively influences adoption	Kshetri (2017); Yli-Huumo et al. (2016)	Confirms blockchain-specific trust mechanisms
System integration compatibility enhances adoption	Tornatzky & Fleischer (1990)	Reinforces TOE technological dimension
Top manasgement support is the strongest predictor	Thong (1999); Oliveira & Martins (2011)	Confirms leadership dominance in adoption
Organizational readiness positively affects adoption	Zhu & Kraemer (2005)	Supports organizational preparedness theory

Organizational learning capability promotes adoption	Huber (1991); Chen & Tsou (2012)	Extends TOE with learning perspective
Regulatory framework encourages adoption	Puschmann (2017)	Supports institutional theory
Competitive pressure drives adoption	Teo et al. (2003)	Consistent with environmental pressure argument
Market uncertainty inhibits adoption	Pavlou & El Sawy (2006)	Confirms risk and uncertainty effects
Organizational dimension dominates TOE framework	Oliveira & Martins (2011)	New evidence from Indian financial sector

This table compares the study's key empirical findings with prior technology and blockchain adoption literature, demonstrating strong theoretical consistency while extending the TOE framework through context-specific evidence from Indian financial institutions.

9. Implications of the Study

The findings of this study offer important theoretical and practical implications for scholars, policymakers, and practitioners seeking to understand and promote blockchain adoption in financial institutions.

9.1 Theoretical Implications

This study provides empirical validation of the Technology–Organization–Environment (TOE) framework in the context of blockchain adoption within Indian financial institutions. By demonstrating that technological, organizational, and environmental factors jointly influence adoption intention, the study reinforces the robustness and applicability of the TOE framework for examining emerging digital technologies in highly regulated sectors.

Further, the study extends organizational technology adoption literature by highlighting the dominant role of organizational factors, particularly top management support, organizational readiness, and organizational learning capability. While prior research has largely emphasized technological attributes or external pressures, the present study empirically confirms that blockchain adoption is fundamentally a strategic and managerial decision. The inclusion of organizational learning capability also contributes to theory by emphasizing the importance of knowledge creation and continuous learning in adopting complex and evolving technologies such as blockchain.

9.2 Practical Implications

The findings provide actionable guidance for policymakers and regulators, including the Reserve Bank of India (RBI) and other financial authorities. The positive influence of regulatory clarity on adoption intention suggests that clearly defined legal frameworks, compliance guidelines, and sandbox initiatives can significantly reduce uncertainty and encourage responsible blockchain implementation across financial institutions.

For financial institutions and fintech firms, the study offers strategic insights into effective adoption pathways. Strengthening leadership commitment, investing in organizational readiness, and fostering a learning-oriented culture are critical for successful blockchain adoption. Additionally, addressing technological challenges related to system integration and security assurance can enhance organizational confidence and reduce resistance. Collectively, these insights can assist institutions in designing informed blockchain strategies that balance innovation with operational and regulatory considerations.

10. Limitations of the Study

Despite its contributions, the study has several limitations:

1. Sample Scope: The study focused on managers, IT heads, and compliance officers from select Indian financial institutions. While sufficient for exploratory SEM–PLS analysis, the sample may not fully capture perspectives from smaller fintech startups or rural banking institutions.
2. Cross-sectional Design: Data were collected at a single point in time, limiting the ability to capture temporal changes in blockchain adoption intentions.
3. Self-reported Measures: Responses were based on perceptions, which may be subject to social desirability or response bias.
4. Context-specific Findings: The results are specific to the Indian financial sector; generalization to other countries or industries may require caution.

11. Future Research Directions

1. Longitudinal Studies: Future research could track blockchain adoption over time to assess changes in adoption intention and actual implementation.
2. Broader Stakeholder Perspectives: Including regulators, technology vendors, and customers could provide a more comprehensive understanding of adoption drivers and barriers.
3. Comparative Studies: Cross-country or cross-industry studies can explore how regulatory frameworks, competitive pressures, and technological readiness vary across contexts.
4. Integration with Other Theories: Combining TOE with other theoretical perspectives, such as Diffusion of Innovation (DOI) or Institutional Theory, may enhance explanatory power.
5. Exploration of Emerging Technologies: Future studies can examine blockchain adoption alongside AI, IoT, and cloud computing to understand technology co-adoption strategies.

12. Conclusion

This study empirically examined the challenges and enablers of blockchain adoption in Indian financial institutions using the TOE framework and SEM–PLS methodology. The results confirm that organizational factors—particularly top management support, readiness, and learning capability—dominate adoption decisions, followed by technological and environmental factors. While security assurance and system compatibility enhance adoption, technical complexity and market uncertainty remain key barriers. The study validates the TOE framework as a robust tool for analyzing blockchain adoption in emerging economies and provides actionable insights for policymakers, financial institutions, and fintech firms. By integrating organizational, technological, and environmental perspectives, the study contributes both theoretically and practically to the understanding of blockchain implementation in the Indian financial sector.

12.1 Policy and Managerial Recommendations

1. Regulatory Clarity: Policymakers, including RBI, should provide clear guidelines, compliance frameworks, and sandbox initiatives to reduce uncertainty.
2. Leadership Commitment: Financial institutions should strengthen top management support for blockchain initiatives to ensure strategic alignment and resource allocation.
3. Organizational Readiness: Institutions must invest in infrastructure, skill development, and process reengineering to facilitate seamless blockchain integration.
4. Training and Learning: Promote organizational learning and continuous employee training to enhance knowledge of blockchain applications and risks.
5. Technological Support: Ensure robust security measures and system integration capabilities to build confidence among stakeholders.
6. Competitive Awareness: Institutions should monitor competitive trends and adopt blockchain strategically to maintain market position.

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