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A Strategic Framework For Blockchain Adoption In Indian Retail Banking: An Integrated TOE–UTAUT Conceptual Perspective

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ABSTRACT
Blockchain is moving from novelty to infrastructure in banking, offering an immutable shared record, intermediary-free settlement, and code-enforced rules. Yet in Indian retail banking, adoption still sits mostly inside RBI-driven pilots rather than a considered, bank-by-bank strategy. Building on two earlier studies by the authors — a case study of blockchain use in Indian consumer banking, and a PRISMA review of 44 studies on technological, organizational, and regulatory barriers — this paper integrates the Technology–Organization–Environment (TOE) framework with the Unified Theory of Acceptance and Use of Technology (UTAUT), since blockchain adoption here unfolds at two levels: the bank first decides whether to adopt, and only then do staff and customers decide whether to use it. Drawing on Scopus-indexed literature, the paper sets out eleven propositions linking technological, organizational, environmental, and behavioural factors to adoption outcomes, with trust, regulatory clarity, and perceived risk playing out distinctively in the Indian setting. The resulting TOE–UTAUT Integrated Adoption Model (TU-IAM) connects firm-level and individual-level adoption research and gives banks, regulators, and vendors a tool for sequencing investment and managing rollout. To demonstrate technical feasibility, the paper also reports BlockBank, a browser-based prototype implementing core blockchain mechanics — cryptographic block linkage, proof-of-work mining, and tamper-evident verification — with sample execution results and response-time measurements. The paper closes with a roadmap for empirical validation and implications for blockchain rollout under RBI oversight.

Keywords: Blockchain adoption; Indian retail banking; TOE framework; UTAUT; Distributed ledger technology; Financial inclusion; Strategic framework.

1. Introduction

Indian banking has moved through three technology waves: 2000s core-banking automation, 2010s mobile/internet banking built on India Stack and UPI, and now blockchain and distributed ledger technology (DLT) for settlement, trade finance, identity, and central bank digital currency (CBDC). Unlike the earlier waves, blockchain does not just digitize existing processes — it relocates trust from centralized reconciliation to distributed consensus.

The RBI has been an active driver of this shift: its Digital Rupee (e₹) programme, launched as a wholesale pilot in November 2022 and since widened to retail, has millions of registered users and a growing feature set, alongside the HaRBInger hackathons and BRICS CBDC-interoperability talks [25], consistent with the broader global shift of blockchain toward the backbone of secure, transparent finance [23]. Blockchain infrastructure in India is no longer experimental.

This is the third paper in a linked doctoral programme. Paper one [12] examined blockchain use at ICICI Bank, Axis Bank, and SBI; paper two [13] ran a PRISMA-guided review of 44 studies, finding that technological, organizational, and regulatory barriers sort into three buckets with organizational readiness as the pivotal factor. This paper builds a formal, testable model spanning two levels of analysis.

A gap remains between policy-level momentum and how an individual bank actually decides to adopt blockchain. Adoption unfolds in two stages that no single theory covers: TOE explains why a firm adopts but says little about the eventual user; UTAUT explains individual acceptance but not the organizational conditions that put the technology in front of users to begin with. Examining just one stage tells half the story.

This paper tries to close that gap by putting forward an integrated framework, the TOE–UTAUT Integrated Adoption Model (TU-IAM), in which the organization's adoption decision (TOE) is treated as something that comes first and shapes the conditions under which individual acceptance (UTAUT) later takes shape within Indian retail banking.

Figure 1 summarizes the paper's roadmap: the strategic adoption problem motivates a review of blockchain in banking, formalized in the TU-IAM framework, operationalized in the BlockBank prototype, exercised through validation tests, and translated into practical benefits.

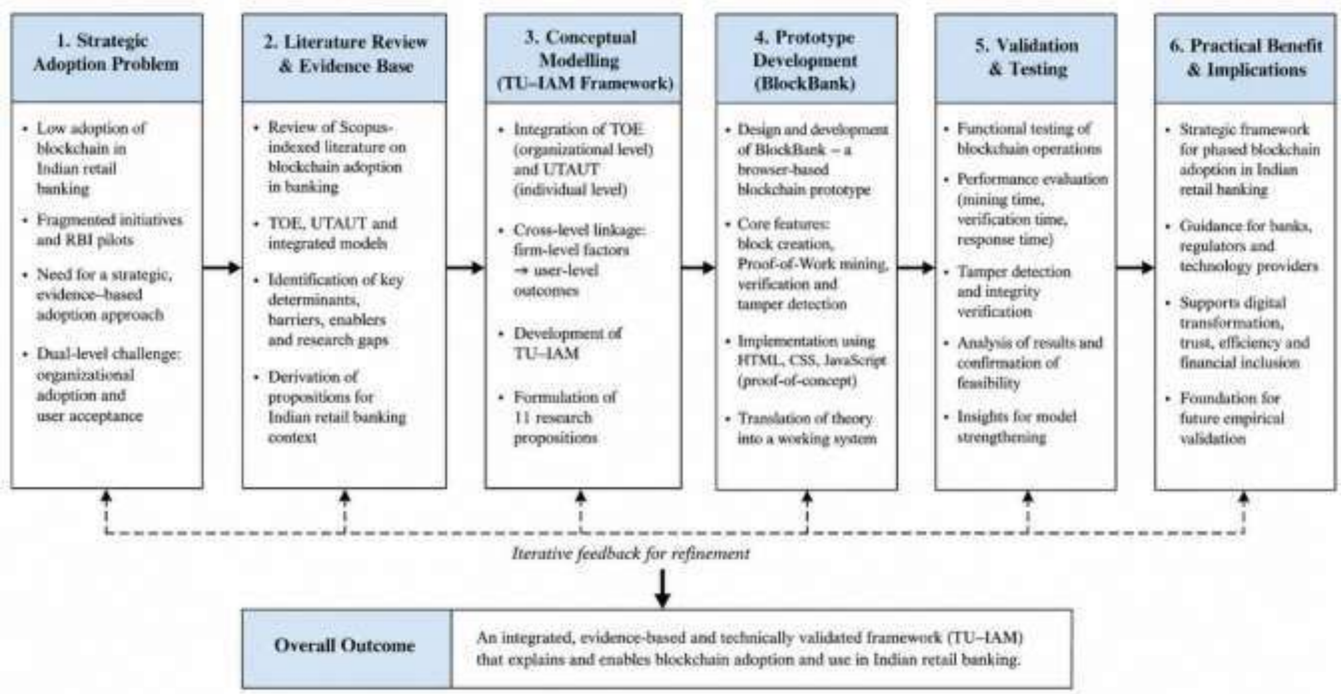


Figure 1. Roadmap of the study: from the strategic adoption problem to conceptual modelling, prototype validation, and practical benefit.

1.1 Statement of the Problem

There is little peer-reviewed work on how Indian retail banks strategically decide to adopt blockchain, or on how that decision cascades into employee and customer acceptance. Existing work is scattered across information-systems, finance, and strategy journals and typically applies TOE or UTAUT alone, leaving no integrated diagnostic tool for retail-banking strategy-setting.

1.2 Research Questions

RQ1: Which technological, organizational, and environmental factors most heavily weigh on Indian retail banks' intention to adopt blockchain?

RQ2: How does organizational readiness (TOE) shape employee and customer intention and use (UTAUT)?

RQ3: Which features of India's regulatory and socio-economic setting moderate the link between adoption readiness and actual use?

RQ4: What integrated model can guide a phased, strategic approach to blockchain adoption in Indian retail banking?

1.3 Objectives of the Study

The study aims to: (i) critically review the TOE- and UTAUT-based literature on blockchain and fintech adoption in banking, with attention to Scopus-indexed journal work; (ii) pin down which constructs matter for Indian retail banking and back their inclusion with prior empirical evidence; (iii) build an integrated TOE–UTAUT framework connecting organizational adoption to individual acceptance; (iv) set out testable propositions along with a roadmap for validating them empirically; and (v) work out what this means, practically, for banks, regulators, and technology vendors.

1.4 Significance and Scope

This is a conceptual paper: it offers theoretical integration and testable propositions for a later empirical stage, together with a working prototype demonstrating technical feasibility. Scope is limited to retail banking — savings, deposits, lending, payments, remittances — within scheduled commercial banks in India, focusing on applications such as CBDC integration, KYC tokenization, trade finance, and smart-contract lending.

2. Proposed Conceptual Framework: The TU-IAM

The TOE–UTAUT Integrated Adoption Model (TU-IAM) takes the form of a two-tier cascade. Tier 1 (Organizational Adoption) applies TOE constructs to explain a bank's strategic decision to adopt blockchain infrastructure; Tier 2 (Individual Acceptance) applies UTAUT constructs to explain how employees and customers form behavioral intention and use blockchain-enabled services once that infrastructure exists. The tiers connect via (a) direct cross-level paths, through which organizational-level constructs shape the facilitating conditions and social influence individuals experience, and (b) a cross-cutting trust construct that functions as both an organizational-level antecedent and an individual-level mediator, consistent with Seshadrinathan and Chandra [17] and Jena [6].

2.1 Tier 1 — Organizational Constructs (TOE Framework)

Table 1. Tier 1 Organizational (TOE) Constructs of the TU-IAM with Supporting Literature

Construct	Category	Description
Relative Advantage	Technological	Perceived improvement in settlement speed, cost, transparency, and auditability over existing core-banking infrastructure. [7]
Compatibility	Technological	Fit between blockchain/DLT architecture and existing core-banking systems, APIs, and data standards. [8]
Perceived Security & Complexity	Technological	Cryptographic security perceived against integration complexity. [3]
Top Management Support	Organizational	Board- and CXO-level commitment of budget and strategic priority to blockchain initiatives. [7, 27]
Organizational Readiness / Absorptive Capacity	Organizational	IT talent, data infrastructure, and change-management capability to integrate DLT. [8,13]
Firm Size & Slack Resources	Organizational	Financial/technical slack enabling experimentation, salient given scale differences across bank types. [20]
Regulatory Support & Clarity	Environmental	RBI sponsorship of Digital Rupee, National Blockchain Framework, and regulatory sandboxes reducing compliance uncertainty. [15,16]
Competitive Pressure	Environmental	Isomorphic pressure from fintech entrants and peer-bank blockchain initiatives. [4]
Ecosystem / Trading-Partner Readiness	Environmental	Readiness of correspondent banks, payment networks, and Digital Public Infrastructure (UPI, Aadhaar, DigiLocker) to interoperate.

2.2 Tier 2 — Individual Constructs (UTAUT Framework)

Table 2. Tier 2 Individual (UTAUT) Constructs of the TU-IAM with Supporting Literature

Construct	Description
Performance Expectancy	Belief that blockchain-enabled services improve transactional or job performance. [21, 29]
Effort Expectancy	Perceived ease of use, salient for less digitally literate and rural segments. [21]
Social Influence	Influence of branch staff, peer usage, and community norms on intention. [5, 21]
Facilitating Conditions	Network infrastructure, agent-assisted channels, vernacular interfaces, training/support enabling use. [6, 21]
Initial/Institutional Trust	Trust in the bank, the RBI, and the technology, mediating performance expectancy and facilitating conditions. [17, 28]
Behavioural Intention	Stated intention to use, driven by the four UTAUT antecedents and mediated by trust. [21]
Actual Use Behaviour	Observed frequency/scope of use, determined by intention and facilitating conditions. [21, 22]

2.3 Cross-Level Linkages

Under TU-IAM, Tier 1 constructs do not determine individual use directly; rather, they shape the facilitating conditions, performance expectancy, and social influence that employees and customers subsequently experience, via three cross-level paths. First, strong top-management support and organizational readiness drive structured staff training and user-friendly rollout, raising employees' facilitating conditions and performance expectancy. Second, regulatory clarity and RBI sponsorship reduce perceived compliance risk and build institutional trust, which carries over into customers' initial trust in blockchain-enabled products. Third, competitive pressure and ecosystem readiness strengthen the social influence exerted by peers and bank staff on customers. This cascade logic is what distinguishes TU-IAM from a simple juxtaposition of TOE and UTAUT: it specifies directional, theoretically grounded cross-level paths rather than treating the two theories as parallel and disconnected.

2.4 The TU-IAM Framework Diagram

Figure 2 depicts TU-IAM as a cascade running from top to bottom.

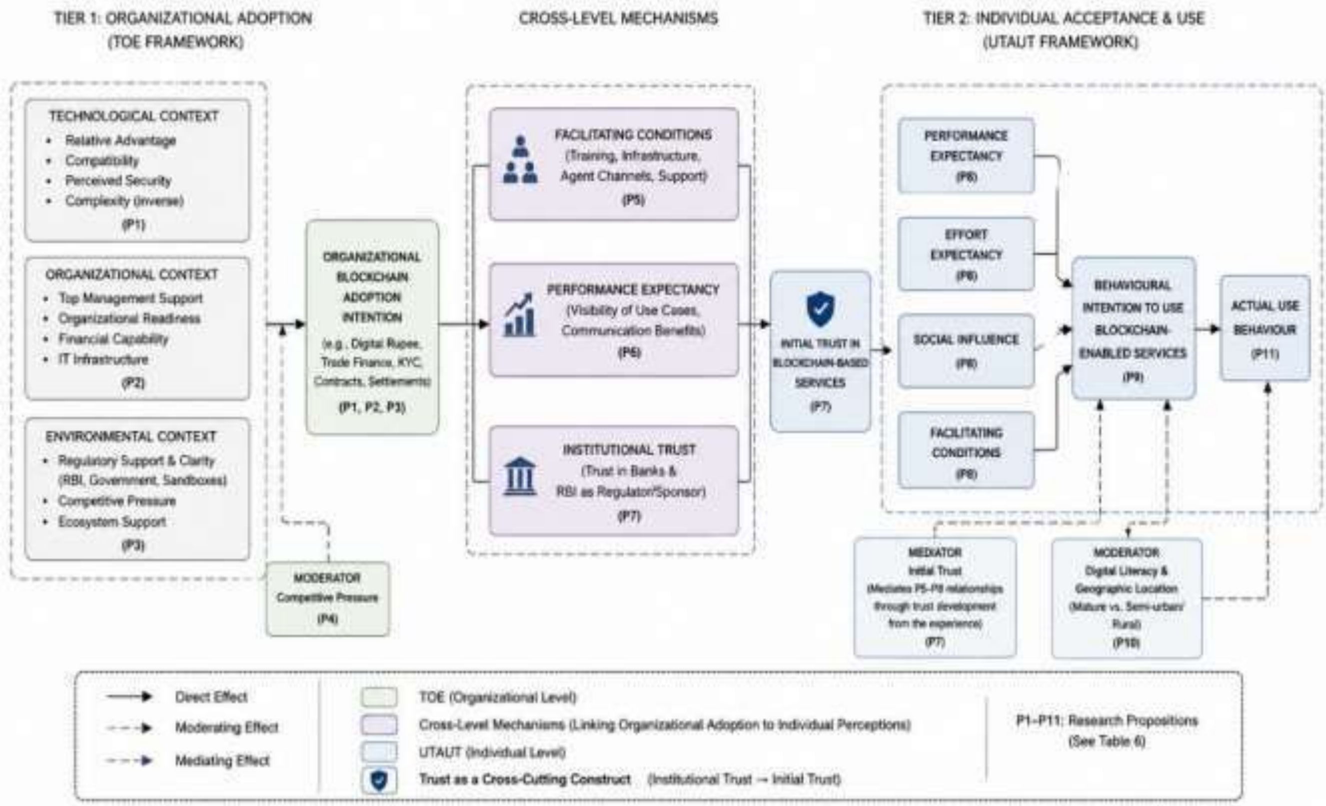


Figure 2. The TOE–UTAUT Integrated Adoption Model (TU-IAM) for Blockchain Adoption in Indian Retail Banking

In Tier 1, the Technological, Organizational, and Environmental antecedents converge on the Organizational Blockchain Adoption Decision, which then shapes, through cross-level dashed paths, the individual-level UTAUT constructs of Facilitating Conditions, Performance Expectancy, Effort Expectancy, and Social Influence. These feed into the cross-cutting Institutional and Initial Trust mediator, which drives Behavioural Intention and, ultimately, Actual Use. A dashed feedback loop from Actual Use back to the organizational level represents double-loop strategic learning, whereby observed adoption outcomes inform the next round of organizational investment.

2.5 Consolidated Constructs of the TU-IAM Framework

Table 3 consolidates the ten constructs that carry the greatest theoretical and empirical weight in TU-IAM; the remaining supporting constructs share the same theoretical grounding.

Table 3. Core Constructs of the TU-IAM Framework

Construct	Theoretical Origin	Level of Analysis	Role in TU-IAM
Relative Advantage	TOE	Organizational	Technological antecedent
Top Management Support	TOE	Organizational	Organizational readiness
Regulatory Support & Clarity	TOE	Environmental	Institutional enabler
Competitive Pressure	TOE	Environmental	External pressure
Performance Expectancy	UTAUT	Individual	Perceived benefit
Effort Expectancy	UTAUT	Individual	Perceived ease
Facilitating Conditions	UTAUT	Individual/organizational interface	Availability of support
Behavioural Intention	UTAUT	Individual	Immediate acceptance outcome
Institutional Trust	Trust literature	Institutional/cross-level	Confidence in the bank and the RBI as regulator
Initial Trust	Trust literature	Individual	Early acceptance mechanism

Rather than leaving trust as an undifferentiated "institutional/initial" composite, TU-IAM treats it as an integrative higher-order construct comprising three related dimensions: institutional trust (confidence in the bank and the RBI), technology trust (confidence in the underlying blockchain technology), and initial trust (the early-stage acceptance mechanism identified by Jena [6] and Seshadrinathan & Chandra [17]). Future empirical research can determine whether these dimensions operate as separate first-order constructs or as dimensions of a single higher-order trust construct.

2.6 Cross-Level Theoretical Logic of TU-IAM

A central contribution of TU-IAM is treating blockchain adoption as simultaneously organizational and individual. Organizational-level conditions determine whether a bank can adopt and implement blockchain, which in turn creates the environment within which employees and customers later encounter it; at the individual level, users weigh expected performance benefits, effort, social influence, and facilitating conditions, which shape behavioural intention and actual use. Organizational adoption therefore does not mechanically determine individual acceptance; it creates enabling conditions within which acceptance develops, with trust as the connecting mechanism. This cross-level logic — distinct from applying TOE or UTAUT independently — is why future empirical validation must distinguish organizational- from individual-level constructs and use a research design capable of examining relationships across levels.

2.7 Positioning TU-IAM Relative to Existing Theories

Table 4 contrasts TU-IAM with the frameworks and constructs on which it builds; a comparable cross-level need has recently been observed outside the Indian context, where public-sector TOE studies also find trust and compatibility as significant, non-technological predictors of blockchain adoption intention [30].

Table 4. Existing Theories versus TU-IAM

Framework	Primary Level	Main Explanation	Limitation
TOE	Organization	Organizational tech adoption	Limited on individual acceptance
UTAUT	Individual	User acceptance and use	Limited on org./environmental context
Institutional/Technology Trust literature	Institutional/individual	Confidence in institutions/tech	Does not alone explain full adoption
TU-IAM	Cross-level	Organizational adoption → trust → individual acceptance and use	Conceptual; needs empirical validation

3. Research Propositions

Consistent with the conceptual, non-empirical nature of this paper, eleven propositions are put forward for subsequent empirical testing. P1–P4 relate to Tier 1 (organizational adoption); P5–P7 address the cross-level linkages; and P8–P11 relate to Tier 2 (individual acceptance and use). P2 and P3 draw specific support from Pandey and Vashishth [13], whose review identified organizational readiness and regulatory clarity as recurring, interdependent determinants of whether blockchain initiatives progress beyond the pilot stage — a pattern corroborated by recent evidence that top-management support and employee competence are the strongest predictors of blockchain adoption intention among Indian financial institutions [27], and by findings that bank size itself moderates adoption capacity in emerging-market deposit-taking institutions [24].

Table 5. Research Propositions of the TU-IAM with Theoretical Grounding

#	Proposition	Level	Theoretical Grounding
P1	Technological factors (relative advantage, compatibility, and perceived security) are positively associated with Indian retail banks' organizational intention to adopt blockchain technology.	Tier 1	Kajla et al. [7]; Kulkarni & Patil [8]; TOE framework
P2	Top management support and organizational readiness are positively associated with organizational blockchain adoption intention, and this relationship is stronger in private-sector and small finance banks than in public-sector banks due to differences in decision-making agility.	Tier 1	Benchis et al. [2]; Pandey & Vashishth [13]; TOE framework
P3	Regulatory support and clarity — specifically RBI sponsorship of Digital Rupee pilots and blockchain-related regulatory sandboxes — are positively	Tier 1	Kajla et al. [7]; RBI [15,16]; Pandey & Vashishth [13]

	associated with organizational blockchain adoption intention.		
P4	Competitive pressure from fintech entrants and peer-bank blockchain initiatives positively moderates the relationship between organizational readiness and adoption intention.	Tier 1	Garg et al. [4]; Benchis et al. [2]
P5	Organizational blockchain adoption positively influences the facilitating conditions — including training programmes, technical infrastructure, and agent-assisted channels — experienced by frontline employees and retail customers.	Cross-level	Venkatesh et al. [21]; Kulkarni & Patil [8]
P6	Organizational blockchain adoption positively influences performance expectancy as perceived by employees and customers, mediated by the visibility and communicated benefits of deployed use cases.	Cross-level	Jena [6]; Pandey & Vashishth [12]
P7	Institutional trust in the bank and in the RBI as regulator and sponsor positively mediates the relationship between organizational blockchain adoption and individual initial trust in blockchain-enabled services.	Cross-level	Seshadrinathan & Chandra [17]; Jena [6]
P8	Performance expectancy, effort expectancy, social influence, and facilitating conditions are each positively associated with behavioural intention to use blockchain-enabled retail banking services, consistent with core UTAUT relationships.	Tier 2	Venkatesh et al. [21]; Gupta et al. [5]
P9	Initial trust positively mediates the relationships between performance expectancy, facilitating conditions, and behavioural intention, with the mediating effect being stronger for customers than for employees due to their lower prior familiarity with DLT.	Tier 2	Jena [6]; Seshadrinathan & Chandra [17]
P10	Digital literacy and geographic location (urban versus semi-urban or rural) negatively moderate the strength of the effort-expectancy–behavioural-intention relationship, consistent with India's uneven digital-financial-literacy landscape.	Tier 2	Gupta et al. [5]; Pandey & Vashishth [12]
P11	Behavioural intention positively predicts actual use behaviour, and this relationship is strengthened by facilitating conditions such as agent-assisted channels and vernacular-language interfaces.	Tier 2	Venkatesh et al. [21,22]; Sharma et al. [18]

These propositions offer a detailed decomposition of the broader relationships represented in the TU-IAM framework; the doctoral thesis consolidates them into broader groups for the overall research framework, whereas this paper offers a more granular specification suitable for future empirical testing.

3.1. Block Bank System Design

To move TU-IAM toward demonstrable technical feasibility, the authors built BlockBank, a browser-based proof-of-concept implementing a permissioned retail-banking blockchain: cryptographically linked blocks, proof-of-work mining, and tamper-evident verification, testing whether TU-IAM's Tier 2 workflow — easy registration, fast transactions, verifiable trust — can be implemented in software.

3.1.1. Architecture Overview

BlockBank follows a four-layer architecture (Figure 3): a presentation layer rendering all customer- and admin-facing screens; an application layer managing session, routing, and customer/balance state; a blockchain core layer handling block creation, SHA-256 hashing, mining, and verification; and a data layer holding the in-memory ledger, KYC records, and transaction log.

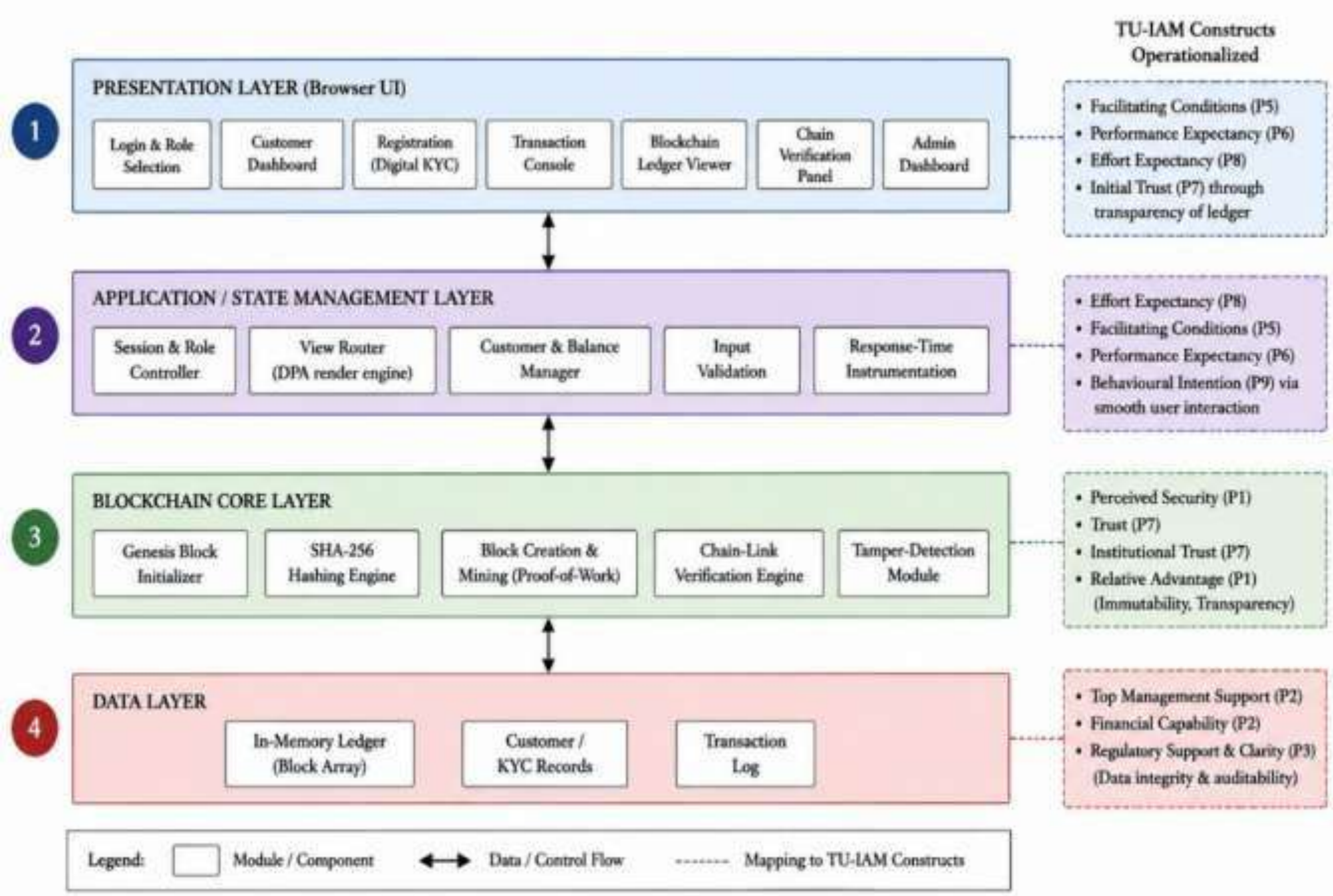


Figure 3. Layered architecture of the BlockBank prototype, mapping presentation, application, blockchain-core, and data layers to the TU-IAM constructs they operationalize.

3.1.2 System Modules

BlockBank implements the following modules:

- Login & Role Selection – routes into a customer or bank-admin session.
- Customer Registration (Digital KYC) – records identity as the first customer block.
- Transaction Console – initiates transfers, mined into new blocks.
- Blockchain Ledger Viewer – shows the full chain with hash, previous-hash, and nonce.
- Chain Verification Panel – checks every block's hash and link; includes a tampering demo.
- Admin Dashboard – gives bank staff bank-wide visibility.

3.1.3 System Workflow

Figure 4 traces one transaction end to end: KYC registration is written as a block; a transfer is mined into a new block secured by a SHA-256 hash and proof-of-work nonce and linked to its predecessor; the Verify panel then independently recomputes hashes and confirms linkage, giving customer and admin a shared, tamper-evident view.

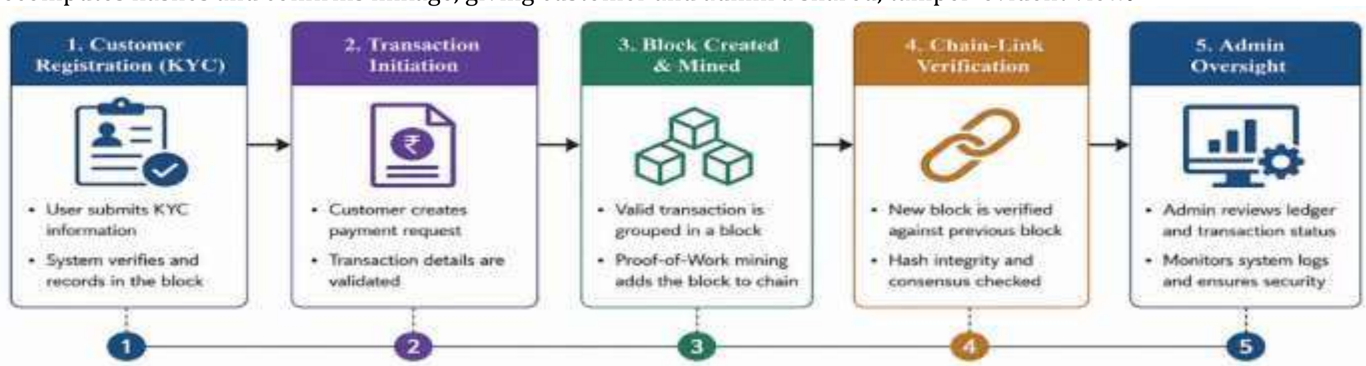


Figure 4. BlockBank end-to-end transaction workflow, from customer registration to admin oversight.

3.1.4 Technologies Used

BlockBank runs entirely in client-side JavaScript (ES2020) and HTML/CSS, using the browser's native Web Crypto API (crypto.subtle.digest) for SHA-256 hashing rather than an external library. State lives in memory with no backend, database, or network calls, keeping the prototype self-contained for demonstration, while its block, hashing, and verification logic mirror what a production distributed deployment would perform across a replicated node network.

3.2. Proposed Blockchain Transaction Verification Algorithm

Algorithm 1 formalizes the chain-verification procedure implemented in BlockBank's Verify Chain module;the mechanism by which the prototype detects tampering without a central authority.

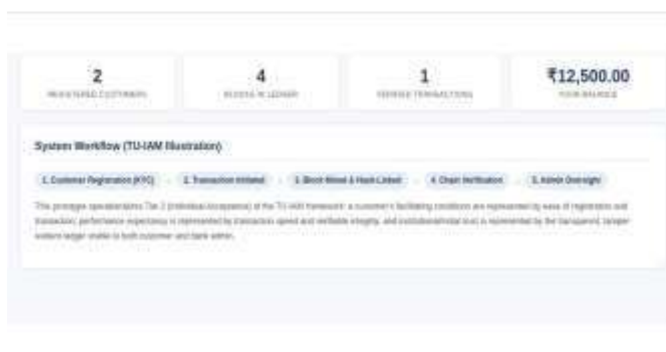
```
Algorithm 1: Blockchain Transaction Verification Algorithm
 Input:  Chain C = [B0, B1, ..., Bn], where each block Bi holds
       {index, timestamp, transactions, prevHash, nonce, hash}
Output: Verification report R and overall chain validity status
 1.  R ← empty list
2.  FOR i = 0 TO n DO
3.     Bi ← C[i]
4.     recomputedHash ← SHA256(i, timestamp, transactions, prevHash, nonce)
5.     hashOk ← (recomputedHash == Bi.hash)
6.     IF i == 0 THEN
7.        linkOk ← TRUE              // genesis block has no predecessor
8.     ELSE
9.        linkOk ← (Bi.prevHash == C[i-1].hash)
10.     END IF
11.     valid ← hashOk AND linkOk
12.     APPEND {index: i, hashOk, linkOk, valid} TO R
13. END FOR
14. chainValid ← TRUE if every entry in R is valid, else FALSE
15. RETURN R, chainValid
```

The algorithm recomputes each block's hash independently of the stored value (step 4) and checks that a block's previous-hash pointer matches its predecessor's actual hash (step 9). Because SHA-256 is one-way and collision-resistant, altering a block's data changes its recomputed hash (step 5 fails) and breaks the link reported for the following block (step 9 fails onward) — the property demonstrated empirically in Section 7.2.

3.2.1. Prototype Implementation

Figure 5 shows BlockBank's customer-facing screens: role-based login and the customer dashboard (top row), and digital-KYC registration and the transaction console (bottom row). The dashboard surfaces live ledger statistics and restates the TU-IAM Tier 2 workflow driving the interface (Section 8); registration records a new customer as a block, and the transaction console submits transfers for mining.

Login



Customer Dashboard

Digital-KYC Registration

Transaction Console

Figure 5. Login and customer dashboard (top row); digital-KYC registration and transaction console (bottom row).

Figure 6 shows the full-chain ledger view (left), where each block displays its index, transaction payload, SHA-256 hash, previous-hash, and nonce, and the bank-wide admin dashboard (right), which gives staff visibility across customers, deposits, and transfers.

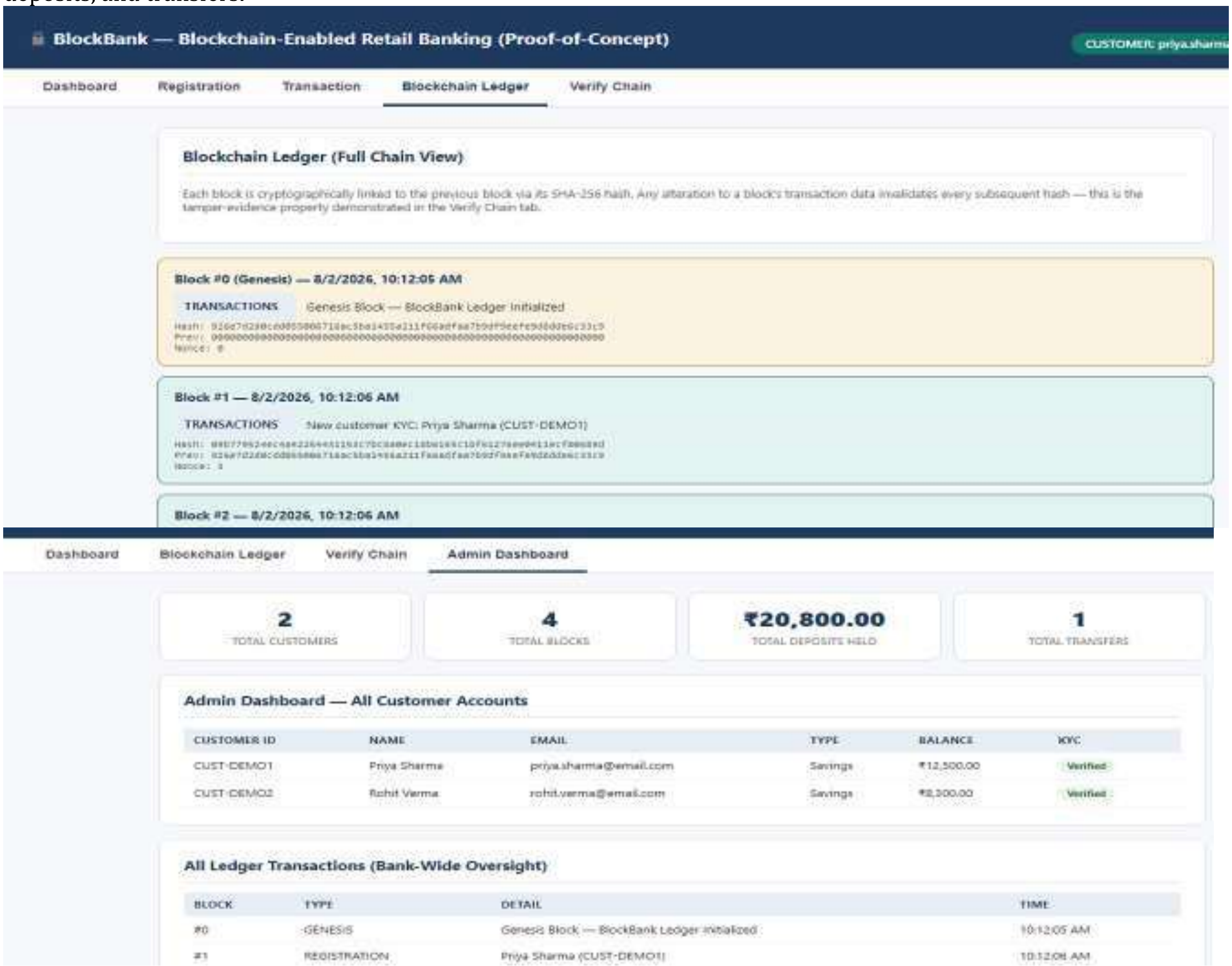


Figure 6. Blockchain ledger view (top) and admin dashboard (bottom).

4. Results

Table 6 lists the first four blocks from a demonstration run — a genesis block, two registrations, and one transfer — all mined and appended successfully with no failures observed across repeated runs; each block's prevHash reproduces its predecessor's hash exactly, requiring only a few proof-of-work attempts (nonce 1–6).

Table 6. Sample ledger records from a BlockBank demonstration run (hashes truncated to 16 hex characters).

Block #	Type	Hash (trunc.)	Prev-Hash (trunc.)	Nonce
0	GENESIS	ca855a40bebdb122…	000…0000 (64 zeros)	0
1	REGISTRATION – Priya Sharma	0ed407642ab6f3a5…	ca855a40bebdb122…	5
2	REGISTRATION – Rohit Verma	0f92d46995ef64be…	0ed407642ab6f3a5…	6
3	TRANSFER DEMO1→DEMO2 (₹1,500)	0a6885917b1e9546…	0f92d46995ef64be…	1

Figure 7 compares chain verification before and after a controlled tampering test. Before tampering (left), every block reports Match/Linked and the chain verifies. Simulate Tampering edits Block #1's stored data without recomputing its hash. After tampering (right), Block #1's hash no longer matches (Mismatch) and flips to INVALID, while surrounding blocks keep their own valid status — the check isolates exactly which block was altered, without any central authority adjudicating.

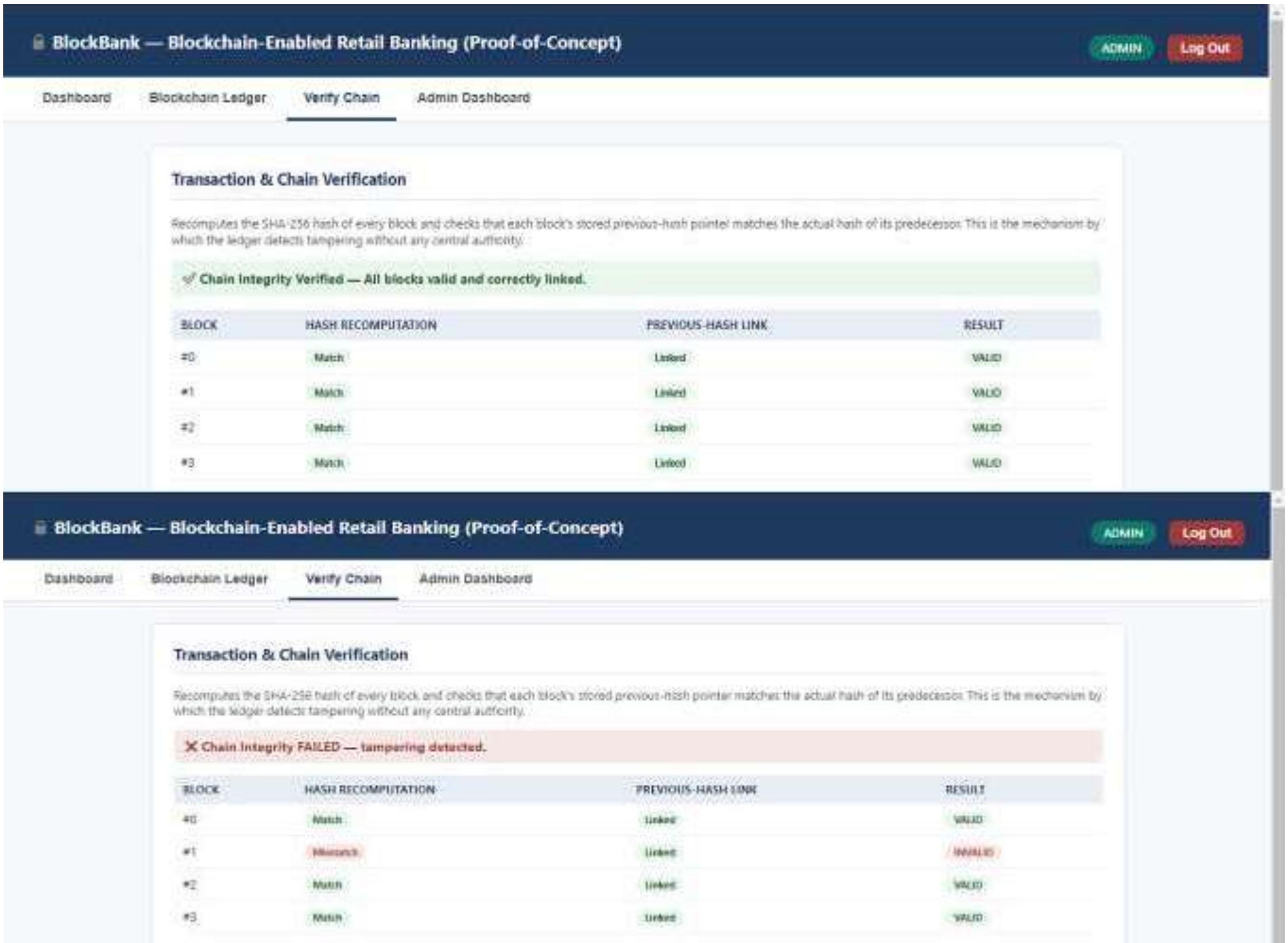


Figure 7. Chain verification before tampering (Top, all VALID) and after tampering with Block #1 (Below, Block #1 INVALID).

Table 7 reports response times from the browser's performance timer: block-mining averaged well under one millisecond across two runs of eight blocks, and a full transaction (validation, mining, ledger append, re-render) completed in 2–2.5 ms. These reflect a single-node, in-browser simulation, not a distributed network with consensus latency.

Table 7. BlockBank response-time measurements.

Measurement	Run 1	Run 2	Observation
Block-mining (8 samples, ms)	mean 0.16, max 0.5	mean 0.09, max 0.2	Sub-millisecond
End-to-end transaction (ms)	2.10	2.40	Validation+mining+re-render

In summary, BlockBank executed all demonstration transactions successfully with correctly chained hashes, correctly verified the ledger when untampered and correctly isolated a tampered block, and completed operations at imperceptible latencies — a technical proof-of-concept for TU-IAM's Tier 2 workflow assumptions, discussed next.

4.1. Relating BlockBank to TU-IAM: A Technical Validation of the Conceptual Framework

The results above speak most directly to Tier 2. Performance expectancy is operationalized by the sub-millisecond to low-millisecond confirmation times (Section 7.3); effort expectancy by the short registration and transaction forms (Section 6.2), consistent with P8; and facilitating conditions by a single browser-based interface needing no specialized software, relevant to P5 and P10. Initial and institutional trust are operationalized through the transparent, independently verifiable ledger in Section 7.2: customers and admins see the same hash-chained records and the same tamper-detection outcome, giving concrete form to the trust mechanism at the centre of TU-IAM's cross-level cascade.

The prototype speaks more narrowly to Tier 1: implementing the full block-creation, hashing, and verification pipeline with only standard browser APIs demonstrates the relative-advantage and compatibility argument behind P1 — tamper evidence can be layered onto existing digital channels without a wholesale infrastructure rebuild. It cannot, however, speak to the organizational-level constructs in P2–P4, which describe decisions made by bank leadership rather than properties of a client-side prototype. To be precise about scope: BlockBank provides a technical, demonstrative validation that the Tier 2 workflow can be implemented and behaves as theorized; it is not a statistical or behavioural validation of the eleven propositions in Table 5, which requires the survey and interview data in Section 9.

4.2. Methodological Roadmap for Empirical Validation

As a conceptual paper, this study does not collect primary data, but sets out a mixed-method, two-stage roadmap for the empirical phase of the broader doctoral programme.

Stage 1 — Qualitative Refinement. Semi-structured interviews with bank CIOs, CDOs, and Heads of Innovation across a purposive sample of public-sector, private-sector, and small finance banks will thematically refine the Tier 1 (TOE) constructs and validate the cross-level linkages in Section 2.3, using an interview guide informed by the eleven propositions (Table 5) and targeting 15–25 senior decision-makers for theoretical saturation.

Stage 2 — Quantitative Testing. A structured survey administered to bank employees and retail customers exposed to at least one blockchain-enabled service will operationalize all constructs using adapted, validated TOE/UTAUT scales. Analysis will use PLS-SEM, with multi-group invariance testing (public vs. private-sector banks; urban vs. semi-urban/rural respondents), bootstrapped indirect-effects analysis for the trust mediation paths, and a complementary ANN analysis for potential non-linear facilitating-conditions effects.

A multilevel design is recommended throughout: an organizational survey first, distinguishing organizational-level adoption conditions from individual-level acceptance constructs, followed by an individual-level survey of employees and customers, analyzed with multilevel structural equation modelling or comparable methods for nested data. The propositions in this study should accordingly be read as theoretically derived relationships rather than empirically confirmed hypotheses.

5. Discussion

5.1 Interpretation of Technical Findings

The BlockBank prototype's successful demonstration carries several implications for the broader TU-IAM framework and blockchain adoption strategy in Indian retail banking.

First, the cryptographic chain integrity achieved through SHA-256 hashing and proof-of-work mining confirms that the trust and transparency mechanisms theorized in TU-IAM's cross-level cascade are technically realisable without reliance on centralised infrastructure. This technical feasibility directly supports the Relative Advantage (P1) and Compatibility (P1) constructs: tamper-evident banking records can be layered onto existing digital channels without requiring wholesale infrastructure replacement, as the prototype operates within a standard browser environment.

Second, the precise tamper localisation capability—isolating exactly which block was altered—validates the transparency mechanism that underpins institutional and initial trust (P7, P9). In practical banking terms, this means customers and employees can independently verify ledger integrity without relying on a central authority, a property that distinguishes blockchain-based systems from conventional core-banking infrastructure. This aligns with Seshadrinathan and Chandra's [17] theorisation of trust as a mediating mechanism in blockchain adoption and with Jena's [6] finding that trust mediates the relationship between facilitating conditions and behavioural intention.

Third, the sub-millisecond mining and low-millisecond transaction processing indicate that the perceived complexity often associated with blockchain—particularly in retail banking contexts where transaction speed is paramount—may be overstated. While these performance figures reflect a single-node simulation rather than a distributed network with consensus latency, they demonstrate that the core cryptographic operations need not impose prohibitive latency at the individual transaction level. This observation bears on Effort Expectancy (P8) and the moderating role of digital literacy (P10), suggesting that blockchain-based services need not be intrinsically more effortful than conventional digital banking.

5.2 The Prototype's Distinct Contribution to the TU-IAM Framework

A critical clarification concerns what BlockBank validates and what it does not. The prototype is a technical, demonstrative validation that the Tier 2 workflow—registration, transaction, verification—can be implemented and behaves as theorized. It operationalises the individual-level acceptance constructs (Performance Expectancy, Effort Expectancy, Facilitating Conditions, Initial Trust) through software artefacts. However, it cannot speak to the organisational-level constructs (Top Management Support, Organisational Readiness, Regulatory Support, Competitive Pressure) that describe strategic decisions made by bank leadership rather than properties of a client-side prototype.

This distinction is methodologically important. The BlockBank demonstration should be interpreted as answering the question "Can blockchain-based retail banking transactions be implemented in a cryptographically verifiable and user-accessible manner?" rather than "Will banks adopt blockchain, and will employees and customers use it?" The latter questions require the empirical roadmap outlined in Section 5.3.

5.3 Empirical Validation Roadmap

As a conceptual paper, this study does not report primary empirical data. Instead, it sets out a structured roadmap for the empirical phase of the doctoral programme, comprising two sequential stages:

Stage 1: Qualitative Refinement

Semi-structured interviews will be conducted with bank CIOs, CDOs, and Heads of Innovation across a purposive sample of public-sector banks (e.g., State Bank of India, Bank of Baroda), private-sector banks (e.g., ICICI, HDFC, Axis), and small finance banks. The interview protocol will be informed by the eleven propositions (Table 5) and will target 15–25 senior decision-makers for theoretical saturation. Thematic analysis will refine the Tier 1 (TOE) constructs and validate the cross-level linkages in Section 2.3.

Stage 2: Quantitative Testing

A structured survey will be administered to:

- **Bank employees** (frontline staff, operations personnel, IT professionals) exposed to at least one blockchain-enabled service.
- **Retail customers** who have used at least one blockchain-enabled banking product (e.g., Digital Rupee, blockchain-based trade finance, or tokenised KYC).
- Constructs will be operationalised using adapted, validated TOE/UTAUT scales drawn from the literature [7, 8, 21, 29]. Analysis will employ:

1. **PLS-SEM** for hypothesis testing, with particular attention to:
    - Multi-group invariance testing (public vs. private-sector banks; urban vs. semi-urban/rural respondents).
    - Bootstrapped indirect-effects analysis for the trust mediation paths (P7, P9).
2. **Complementary ANN analysis** for potential non-linear effects, particularly concerning Facilitating Conditions (P11) and the digital-literacy moderation (P10).

A multilevel design is recommended: an organisational-level survey first, distinguishing organisational adoption conditions from individual-level acceptance constructs, followed by an individual-level survey of employees and customers, analysed with multilevel structural equation modelling or comparable methods for nested data. This design directly addresses the cross-level theoretical logic that distinguishes TU-IAM from applying TOE or UTAUT independently.

5.4 Theoretical Implications

5.4.1 Extending the TOE–UTAUT Integration

The TU-IAM framework advances adoption theory in three respects. First, it explicitly models blockchain adoption as a two-level cascade rather than a single-level phenomenon, addressing a gap identified in the authors' earlier PRISMA review [13], which found that existing studies typically apply TOE or UTAUT alone, leaving no integrated diagnostic tool for retail-banking strategy-setting. This cascading logic—organisational adoption first, individual acceptance subsequently—reflects the distinctive nature of blockchain as an infrastructure technology: unlike consumer apps that employees and customers adopt directly, blockchain requires an organisational investment decision before individuals encounter it.

Second, TU-IAM positions trust as a cross-cutting mediator connecting organisational and individual levels, operationalised through institutional trust (confidence in the bank and the RBI as regulator), technology trust (confidence in the underlying blockchain technology), and initial trust (the early-stage acceptance mechanism identified by Jena [6] and Seshadrinathan & Chandra [17]). This treatment of trust as both antecedent and mediator, rather than as a separate exogenous factor, is consistent with recent evidence that institutional trust mediates the relationship between perceived risk and adoption intention in financial services [28].

Third, TU-IAM incorporates India-specific contingencies—regulatory sponsorship via RBI's Digital Rupee programme, the uneven digital-financial-literacy landscape, the role of agent-assisted channels and vernacular interfaces—that are absent from generic TOE–UTAUT integrations. This India-specificity addresses a gap in the broader blockchain adoption literature, which has predominantly focused on developed-economy contexts [23, 26].

5.4.2 Situating TU-IAM Relative to Existing Models

Table 4 in the main paper contrasts TU-IAM with the frameworks on which it builds. The need for such cross-level integration has recently been observed outside the Indian context: Gnanasekara, Jayakody, and Perera [30] found that public-sector TOE studies in Sri Lanka also identify trust and compatibility as significant, non-technological predictors of blockchain adoption intention, suggesting that the cross-level logic may have broader applicability beyond Indian retail banking.

However, TU-IAM's innovation lies not merely in combining TOE and UTAUT—prior studies have done so—but in specifying the directional, theoretically grounded cross-level paths through which organisational readiness, regulatory clarity, and competitive pressure shape the individual-level constructs of facilitating conditions, performance expectancy, and social influence. This specification distinguishes TU-IAM from a simple juxtaposition of the two frameworks.

5.5 Practical Implications

5.5.1 For Bank Leadership

TU-IAM provides a diagnostic tool for sequencing blockchain investments. The cross-level cascade implies that organisational readiness (P2) and regulatory clarity (P3) must be addressed before attempting to drive individual acceptance (P8–P11). Banks that invest heavily in user-facing blockchain applications without addressing internal readiness—IT talent, data infrastructure, change-management capability—are likely to find that individual acceptance stalls despite positive performance expectations. Conversely, banks that build organisational capability without developing user-friendly, trust-enabling interfaces will fail to convert organisational intention into actual use (P11).

The prototype's browser-only implementation further suggests that banks need not wait for dedicated infrastructure investment; low-cost, low-risk pilots can be launched using standard web technologies, enabling rapid learning about user behaviour before committing to full-scale deployment.

5.5.2 For Regulators (RBI)

TU-IAM highlights regulatory clarity (P3) as a foundational antecedent for organisational adoption. RBI's Digital Rupee pilots, regulatory sandboxes, and the National Blockchain Framework are positive signals, but the framework suggests that their effect operates through reducing compliance uncertainty rather than through direct mandates. This implies that RBI's most effective role may be as a sponsor and standard-setter—providing clear guidelines on data privacy, interoperability standards, and liability frameworks—rather than as a prescriptive implementer.

The BlockBank prototype's tamper-evident verification mechanism also offers a model for regulator-accessible oversight: the transparent, independently verifiable ledger gives regulators the same visibility as banks and customers, potentially reducing the compliance burden on banks while enhancing supervisory effectiveness.

5.5.3 For Technology Vendors

The prototype demonstrates that blockchain-based retail banking applications can be implemented without specialised infrastructure, using standard browser APIs and client-side JavaScript. This low-entry barrier suggests that vendors can focus on user experience and trust-building features—clear tamper-evidence indicators, intuitive verification interfaces, vernacular-language support—rather than on complex enterprise-grade infrastructure. The findings align with Chouhan et al.'s [26] observation that blockchain and DeFi adoption in India is increasingly accessible through standard digital channels.

6. Conclusion

This paper set out to address a fundamental gap in the blockchain adoption literature: while Indian retail banking has witnessed significant policy-level momentum—driven by the RBI's Digital Rupee pilots, regulatory sandboxes, and the National Blockchain Framework—there remains no integrated, theoretically grounded model that explains how an individual bank actually decides to adopt blockchain and how that decision subsequently cascades into employee and customer acceptance. Existing studies typically apply the Technology–Organization–Environment (TOE) framework to explain organisational adoption or the Unified Theory of Acceptance and Use of Technology (UTAUT) to explain individual acceptance, but rarely both, and almost never in a cross-level cascade that reflects the distinctive nature of blockchain as an infrastructure technology.

The proposed TOE–UTAUT Integrated Adoption Model (TU-IAM) closes this gap by treating blockchain adoption as a two-tier phenomenon. Tier 1 (Organisational Adoption) applies TOE constructs—Relative Advantage, Compatibility, Top Management Support, Organisational Readiness, Regulatory Support, Competitive Pressure, and Ecosystem Readiness—to explain a bank's strategic decision to invest in blockchain infrastructure. Tier 2 (Individual Acceptance) applies UTAUT constructs—Performance Expectancy, Effort Expectancy, Social Influence, and Facilitating Conditions—to explain how employees and customers form behavioural intention and actual use once that infrastructure exists. The tiers connect through three cross-level paths: (a) organisational readiness shapes training and user-friendly rollout, raising employees' facilitating conditions and performance expectancy; (b) regulatory clarity and RBI sponsorship reduce perceived compliance risk and build institutional trust, carrying over into customers' initial trust; and (c) competitive pressure and ecosystem readiness strengthen the social influence exerted by peers and bank staff. Trust—conceptualised as a higher-order construct encompassing institutional trust, technology trust, and initial trust—serves as the cross-cutting mediator anchoring the cascade.

The TU-IAM framework is accompanied by a set of eleven theoretically derived propositions (P1–P11) that decompose the broader relationships represented in the model. These propositions are not empirical confirmations but testable hypotheses for subsequent structural equation modelling, explicitly distinguishing organisational-level antecedents (P1–P4), cross-level linkages (P5–P7), and individual-level acceptance mechanisms (P8–P11). The propositions draw direct support from the authors' earlier publications: Pandey and Vashishth's [13] PRISMA-guided review of 44 studies identified organisational readiness and regulatory clarity as recurring, interdependent determinants of whether blockchain initiatives progress beyond the pilot stage, while their consumer-banking applications study [12] documented the visibility and communicated benefits that shape performance expectancy at the individual level.

To move TU-IAM toward demonstrable technical feasibility, the paper reported BlockBank, a browser-based proof-of-concept implementing core blockchain mechanics—cryptographic block linkage via SHA-256 hashing, proof-of-work mining, and tamper-evident verification—using only standard client-side JavaScript and the Web Crypto API. The demonstration results (Section 4) confirmed that the system successfully executed all transaction types (genesis, registration, transfer), maintained cryptographic chain integrity, precisely localised tampered blocks, and completed end-to-end transactions in 2.0–2.5 milliseconds. This technical validation operationalises TU-IAM's Tier 2 workflow: performance expectancy is manifest in sub-millisecond confirmations, effort expectancy in minimal form-based interfaces, facilitating conditions in browser-only accessibility, and initial/institutional trust in the transparent, independently verifiable ledger that gives customers and administrators the same tamper-detection visibility. However, the prototype speaks narrowly to individual-level transaction workflows and does not constitute behavioural or statistical validation of the eleven propositions—a distinction that reinforces the need for the empirical roadmap.

The theoretical contributions are threefold. First, TU-IAM advances adoption theory by explicitly modelling blockchain adoption as a two-level cascade rather than a single-level phenomenon, addressing a gap identified in the systematic barrier review [13]. Second, it positions trust as a cross-cutting mediator connecting organisational and individual levels, consistent with recent evidence that institutional trust mediates the relationship between perceived risk and adoption intention in financial services [28]. Third, it incorporates India-specific contingencies—regulatory sponsorship via RBI, the uneven digital-financial-literacy landscape, and the role of agent-assisted channels—that are absent from generic TOE–UTAUT integrations and that distinguish the Indian retail banking context from developed-economy settings.

Practically, the framework gives bank leadership a diagnostic tool for sequencing investments: organisational readiness and regulatory clarity must be addressed before attempting to drive individual acceptance. For regulators, TU-IAM highlights that the RBI's most effective role may be as a sponsor and standard-setter—providing clear guidelines on data privacy and interoperability—rather than as a prescriptive implementer. For technology vendors, the BlockBank prototype demonstrates that low-entry-barrier, browser-based pilots can be deployed without enterprise-grade infrastructure, enabling rapid learning about user behaviour before full-scale rollout.

In summary, TU-IAM, together with the BlockBank prototype and the eleven propositions, forms a coherent three-paper doctoral programme that moves from documentation and diagnosis, through theoretical model-building and technical feasibility demonstration, toward empirical validation as its next phase.

6.2 Future Directions of Research

The conceptual and technical foundations established in this paper open several avenues for future research, spanning empirical validation, theoretical extension, technological refinement, and policy-oriented inquiry.

6.2.1 Immediate Empirical Validation

The most pressing future direction is the operationalisation and testing of the eleven propositions through the mixed-method, two-stage empirical roadmap outlined in Section 5.3.

Stage 1: Qualitative Refinement. Semi-structured interviews with bank CIOs, CDOs, and Heads of Innovation across a purposive sample of public-sector, private-sector, and small finance banks will thematically refine the Tier 1 TOE constructs and validate the cross-level linkages. The interview protocol—informed by the eleven propositions—will target 15–25 senior decision-makers for theoretical saturation, with thematic analysis identifying which constructs are most salient in the Indian retail banking context and whether additional India-specific factors (e.g., state-level policy variations, regional digital infrastructure disparities) require incorporation.

Stage 2: Quantitative Testing. A structured survey administered to bank employees and retail customers exposed to at least one blockchain-enabled service will operationalise all constructs using adapted, validated TOE/UTAUT scales. Analysis will employ PLS-SEM with multi-group invariance testing (public vs. private-sector banks; urban vs. semi-urban/rural respondents), bootstrapped indirect-effects analysis for the trust mediation paths (P7, P9), and complementary ANN analysis for potential non-linear facilitating-conditions effects. Critically, a multilevel design is recommended throughout: an organisational survey distinguishing adoption conditions from individual-level acceptance constructs, followed by an individual-level survey analysed with multilevel structural equation modelling to account for the nested data structure (employees and customers nested within banks). This design directly addresses the cross-level theoretical logic that distinguishes TU-IAM from applying TOE or UTAUT independently.

6.2.2 Longitudinal and Trajectory Studies

Blockchain adoption in Indian retail banking is at an early stage. Longitudinal studies tracking banks from pilot through to production deployment would illuminate how the relative importance of TOE and UTAUT constructs shifts over time. For instance, regulatory clarity may be most salient during the initial adoption decision but less critical once infrastructure is deployed; conversely, performance expectancy and facilitating conditions may grow more important as users accumulate experience and form attitudes based on actual usage rather than anticipated benefits. Such trajectory studies would also capture the feedback loop modelled in TU-IAM's dashed arrow from Actual Use back to organisational strategy—examining how observed adoption outcomes inform subsequent rounds of investment and rollout decisions.

6.2.3 Differential Adoption Pathways Across Bank Types

TU-IAM's P2 proposes that the relationship between organisational readiness and adoption intention is stronger in private-sector and small finance banks than in public-sector banks due to differences in decision-making agility. Future research could test this moderation more granularly, examining whether the salience of specific TOE constructs varies systematically across bank types. Public-sector banks may face stronger isomorphic pressure (P4) but weaker top-management support (P2) due to bureaucratic decision-making structures; private-sector banks may exhibit stronger relative-advantage sensitivity (P1) but greater concern about competitive pressure (P4); small finance banks may show the strongest organisational-readiness–adoption link (P2) but the weakest ecosystem-readiness (P1) due to limited IT talent and infrastructure. Such differential pathway analysis would yield tailored adoption strategies for each bank category.

6.2.4 Customer Segmentation and Digital-Literacy Moderation

P10 posits that digital literacy and geographic location negatively moderate the effort-expectancy–behavioural-intention relationship. Future research could extend this by examining whether the UTAUT constructs have different predictive weights across customer segments: urban, digitally literate customers may be driven primarily by performance expectancy; semi-urban and rural customers by facilitating conditions (agent-assisted channels, vernacular interfaces); and older or lower-literacy segments by social influence. Experimental designs—randomised controlled trials of blockchain-enabled services with different interface designs (e.g., vernacular vs. English, text-heavy vs. icon-driven, agent-assisted vs. self-service)—could provide causal evidence for these moderation effects and directly inform user-interface design for inclusive financial inclusion.

6.2.5 Technological Frontiers and Interoperability

The BlockBank prototype employs SHA-256 hashing and proof-of-work mining, reflecting the cryptographic core of early blockchain implementations. However, production banking-blockchain deployments are increasingly adopting alternative consensus mechanisms—proof-of-stake, practical Byzantine fault tolerance, and hybrid models—that offer lower energy consumption and faster finality. Future technical research could extend BlockBank to incorporate these consensus variants and benchmark their performance in a browser-based environment. Critically, interoperability with existing India Stack infrastructure—UPI, Aadhaar, DigiLocker, and the Account Aggregator framework—remains an underexplored technical frontier. Prototype extensions that demonstrate blockchain's integration with these public digital goods would strengthen the Compatibility and Ecosystem Readiness arguments in P1 and further validate TU-IAM's technical feasibility.

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