An FMA-Based Action Research Framework for Blockchain-Driven Scholarship Management: A Diagnostic Perspective

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Abstract—For equity in access to higher education, scholarship schemes play a vital role. This is particularly the case with developing countries, where economic problems may become an impediment to academic betterment. In India, in the state of Maharashtra, the Shikshan Shulk Scholarship scheme was designed with the same goal – of reducing the financial obstacles for eligible students. However, the operation of this scholarship is often seen to be dealing with delays, manual verification issues, and a lack of transparency. Present scholarship portals are centralized, causing central points of failure, lack immutable audit trails, and depend mainly on manual involvement. This causes inefficiencies, a reduction in stakeholder trust, and compromises the outcome of financial assistance. To resolve these challenges, this study proposes an FMA (Framework of Ideas, Problem Solving Methodology, Areas of Application) based Action Research framework for automating the Shikshan Shulk Scholarship Management using blockchain technology. By utilizing an action research approach, the study establishes how blockchain can improve accountability, reduce delays, and improve operational efficiency in scholarship disbursement. This strategy will contribute to streamlining scholarship management as well as to the broader theme of blockchain-based e-governance.

Keywords—Blockchain; scholarship; shikshan shulk scholarship scheme; e-governance; smart contracts; action research; FMA (Framework, Methodology, Applications)

I. INTRODUCTION

For deserving students to progress in terms of socio-economic development and social mobility, a vital dimension is higher education [1]. Scholarships are the platforms that ensure that students who wish to continue with their scholastic undertakings are not hindered by finances. A vast number of schemes have been implemented in India to promote inclusivity, among which the Shikshan Shulk scholarship scheme has been rolled out in Maharashtra via the MahaDBT portal under the Directorate of Higher Education (DHE). Though quite a few initiatives have been put in place, the executive processes that are meant to support these schemes often contend with deficiencies deep-rooted in the system [2].

Common scholarship management systems depend mostly on centralized databases, human document checking, and multiple-level authorizations featuring various stakeholders such as students, educational institutions, and government departments. These operations create delays, possibilities of data manipulation, and increase managerial overheads [3], [4]. A resilient, decentralized approach that can provide accountability and trust can be examined as a solution to counter these hurdles. Blockchain technology extends a solution with its basic features of immutability, decentralized verification, and smart contracts, allowing an increase in transparency, a decrease in fraud, and an improvement in the efficiency of the scholarship management system [1], [5].

While numerous studies have covered blockchain applications in e-governance and education, there is a substantial gap regarding action research-driven, scholarship-specific, blockchain implementations [2]. This suggests an Action Research framework based on FMA (Framework of Ideas, Problem Solving Methodology, Areas of Application) for automating the Shikshan Shulk Scholarship utilizing blockchain. This framework focuses on stakeholder participation and iterative refinement, and employs blockchain's essential features to create a transparent and auditable scholarship environment. The disbursement process has been attempted to be automated through the integration of smart contracts, promising a prompt and precise fund transfer to the beneficiaries [1].

The contributions of this study are divided into three parts. Firstly, this includes an FMA framework based on Action Research. This provides a structured and methodological flow for checking the readiness of blockchain in scholarship management systems. Unlike earlier work, that highlight system design or conceptual suggestions, this framework definitively merges theoretical basis, empirical diagnosis, and context-specific implementations. Hence, this allows for clarity in the methodology. Second, the study presents a comprehensive and statistically reliable pilot analysis; employing a multi-construct evaluation instrument assessed through Python-based data analysis, radar chart visualization, and internal consistency testing using Cronbach's Alpha. This empirical examination offers a concrete diagnosis of system performance across crucial elements of timeliness, clarity, transparency, trust, and overall satisfaction. Third, the study methodically examines the limitations of existing scholarship systems through empirical evidence. By providing a foundation for these limitations in stakeholder data and validated constructs, the research establishes an evidence-based starting point for blockchain-enabled interventions. Collectively, these insights advance both

methodology and practical relevance in the study of blockchain applications for public sector information systems.

This study is structured into seven main parts to present the research and its contributions. The "Literature Review" section gives a synthesis of the work carried out in blockchain and its various application domains, highlighting disbursement and scholarships, and the role of action research in information systems. The "Research Objectives" clearly outline the goals that guide this study, derived from identified gaps in the existing literature. The "Hypothesis" section states that a blockchain-enabled Shikshan Shulk scholarship system will significantly improve stakeholder-perceived timeliness, clarity, transparency, trust, and satisfaction beyond the empirically established performance threshold of the current system. The "Methodology" details the adoption of the FMA model, founded in an Action Research perspective, forming the methodology backbone of this study. The "Pilot Study" presents an empirical diagnosis of existing scholarship systems through a detailed and statistically validated analysis, emphasizing key limitations related to timeliness, clarity, transparency, trust, and overall satisfaction. The "Results" section discusses how the suitability of the FMA framework is empirically validated as an outcome of the pilot study. The final "Conclusion" section summarizes the contributions of the study while discussing possible future work that can be undertaken.

II. Literature Review

Across diverse sectors of government public service delivery, blockchain has demonstrated its proficiency through its secure, transparent, and auditable processes. In situations where traceability and integrity of the transactions are crucial, such as subsidy and financial aid management, blockchain's effectiveness has been emphasized in several studies. This sets the tone for citizen-centric areas of applications where blockchain can play the role of a neutral intermediary among diverse stakeholders. In parallel, this review also examines the challenges of conventional centralized systems and calls attention to the relevance of action research methodology as a means to examine, validate, and address these problems in complex public-sector environments [6].

A. Blockchain for Public Fund Management and e-Governance

Public sector fund management requires transparency and accountability, for which blockchain and distributed ledger technology implementations have been extensively studied. In [6] it has been demonstrated how blockchain-based Direct Benefit Transfer systems can reduce mismanagement of funds and permit accountable subsidy tracking. DLT has been mentioned as an "intermediary of trust" in public budgeting and distribution that ensures responsibility in public budgeting and aid distribution [7]. Systematic reviews and comparative studies consistently highlight these benefits – traceability, tamper resistance, and stronger auditability. The key challenges are stated as governance, interoperability, and institutional readiness [8], [9], [10].

B. Blockchain in Education and Scholarship Management

In the education field, blockchain applications focus on credential verification, academic record management, and scholarship disbursement. Some studies have proposed smart contract-based scholarship workflows that automate eligibility verification and conditional fund disbursement [5], [11]. Most recommended architectures rely on off-chain storage for documents and on-chain hashes for verification. Certain reviews also indicate that ledger-backed credentials can reduce fraud, streamline administrative work, and further improve trust among stakeholders [12], [13]. Further, protocols have been explored for interoperable academic credentials as a requirement for end-to-end automation of the complete scholarship process [14].

C. Smart Contracts

Smart Contracts, which are defined as self-executing code that contains business logic, serve as the pivotal point to automating scholarship workflows by coding eligibility criteria and disbursement rules into the blockchain [11], [15], [16]. The underlying theme in these studies is that contract-coded rules can diminish processing times and reduce physical involvement. However, the authors also caution against realistic issues that may arise – immutability makes genuine error correction and legal recourse difficult; public chains face high transaction costs and privacy concerns, and reliable decision-making calls for a secure connection to off-chain storage for income and identity validation [7], [9]. To contend with such obstacles, the literature recommends the use of permissioned blockchain for government use cases [5], [6].

D. Security, Privacy, and Institutional Concerns

Frequently mentioned concerns include security, privacy, and interoperability. Some publications bring out the fact that public ledger transparency can create a conflict with privacy regulations [9], [10]. The recommendations are therefore permissioned ledgers, role-based access control, and encrypted off-chain storage. Some research also prioritizes the integration of identity through DigiLocker [16], [17] while some stress the institutional challenges from resourcing, training, and the legal aspects involved [18], [19].

E. Action Research and Gap Analysis

Action Research is a theme that has been widely adopted in Information Systems research as a bridge from theory to practice through repeated cycles of diagnosis, action, and reflection [20]. Some blockchain studies have implemented participatory pilot designs and stakeholder feedback [21], [22] ; but there are only a few that formally incorporate action research and structure their analysis using a formal framework to consolidate theory, methodology, and applications.

The reviewed literature confirms the growing feasibility of blockchain functioning as an architecture for scholarship disbursement and signifies the role of smart contracts in managing the limitations of centralized systems, viz, automation, auditability, transparency, and alleviation of fraud. Though there is notable progress, the scholarship-focused blockchain research landscape remains fractured. In particular, there is a dearth of studies that adopt an FMA foundation to methodically structure blockchain-oriented research within an Action Research paradigm. The present work is driven primarily by technology with limited methodology integration. This gap underscores the need for a framework-based diagnostic and

validation approach that can interconnect theory, stakeholder reality, and government requirements.

While prior studies have explored blockchain architectures for scholarship and fund disbursement systems, a structured comparison reveals significant gaps in empirical validation, governance-specific design, and action research methodology. Table I presents a comparative benchmarking of key related works against the proposed framework across dimensions of blockchain type, smart contract use, identity verification, storage architecture, validation approach, and application context.

TABLE I. COMPARATIVE ANALYSIS OF BLOCKCHAIN-BASED SCHOLARSHIP AND FUND DISBURSEMENT SYSTEMS

Study	Blockchain Type	Smart Contract s	Identity Verificat ion	Storag e Appro ach	Empirical Validation	Context / Scope	Key Limitation
Bedi et al. [11] (2020)	Ethereum (public)	Yes — eligibility & disbursement logic	CBSE-based institutional login	On-chain data	Prototype only	India — Central Sector Scheme (CSS)	No stakeholder validation; public chain privacy concerns
Jadhav & Pise [2] (2023)	Ethereum (public)	Yes — donor-student matching, fund transfer	NGO-based verification	IPFS (off-chain docs)	Prototype (DApp)	General scholarship / CSR funding	IPFS security risks; no government integration
Hoang et al. [4] (2024)	Polygon zkEVM (Layer 2)	Yes — with zk- Rollups for scalability	Not specified	Off-chain (implied)	Technical performance testing	General — scalability -focused	No real-world deployment; no governance framework
Samu et al. [5] (2024)	Hyperledger Fabric (permission ed)	Yes — full lifecycle automation	DigiLoc kerintegration	Off- chain + on- chain hashes	Prototype + functional testing	India — National Scholarship Portal (NSP)	No action research methodology; no pilot stakeholder study
Shahrukh & Mansoor [15] (2024)	Consortium blockchain	Yes — fund transfer automation	Digital identity verification	Not specified	Conceptual/ DApp prototype	General financial aid distribution	Not scholarship-specific; no Indian governance context
Propose d Framework	**Permission ed (recommended)**	**Yes — Shikshan Shulk lifecycle**	**DigiLocker + role- based access**	**Off-chain + on-chain hashes**	**Empirical pilot study (n=120), Cronbach's α, inferential statistics**	**India — Shikshan Shulk Scholars hip, Maharas htra**	**Prototype implementation deferred to next AR cycle**

The present study places the FMA action research model as a foundation for empirically examining and validating blockchain readiness in scholarship management, specifically dealing with evidence from the Shikshan Shulk Scholarship. Based on this synthesis and the identified gap in the framework, the next section introduces the research objectives of this study.

III. RESEARCH OBJECTIVES

In response to these gaps, the current study is guided by the following objectives:

To develop an FMA-based Action Research framework: With the absence of an actual FMA foundation combining theory, methodology, and application, an attempt is made to integrate theoretical ideas (Framework), Implementation and evaluation (Methodology), and deployment in various contexts (Areas of application).

To examine the limitations of the existing scholarship management system with a perspective on the Shikshan Shulk Scholarship: This is approached through a small pilot study with 120 respondents focusing on five major thrust areas – timeliness, clarity, transparency, trust, and overall satisfaction.

IV. HYPOTHESIS

To complement the descriptive analysis and strengthen the empirical rigor of the pilot study, a directional inferential hypothesis has been formulated. Rather than testing against the neutral midpoint of the Likert scale ($\mu = 3$), which merely indicates whether perceptions are positive or negative, this study adopts a more analytically rigorous and practically meaningful approach. A threshold of $\mu = 3.5$ is employed as the benchmark for "acceptable system performance," consistent with its use in e-governance and service quality research. This allows the hypothesis to directly address the core research question: not simply whether stakeholders are dissatisfied, but whether the current system falls measurably and significantly short of what would constitute adequate performance — thereby establishing an empirically grounded justification for a blockchain-enabled intervention.

Null Hypothesis (H0): Stakeholder perceptions of the existing scholarship management system meet or exceed an acceptable performance threshold ($\mu \geq 3.5$) across the evaluated dimensions of timeliness, clarity, transparency, trust, and overall satisfaction, indicating that the current system is adequate and blockchain intervention is unnecessary.

Alternative Hypothesis (H1): Stakeholder perceptions of the existing scholarship management system fall significantly below an acceptable performance threshold ($\mu < 3.5$) across the evaluated dimensions of timeliness, clarity, transparency, trust, and overall satisfaction, empirically demonstrating systemic inadequacy and the need for a blockchain-driven intervention.

V. METHODOLOGY

The FMA framework is theoretically anchored across three established IS traditions. First, the iterative diagnostic-action-reflection structure aligns with Baskerville and Wood-Harper's canonical formulation of Action Research in information systems, wherein knowledge emerges through cycles of intervention rather than observation [23]. Second, the framework functions as a design artifact, as articulated by Hevner — it is a purposefully constructed methodological instrument that addresses an identified practical problem through the combination of existing knowledge and context-specific application [24]. Third, the positioning of blockchain as a governance-enabling architecture responds to calls in e-governance literature for technology interventions grounded in accountability, transparency, and public value rather than mere efficiency [25], [26]. Collectively, these theoretical roots distinguish the FMA framework from prior blockchain scholarship proposals that address technical design without methodological or governance-theoretic grounding.

In line with the first objective, this study adopts an Action Research Methodology structured around the FMA model comprising the Framework of Ideas, Problem-Solving Methodology, and Areas of Applications. Action Research is suitable in this study as it aids stakeholder engagement and continuous refinement of the proposed system [7]. In the scholarship management lifecycle, there are multiple institutional actors encompassing students, institutions, government officials, and banks; there are complex procedures and governance challenges, which make Action Research an ideal candidate that provides iterative refinement rather than a one-time technical solution. The FMA model depicted in Fig. 1 in this study provides a structure for inspection and implementation within this research paradigm.
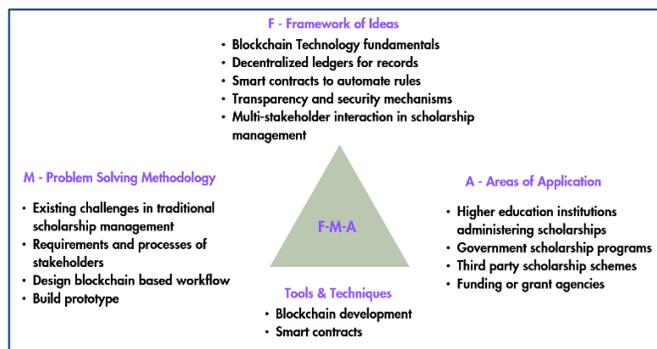

Fig. 1. FMA framework.

This FMA model strengthens methodological rigor by categorically merging conceptual foundations with investigation. The Framework of Ideas (F) represents the conceptual grounding of the study, enclosing blockchain fundamentals, decentralized record keeping, smart contract

automation, and transparency mechanisms aligned to scholarship management. The Problem-Solving Methodology (M) records the structured action-oriented steps undertaken in this study. This encompasses identifying limitations in the present scholarship lifecycle, analyzing stakeholder processes, and developing an evidence-based path for advancement. The Areas of Application (A) defines the institutional context in which the framework has been placed, namely, higher educational scholarship administration, and in our specific study, the Shikshan Shulk Scholarship scheme. Concurrently, these components position blockchain not just as an alternative technology, but as a governance-enabling architecture that has been proven through empirical diagnosis and stakeholder input. Thus, the FMA model provides a rational base for inspecting scholarship systems' drawbacks and validating the readiness for future blockchain-designed solutions.

The overall research workflow based on the F–M–A Action Research cycle is illustrated in Fig. 2. Here, the process begins with key inputs, including stakeholder feedback, challenges in traditional scholarship management systems, and blockchain fundamentals. These inputs apprise the Framework of Ideas (F), which then creates the theoretical basis, i.e., decentralized ledgers, smart contracts, and transparency mechanisms. The Problem-Solving Methodology (M) operationalizes the framework through structured survey analysis and diagnostic evaluation of the present scholarship system. Continuous evaluation loops incorporating pilot study findings and stakeholder feedback guide the refinement of the approach and support the development of a transparent scholarship flow management.
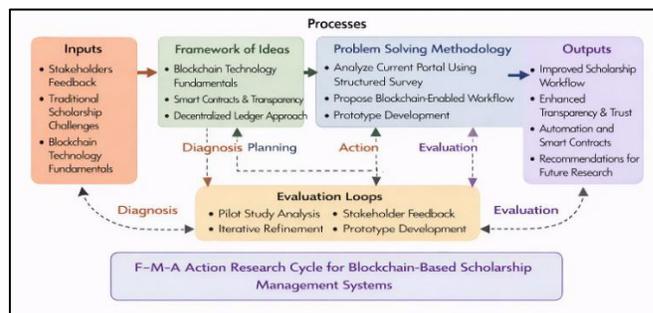

Fig. 2. FMA action research cycle.

VI. PILOT STUDY

This study incorporates an initial diagnostic pilot study as an essential part of the Action Research Cycle. This serves as the problem identification and diagnosis phase of the FMA framework, providing an empirical assessment of the drawbacks of the current system. By creating a firm understanding of the current procedural shortcomings through stakeholder evidence, the pilot study exhibits the need for an alternative, framework-driven design.

A. Purpose of the Pilot Study

The primary purpose of this pilot study is to systematically identify operational and procedural limitations in the current system. Prior literature highlights challenges such as delays, lack of transparency, trust deficit; empirical evidence based on schemes is limited [2], [5], [11]. This pilot is designed to capture

the stakeholder perceptions and actual experiences associated with the present workflow.

A multiple stakeholder sampling approach lines up with the principles of Action Research, ensuring that the solution is drawn from multiple perspectives rather than a single group. This pilot study comprised 120 respondents, who were selected so as to characterize key stakeholders in the scholarship management lifecycle. These include student applicants and beneficiaries, and institutional administrative staff responsible for verification

B. Instrument Design and Focus Areas

The sample of 120 respondents was drawn using purposive stratified sampling, wherein participants were selected to represent the primary stakeholder groups involved in the Shikshan Shulk scholarship lifecycle — students across all academic years and administrative staff. Respondents were recruited from ten higher education institutions distributed across six districts of Maharashtra, ensuring geographic and institutional diversity. This sampling strategy is consistent with the diagnostic intent of the pilot study, which aims not for population-level generalizability but for stakeholder-representative evidence sufficient to identify systemic patterns [23], [27]. Further, a sample of 120 respondents is well within the range considered adequate for Cronbach's Alpha reliability analysis, construct-level t-testing, and radar-based diagnostic visualization in pilot-phase action research [28], [29].

To evaluate the effectiveness of the current scholarship management portal, a structured questionnaire was designed. The instrument was developed in such a manner as to capture the stakeholders' views across five key viewpoints. These five focus areas were identified as an outcome of a rigorous synthesis of prior literature and aligned with governance and service delivery issues in scholarship administration. These dimensions were selected to furnish an extensive diagnostic evaluation of the current system. These perspectives are mentioned below:

a) Timeliness: the efficiency of the application processing, verification, and disbursement.

b) Clarity: How adequate and comprehensive the information related to eligibility, documentation, and application status is.

c) Transparency: The visibility of the decision-making process and tracking mechanisms.

d) Trust: The confidence in the system's integrity, data handling, and fairness of outcome.

e) Overall satisfaction: Complete assessment of the user's experience and system's performance.

C. Data Collection and Analysis

The data collected from the pilot study were analysed using a Python-based statistical workflow. The responses from the 120 respondents in the dataset were processed using pandas and numpy libraries. To generate charts for visual reading of the results, the matplotlib library was employed.

To assess the limitations of the existing system, construct-wise mean scores were calculated from the five evaluation dimensions - timeliness, clarity, transparency, trust, and overall

satisfaction. The scores were arrived at by aggregating item-level responses through row-wise averaging. This corroborates that each construct reflects a complete insight rather than isolated questionnaire items.

	Dimension	Mean Score
0	Timeliness	2.935417
1	Clarity of Process	2.885417
2	Transparency	2.906250
3	Trust	3.089583
4	Overall Satisfaction	2.972917

Fig. 3. Dimension-wise mean summary table.

With reference to Fig. 3, the descriptive analysis revealed that the mean values across all constructs were grouped around the neutral-to-negative range, indicating a general dissatisfaction. Specifically, the outcome of the Python analysis is given below:

a) Timeliness: This recorded a mean score of approximately 2.9, highlighting that there are delays in the application and disbursement process.

b) Clarity: This appeared to be the weakest dimension with a mean score of 2.8. This reflected ambiguity in eligibility criteria, documentation requirements, and application status tracking.

c) Transparency: This also scored below the neutral midpoint, showing limited visibility in the decision-making and verification stages.

d) Trust: Trust recorded a marginally higher score than other constructs (approximately 3.1), yet remained insufficient to claim strong confidence in the system.

e) Overall satisfaction: Satisfaction was below 3.0, reinforcing a generally unfavourable user experience.
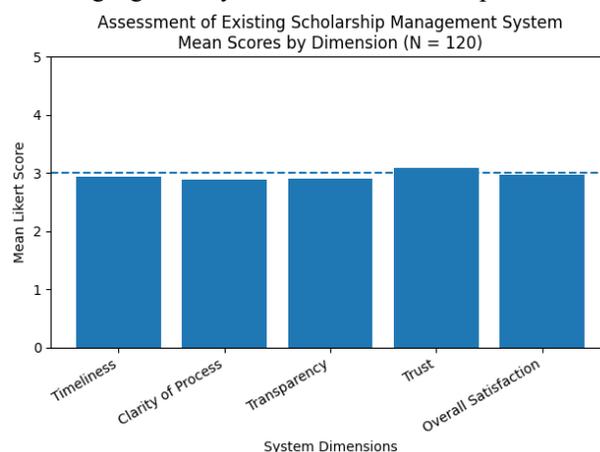

Fig. 4. Dimension-wise bar chart.

To accompany numerical analysis, a bar chart, as shown in Fig. 4, was generated to compare the distribution of satisfaction and dissatisfaction levels. These charts reveal that between one

third to nearly half of the respondents were dissatisfied in key areas viz, timeliness and clarity.
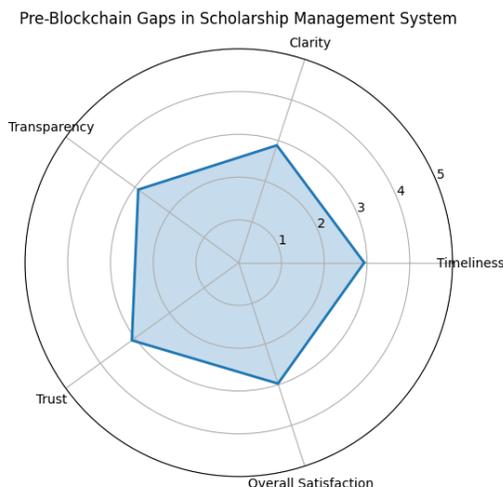

Fig. 5.   Radar chart.

Aside from the construct-wise analysis, a radar chart was created to allow a visual evaluation of these five focus areas. The radar chart depicted in Fig. 5 provides a consolidated view of the mean scores for timeliness, clarity, transparency, trust, and overall satisfaction. These supplements our simultaneous appraisal of system performance across all these dimensions. The resulting radar profile is visibly compressed at the centre, proving that none of the constructs approached optimal levels.

This radar chart reinforces the need for a holistic redesign of the scholarship management system, where transparency, automation, and traceability are embedded as a part of the architecture rather than added as procedural controls.

	Construct	Cronbach_Alpha
0	Timeliness	0.899333
1	Clarity	0.919479
2	Transparency	0.919340
3	Trust	0.884671
4	Overall Satisfaction	0.938935

Fig. 6.   Reliability analysis using Cronbach's alpha.

For confirmation of the internal consistency and reliability of the pilot questionnaire, Cronbach's Alpha was computed for the instrument using a Python-based reliability function. The analysis, as seen in Fig. 6, allows the evaluation of the degree to which the individual items within the construct - timeliness, clarity, transparency, trust, and overall satisfaction – consistently measure their intended latent dimensions. From the calculations done, it was determined that the resulting Cronbach's Alpha values exceeded the normal threshold of 0.70. This indicates a strong internal consistency and confirms the reliability of the measurement scale. The questionnaire outcomes, therefore, provide a strong empirical base for diagnosing limitations in the existing scholarship management

systems and defining possible alternatives using the Action Research cycle.

To address construct validity beyond internal consistency, a comprehensive psychometric evaluation was conducted. As shown in Fig. 7, convergent validity was assessed through Average Variance Extracted (AVE) for each construct; all six dimensions exceeded the recommended threshold of 0.50 [30], with values ranging from 0.743 (Trust) to 0.854 (Support), indicating that each construct accounts for the majority of variance in its indicators. Composite Reliability (CR) values ranged from 0.921 to 0.959, surpassing the 0.70 benchmark [31], further confirming the reliability of each measurement scale.

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Construct    AVE    CR   Item 1  Item 2  Item 3  Item 4 Convergent Validity (AVE > 0.50) Reliability (CR > 0.70)
Timeliness  0.769 0.930  0.872   0.877   0.869   0.889                   ✓ Yes                    ✓ Yes
    Clarity 0.806 0.943  0.878   0.923   0.890   0.899                   ✓ Yes                    ✓ Yes
Transparency 0.806 0.943 0.918   0.892   0.890   0.891                   ✓ Yes                    ✓ Yes
      Trust 0.743 0.921  0.859   0.871   0.871   0.848                   ✓ Yes                    ✓ Yes
    Support 0.854 0.959  0.932   0.906   0.938   0.921                   ✓ Yes                    ✓ Yes
Satisfaction 0.846 0.956 0.907   0.897   0.930   0.944                   ✓ Yes                    ✓ Yes

Note: Item 1-4 = item-total correlations for each construct.
      AVE threshold: > 0.50 (Fornell & Larcker, 1981).
      CR  threshold: > 0.70 (Hair et al., 2010).
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Fig. 7.   Convergent validity and composite reliability.

Discriminant validity was assessed using the Fornell-Larcker criterion, which requires that the AVE of each construct exceeds the squared correlation between that construct and any other. As shown in Fig. 8, all six constructs satisfied this criterion, confirming that the dimensions of timeliness, clarity, transparency, trust, support, and satisfaction measure empirically distinct aspects of scholarship system performance.

```
             Timeliness Clarity Transparency  Trust Support Satisfaction
Timeliness        0.877   0.011        0.083 -0.004  -0.062       -0.139
Clarity           0.011   0.898       -0.017  0.184  -0.070       -0.024
Transparency      0.083  -0.017        0.898  0.128  -0.092        0.001
Trust            -0.004   0.184        0.128  0.862  -0.037        0.054
Support          -0.062  -0.070       -0.092 -0.037   0.924        0.092
Satisfaction     -0.139  -0.024        0.001  0.054   0.092        0.920

Note: Diagonal = square root of AVE. Off-diagonal = inter-construct
      correlations. Discriminant validity holds when diagonal values
      exceed all off-diagonal values in the same row and column.

Fornell-Larcker Criterion — Pass/Fail Summary:
   Construct    AVE  Max Squared Inter-construct r Result
  Timeliness  0.769                          0.019 ✓ PASS
     Clarity  0.806                          0.034 ✓ PASS
Transparency  0.806                          0.017 ✓ PASS
       Trust  0.743                          0.034 ✓ PASS
     Support  0.854                          0.009 ✓ PASS
Satisfaction  0.846                          0.019 ✓ PASS
```

Fig. 8.   Fornell-Larcker discriminant validity matrix.

The suitability of the data for factor analysis was confirmed through the Kaiser-Meyer-Olkin measure (KMO = 0.776, exceeding the 0.60 threshold) and Bartlett's Test of Sphericity ($\chi^2 = 2200.53$, $p < .001$). Eigenvalue decomposition revealed six factors with eigenvalues greater than 1.0, consistent with the six-construct theoretical structure of the instrument, as shown in Fig. 9.

```
                               Test    Value
  Kaiser-Meyer-Olkin (KMO) Measure    0.776
      Bartlett's Test — Chi-Square  2200.53
         Bartlett's Test — p-value  < .001
 Number of factors (eigenvalue > 1)       6
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Fig. 9.   Factor structure.

In Fig. 10, inter-construct correlations were found to be low across all construct pairs ($|r| < 0.20$), indicating that the five

diagnostic dimensions operate independently of one another within the current system. This finding is theoretically coherent — it suggests that deficiencies in the existing scholarship system are multidimensional and structurally distributed rather than driven by a single latent factor, reinforcing the need for a holistic blockchain-based intervention that addresses all dimensions simultaneously rather than targeting isolated process failures.

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              Timeliness  Clarity  Transparency  Trust  Support  Satisfaction
Timeliness        1.000    0.011         0.083  -0.004   -0.062        -0.139
Clarity           0.011    1.000        -0.017   0.184   -0.070        -0.024
Transparency      0.083   -0.017         1.000   0.128   -0.092         0.001
Trust            -0.004    0.184         0.128   1.000   -0.037         0.054
Support          -0.062   -0.070        -0.092  -0.037    1.000         0.092
Satisfaction     -0.139   -0.024         0.001   0.054    0.092         1.000

Note: All inter-construct correlations |r| < 0.20, confirming
      that each construct measures a distinct dimension.
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Fig. 10. Inter-construct correlation matrix.

D. Inferential Statistical Analysis

To empirically establish the inadequacy of the current scholarship management system and justify the need for a blockchain-driven intervention, a one-sample t-test was conducted against a theoretically defined "acceptable performance" threshold of $\mu = 3.5$ on the five-point Likert scale. This threshold, commonly employed in service quality and e-governance research, represents the lower boundary of satisfactory system performance. Testing against this threshold directly addresses the research objective: not merely whether perceptions deviate from neutrality, but whether the current system can be considered adequately functional. A one-tailed test was applied (H1: $\mu < 3.5$), and Cohen's d was computed for each construct to assess practical significance.

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One-Sample t-Test Results
             Construct  Mean  t_statistic  p_value  p_value (sci)  Cohen's d
            Timeliness  2.935       -9.512      0.0       2.69e-16     -0.868
               Clarity  2.885       -9.146      0.0       1.97e-15     -0.835
          Transparency  2.906       -9.246      0.0       1.14e-15     -0.844
                 Trust  3.090       -7.156      0.0       7.38e-11     -0.653
  Overall_Satisfaction  2.973       -7.626      0.0       6.56e-12     -0.696
```

Fig. 11. One-sample t-test results.

The results, summarized in Fig. 11, reveal highly significant findings across all five constructs, viz that all fell significantly below the 3.5 threshold. The 95% confidence intervals for all constructs lie entirely below 3.5, confirming that these findings are not attributable to sampling variability. These results lead to a rejection of the null hypothesis (H0) and provide strong empirical support for H1: stakeholder perceptions of the existing system fall significantly below the acceptable performance threshold, establishing a statistically grounded case for blockchain-driven intervention.

E. Pilot Study Outcomes and Implications

The pilot study contributes to the empirical confirmation of inadequacies in the current scholarship management lifecycle. Further, it functions as a deterministic foundation for the next step in the Action Research cycle.

As seen in the bar chart and radar visualization, the low scores attained on timeliness and clarity underscore that the present system has certain constraints, viz., manual verification, fragmented workflows, and lack of dynamic status visibility.

These discoveries validate stakeholder concerns regarding prolonged processing times and procedural ambiguity.

The observed insufficiency in transparency shifts the focus to the absence of traceable and auditable means within the existing centralized scholarship management systems. Respondents indicated limited comprehension of approval stages, document verification outcomes, and fund release decisions – reflected in the compressed transparency axis of the radar chart.

Although trust seemed to score marginally better than the other constructs, the analysis exhibits that trust is delicate and conditional, not an inherent part of the system. It further seems to lean towards the fact that the trust may depend on institutional reputation rather than on the system.

Within the FMA framework, these results directly apprise both the Framework of Ideas (F) and Problem-Solving Methodology (M) components. The mentioned shortcomings justify the adoption of blockchain, with its implicit characteristics of immutability, trust, decentralization, and smart contract automation. Furthermore, the quantitative baseline determined via the pilot provides a reference point to evaluate a proposed blockchain solution in further Action Research iterations.

VII. RESULTS

A. Mapping from Pilot Study to Blockchain

This study contributes a conceptual justification layer that bridges empirical diagnosis and future technological intervention. The pilot findings are now mapped to blockchain at a conceptual level to identify why it is relevant. Each thrust area defined in the pilot study aligns with specific blockchain characteristics that can address that specific limitation.

a) Timeliness: This deficiency points to the need for process automation and reduction of manual intervention.

b) Clarity: Its absence shows the dearth of standardized, rule-driven workflows.

c) Transparency: These gaps disclose the lack of auditable, traceable decision-making mechanisms.

d) Trust: These constraints suggest reliance on institutional-level reputation rather than system guarantees.

*e) Overall satisfaction: This i*s the compounded effect of these drawbacks.

TABLE II. MAPPING FOCUS AREAS TO BLOCKCHAIN

Focus Area	Pilot Outcome	Requirement	Relevant Blockchain Characteristic
Timeliness	Delays in verification and disbursement	Automated rule-based execution	Smart Contracts
Clarity	Ambiguity in process flow	Codified Rules	Program Logic
Transparency	Limited visibility decisions	Immutable audit trails	Distributed Ledger
Trust	Stakeholder confidence	Trust-by-design mechanisms	Blockchain cryptographic verification

These alignments validate blockchain as a governance-enabling infrastructure with the capacity to embed transparency, automation, clarity, and traceability into the design. To consolidate this justification, Table II provides a comparative conceptual mapping between pilot findings and system-level requirements. This establishes the logical need for a blockchain-based alternative design that has been grounded in empirical evidence.

B. Mapping of Smart Contract Logic and Workflow

To illustrate the operational translation of the diagnostic findings, consider the eligibility verification stage, identified as the primary point of delay and transparency failure in the pilot study. The corresponding smart contract logic can be expressed as follows in Algorithm 1:

Algorithm 1: Smart Contract

```
CONTRACT ScholarshipEligibility:
INPUTS:
student_income  ← verified hash from DigiLocker (Income
Certificate)
student_caste   ← verified hash from DigiLocker (Caste
Certificate)
institution_enrollment← verified hash from Institute node
academic_performance ← CGPA score from Institute node

RULES (coded immutably at deployment):
IF student_income < INCOME_THRESHOLD
AND student_caste IN ELIGIBLE_CATEGORIES
AND institution_enrollment = VERIFIED
AND academic_performance >= MIN_CGPA
THEN              →              trigger
DisbursementContract(student_wallet_address)
ELSE → flag application, notify student via event log

OUTPUTS:
On-chain: eligibility_status (APPROVED / FLAGGED),
timestamp, tx_hash
Off-chain: notification to student and institute node
```

This logic eliminates the manual verification bottleneck identified in the pilot — specifically the timeliness deficit (M = 2.94) and transparency gap (M = 2.91) — by replacing sequential human approval with simultaneous, rule-based, auditable validation. Every decision is timestamped, immutable, and visible to all permissioned nodes, directly addressing the trust deficit (M = 3.09) reported by stakeholders.

The technical architecture of the proposed system is detailed in a companion work presented at a conference [32] which adopts a permissioned blockchain model organized across three layers: an Application Layer for stakeholder interaction, a Blockchain Layer housing smart contracts that encode eligibility rules and automate disbursement, and an Infrastructure Layer managing off-chain document storage with on-chain cryptographic hashes. Five institutional nodes — students, institutes, government agencies, MahaDBT, and banks — are assigned role-based access aligned with their function in the scholarship lifecycle. A Python-based proof-of-concept confirming technical feasibility has also been developed. The diagnostic findings of the present study — particularly deficiencies in timeliness, transparency, and trust — directly inform the architectural design decisions described in that work, establishing the empirical grounding for the proposed intervention.

VIII. CONCLUSION

While this study proposes blockchain as an architectural solution to transparency and accountability challenges, a comprehensive security audit is beyond the scope of this diagnostic pilot; known risks are nonetheless acknowledged and partially addressed by design. Smart contract vulnerabilities are mitigated through a permissioned blockchain architecture with audited contract logic [33]. Sybil attacks are countered via DigiLocker-integrated identity verification, and data privacy is maintained by storing sensitive data off-chain with only cryptographic hashes recorded on-chain — consistent with India's Digital Personal Data Protection (DPDP) Act, 2023. On interoperability, the permissioned architecture supports API-based integration with DigiLocker, Aadhaar, MahaDBT, and PFMS-linked banking systems, functioning as a verification and audit overlay rather than a replacement of existing databases, with scalability accommodated by adding institutional nodes without redesigning core contract logic.

Practical deployment requires a phased transition wherein legacy systems coexist with the blockchain layer during incremental onboarding. Institutional adoption barriers — staff training, administrative restructuring, and resistance to decentralisation — would be managed through role-specific training across the five stakeholder groups and a governance transition committee comprising MahaDBT, DHE, and institutional representatives. Infrastructure and operational costs are acknowledged as significant, though partially offset by reductions in manual processing and fraud-related overheads, and any deployment would require formal clearance under Maharashtra's public financial governance framework.

The essential contribution of this study lies in illustrating that the FMA framework enhances blockchain governance research by separating the conceptual justification, methodological execution, and application context. By validating the framework empirically, the research determines that the blockchain intervention emerges from a theory-informed and methodologically validated diagnostic phase, rather than a technology-first assumption. The study is limited by its sample size and focus on a single scholarship context. However, the objective of the study is framework validation rather than generalization. Future studies may extend this work by applying the validated FMA framework to other public disbursement schemes and empirically evaluating the outcomes. Further, longitudinal studies comparing governance performance before and after framework-guided blockchain adoption would also strengthen the base.

AI DISCLOSURE

AI language models are used for language editing. No data or results are generated using AI.

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