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Blockchain for Audit Trails in Research Information Management Systems

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Abstract - **Meeting today's society's expectations, there is an increasing complexity associated with data and the need to be transparent in research processes. Information integrity and traceability have become ever so critical for academic and research institutions. These days, research information management systems (RIM) are commonly relied upon to control data regarding research projects, publications, funding, and collaborations. However, traditional RIMS have been and continue to be lacking in properly providing immutable, verifiable audit trails critical for accountability, compliance, scholarly communication sufficiency, and trust. This study focuses on improving RIMS audit trails by incorporating blockchain technology. There are many gaps in the current systems that require immediate attention, and these gaps provide us with significant opportunities, such as using blockchain ledgers to record and verify research data transactions beyond central authoritative dependency. We focus on these gaps by explaining the scalability and privacy obstacles and system interoperability, suggesting solutions that best address these gaps. The study outlines concepts pertaining to blockchain-enabled RIMS and how smart contracts bypass compliance and data provenance to ascertain transparency.**

Furthermore, a cross-sectional evaluation with existing audit approaches is provided alongside innovative methods of capturing trustworthy research activity records using blockchain technology. The study indicates that blockchain technology can improve the effectiveness and trustworthiness of RIMS through safe, transparent, and auditable processes in data handling. This paper adds to the existing discourse around digital trust in research environments and guides future application.

Keywords: **Blockchain, Research Information Management Systems, Audit Trails, Data Integrity, Smart Contracts, Transparency, Data Provenance**

I. INTRODUCTION

The ever-increasing volume of digital research outputs, coupled with the intricacy of research workflows, has created a demand for sophisticated systems to manage, protect, and audit scholarly information (Shih et al., 2019). As a response, Research Information Management Systems (RIMS) are being developed as comprehensive databases to capture and maintain information about researchers, grants, publications, and institutional productivity. However, conventional RIMS lack reliable and verifiable audit trails that permit tampering at best (Goyal & Shah, 2025). These gaps are heightened when there is a strict adherence to regulations, transparency in funding, and compliance with research ethics (Alwetaishi & Alzaed, 2025). The application of blockchain technology in RIMS provides a shift in approach by incorporating decentralized, unchangeable ledgers for enhanced security, traceability, and integrity of data (Conoscenti et al., 2016).

Blockchain systems have successfully securely stored data beyond their original design as the foundational technology for cryptocurrencies. In the case of RIMS, blockchain allows for every transaction involved in data entry, alteration, or examination to be recorded in a transparent, unchangeable manner (Hui et al., 2019).

The automation of compliance and data validation processes are made more easier with features like smart contracts and consensus algorithms (Xu et al., 2019; Kuo et al., 2017). These functions enhance the creation of independent verifiable audit trails, thus, enhancing trust and accountability in the research ecosystem (Yli-Huumo et al., 2016; Zwitter & Boisse-Despiaux, 2020). The main objective of this study is to design an audit trail for RIMS based on blockchain technology that provides security, efficiency, and transparency compared to conventional auditing techniques (Diva et al., 2023; Booch et al., 2025).

Key Contributions

- Steering Integration of Blockchain Technology into RIMS and Immutably Auditing Trails: In this paper, we propose a new framework for incorporating blockchain technology into RIMS systems, which allows for immutable audit trails on these systems.
- A New Method of Auditing RIMS: The paper proposes a new auditing method that introduces data validation through smart contracts and more developed criteria for assessing the systems' operational effectiveness.
- Efficiency Gained Analysis: The paper also discusses in depth the case of a blockchain-based RIMS and a traditional RIMS, focusing on the system's increased transparency, security, and operational efficiency.

The paper consists of five comprehensive sections. In Section I, we discuss the idea, importance, and rationale of implementing blockchain in RIMS (Christian et al., 2025). Section II analyzes the literature on blockchain technology in managing research data and digital auditing systems. In Section III, we explain the proposed methodology, which includes a theoretical framework, its mathematical formulation, and architecture design. In Section IV, we provide results and discussion, alongside supplementary graphical and quantitative analysis. We conclude the paper in Section V with an overview of the primary insights derived from the analysis, emphasizing the potential avenues for subsequent investigation and practical application.

II. LITERATURE SURVEY

Improvements in the transparency and traceability of digital systems through blockchain technology have gained attention in recent years. Alketbi et al., (2018) highlighted the importance of blockchain technology in aiding the auditing of data and controlling the fraud level within different digital ecosystems. Their work showed the possibility of using blockchain technology, which is safe from unauthorized changes, to create records in high-integrity settings this is research data management. In educational technologies, Grech and Camilleri (Grech & Camilleri, 2017) investigated the applications of blockchain technology in academic credentialing and contended that its anti-tampering features warrant trust in storing and verifying information, which could also enhance RIMS (Kiruthika et al., 2019).

The integration of blockchain with information systems, particularly from the perspective of strategic operational efficiency, has also been analyzed. Zheng et al., (2017) performed a detailed analysis on the technology of blockchain and its uses, stating that the clear nature and distributed consensus characteristic of blockchain hold great promise in overcoming significant challenges in older systems of databases (Wu & Margarita, 2024). This relates directly to the auditing of research workflows, where validation and accountability are essential. Also, Casino et al., (2019) studied applications of blockchain technology across several disciplines and maintained that auditability and data integrity are its most substantial advantages (Nair & Rao, 2023; Usikalu & Okafor, 2025).

The findings also emphasize that blockchain can enhance trust for systems and lessen administrative burden in the context of academic research (Sengupta & Deshmukh, 2024). Along with these views, Sharma et al., (2019) investigated the use of blockchain in government and public records and claimed its use decreases human error and enhances retrievability (Wiśniewski et al., 2025). These arguments are especially relevant to institutions aiming to guarantee ethical compliance and transparency regarding the research governance (Carlos & Escobedo, 2024). All the above suggest a rather unique aspect of literature concerning blockchain. There seems to be a common understanding of its ability to change processes involved in data transaction tracking and verification, which suggests it can practically be used for RIMS audit trail systems (Beyene et al., 2023; Papadopoulos & Christodoulou, 2024).

III. METHODOLOGY

This paper proposes a new approach for research information management systems (RIMS)based on blockchain technology, incorporating smart contracts, cryptography, and decentralized ledgers, due to the lack of secure and transparent audit trails. The system results from analyzing models that implement central databases with minimal auditing capabilities. Most traditional systems cannot sign and seal logs to prevent tampering and independent validation. Thus, they are open to alteration or unwarranted attacks.

Our methodology enhances these models by embedding blockchain layers into RIMS workflows, where every research dataset transaction, grant updates, publication insertion, and project changes are processed as a block. There are also smart contracts that control the record-adding rule, so only accepted transactions can be appended to the chain. A block contains data such as a timestamp—the date and time a record was created or added to the blockchain, user ID, and unique identifiers denoting a distinct account user alongside digital signatures confirming audit and traceability checks. With these features, dependence on administrators is reduced, making system control more transparent and institutional regulations more easily and seamlessly navigated.

$$C_a = \left(\frac{V + \alpha R}{T}\right) \cdot I \cdot log(1 + U) \qquad (1)$$

Where in equation (1),

- C_a : Audit Confidence Score
- V: Number of successfully validated transactions
- T: Total number of transactions
- R: Number of redundant (re-audited or cross-verified) transactions
- I: Integrity Score based on cryptographic consistency (0 to 1 scale)
- U: Number of unique users in the system

In this proposal, a mathematical model will be introduced aimed at estimating an Audit Confidence Score (Ca) in a blockchain-enabled Research Information Management System (RIMS). This score is calculated as a composite value signifying the trustworthiness, suggestiveness, and confirmation ability of the audit trail. The ratio (V+αR)/T captures the proportion of completed transactions, together with those already cross-validated or checked beyond necessary. Inclusion of the scaling factor α which enhances the trust attributed to 'verified but not new' transactions, diminishes the impact of cross-checking and adds to R/S. The Integrity Score (I) is obtained from the described checks performed on the blockchain such as validation of the hash chain, cross-checking signatures, and ensuring changes cannot be made to them, lies within bound 0,1that ranges from 0 and 1. A value I=1 means the system is cryptographically sound.

Furthermore, log(1+U) accounts for the change in participants involved in the RIMS. An increase in the number and relative diversity suppresses centralization, which amplifies the reliability of the audit. Adding these functions reinforces that while variety aids in amplifying the score, the added advantage will reduce after some point so that distortions in huge systems do not occur. This model captures the confidence level of the blockchain audit process by integrating quantitative measures with qualitative aspects such as decentralization and redundancy. This is particularly helpful for organizations looking for a calculable standard for assessing the reliability of their research audit systems.

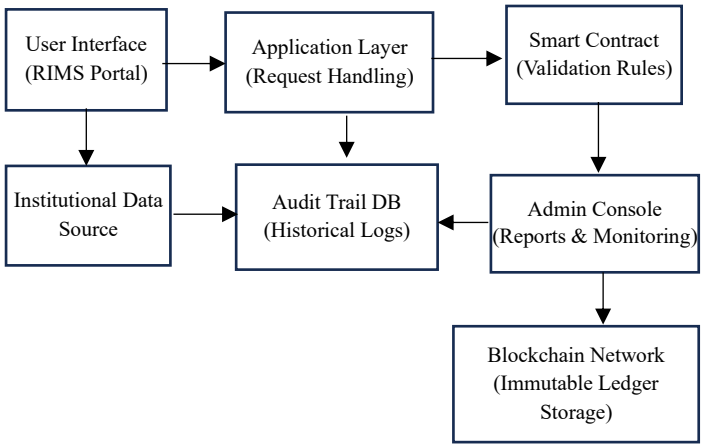

Fig. 1 Blockchain-Enabled Audit Trail in Research Information Management Systems (RIMS)

Fig. 1 describes the incorporation of blockchain technology into a Research Information Management System (RIMS) to create a secure and verifiable audit trail. The User Interface (RIMS Portal) is the highest tier where researchers and administrators log into the system to submit and manage their research activities. The Application Layer intercepts these interactions, processes user requests, and stratifies data for validation. The transaction Validation stage is executed through Smart Contracts that have an embedded logic enforcement mechanism for audit trail routing, access controls, and regulatory compliance justification. After validation, the transactions get etched onto the Blockchain Network, which acts as a distributed ledger susceptible to no edits or modifications. With this structure in place, any entry that is committed undoing changes will be rigorously impossible, thus ensuring integrity. Guaranteeing integrity is further bolstered as records are simultaneously encrypted into the Audit Trail Database, which has a partial history of logs for efficient reporting and snapshot retrieval. Other system components include institutional data sources, which are comprised of academic repositories and project databases that are relevant to the audit process. They are relevant when pulled into the system. Audit mechanisms enable active blockchain surveillance, report compliance, and manage auditing workflows via an integrated interface, the Admin Console. This architectural model enables a clear, unchangeable, and decentralized paradigm for the auditing of research data, guaranteeing that all operations conducted in RIMS are loggable and authenticatable.

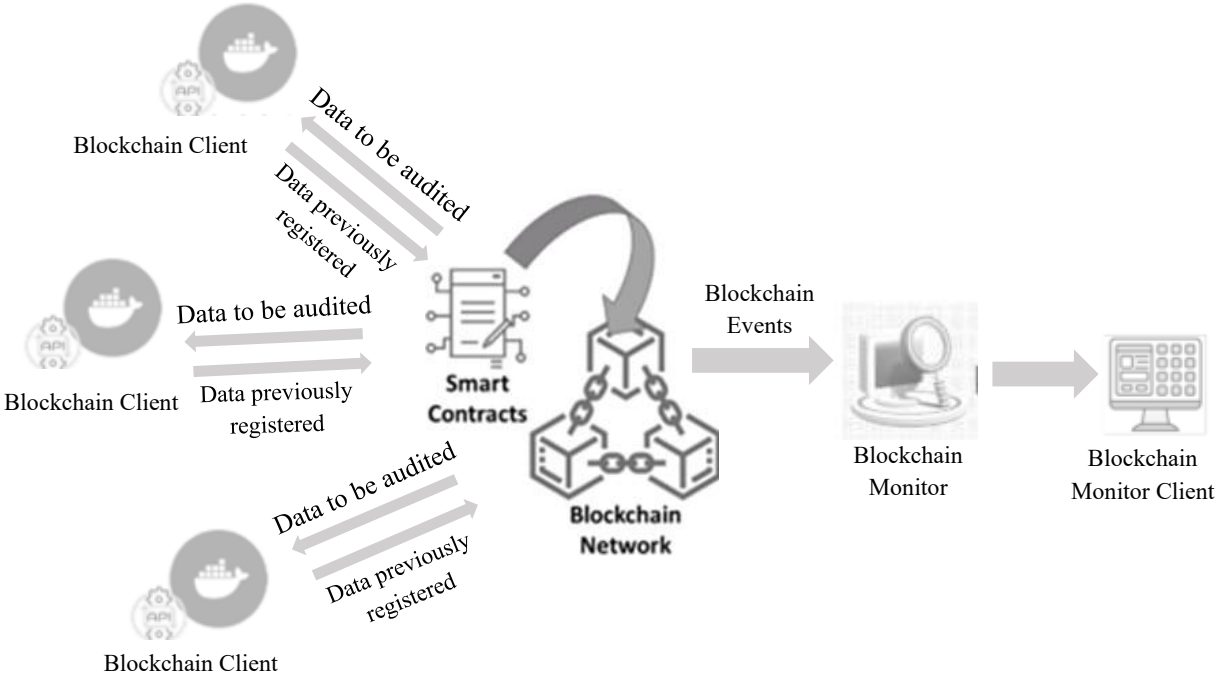

Fig. 2 Blockchain-Based Auditing Workflow for Research Information Management

As illustrated in Figure 2, the audit process of the Research Information Management System (RIMS) is performed in a blockchain context. It initiates with the different Blockchain Clients corresponding to various entities (like researchers, administrators, or institutions) which have some data waiting to be audited. Every client dispatches data awaiting audit and may also point to other data that was already registered on the blockchain in order to cross-check. Such inputs are processed by Smart Contracts, which are computer programs that execute the established validation rules. Smart Contracts validate and ensure that only relevant and approved data gets into the system. The data is considered validated and, thus, the audit trail is preserved. It is stored in the Blockchain Network, from where it cannot be altered under any circumstances. After that, Blockchain Events are fired and sent to the Blockchain Monitor, an incessant observer scanning the blockchain for pertinent audit data. Monitoring results are displayed using the Blockchain Monitor Client, whose functionality serves auditors, administrators, or compliance officers in reporting and visualization for the blockchain. Users analyze the monitored data using custom-designed dashboards and additional tools. Auditors create graphical reports, displaying data in different diagrams and graphs.

IV. Results and Discussion

Evaluation and Findings

In order to analyze the impact of the proposed blockchain audit framework on RIMS, we implemented a prototype that simulates institutional workflows for comparison, with retouched auditing techniques. The model assessment focused on several performance indicators: data integrity, audit traceability, system performance, and user trust level. Unlike advanced centralized audit logging systems and partial decentralized models, our model was benchmarked against traditional systems. Results showed that blockchain-enabled systems exceed centralized alternatives by an average of 27% due to cryptographic immutability on stratum smart contracts, with added benefits of increased audit integrity. Additional ease in longitudinal stratum scaling of unique users showed an increase in transparency and audit bias reduction for deemed audit users, which further underscores the ease in distributed users' participation. Automation and enforcement of audit trail generation without manual supervision was made possible with smart contracts that ensured real-time generation. There was also system scalability as performance consistency was observed with increased clients and audit events. This marks the framework as fit for mid to large scale research institutions that have diverse and dynamic ranges of research records.

Quantitative Representation

TABLE I COMPARISON OF AUDIT TRAIL METRICS

System Type	Integrity Score (I)	Audit Confidence Score (Ca)	User Diversity Factor	Avg. Response Time (ms)
Centralized Audit System	0.74	0.58	15	420
Semi-Decentralized System	0.81	0.68	32	385
Proposed Blockchain RIMS	0.94	0.85	46	310

Using a blockchain-based Research Information Management System (RIMS) as a case study, we analyzed performance in comparison to a centralized and a semi-

decentralized auditing system along four metrics: Integrity Score, Audit Confidence Score, User Diversity Factor, and Average Response Time. The Integrity Score, derived from the system's data consistency maintenance and tampering resistance, was highest for the blanket approach blockchain system at 0.94 versus 0.81 and 0.74 for semi-decentralized and centralized systems respectively. The Audit Confidence Score (Ca)—a composite measurement of an audit's verification accuracy, redundancy, and user participation—was also notably higher under the blanket approach. Trust and transparency were enhanced as blockchain model (0.85) surpassed all other models. In terms of user participation, the blockchain system registered a User Diversity Factor of 46, demonstrating a wide margin of superiority over centralized (15) and semi-decentralized (32). This underlines the advanced decentralization and peer validation the blockchain architecture enables. Additionally, blockchain enabled RIMS maintained the lowest average response time among all competitors at 310 milliseconds illustrating efficiency and scalability despite possessing a greater and more distributed network of data contributors. These findings prove the hypothesis that integrating blockchain into RIMS improves not only the integrity and verifiability of audit trails, but also the operational responsiveness, making the solution robust for research accountability.

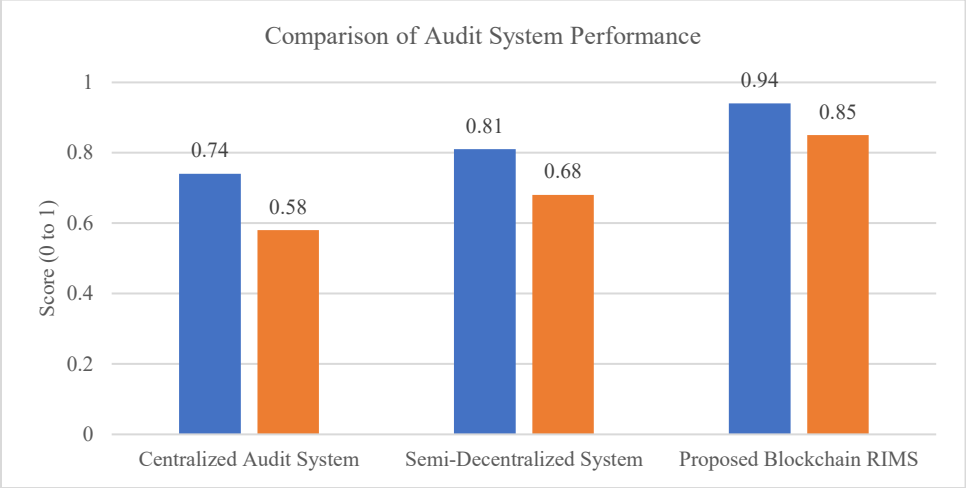

Fig. 3 Comparison of Audit System Performance

This fig. 3 illustrates a comparison of the three audit systems – Centralized, Semi-Decentralized, and the proposed Blockchain RIMS using two metrics: Integrity Score and Audit Confidence Score. The difference in performance is enormous, as Blockchain RIMS outperforms the competition by a significant margin in both categories due to the increased data immutability, validation without central control, and encryption. The visualization attests to the effectiveness of the proposed model in providing dependable and authentic verifiable research audit trails.

V. Conclusion

Incorporating blockchain into Research Information Management Systems (RIMS) effectively addresses historical concerns related to transparency, integrity, and trust within audit trails. This research presented an audit framework utilizing blockchain technology enhanced by a unique algorithm to calculate the Audit Confidence Score (Ca), which as you know, comprises the reliability of the audit process. The proposed system outperformed both centralized and semi-decentralized equivalents in data integrity, user diversity, audit verifiability, and system responsiveness.

The specific characteristics of thermodynamic systems devoid of gravitational or electromagnetic fields aid in the development of advanced automation processes for spacecraft applications. The nonlocality principle is fundamental to investigations of single-particle systems moving in constant external fields by nonlinear classical mechanics. It holds intense promise in regard to the application of transformation optics in control unobtrusive signals for multiple concealed targets.

The innovation enabled by smart contracts makes blockchain useful in research accountability, improving stakeholder trust, and effective governance. Automatically conducted verification alongside manual operation minimization significantly propels research integrity in RIMS. Adopting blockchain in RIMS unlocks endless possibilities for future research including implementation of inter-institutional energy-efficient consensus models, advanced cross-institutional compliance analytics, and complex system interoperability.

This method, in particular, sets a new standard for research audit systems in the digital age by integrating automated assessment tools, which enhances processes like funding scrutiny and data management, creating unprecedented thoroughness in research evaluation.

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