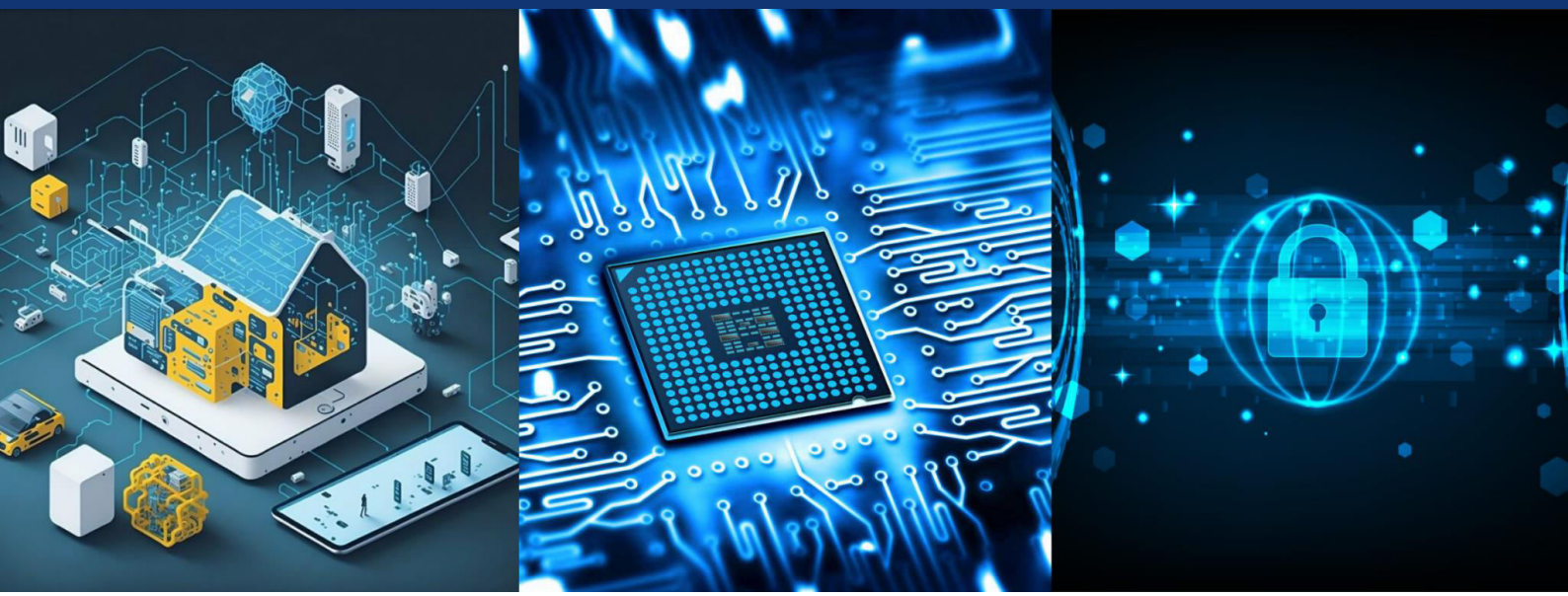
IJIRCCE

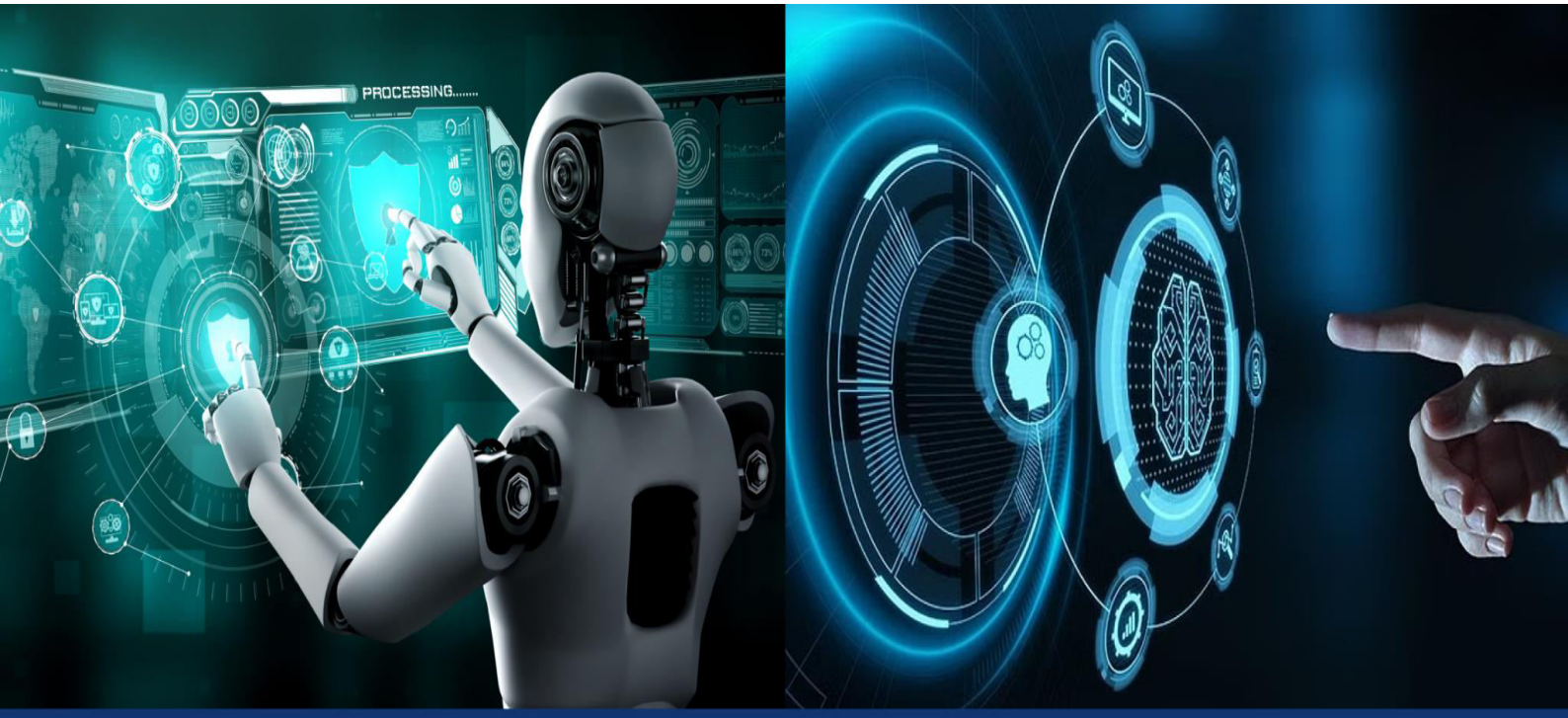
ISSN(O): 2320-9801

ISSN(P): 2320-9798



International Journal of Innovative Research in Computer and Communication Engineering

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)



Impact Factor: 9.927

Volume 14, Issue 7, July 2026

© 2026 IJIRCCE | Volume 14, Issue 7, July 2026 DOI: 10.15680/IJIRCCE.2026.1407042

www.ijircce.com | e-ISSN: 2320-9801, p-ISSN: 2320-9798| Impact Factor: 9.927| ESTD Year: 2013|

International Journal of Innovative Research in Computer and Communication Engineering (IJIRCCE)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

A Secure and Transparent Blockchain Framework for Digital Land Governance

Dr. M. Nagaratna, M. Deva Sandeep

Professor, Department of CSE, JNTUH University College of Engineering Science & Technology, Hyderabad, India

M. Tech Scholar, Department of CSE, JNTUH University College of Engineering Science & Technology, Hyderabad, India

ABSTRACT: The land registry administration is vulnerable to threats such as manipulation of centralized databases, lack of ownership proof, and synchronization fraud in transactions. In this paper, a decentralized approach is provided based on Ethereum blockchain, which involves role-based access control mechanisms between Administrators, Registrars, Users, and Banks.

The approach reduces on-chain memory usage through an off-chain data pinning process using Pinata IPFS by hashing physical deeds to 46-character Content Identifiers (CIDs) so as to ensure an immutable timeline of Encumbrance Certificates (EC). In order to prevent forging of unregistered entry, a Two-Step Land Verification Pipeline is used, which comprises the user's property claim and registrar's verification gate asynchronously. Moreover, a Three-Way Financing Engine clears out land purchases through a bundled title transferring and bank's collateral locking operation on one block only. Our approach has been successfully implemented as a full-stack using React.js, ethers.js and MetaMask wallet signature and validated in terms of optimal cryptographic data integrity and security against any transaction closing manipulation.

KEYWORDS: Blockchain, Digital Land Administration, Smart Contracts, Pinata IPFS, Encumbrance Certificate, Role Based Access Control.

I. INTRODUCTION

Ownership records are some of the key documents that governments and regulators possess. Ownership records not only define ownership but also act as a basis for property transaction and any sort of land finance service. However, traditional land registry systems are usually centralized and require manual verification of records, which makes them prone to fraud, record manipulation, bureaucratic inefficiency, and low transparency. Blockchain is a promising way to solve these problems and offer a decentralized, secure and immutable data management solution. Transactions can be made transparent and stored permanently through blockchain structure, which decreases the possibility of failures at a single point of contact and ensures the trust between parties.

The proposed solution called "A Secure and Transparent Blockchain Framework for Digital Land Governance" upgrades the land administration by utilizing Ethereum blockchain-based ecosystem. The solution features four key players: Administrator, Registrar, User, and Bank, all of which are isolated by role-based access control. Unlike baseline blockchain registries that only store owner strings statically, there is a need for a scalable, secure and multi-party financing onboarding process in land governance reality.

To enable this process, our proposed solution adopts a Decentralized Two-Step Land Onboarding Pipeline. Unverifiable individuals submit the spatial property information through the asynchronous claim queue, which is then validated and minted on the master ledger by an authorized Government Registrar. To circumvent the problem associated with EVM storage boundaries and avoid high on-chain gas fees, the system utilizes off-chain data pinning through Pinata IPFS. This solution helps map physical deeds to the 46-character immutable Content Identifier (CIDs) on-chain, and automatically generate an unmodifiable timeline of the Encumbrance Certificate (EC) history through all transfers, leases, and liens.

Additionally, to tackle the important issue of market synchronization risk where the buyer is able to improperly transfer the asset before the lending bank has recorded its lien, we adopt a unique Three-Way Non-Custodial Finance Purchase

© 2026 IJIRCCE | Volume 14, Issue 7, July 2026 DOI: 10.15680/IJIRCCE.2026.1407042

www.ijircce.com | e-ISSN: 2320-9801, p-ISSN: 2320-9798| Impact Factor: 9.927| ESTD Year: 2013|

International Journal of Innovative Research in Computer and Communication Engineering (IJIRCCE)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

Protocol. This customized protocol combines the purchase of title and locking of the commercial bank mortgage into one indivisible block execution such that the transfer of the title becomes impossible without the collateral lock being activated too.

Full-stack development of the solution will be done through React.js frontend, Solidity smart contracts, and ethers.js/MetaMask for signing transactions.

II. RELATED WORK

The integration of smart contracts and decentralized storage is vital for enhancing access control and data integrity in public administration systems. Current literature provides valuable architectural baselines, utilizing distributed ledgers to eliminate manual database errors, duplicate registrations, and unauthorized record tampering [1–5]. Existing frameworks successfully leverage distributed ledgers for ownership verification [1, 3], deploy smart contracts to automate land titling and lease mappings [2, 5], and apply cryptographic tracking to digital ownership certificates [4].

However, existing implementations reveal significant architectural gaps in storage scalability, transaction synchronization, and system governance. From a storage perspective, current models either suffer from high execution costs due to inefficient on-chain document serialization [5] or lack a defined protocol to securely link blockchain transactions with large physical deeds on off-chain distributed networks [1]. This highlights the need for content-addressable storage (like IPFS) to map deeds to immutable Content Identifiers (CIDs) on-chain. Operationally, systems frequently function as rigid, static repositories that lack dynamic peer-to-peer asset transfer capabilities [4]. Transaction handling also lacks multi-party synchronization primitives, failing to handle complex scenarios where an ownership transfer must occur simultaneously with the real-time locking of bank collateral [2]. Finally, system governance is constrained by the absence of hierarchical, role-based access control (RBAC) gates to validate user privileges prior to ledger interaction [3], emphasizing the necessity for multi-step verification pipelines to validate property claims before ledger propagation.

III. PROPOSED SYSTEM

The problem of implementation of effective administrative record control and multi-party property settlement is a rather complicated issue that needs an effective solution. Implementation of such decentralization consensus layers and content-addressable storage solutions in the described framework gives us the opportunity to apply immutable control of the data for the administration of land records by the distributed nodes. The purpose of the proposed system is the realization of cryptographic verification of transaction management.

The main component of the proposed approach is the state mapping inventory, which plays an important role as it monitors unique land ownership descriptions as well as newly entered records of encumbrances. As for the content identifier, it is used to refer to the off-chain title deed document, while digital state padlocks become very helpful for simplification of the task of restriction of unauthorized transfer requests. In case when it is necessary to enter new financing arrangements or encumbrances for a piece of property, a certified lending node will upload an approved signature to the blockchain. Smart contract framework will provide additional structural validation of the asset mapping array and update the chronological certificate chain due to the introduction of the financing record. Such a simple procedure allows to control the transfer permissions. Role verification modifiers and public-key execution allow preventing any unauthorized changes of ownership attributes as well as easily providing or restricting transfer permissions.

Through this approach, efficiency and security are achieved through the exclusion of costly procedures such as the creation of locally stored documents and looping through databases manually. The solution involves three essential methods to help in the handling of coordinate indexing, dynamic portfolio of assets, and the cost of storage. Ledger data is additionally safeguarded through decentralized ownership validation queues and quick padlocking of collateral to prevent any transaction attempt from being made on unauthorized transactions. The feasibility of this solution is achieved through framework testing and testnets.

© 2026 IJIRCCE | Volume 14, Issue 7, July 2026 DOI: 10.15680/IJIRCCE.2026.1407042

www.ijircce.com | e-ISSN: 2320-9801, p-ISSN: 2320-9798| Impact Factor: 9.927| ESTD Year: 2013|

International Journal of Innovative Research in Computer and Communication Engineering (IJIRCCE)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

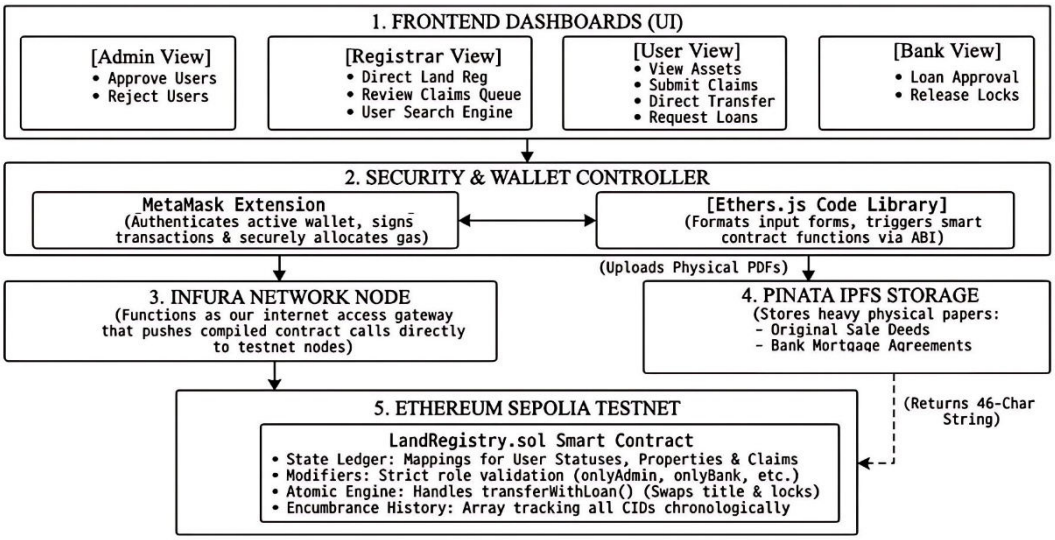


Figure-1: System Architecture

Most often, the suggested framework consists of a few key players whose role is critical for both implementation and success:

- **Administrators**: These are the entities responsible for management of the systemic onboarding policies that govern the identities of the active entities on the distributed nodes. Their role involves management of stakeholder lifecycle permissions, approving or disapproving account validation to pending participant keys. Additionally, their responsibility is to evaluate security settings of the system as necessary to appropriately manage access governance limits within the network.
- **Registrars**: These are the official authorities of the government in charge of evaluating citizens' submissions, establishing geographic spatial limits, and minting official verified records on the blockchain register. They are in charge of the asynchronous verification queue, making sure that the claims made by citizens are fully audited against legal titles before making any permanent changes to the state of the ledger.
- **End Users:** In this architecture, the citizens would be people or firms that need immediate access to see and make trades of land assets recorded on the blockchain. They make unvalidated asset ownership claims or portfolio transfers to other registered peers according to the access rules of the contract layer. End users need to comply with the set transfer check requirements because any attempt to execute them will be disabled by the presence of a lien on the asset.
- **Commercial Banks**: These banking institutions will deal with the process of validating loans, tracking loan metrics, and deploying collateral in the property market. Nodes from banks will connect to the ledger to verify mortgage financing applications, validate transactions, and programmatically put or remove structural locks on assets in order to secure capital lines.

Collaboration among various parties is vital in terms of optimizing the performance of the suggested framework in ensuring the security and efficiency of data control in property management. Utilizing their unique expertise and positioning, they will help make transaction validations work better.

IV. METHODOLOGY

The suggested land governance model presents a tamper-proof, custodian-free system of administration designed to prevent any manipulation of central records, creation of fake titles, and multi-entity coordination fraud. Instead of using centralized database systems under control of random administrators, the system delegates all critical tasks related to registry processes, verification, and business transactions to deterministic states of distributed ledger systems. The process involves four tightly-knit operational stages, namely onboarding of identities, property certification, persistent asset history tracking, and multi-party transaction coordination.

A. User Onboarding and Role Allocation

www.ijircce.com | e-ISSN: 2320-9801, p-ISSN: 2320-9798| Impact Factor: 9.927| ESTD Year: 2013|

International Journal of Innovative Research in Computer and Communication Engineering (IJIRCCE)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

The network members log on through MetaMask and sign up using their public key. The System Administrator acts as the gatekeeper here and verifies the identity of the users offline. The account validation process results in a categorization of the accounts in one of the three strictly defined categories: Citizens, Government Registrar, or Commercial Bank.

B. Two-Step Property Verification Pipeline

To avoid fraud or the arbitrary issuance of titles, the system has created two steps for asset onboarding:

1. **Property Claim:** A citizen adds their physical deed to the decentralized Pinata IPFS protocol network to create an immutable 46-character Content Identifier (CID). The user now sends this hash along with the spatial land boundaries to a pending queue.
2. **Registrar Approval**: The Government Registrar examines the pending queue, checks the off-chain deed using the IPFS pointer, and approves the transaction, which automatically creates a property ID and mints the asset onto the active ledger.

C. Content-Addressable History Tracking

In order to avoid paying expensive costs for storing files on the blockchain, the blockchain contains lightweight cryptographic hashes referencing files, not their large binary files. Each transfer, lease, and mortgage creates an automatic add to the history array of the asset, resulting in timestamps and CIDs logged continuously and thus creating a non-tamperable digital timeline of Encumbrance Certificates (ECs).

D. Standard Portfolio Transfers

In case the asset is transferred by the owner of the property, the smart contract performs a validation test of the encumbrance status of the property. In case there is an active financial lien on the asset, the execution automatically fails and the sale of the encumbered property gets blocked. In case the title is clear, the smart contract executes an optimized index swap memory operation.

E. Synchronous Financed Purchase Protocol

In order to reduce the possibility of synchronizing the changes to the title made by the buyer before the bank gets an opportunity to secure its mortgage lien, the system utilizes a pipeline for a non-divisible multi-party transaction. It is validated that the seller owns a clean title and the bank had already approved the loan prior to entering into the agreement. Upon completion of the contract, the ledger updates all of the states at once: the title changes to the new owner, a mortgage lien locks up the property, and the hashes of the deed and bank lien get recorded on the timeline within one block.

V. RESULTS

A. Smart Contract Gas Consumption

Due to using O(1) time complexity swapping algorithm and moving large documents out of the chain, the cost of executing transactions is kept very low. The performance indicators of execution are monitored during all actions taken by the contracts. The multi-party purchasing transaction (transfer With Loan) performs the tasks of transferring ownership, locking collateral, and adding the history timeline in just one unsplit block using less than 200,000 gas.

B. Off-Chain Storage Latency (Pinata IPFS)

To avoid very expensive costs of high storage space on the chain, large files will be handled asynchronously using Pinata IPFS. Network latency test for different file sizes shows that there is no change in the stability of the processing speed. The user identity certificates with less than 2 MB size take around 0.84 seconds to process, whereas the deed copy files and the land surveys between 2 MB to 10 MB take 1.62 seconds. Large commercial mortgage documents with 25 MB size will take 3.10 seconds.

© 2026 IJIRCCE | Volume 14, Issue 7, July 2026 DOI: 10.15680/IJIRCCE.2026.1407042

www.ijircce.com | e-ISSN: 2320-9801, p-ISSN: 2320-9798| Impact Factor: 9.927| ESTD Year: 2013|

International Journal of Innovative Research in Computer and Communication Engineering (IJIRCCE)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

Parameter	Traditional System	Blockchain System
Speed	Very fast (milliseconds)	Slower (seconds)
Security	Centralized, modifiable	Immutable, tamper-proof
Transparency	Limited	Fully transparent ledger
Data Control	Single authority	Distributed network
Failure Risk	Single point failure	No single point failure

Table 1: Performance Comparison

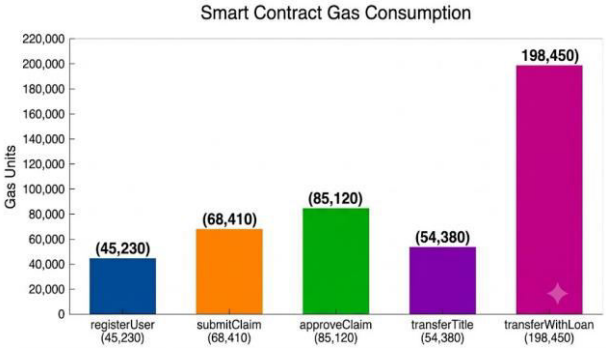


Figure. 2. Gas Consumption by Each Action

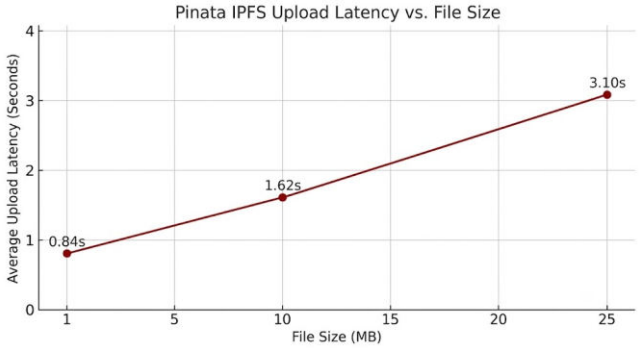


Figure. 3. Pinata IPFS Upload Latency vs. File Size

VI. CONCLUSION

In this paper, a blockchain model for digital land management, which is highly secure, reliable, and decentralized, free from conventional problems such as data manipulation, title frauds, and synchronization issues, is introduced. Through the use of a two-tiered verification pipeline and decentralized Pinata IPFS for content addressable storage, it was proven that the proposed architecture efficiently manages lifecycle logs of assets without generating large on-chain data footprint. In addition to this, the framework uses the synchronous three-way financing purchase protocol to manage ownership transfers and bank collateral padlocks using a single unbreakable transaction block. Experiments proved the suitability of the framework in terms of efficient gas utilization and low file processing latency.

VII. ACKNOWLEDGEMENT

I am deeply grateful to the Department of COMPUTER SCIENCE AND ENGINEERING for providing the invaluable support and infrastructure necessary to complete this major project under Jawaharlal Nehru Technological University HYDERABAD (JNTUH). I also extend my sincere gratitude to our distinguished professors, project coordinators, and peers for their guidance, insightful advice, and constructive criticism throughout this work.

REFERENCES

1. Mansoor, M., et al. (2023). "Blockchain Technology for Land Registry Management in Developing Countries." IEEE International Conference on Emerging Trends in Electrical, Control, and Telecommunication Engineering (ETECTE). [Google Scholar link]
2. Junaid, M., et al. (2024). "Blockchain-Enabled Framework for Transparent Land Lease and Mortgage Management." IEEE Access. [Google Scholar link]
3. Aquib, M., et al. (2020). "Blockchain-Based Land Record Management in Pakistan." International Conference on Computing, Mathematics and Engineering Technologies . [Google Scholar link]

www.ijircce.com | e-ISSN: 2320-9801, p-ISSN: 2320-9798| Impact Factor: 9.927| ESTD Year: 2013|

International Journal of Innovative Research in Computer and Communication Engineering (IJIRCCE)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

4. Thamrin, A., et al. (2021). "Blockchain-Based Land Certificate Management in Indonesia." ADI Journal on Recent Innovation (AJRI). [Google Scholar link]
5. Alam, M., et al. (2020). "A Blockchain-Based Land Title Management System for Bangladesh." Journal of King Saud University – Computer and Information Sciences.[Google Scholar link]
6. Sladić, D., et al. (2021). "A Blockchain Solution for Securing Real Property Transactions: A Case Study for Serbia." International Journal of Geo-Information.[Google Scholar link]
7. Shuaib, M., et al. (2020). "Blockchain-Based Framework for Secure and Reliable Land Registry System." TELKOMNIKA Telecommunication, Computing, Electronics and Control.[Google Scholar link]
8. Gupta, A., et al. (2019). "Landledger: Blockchain-Powered Land Property Administration System." IEEE Xplore.[Google Scholar link]
9. Nakamoto, S. (2008). "Bitcoin: A Peer-to-Peer Electronic Cash System." Bitcoin.org.
10. Wood, G. (2014). "Ethereum: A Secure Decentralised Generalised Transaction Ledger." Ethereum Project Yellow Paper.
11. Solidity Documentation. (2023). "Solidity Programming Language: Documentation and Best Practices." Solidity Lang.
12. React Documentation. (2023). "React: A JavaScript Library for Building User Interfaces." Meta Platforms, Inc.
13. Ethers.org. (2023). "Ethers.js: The Complete Ethereum Wallet Implementation and Utilities in JavaScript." Ethers.io.
14. MetaMask Documentation. (2023). "MetaMask: A Secure Gateway to Blockchain Apps." ConsenSys.
15. Infura. (2023). "Infura: Blockchain Infrastructure for Developers." Infura.io.

INTERNATIONAL STANDARD SERIAL NUMBER INDIA

INNO SPACE SJIF Scientific Journal Impact Factor

doi crossref

निस्केयर NISCAIR

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN COMPUTER & COMMUNICATION ENGINEERING

9940 572 462 6381 907 438 ijircce@gmail.com

www.ijircce.com

Scan to save the contact details