

A Secure and Transparent Land Registration Framework Utilizing Blockchain and Artificial Intelligence

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ABSTRACT

In the digital era, traditional systems for titling land are facing several challenges, including centralized data silos, administrative delays, and the risk of fraudulent activity. In several urban areas within developing countries, the use of paper-based or centralized registries creates a single point of failure, resulting in opportunities for corruption and a lack of transparency. This research proposes a multi-layer computational framework that integrates decentralized ledger technology (DLT) with an intelligent pre-processing mechanism to increase trust and efficiency.

The machine learning component is a LightGBM [7] based module and acts as a validation layer at the core of the system. Unlike traditional blockchain systems that store all incoming transactions, this model will filter and validate transactions before they are stored on the blockchain. This model will detect anomalies, such as inconsistent geolocation data or irregular patterns of KYC (know your customer) activity, ensuring only transaction data that has undergone a validation process will be recorded on the blockchain. Consequently, this approach to validation-first will enhance the quality of data being transmitted to the blockchain and minimize the risk that fraudulent data will be added to the blockchain.

Additionally, smart contracts [10] will be implemented as a means of automatically executing transactions and the use of IPFS (InterPlanetary File System) [9] will facilitate scalable off-chain storage of legal documents. The hybrid design of the proposed system will enable the production of lightweight, efficient blockchains while providing a secure and tamper-proof method to access the records of land registrations (the records). Ultimately, by relying on the proposed system, land registration processes will experience less dependence on manual oversight and establish a transparent, secure, and reliable land registration ecosystem.

Keywords: *Blockchain, Artificial Intelligence, LightGBM, IPFS, Land Registration, Smart Contracts, Data Integrity.*

1. INTRODUCTION

Land ownership is an essential element for economic stability; it provides people with security, and also allows them to accumulate wealth over time. In the context of the rapidly expanding urban areas such as Pune, accurate land records are critical to fuelling continued economic development and avoiding potential disputes about land ownership.

Unfortunately, the majority of current land registration systems still use either centralised databases or old-fashioned paper-based records; therefore, the legacy systems are subject to risk of data loss, human error, and unauthorised modifications [4]. This often causes inefficiencies and loss of public confidence [8].

The advent of blockchain technology [6] presents a potentially revolutionary way to change how land ownership records are maintained, as it can support a decentralised, immutable, and transparent manner of maintaining records [5]. However, the fact that blockchain is only as good as the data entered into it means that it does not by itself guarantee the authenticity of data [3]. To overcome this limitation, the current research suggests the use of a hybrid architecture that combines Distributed Ledger Technology (DLT) with machine learning techniques [1].

The proposed architecture operates in three phases; first, the classification layer (built using LightGBM [7]) will evaluate transactional data and the associated KYC information for anomalies prior to submitting this data to the blockchain. Second, the use of smart contracts [10] will facilitate the automated transfer of ownership in a secure and transparent manner [2]. Third, IPFS [9] will be utilised for storing larger property records in an efficient manner using off-chain storage. In combination, this architecture will enhance scalability and data integrity, while establishing a secure, transparent, and self-verifying land registration ecosystem.

2. LITERATURE SURVEY

Scholarly discussions and international pilot projects have recently shown a strong interest in "blockchainizing" land titles [4]. A thematic analysis of relevant research shows that a few individual parts of De-Centralized Ledger Technology (DLT) and Machine Learning were previously written about and studied, but the gap between how these technologies integrate and get governed is significant.

2.1. Evolution of Security Frameworks (AI and Verification)

Early efforts towards creating digital registries were mainly focused upon the fact that once the data had been stored, it could not be changed (immutability) [5]. In 2024, Naguji et al. [3] proposed a smart "gatekeeper" as part of their GreenLand project, which represented a shift from solely focusing on the immutability of the data to considering how to reliably issue a

digital identity to a transaction before the transaction is added to the blockchain, thus preventing data pollution.

Limitation: Although the introduction of the "gatekeeper" reduces the workload of the blockchain, the effectiveness of the model is reliant on the quality of the training dataset [8]. Furthermore, numerous research studies, including Aquib's 2020 research on Pakistan, used only "pseudo" data to evaluate their models, which raises questions about how well the AI filters will perform under real-world conditions.

2.2 Decentralization & Scalability Solutions for Data Storage on a Blockchain

Data Bloat will be an Important Technical Barrier to Block Chain Networks as they continue to Expand [6]. The Research by Kamble et al. (2025) [2] Built the "Landex" Proof of Concept that used Ethereum and the InterPlanetary File System (IPFS) [9] to Store Heavy Legal Documents Outside of the Blockchain. To Proof the Concept of Building a System that is Scalable While Retaining Integrity, all they Stored on the Blockchain was the Cryptographic Hash of the Document(s) and the Documents Were Retrieved from IPFS Using their Respective Hash When Needed.

2.3 Geospatial Mapping and Public Confidence

Geospatial Mapping plays a major role in ensuring that duplicate claimants are prevented from having their claims accepted. In a study conducted by Vayadande and others (2022) [5], a hybrid system was proposed to show land claims in India using Google Maps. The Google Maps API is used to anchor digital certificates to actual physical geocoordinates.

Limitations: This concept has helped to develop trust in the public through this new technology [8] as well as the Republic of Georgia through their project to timestamp land records (Shang & Price, 2021), but most of the studies mentioned here work more on viewing the information than how the individuals responsible for managing the information will govern themselves. There are few automated systems in place that allow for AI filtering and "Logged Administrative Roles". To provide accountability internally, automated systems that allow for AI filtering and the use of "Logged Administrative Role" to identify an individual's identity, must be implemented in these types of processes [10].

2.4 Summary of Research Gaps and Innovation Plan

Thanking the writers, I have analyzed the current state of affairs and identified that there is an important "Integration and Accountability Gap." While other authors have looked at AI filtering in Naguji [3], storage with an IPFS (Kamble) [2], and Geospatial Mapping through Vayadande [5], in this study they have each been treated as stand-alone systems. This study approaches the "Integration and Accountability Gap" from a different angle than past research, which has used "post-entry"

security processes. This study proposes an Integrated Validation Pipeline that combines elements of:

1. Proactive AI Filtering by blocking fraud at the entrance using LightGBM [7] before it can reach the ledger,
2. Connecting all records to Google maps real-time geospatial coordinates to minimize the potential for so-called "phantom" or fictitious property registrations,
3. Establishing a Hybrid method of storing records in IPFS [9] to maintain low-costs and fast access to records for areas with high population densities such as Pune.
4. Using a controlled administrative system (Anti-Tamper Logic) where every "add" or "delete" action is cryptographically signed and permanently recorded to the blockchain [1]. By binding the administrative user to the smart contract [10] logic, we are ensuring that even a user who has access to make changes to records will leave a permanent, immutable record of their actions that will be open for all other stakeholder/users to see.

3. PROBLEM STATEMENT

The Vulnerability to Fraud and Bureaucratic Inefficiency of the Current System Creates a Major Blind Spot with Property Ownership of Lack of Transparency and Trust in Property Ownership. The Problem is the Systemic Centralization of Real Estate Ownership. Putting all of a community's real property ownership history into one closed database has created four distinct points of systemic centralization where failures frequently occur:

- **Manipulation and Fraud of Records:** When all records are centrally controlled, bad actors or hackers are often able to change ownership records [5]. This results in cases of double ownership where one property may be transferred to multiple buyers because there is not a public real-time ledger to verify the transaction [1].
- **Inefficiency of the Operations:** The inefficiency of present procedures is caused by creating multiple steps (aka middlemen) in the process for each of the participants (real estate brokers, lawyers, and government agencies). Each of these steps adds weeks to the transaction process and increases administrative costs, and the likelihood of errors in manual entry of data by each step (aka middleman) [4].
- **The Fragility of Physical and Digital Records:** Since a central server holding all the records is a "Single Point of Failure," if any of the following events occur: (1) physical or electronic crash of the server; (2) The server is hacked; or (3) Physical documents are destroyed, it is entirely possible the legal proof of a citizen's generational

wealth could be lost forever because of the lack of a decentralized repository of the records [6].

- **Trust Deficit:** The difficulty of creating a secure and tamper-resistant system creates a legal dispute cycle within the system. This also presents difficulties in using land as a collateral. Thus the economic development of both the individual and state is stifled due to the lack of a clear title to the land [8].
- **Importance of Research** By changing land registration from a "Trust" to "Truth" based system (trust in people not to be corrupt - evidence through math and code), this research will address four separate failure points in the system. In doing so,

we will protect people's most significant asset and ensure that property's rights are based on immutable physical conditions, not arbitrary bureaucratic decisions [10].

4. OBJECTIVE OF THE STUDY

This research project is focused on creating a self-verifying digital ecosystem for land registry and replacing the existing trust-based system which is currently vulnerable to fraud. This study's objectives include:

- **Decentralized Ledger Architecture:** To develop a distributed network to eliminate Single Points of Failure (SPFs) such that property records are synchronized, always available and can never be deleted [6].
- **AI Fraud Filter Development:** Create a real-time fraud detection system using machine learning (LightGBM [7]) that will screen transaction metadata to identify and screen out potential fraudulent entries prior to full time being recorded [3].
- **Smart Contracts To Automate Title Transfers:** Create self-executing code (smart contracts [10]) that will automatically handle legal verification of ownership and updates to ownership records, thus eliminating the need for expensive and time consuming manual third-party processes [2].
- **Geospatial Mapping Integration:** Use Google Maps API to tie digital certificates to exact physical coordinates, thereby assuring the digital record of land and the legal property will always be accurate with the actual land [5].
- **Scalable Data Storage:** Design and develop a hybrid storage construction (IPFS [9]) that allows a system to process high-resolution legal documents and deeds with no impact on speed or cost-efficiency of the blockchain [2].

- **Validation Of Data Integrity:** Create a "Chain of Trust" by utilizing cryptographic hashing to identify attempts to alter historical records when those attempts occur [1].

5. OVERVIEW OF BLOCKCHAIN TECHNOLOGY

Blockchain is a collective digital record in which multiple computers run simultaneously on the same instance. The entire network serves as a "co-admin" of the database and no one person has complete control of the database, making it safe to store information like land titles because you do not have to put all your trust in one party [6]. The blockchain is made secure using these three principles:

- **Unchangeable:** Imagine a notebook where you can only write on the next page; if you try to erase the old pages it gets messy and confusing, so we will not do that. Each new block is mathematically linked to the prior block using a cryptography-generated hash. When an individual tries to edit or change an entry to the system from prior years, their entry breaks the mathematical link, and as a result all of the networks will see the change at the same time [5].
- **Consensus:** The "Group Agreement". On a "normal" database ("centralized"), an administrator can change a number and that number will be updated in the database instantly. In a blockchain, the entire network ("nodes") ("computers") must agree that a transaction is valid before it can be executed. The consensus determines whether the transaction is valid through the use of protocols, such as "Proof of Authority" (PoA), which prevents any one person from inserting an invalid record ("fake") into the blockchain database [1]. If a record added to the blockchain contradicts another record of that same transaction in the blockchain database, the record will not be added by the blockchain, and the action of attempting to add this false record will be prevented.
- **Smart Contract:** Smart contracts are just a piece of code that acts as a digital "If-Then" agreement between buyers/sellers [10]. An example of this might be: "If the AI verifies (using a set of defining characteristics) that the documents are valid and if the buyer has paid the seller, then the seller transfers the title to the land to the buyer." By allowing this process to occur without any middlemen (such as a clerk who must hit an "approved" button) means that there will be no such opportunity for corruption (taking a bribe) by anyone in the system [2].
- **Transparency & Digital Logs:** Everything that occurs in the blockchain is recorded in individual blocks at specific times and is validated by a digital fingerprint. If an administrator (an individual with a higher level of access) modifies (adds or deletes) a record in the blockchain, then

that administrator's name will be permanently recorded with any changes made by them [4].

6. PROPOSED FRAMEWORK AND SYSTEM ARCHITECTURE

The purpose of this proposal is to address the weaknesses related to conventional registries - namely GIGO (Garbage In, Garbage Out) and admin modifications - by creating A Three Tier Unified Validation Pipeline. In comparison with other systems that simply store data without any influence or responsibility for recording the data submitted to them [4], this new system will filter and substantiate all transactions prior to them being recorded as an entry on the ledger.

Tier 1: The Geospatial and Input Layer

The user interface is where the tools all start: the Buyer, Seller and Government Officials enter in the details of their transactions and KYC documentation will be done here.

The Innovation: To combat "phantom" property registrations, the Google Maps API will be integrated to mathematically anchor every digital deed to its actual physical geocoordinates [5].

Internal Accountability: This layer also contains the Admin Planning module. In order to eliminate the "Internal Tamper" issue, every administrative function (adding or deleting processing slots) will be digitally signed using an encrypted digital signature [8]. This way, the admin cannot work "under the radar"; every move they make will be permanently recorded on the blockchain with their unique digital fingerprint.

Tier 2: AI Intelligence Layer (Proactive Gatekeeper)

The second tier of the hierarchy provides a layer of security protection for the solution as it will serve as the interface to identify and classify "trust" through mathematical computation as opposed to human intervention.

What is the process? We use the LightGBM [7] model (Light Gradient Boosting Machine) in order to evaluate incoming meta-data on a "real-time" basis.

How does it work? The AI uses the transaction history of historical fraudulent patterns and price fluctuations to risk score any incoming transaction [3]. If the AI determines that a transaction is "High Risk" or "Fraudulent," it will reject that transaction completely. Only transactions that have successfully passed through the AI evaluation will be allowed to transfer to the final ledger and will maintain the blockchain's integrity as the only "Single Source of Truth."

6.3 Tier 3: The Blockchain and Hybrid Storage Layer

Once transaction validation has occurred, transactions are completed using two different storage methods in order to keep the system fast and inexpensive, even for a city as large as Pune.

Smart Contract Execution: Smart Contracts [10] that are self-executing will perform the final title transfer, they will automatically check to ensure that both AI clearance and payment have been executed before performing the transfer, thus eliminating the requirement of having to click an "Approve" button manually; which may be subject to corruption [1].

Optimized Scalability (IPFS): The Interplanetary File System(IPFS) [9] will be used to prevent "data bloat" and high gas fees from utilizing the blockchain for heavy files (scans of deeds/annotations) [6]. The heavy file will be stored outside of the blockchain, and only the unique IPFS Hash (CID) - A digital pointer that can never be broken - will be stored in the blockchain, making the system globally accessible, tamper-proof and efficient [2].

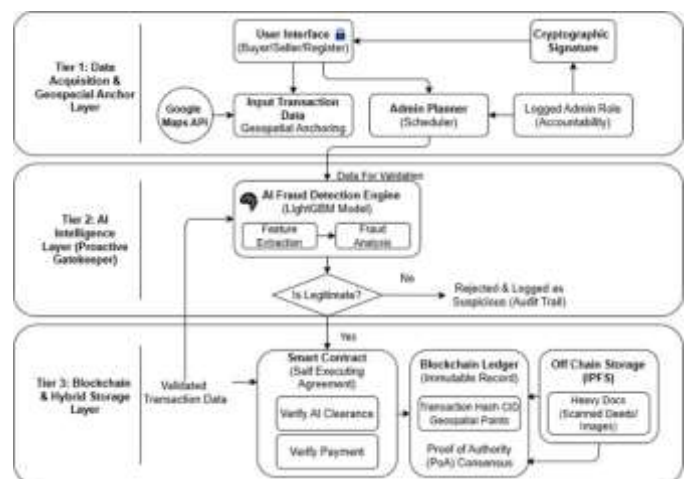


Diagram: System Architecture

7. ADVANTAGES OF THE PROPOSED SYSTEM

The registry makes several important advancements over the current manual system by transitioning from a centralized database to the new AI-Blockchain pipeline:

- **Immutable Security (Tamper-Proofing):** The greatest advantage of this transition is that each record is locked once the AI validates it and writes it to the blockchain [3]. No clerk or hacker can fraudulently alter a land title because the ledger is distributed, thereby creating a permanent, unalterable record of ownership [5].
- **Radical Transparency:** All stakeholders (Buyer, Seller, and Registrar) will see the same version of reality as it exists in real time and will be able to utilize this common repository ("single source of truth") to eliminate the issue of selling two different parcels of the same property at the

same time because the full history of ownership will be available to view and validate [1]

- **Cost and Efficiency Savings (Disintermediation):** Smart Contracts can be used to eliminate redundant costs associated with various intermediaries (e.g., brokers, escrow agents) [10]. By using Smart Contracts, we can reduce the time it takes to complete a transaction from weeks to minutes [2].
- **Continuity and Failover:** Unlike government servers that may go offline for maintenance or have local power outages, a Decentralized Ledger is considered "always on" [6]. Because the data is stored on different nodes, it can be accessed from anywhere in the world, 24 hours a day, 7 days a week [4].

8. LIMITATIONS AND CHALLENGES

The AI-Blockchain framework proposed will help solve the issues associated with trust and fraud, but there are significant obstacles that must be overcome before its implementation in the real world:

- **"Legacy Data" Problem (Migration):** For a blockchain to be utilized, all of the thousands of old land records in paper form must first be digitized. If there is an error or tampering in an original paper record, migrating that record onto a blockchain simply locks that error into place forever on the blockchain [8]. Therefore, cleansing this historical data is an enormous manual effort [4].
- **Social Technical Resistance:** There is also a large amount of resistance from government employees who are used to doing things the old-fashioned way (manually). Since the proposed system removes the need for many middlemen, there is fear that people will lose their jobs as a result of automating the process [10]. Additionally, it is currently extremely difficult to locate local IT personnel with sufficient knowledge of Web3 and Smart Contract technologies to maintain a blockchain-based system on a 24-hour basis.
- **Laws and Regulations:** In most places there is no legal status to Digital Smart Contracts that will appear in court. For this to work, new legislation must be created to give the Blockchain Hash the same legal authority as a stamp on paper documents [1].
- **Digital Exclusion:** Because not everyone has access to reliable high-speed Internet or a smartphone, there is a potential for digital exclusion of those who can't use the register due to geographic location (rural farmers) or lack of technical knowledge among the elderly [3]. We may need to develop "Physical Kiosks" to fill this gap.

Cost vs Scale: The challenges of operating a blockchain network are real costs to local government and will continue until such time as the number of properties within any

municipality reaches the millions, at which point; the cost of Gas (transaction fees) and energy associated with running the nodes will become financially unmanageable for local governments [6].

9. FUTURE SCOPE

While the proposed framework provides a good starting point, there are many possible improvements to the overall power and user-friendliness of this system in the future:

- **Asset Tokenization & Fractional Ownership:** As we move toward a fully decentralized web (Web3), assets like land could be tokenized (digitally represented) and broken into multiple shares of ownership [6]. By creating shares in an asset, many owners can share in a very expensive piece of real estate. When someone passes away, it will also make it much easier to divide up the shares of the asset between all beneficiaries [1].
- **3D Spatial Mapping & Vertical Rights:** Currently, most registries only contain 2D maps. In the future, a significant enhancement would be to add 3D Asset Mapping capabilities. This would allow for the official registration of vertical (multi-story) residential properties; as well as vertical air rights over densely populated areas like Pune, India, where constructing buildings with height is common [5].
- **Integrate CBDCs or Stablecoins with Smart Contracts:** To create a truly "all-in-one" system, we can integrate Central Bank Digital Currencies (CBDCs) or approved stablecoins. This integration would allow for Smart Contracts [10] to automatically perform the payment at the same time, and would be an instantaneous transfer of funds at the time of title transfer. With this set-up, it would create 100% atomic transactions and eliminate the opportunity for payment fraud [2].
- **Biometric Authentication/Aadhaar Integration:** In addition to being able to identify the person hitting the "sell" button as the legal owner of the land, we can create an additional layer of security by using Biometric Authentication (e.g., fingerprint and/or iris scans) linked to the national identity system (Aadhaar). The use of Biometric Authentication will greatly reduce the likelihood of identity theft [8].
- **IoT Land Monitoring:** The blockchain can be connected to Internet of Things (IoT) sensors or satellites [3]. If an illegal encroachment occurs on a property or someone attempts to place unauthorized structures on the property, the IoT sensors can send a "notice" to the blockchain, which automatically notifies the governing authority and the legal owner of the property [9].

10. CONCLUSION

In this study, we show that a blockchain-based land registration solution that uses AI (LightGBM [7]) and geospatial references produces a much more resilient solution than a conventional digital registry [4]. Our move from a passive database to a proactive verification pipeline solves the problem of Garbage In/ Garbage Out [8].

Our integration of smart contracts [10] and IPFS (InterPlanetary File System) [9] will provide property transfers that are secure from tampering and capable of being processed at scale in densely populated urban environments like Pune [2].

A major milestone in this research is the introduction of Administrative Accountability. By requiring all planners to sign with cryptographic signatures, we have also eliminated the "Internal Tamper" loophole that permitted officials to modify records behind the scenes [5]. While legal validity and the digital divide remain challenges [1], this architecture shows that we can replace the requirement of Human Trust with Mathematical Truth [6]. A successful route toward a fraud-free real estate market will be a hybrid solution whereby the blockchain serves as a transparent audit log [3], prior to evolving to a fully automated system for the transfer of property.

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