EquiKey: A Blockchain Based Real Estate Solution

Submitted in partial fulfilment of the requirements of the degree of

BACHELOR OF COMPUTER ENGINEERING

by

Kunj Patel, 20102149

Prince Pal, 20102147

Saket Nigam, 20102122

Guide

Prof. Pranali S. Patil

Department of Computer Engineering

A. P. SHAH INSTITUTE OF TECHNOLOGY, THANE
University of Mumbai

2023-2024

A. P. SHAH INSTITUTE OF TECHNOLOGY, THANE

CERTIFICATE

This is to certify that the project entitled "**EquiKey: A Blockchain Based Real Estate Solution**" is a bonafide work of **Kunj Patel (20102149), Prince Pal (20102147), Saket Nigam (20102122)** submitted to the University of Mumbai in partial fulfilment of the requirement for the award of the degree of **Bachelor of Engineering** in **Computer Engineering.**

_____   _____

Guide   Project Coordinator

Prof. Pranali S. Patil   Prof. Rushikesh R. Nikam

_____   _____

Head of Department   Principal

Dr. Sachin H. Malave   Dr. Uttam D. Kolekar

Date:

A. P. SHAH INSTITUTE OF TECHNOLOGY, THANE

Project Report Approval for B.E.

This project report entitled **"EquiKey: A Blockchain Based Real Estate Solution"** by **Kunj Patel, Prince Pal, Saket Nigam** is approved for the degree of **Bachelor of Engineering** in **Computer Engineering**, **2023-2024**.

Examiner Name   Signature

1. _____   _____

2. _____   _____

Date:

Place:

Declaration

We declare that this written submission represents our ideas in our own words andwhere others' ideas or words have been included, we have adequately cited and referenced the original sources. We also declare that we have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. We understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly citedor from whom proper permission has not been taken when needed.

- -
Kunj Patel- 20102149

- -
Prince Pal - 20102147

- -
Saket Nigam - 20102122

Date:

Abstract

In order to address the inherent shortcomings associated with the conventional real estate procedure which lengthy expensive, vulnerable to scams and time consuming, this study discusses "EquiKey," a decentralized application as a potential solution to solve the traditional shortcomings of the real estate industry. EquiKey uses blockchain technology to establish a rapid, inexpensive, secure, transparent and automated platform for real estate transactions addressing the issues of fraud and inefficiency in the conventional process. The immutability of blockchain provides for safer, more transparent and tamper proof records and integration of ERC-721 which is an NFT (Non-Fungible Token) standard ensures the unique representation of property ownership. Smart contracts are used to convert real world assests to NFTs providing more liquidity to the marketplace through tokenization. Zk-snarks (Zero-Knowledge Succinct Non-interactive Argument of Knowledge) is employed which allows ownership verification, balancing privacy and security. EquiKey not only presents a remedy for liquidity challenges in real estate but also contributes to the evolution of a more efficient and secure real estate ecosystem.

Keywords: Blockchain, NFT, zk-snarks, ERC-721, Tokenization, Real Estate.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVATION

DApp	Decentralized Application
ZkSnark	Zero-Knowledge Succinct Non-Interactive Argument
NFT	Non-Fungible Token
ERC	Ethereum Request for Content

CHAPTER 1

Introduction

Blockchain technology which initially emerged as a technology which revolutionized the finance market and introduced crypto, has started to expand beyond its intended scope and is revolutionizing various sectors due to its inherent attributes of safety, privacy, transparency and decentralization

In recent years, the evolution of blockchain in real estate has reached new heights, with innovations such as real estate tokenization, which allows for fractional ownership and enhanced liquidity. Non-fungible Tokens (NFTs) based on blockchain technology have reached the market, representing unique digital assets and adding layers of transparency and authenticity to real estate transactions.

The main benefits of tokenization are decentralization from a single source of authority, encryption of data that avoids tampering, and digital proof of ownership. The NFT registers real estate static and dynamic information to be traded in the data marketplace between the different users and stakeholders such as investors, occupiers, insurers and property managers.[4] The history of Non-Fungible Tokens (NFTs) adds another layer to the blockchain narrative. NFTs, which represent unique digital assets, gained traction in 2017 when the Ethereum blockchain's ERC-721 standard was created. While initially connected with digital art and collectibles, NFTs

have found widespread application in the real estate industry. Real estate NFTs began to represent property ownership or specified qualities, introducing a new and secure method of conducting transactions. The incorporation of NFTs into real estate has reimagined the concept of ownership, offering a visible and verifiable record of property rights. These tokens, which are commonly linked to physical properties via metadata, improve the validity and traceability of real estate holdings. Notably, NFTs facilitate fractional ownership, enabling investors to acquire and exchange fractions of high-value properties.

As blockchain technology advances, developments such as Zero-Knowledge Succinct Non-Interactive Argument of Knowledge (zk-SNARKs) have improved its uses. zk-SNARKs, due to their very short proofs and verification times. This makes them well suited to be used as transaction data, hiding all the private details at the same time they guarantee the integrity and accuracy of the transaction, and to be verified on-chain by a smart contract[3]. In the domain of real estate, zk-SNARKs have been used for ownership verification, providing a cryptographic technique for property owners to establish ownership without revealing sensitive information.

To summarize, the history of blockchain, NFTs, and real estate is intertwined with the emergence of decentralized ledgers, smart contracts, and tokenization. From tackling issues in traditional real estate procedures to reinventing ownership structures through NFTs, the combination of these technologies is transforming the industrial landscape, bringing unparalleled levels of efficiency, openness, and accessibility.

Blockchain's widespread influence in real estate is defined by its capacity to transform core processes. One of the most significant examples of this technological transformation is the use of real estate tokenization.

EquiKey, in alignment with these enhancements, uses Zero-Knowledge Succinct Non-Interactive Arguments of Knowledge (zk-SNARKs) for ownership verification. This cryptographic approach provides an unprecedented level of anonymity in the real estate ownership verification procedure. Property owners can list their assets on the blockchain without revealing critical information, resulting in a careful balance of security and confidentiality. The seamless integration of zk-

SNARKs improves the overall trustworthiness of the EquiKey platform by providing a secure method of validating ownership without disclosing confidential information. To fully understand the dynamics, it is necessary to realize blockchain's role as a decentralized and tamper-resistant digital treasury. This system organizes data into secure and interconnected blocks, ensuring transparency and permanence in real estate record-keeping.

Furthermore, the incorporation of smart contracts into the "EquiKey" ecosystem highlights blockchain's disruptive potential in real estate. Smart contracts automate and streamline critical operations like asset management, project financing, and land registration. Smart contracts promote efficiency, transparency, and security by automatically executing predefined rules and circumstances. For example, they can create an immutable ledger of property ownership records, simplifying verification and conflict resolution. Automation and streamlining of contract processes using smart contracts and blockchain technology can effectively reduce fraud while saving time and money. The use of smart contracts offers a crucial development in altering the typical shortcomings of real estate procedures, leading to enhanced efficiency.

This study seeks to shed light on the multifaceted nature and usecase of blockchain, NFTs, zk-SNARKs, and smart contracts in the real estate business, with a particular focus on the EquiKey platform. The study aims to provide a deeper comprehension of how these technologies collectively reshape traditional practices and foster innovation in the real estate landscape by delving into the intricate details of real estate tokenization, the use of NFTs, the innovative ownership verification provided by zk-SNARKs, and the transformative potential of smart contracts. However, there are still challenges to address, such as regulatory compliance, standardization, and interoperability. Furthermore, the use of blockchain technology in the real estate market calls for coordination among a variety of stakeholders, including real estate agents, investors, regulators, government and technology providers.

However, amidst the promise of innovation lies a myriad of challenges—regulatory compliance, standardization, and interoperability chief among them. As such, this research seeks to navigate the complex terrain of blockchain adoption in real estate, shedding light on the collaborative efforts required to realize its full potential. From real estate agents to investors, regulators to

technology providers, the journey towards blockchain-enabled real estate transformation demands a coordinated approach—one that balances innovation with pragmatism, disruption with collaboration. Through a comprehensive analysis of EquiKey's role as a harbinger of change, this study aims to provide valuable insights into the transformative power of blockchain technology in shaping the future of real estate.

To summarize, the history of blockchain, NFTs, and real estate is intertwined with the emergence of decentralized ledgers, smart contracts, and tokenization. From tackling issues in traditional real estate procedures to reinventing ownership structures through NFTs, the combination of these technologies is transforming the industrial landscape, bringing unparalleled levels of efficiency, openness, and accessibility.

CHAPTER 2

Literature Survey

Satoshi Nakamoto's paper introduces Bitcoin, a decentralized digital currency designed to eliminate the need for intermediaries in financial transactions. It outlines the innovative use of a blockchain to record transactions and ensure security. Nakamoto's proposal sets the foundation for a trustless, peer-to-peer electronic cash system, enabling borderless and efficient financial exchanges [1]. The empirical evidence highlights a pragmatic approach to blockchain adoption in the real estate sector, with a focus on smaller-scale, hybrid applications. While the conceptual literature promises transformative benefits, real-world implementations mainly center around land administration [2]. This article proposes a blockchain based system for digitizing transactions in real estate that mitigates the possibility of falsifying documents and other fraudulent activities. The article also proposes a consensus algorithm, which reduces overhead transmissions by around 50% for multicasting nodes. The proposed consensus approach has been compared with five prominent approaches: proof-of-work, proof-of-stake, delegated-proof-of-stake, load-balanced, and trust based approach. The comparative assessment deduces that the proposed consensus process is faster than the compared approaches. The overhead of message exchange communication decreases by up to 50.30% compared to the traditional proof-of-work approach. A detailed design of smart contract is presented and then a use case for renting residential and business buildings are examined [3]. A detailed design of a smart contract is presented and then a use case for renting

residential and business buildings is examined [4]. The proposed application addresses a significant pain point in the transaction process of office buildings by focusing on improving the data structure and quality [5]. This paper discusses various problems and the solutions which blockchain provides along with potential frameworks and API's. The system proposed in this paper will safeguard confidence in doing real estate business over the internet. This paper discusses various problems and the solutions which blockchain provides along with potential frameworks and Apis[6]. This research adopts the Prisma methodology to explore how the application of blockchain and AI has impacted the real estate sector. The main finding is that in real estate, the combination of blockchain and AI has great potential, especially in modeling data and valuation, storing information in digital formats and securing transactions[7]. : The article's integration of a quantum-based encryption algorithm is a notable strength. Quantum computing presents both opportunities and challenges for blockchain technology, and addressing the security aspect with quantum-resistant encryption is forward-thinking[8]. The system proposed in this paper will safeguard confidence in doing real estate business over the Internet. The study shows that blockchain technology can provide for a transparent and errorless interaction between buyers and sellers of real estate. Since smart contracts eliminate the need for third parties in real estate transactions, the cost of transactions shall be considerably reduced due to the elimination of intermediaries and due to process speed and efficiency. Finally, blockchain technology can increase the trust between parties and shall serve as a means to fight corruption and money laundering in real estate investments[10].

	Paper Name	Strengths	Drawback
[1]	"Bitcoin: A Peer-to-Peer Electronic Cash System" by S. Nakamoto, Oct. 2008	Satoshi Nakamoto's paper introduce the groundbreaking concept of blockchain and decentralized currency, providing the foundation.	The paper does not address specific concepts or smart contracts, as it primarily focuses on the foundational principles of a peer-to-peer electronic cash system.

[2]	"Blockchain in real estate: Recent developments and empirical applications" by Anniina Saari, Jussi Vimpari, Seppo Junnila, 2022	The empirical evidence highlights a pragmatic approach to blockchain adoption in the real estate sector, with a focus on smaller-scale, hybrid applications.	The paper does not address specific methods to reach solutions and focuses mostly on problems.
[3]	"Blockchain-based digitization of land record through trust value-based consensus algorithm" by Amrendra Singh Yadav and Dharmendar Singh Kushwaha, 2021	The article proposes a consensus algorithm, which basically reduces the overhead transmissions by around 50% for multicasting nodes.	The paper discusses a new consensus mechanism which is difficult to implement and general focused rather than the topic on hand.
[4]	"A Indy528 — Federated Learning Model Tokenization with Non-Fungible Tokens(NFT) and Model Cards" by Eranga Bandara,Xueping Liang, Sachin Shetty,Ravi Mukkamala, Abdul Rahman, Ng Wee Keong,	A comprehensive and innovative framework for NFT and tokenization.	Demands a patient and diligent approach, especially for those new to the realm of NFT and tokenization.
[5]	"Blockchain and Artificial Intelligence in Real Estate" by C. Ziakis, 2022.	Valuable insights into the potential of blockchain-enhanced using AI for real	The specific challenges and practical implementation details are not extensively

		estate transactions.	explored.
[6]	"Blockchain Real Estate and NFTs" by J. M. Moringiello and C. K. Odinet, 64 William & Mary Law Review, pp. 1131, 2023.	Comprehensive about how the true use case for NFTs and distributed ledgers is in tracking and verifying ownership of intangibles.	The paper discusses real laws too much and not the actual technology which is being used.
[7]	"Challenges of blockchain technology adoption for e-government: a systematic literature review" by F. R. Batubara, J. Ubacht, and M. Janssen, 2018.	Discusses actual challenges which occur while trying to bridge the gap between laws , regulation and blockchain.	Although the challenges are vividly discussed and identified but no potential solution is concluded.
[8]	"Blockchain technology in commercial real estate transactions" by H. P. Wouda and R. Opdenakker, , Aug. 2019.	A blockchain application is proposed, which can improve the transaction process of an office building.	The scope is limited to tokenization of an office building only.
[9]	"Challenges, Opportunities using MultiChain for Real Estate" by Mirko Avantaggiato and Pierluigi Gallo, 2019.	Discusses the various challenges and opportunities for "Multichain" which is a higher level concept in blockchain.	The multichain approach is extremely complex and difficult to work around and requires much more experience to handle.

[10]	"A Transparent and Trusted Property Registration System on Permissioned Blockchain" by T. Ali et al, 2020.	The paper actually discusses a functioning framework which can be used to register lands.	The implications of scaling and various types of transactions one could perform is lacking.
[11]	"Study of factors influencing the decision to adopt blockchain technology in real estate transactions in Kosovo" by Visar Hoxha and Sara Sadiku, 2019.	This paper explores, the view of buyers and sellers, the relationship between the blockchain technology and various important aspects of real estate transactions such as transparency, security and cost reduction	The paper is more of a Q&A which they conducted on a small scale and just discusses the attributes of blockchain and not potential solutions in the tech.

Table 2.1: Literature Survey Table

CHAPTER 3

Limitation of Existing System

Real estate investors have an important role in the growth of the rental market. However, there are often hindrances to investing for residential rental purposes. In order to overcome these barriers, they first need to be identified and understood. Existing real estate systems have long faced numerous obstacles, ranging from time-consuming paperwork to high transaction costs and limited access to global markets. Traditional models frequently suffer from transparency difficulties, long verification processes, and fraud vulnerability, jeopardizing the efficiency and reliability of real estate transactions. Furthermore, a lack of liquidity, complex regulatory compliance, and inefficiencies in property management have highlighted the importance of transformational solutions. As we explore the landscape of existing blockchain systems, it becomes clear that blockchain has the potential to address these deficiencies, ushering in a new era of openness and efficiency in the real estate market.

- **Lengthy and Paper Intensive Processes:** Traditional real estate systems are sometimes encumbered with excessive paperwork, including countless documents and manual processes. The reliance on physical documents causes transaction delays, creates inefficiencies, and slows down total real estate negotiations. There is also a requirement to keep documents that are prone to physical wear and tear.

- **High Transaction Costs:** The reliance of intermediaries such as brokers, agents, and legal entities incurs significant transaction costs. Commissions, fees, and other expenditures associated with these intermediaries drive up overall transaction costs, making real estate transactions a financially burdensome process.

- **Verification Process:** With current practices, verifying property ownership and doing due diligence might take time. Delays in validating titles, zoning information, and other key facts frequently increase the time required to complete deals, frustrating both buyers and sellers.

- **Scalability:** Blockchain networks, depending on their architecture, can face limitations in transaction processing speed and capacity. Ensuring efficient scalability solutions will be vital.

- **User Education:** Users may require a solid understanding of blockchain technology and its concepts to use the platform effectively. Providing comprehensive educational resources, simple UX and support will be essential to overcome this limitation.

- **Liquidity Issues:** Lot of existing systems fails to manage liquidity & user positions, due to lack of market liquidity for specific tokens, in such cases the huge transactions are not settled correctly.

- **Limited Liquidity:** Traditional real estate transactions include assets that are not liquid, making it difficult for investors to acquire or sell fractional ownership of buildings. This lack of liquidity inhibits market participation and the ease with which real estate holdings can be diversified. Global real estate (RE) investments surpass the size of the stock market. Despite this, the number of RE investors is significantly fewer due to liquidity and global availability.

CHAPTER 4

Problem Statement, Objectives and Scope

4.1 Problem Statement

The real estate industry is mired in a host of enduring challenges that hinder its efficiency and integrity. These challenges include a pervasive lack of transparency, protracted and labyrinthine processes, exorbitant costs resulting from the involvement of intermediaries, and persistent concerns surrounding fraud and ownership disputes. Despite the allure of real estate investments, these issues cast a shadow of doubt over the industry, creating suboptimal conditions for all stakeholders involved. In this context, blockchain technology emerges as a potential panacea, offering the promise of enhanced transparency, efficiency, and trust through the establishment of tamper-proof records and the execution of smart contracts.

4.2 Objectives

- **Enhance Transparency:** Implement blockchain solutions to create a transparent and auditable ledger of real estate transactions, reducing the need for multiple intermediaries and enhancing trust between buyers and sellers.

- **Improve Transaction Efficiency:** Utilize blockchain's decentralized and automated nature to streamline real estate processes, aiming to significantly reduce the time taken to

complete transactions, from weeks or months to a matter of days or even hours.

- **Improve Transaction Efficiency:** Utilize blockchain's decentralized and automated nature to streamline real estate processes, aiming to significantly reduce the time taken to complete transactions, from weeks or months to a matter of days or even hours.

- **Reduce Transaction Costs:** Implement blockchain's secure and immutable nature to create tamper-proof records and smart contracts, ensuring that real estate deals are protected from fraudulent activities and disputes over property ownership.

4.3 Scope

- **Decentralized Property Listings:** A decentralized property listing platform, empowering property owners and developers to list their properties directly on the blockchain. By eliminating the need for intermediaries, we intend to foster a transparent and efficient marketplace for real estate transactions. The focus is on creating a user-friendly, accessible platform that opens up opportunities for a broader range of participants in the real estate market.

- **Smart Contracts:** Implement smart contracts tailored for real estate agreements, these contracts will automate and enforce the terms of transactions, ensuring secure, self-executing processes without the need for traditional contract intermediaries. By developing a reliable and versatile smart contract framework, we aim to streamline the negotiation and execution of real estate deals, reducing the risk of disputes and expediting transactions.

- **Tokenization of Real Estate:** Tokenization of real estate assets, allowing fractional ownership and enabling investors to buy and trade digital tokens representing property shares. This innovative feature is designed to enhance liquidity, increase accessibility to real estate investments, and provide property owners with a modern approach to attract a wider range of investors.

- **Immutable Ownership Records:** Developing a secure and transparent system for storing property ownership records on the blockchain. These records will be tamper-proof, providing an immutable history of property ownership. Our goal is to significantly reduce fraud and ownership disputes in the real estate industry by ensuring the authenticity and permanence of ownership records. We aim to build a user-friendly interface for accessing and validating ownership records while maintaining a high level of security.

CHAPTER 5

Proposed System

5.1 Proposed System:

The proposed system of our project includes a series of modules in which the project work is breakdown and implementation of each module is done by using various software engineering skills required during the process.

5.1.1 Modules:

a. **Dashboard:** The project's central control hub, the dashboard, provides users with an overview of their financial activities and investments. It is the go-to place for tracking assets, loans, and market information.

b. **Wallet Connector:** This module ensures a secure connection between users' wallets and the platform, facilitating easy transactions and providing a gateway for managing their digital assets.

c. **Portfolio:** The portfolio module enables users to monitor their investments and assets. It provides real-time insights into the performance of their holdings, helping them make informed financial decisions.

d. **Marketplace:** The markets module is where users can explore a variety of digital assets, monitor their prices, and execute trades It is also the place where users and list and buy various types of real estates.

5.2   Architecture Diagram

An Architectural diagram is a visual representation that maps out the physical implementation of the components of the software system. Our architectural diagram begins with a user login module for secure access. This module connects to a marketplace—an interface where properties are listed and transactions are initiated. Upon engaging with the marketplace, the "Action?" decision point represents a critical juncture where user-initiated actions are processed. These actions can involve the asset manager, which oversees property validation, and if deemed appropriate, triggers the minting process. The minting operation corresponds to the creation of unique digital tokens that represent ownership or investment in real estate properties. Once minted, these tokens the transaction is recorded on the blockchain.
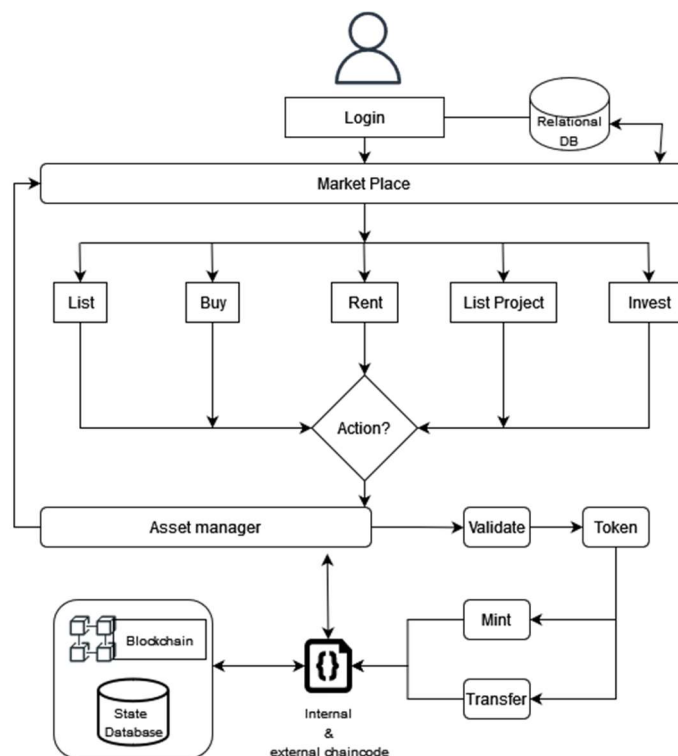

Figure 5.2 – Architecture Diagram

5.3   UML Diagrams: A UML diagram is a diagram based on the UML (Unified Modelling Language) to visually represent a system along with its main actors, roles, actions, artifacts, or classes, to better understand, alter, maintain, or document information about the system.
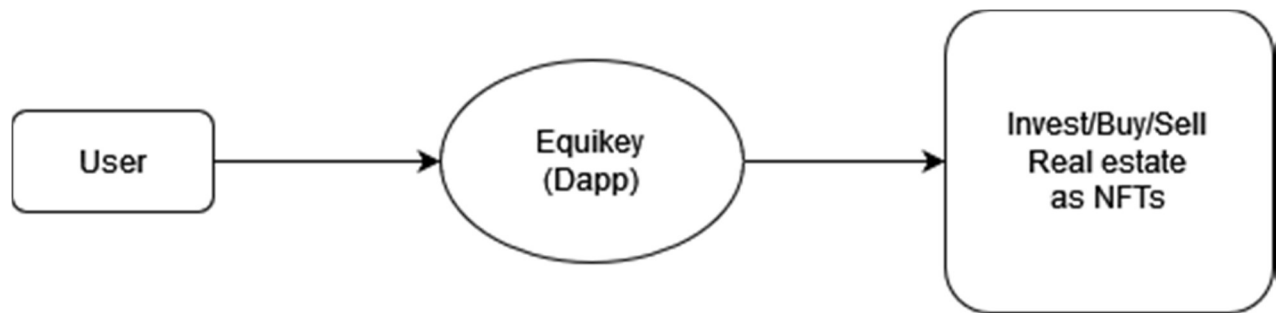
5.3.1   DFD Diagram
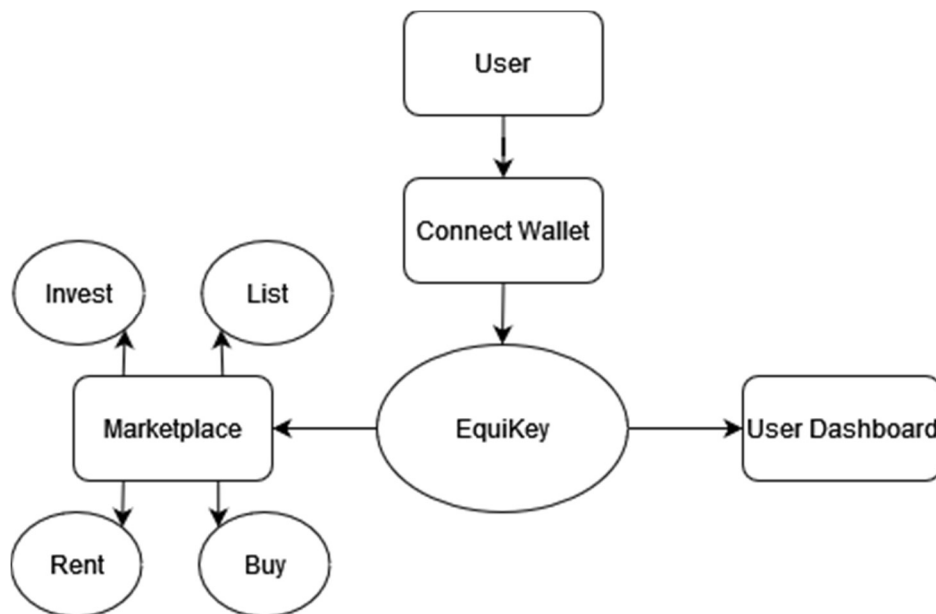

Figure 5.3.1.1 – DFD Level 0 Diagram

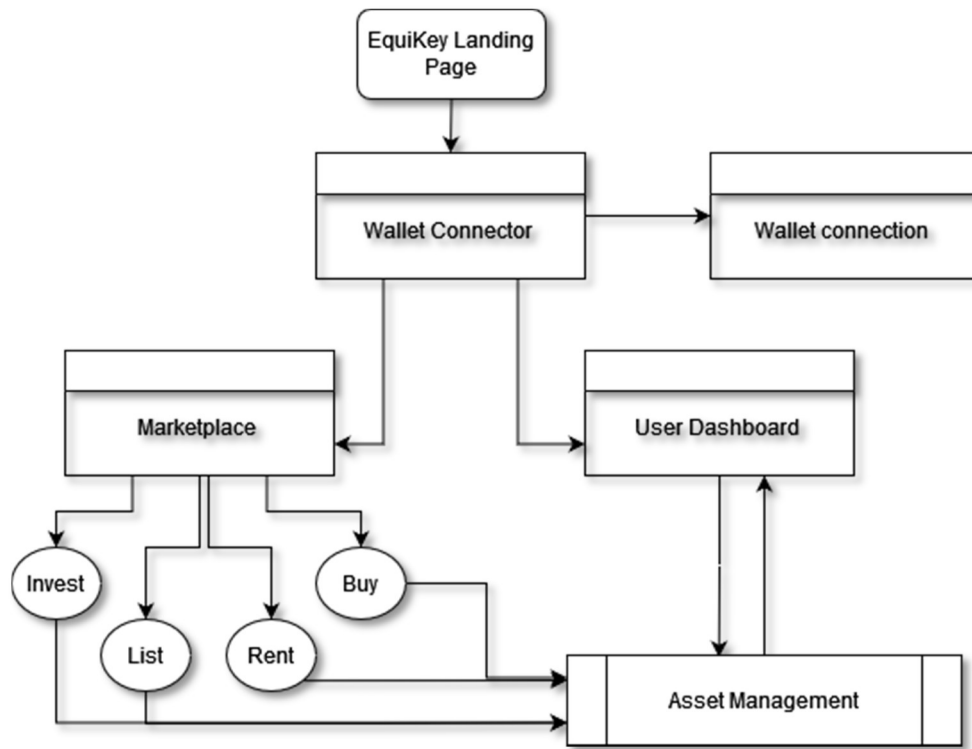**Figure 5.3.1.2 – DFD Level 1 Diagram**

Figure 5.3.1.3 – DFD Level 2 Diagram

A data flow diagram (DFD) maps out the flow of information for any process or system. It uses defined symbols like rectangles, circles, and arrows, plus short text labels, to show data inputs, outputs, storage points, and the routes between each destination. Data flowcharts can range from simple, even hand-drawn process overviews, to in-depth, multi-level DFDs that dig progressively deeper into how the data is handled. They can be used to analyse an existing system or model a new one. The data flow diagram gives clear a picture of the project and the movement of the data from one object to another object as detailed information about the process and functionalities available in the project.
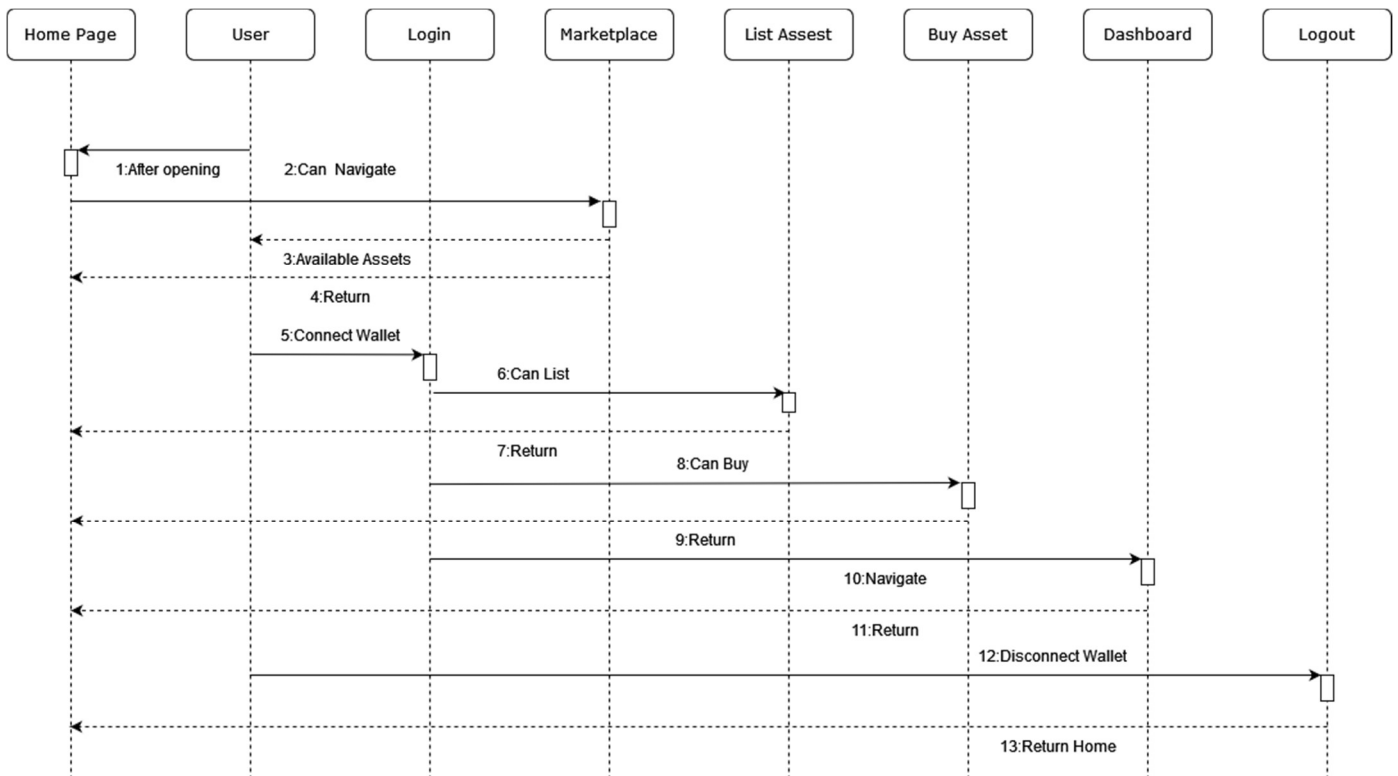
5.4   Sequence Daigram

Figure 5.4 – Sequence Diagram

A sequence diagram simply depicts the interaction between objects in sequential order i.e., the order in which these interactions take place. We can also use the terms event diagrams or event scenarios to refer to a sequence diagram. Sequence diagrams describe how and in what order the objects in a system function. These diagrams are widely used by businessmen and software developers to document and understand requirements for new and existing systems. The above sequence diagram talks about the order in which happenings are taking place, and how the objects and their functions are dependent on each other. In the above diagram, objects are shown in the form of a rectangle shape whereas functionalities are represented in a flowing manner by using solid and dotted arrows.
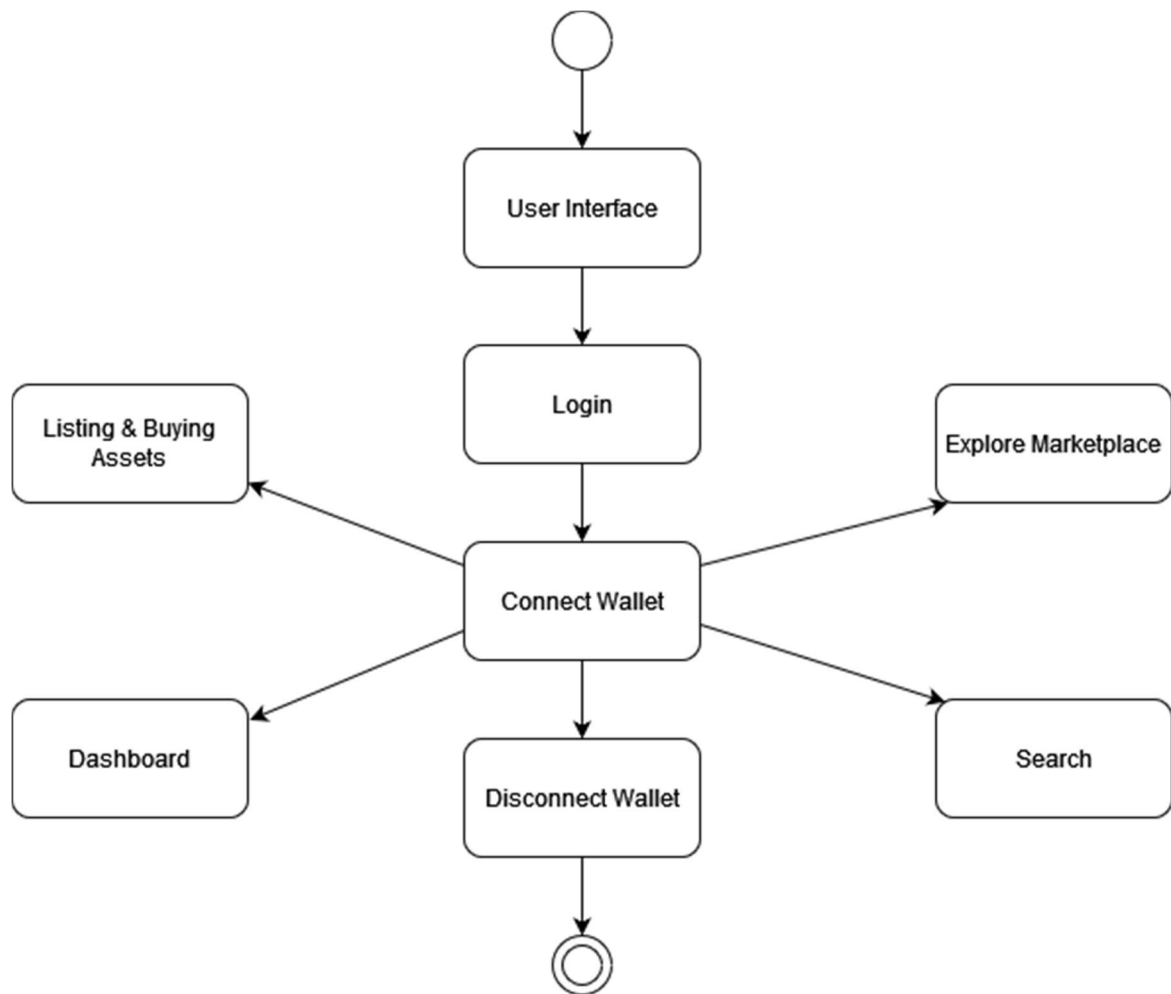
5.5   Activity Diagram

Figure 5.5 – Activity Diagram

The activity diagram is another important diagram in UML to describe the dynamic aspects of the system. An activity diagram is a flowchart to represent the flow from one activity to another activity. The activity can be described as an operation of the system.

The control flow is drawn from one operation to another. This flow can be sequential, branched, or concurrent. Activity diagrams deal with all types of flow control by using different elements such as fork, join, etc. The activity diagram represents the entire work of the application in the flow schema and illustrates each component of the project simply so that the user or the student will be able to understand the whole work of the project.

CHAPTER 6

Experimental Setup

6.1 Technology Stack

6.1.1 Frontend:

For developing the android application to implement our problem definition efficiently and user-friendly, we have used the following technologies:

a. HTML:

The Hyper Text Markup Language, or HTML is the standard markup language for documents designed to be displayed in a web browser. It can be assisted by technologies such as Cascading Style Sheets (CSS) and scripting languages such as JavaScript.

b. CSS:

Cascading Style Sheets (CSS) is a style sheet language used for describing the presentation of a document written in a markup language such as HTML. CSS is a cornerstone technology of the World Wide Web, alongside HTML and JavaScript.

c. JS:

JavaScript, often abbreviated as JS, is a versatile and widely-used programming language. It plays a crucial role in web development, enabling dynamic and interactive features on websites and web applications. In blockchain development,

JavaScript is commonly used for building decentralized applications (DApps) and for front-end development. Its compatibility with web browsers and extensive libraries and frameworks makes it a valuable tool for creating user interfaces that interact with blockchain networks and smart contracts. JavaScript facilitates the integration of blockchain functionality into web-based applications, enhancing user experiences within the decentralized ecosystem.

Some key features of JavaScript include:

- Object-oriented programming: JavaScript supports object-oriented programming (OOP) concepts, such as encapsulation, inheritance, and polymorphism.

- Dynamic typing: JavaScript is a dynamically typed language, which means that variables can hold values of any data type.

- Functions as first-class objects: In JavaScript, functions are treated as first-class objects, which means that they can be assigned to variables, passed as arguments to other functions, and returned from functions.

- Support for AJAX: JavaScript can be used to create asynchronous web applications using AJAX (Asynchronous JavaScript and XML), which allows web pages to update content without requiring a full page reload.

6.1.2 Backend:

In the backend part, we have used Solidity and Typescript which provides detailed documentation.

a. Solidity:

Solidity is a high-level, statically-typed programming language specifically designed for writing smart contracts on blockchain platforms like Ethereum. It combines simplicity and security, making it the go-to language for creating self-executing agreements on decentralized networks. Solidity is used to define the rules and behaviors of smart contracts, enabling developers to implement complex financial logic, automate transactions, and ensure trust and transparency within decentralized applications. Its syntax resembles that of JavaScript, making it accessible to a broad range of developers in the blockchain space.

b. TS:

TypeScript is a statically-typed superset of JavaScript, known for enhancing the development of complex software systems. In the context of blockchain development, TypeScript offers advantages such as type safety, code organization, and scalability. By providing developers with features like static typing, interfaces, and advanced tooling support, TypeScript streamlines the creation of secure and efficient smart contracts. Its ability to catch errors during the development phase helps reduce potential vulnerabilities and improve the overall quality of blockchain applications.

c. JS:

To interact with smart contracts on a blockchain using JavaScript, we will typically use libraries and tools specific to the blockchain we are working with. Ethereum is one of the most popular blockchains for smart contracts, so I will use it as an example.

We can use Web3.js or Ethers.js to connect to a blockchain network. we need to specify the network's URL (e.g., an Ethereum node's URL) to establish a connection.

To interact with a smart contract, we need its ABI (Application Binary Interface). This ABI is a JSON representation of the contract's functions and state variables. Typically, we import this ABI into your JavaScript project. We will use the ABI and the contract address to create instances of the smart contracts in our JavaScript code. This allows us to interact with the contract's functions. We can use the functions provided by Web3.js or Ethers.js to call read-only functions of the smart contract. This does not require a transaction and won't modify the blockchain. we can display the data fetched from the contract on your project's frontend.

For write operations (e.g., sending tokens, updating data), we will use the provided functions from Web3.js or Ethers.js to create and send transactions. These transactions will modify the blockchain, and we may need to sign them with the user's private key.

6.2 Software and Hardware Setup

- **Software Requirements: -**

    1. Ethereum Development Environment: Since Solidity is primarily used for Ethereum-based smart contracts, you will need Ethereum-specific tools. These include:

     a. Ethereum Client: Software like Geth or Parity to connect to the Ethereum network.

     b. Remix: An in-browser Solidity IDE for writing, testing, and deploying smart contracts.

     c. MetaMask: A browser extension for managing Ethereum accounts and interacting with Ethereum-based DApps.

2. IDE
3. GIT
4. Node.JS
5. Ganache
6. Tools and Libraries

• **Hardware Requirements:**

1. Computer:

     a. Operating System: Windows, macOS or Linux. Linux is often preferred for server environments.

     b. Processor: A multi-core CPU, such as Intel Core i5 or equivalent, is sufficient.

     c. RAM: At least of 8 GB of RAM is recommended, but more is better for faster development.

     d. Storage: Minimum 5 GB free storage is required. A Solid-State Drive (SSD) is recommended for performance.

2. Graphics Processing Unit (GPU): Blockchain platforms and applications may require GPU resources, especially if they involve mining or complex computations.

3. Internet Connection: A stable and reasonably fast internet connection is essential, especially if you are interacting with remote blockchain networks.

4. Virtual Machine: If you are using virtualization for development or testing, ensure your host system meets the above requirements.

CHAPTER 7

Implementation and Result

7.1 Implementation

- **Integration of Wallet with our DApp**

```javascript
const connectWallet = async () => {
console.log("1. Connecting to wallet...");
const { ethereum } = window;
const failMessage = "Please install Metamask & connect your Metamask";
try {
if (!ethereum) return; // console.log(failMessage);
const account = await ethereum.request({
method: "eth_requestAccounts",
});

window.ethereum.on("chainChanged", () => {
window.location.reload();
});
window.ethereum.on("accountsChanged", () => {
window.location.reload();
});
const provider = new ethers.providers.Web3Provider(window.ethereum);
const network = await provider.getNetwork();
const networkName = network.name;
const signer = provider.getSigner();
```

```javascript
if (networkName != "mumbai") {
alert("Please switch your network to Polygon Mumbai Testnet");
return;
}
if (account.length) {
  let currentAddress = account[0];
  setMetamaskDetails({
    provider: provider,
    networkName: networkName,
    signer: signer,
    currentAccount: currentAddress,
  });
  console.log("Connected to wallet....");
} else {
  alert(failMessage);
  return;
}
} catch (error) {
reportError(error);
}
};
```

To integrate seamlessly with the MetaMask wallet. Through a simple code snippet, users gained access to their asset portfolios. MetaMask's user-friendly interface made it the perfect ally for both beginners and experts. With support for a variety of networks like Ethereum, Polygon, Sepolia, and Goerli, it opened doors to a world of possibilities in blockchain technology.

- **List Property Smart Contract**

```solidity
function listProperty (address owner,uint256 price, string memory
_propertyTitle, string memory _category, string memory _images, string
memory _propertyAddress, string memory _description) external returns
(uint256){
require(price > 0, "Price must be greater than 0.");
uint256 productId = propertyIndex++;
Property storage property = properties[productId];
property.productID = productId;
property.owner = owner;
property.price = price;
property.propertyTitle = _propertyTitle;
property.category = _category;
```

26

```
property.images = _images;
property.propertyAddress = _propertyAddress;
property.description = _description;
emit PropertyListed(productId, owner , price);
return productId;
}
```

In EquiKey, listing serves as a process of placing/lisitng a property on our Marketplace. These listing events, overseen by smart contracts, guarantee seamless and transparent transactions, shaping a landscape of trust and efficiency.

- **Buy Property Smart Contract**

```
function buyProperty (uint256 id, address buyer) external payable {
uint256 amount = msg.value;
require(amount>= properties[id].price, "Insufficient funds");
Property storage property = properties[id];
(bool sent,) = payable(property.owner).call{value: amount}("");
if(sent){
property.owner = buyer;
emit PropertySold(id, property.owner, buyer, amount);
}
}
```

Users can engage in purchasing various assets on our marketplace. These purchases are handeled by the buying smart contract.

- **Get all Properties Smart Contract**

```
function getAllProperty () public view returns(Property[] memory) {
uint256 itemCount = propertyIndex;
uint256 currentIndex = 0;
Property[] memory items = new Property[](itemCount);
for(uint256 i=0; i < itemCount; i++){
uint256 currentId = i+1;
Property storage currentItem = properties[currentId];
items[currentIndex] = currentItem;
currentIndex +=1;
}
```

```
      return items;
  }
```

This smart contract enables us to gather all the listed properties on the blockchain by our smart contract and lists them on the Marketplace for everyone to view.

- **Dashboard Smart Contract**

```
function getUserProperties (address user) external view
returns(Property[] memory) {

uint256 totalItemCount= propertyIndex;
uint256 itemCount = 0;
uint256 currentIndex = 0;

for(uint256 i=0; i< totalItemCount; i++){
if(properties[i+1].owner == user){
itemCount +=1;
}
}
Property[] memory items = new Property[](itemCount);
for(uint256 i=0; i< totalItemCount; i++){
if(properties[i+1].owner == user){
uint256 currentId = i + 1;
Property storage currentItem = properties[currentId];

items[currentIndex] = currentItem;

currentIndex +=1;

}
}
```

EquiKey allows users to effortlessly monitor all properties from a single interface. No more navigating multiple platforms or maintaining complex records. Simplify property management workflows and unlock new levels of success in real estate.
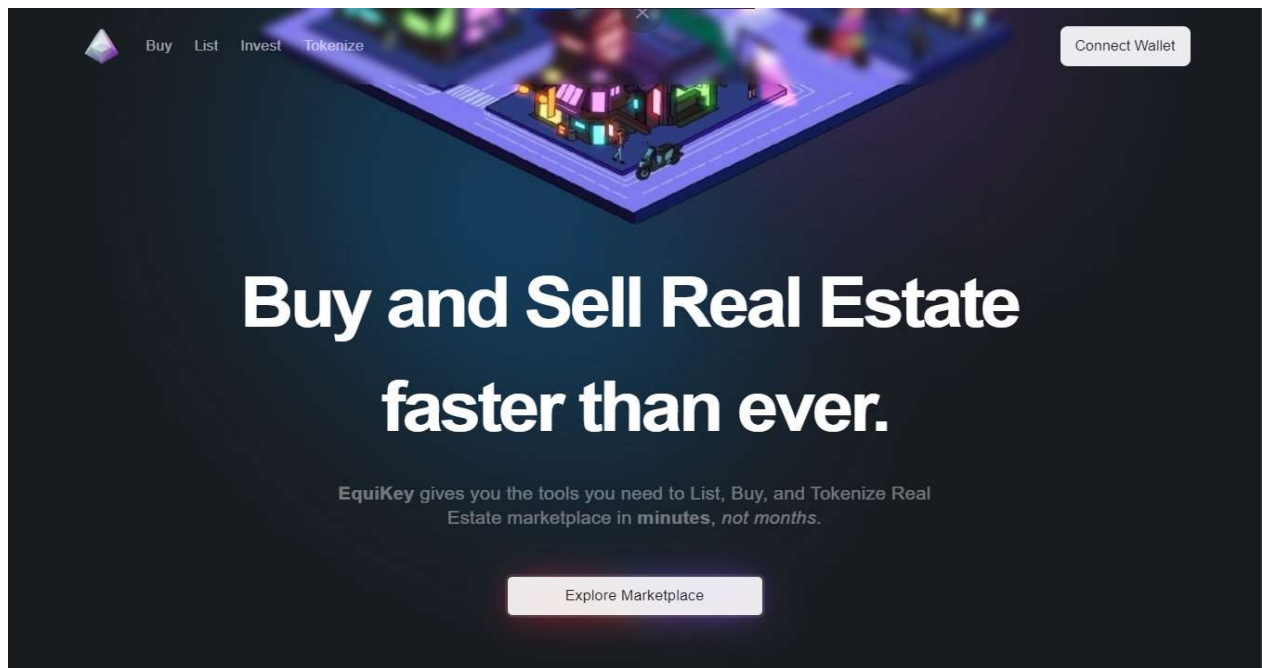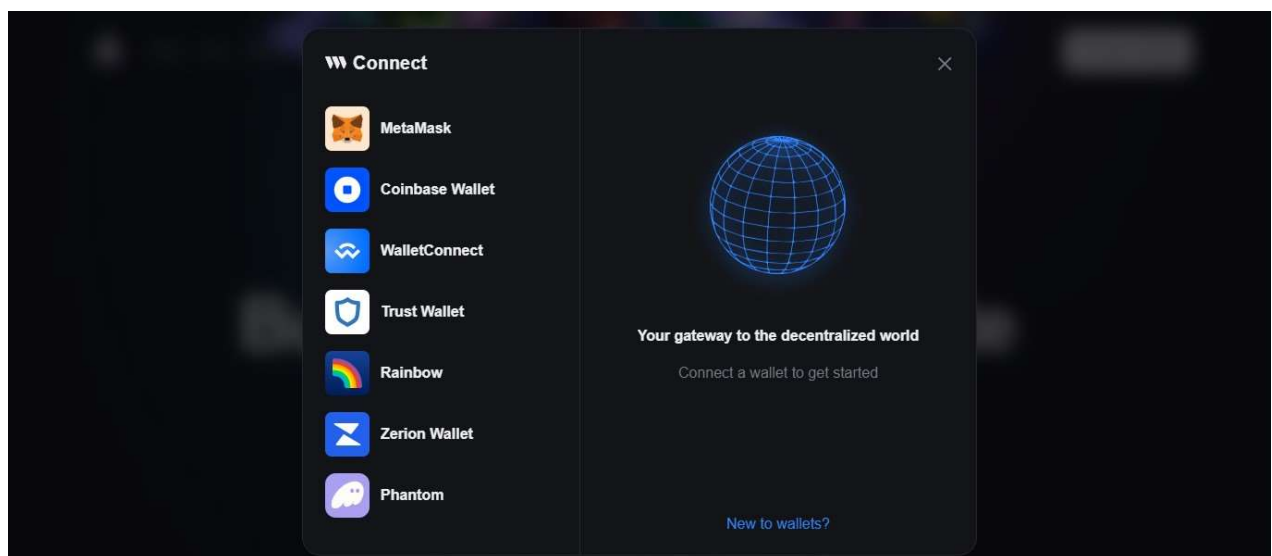
7.2   Results

Figure 7.1 – Home Page

Figure 7.2 – Wallet Connection

Figure 7.1 showcases the Home Page of our DApp, offering users an enticing glimpse into its intuitive interface. In Figure 7.2, present the MetaMask Wallet Connection for our DApp, highlighting the seamless integration of decentralized wallet functionality for enhanced user experience.
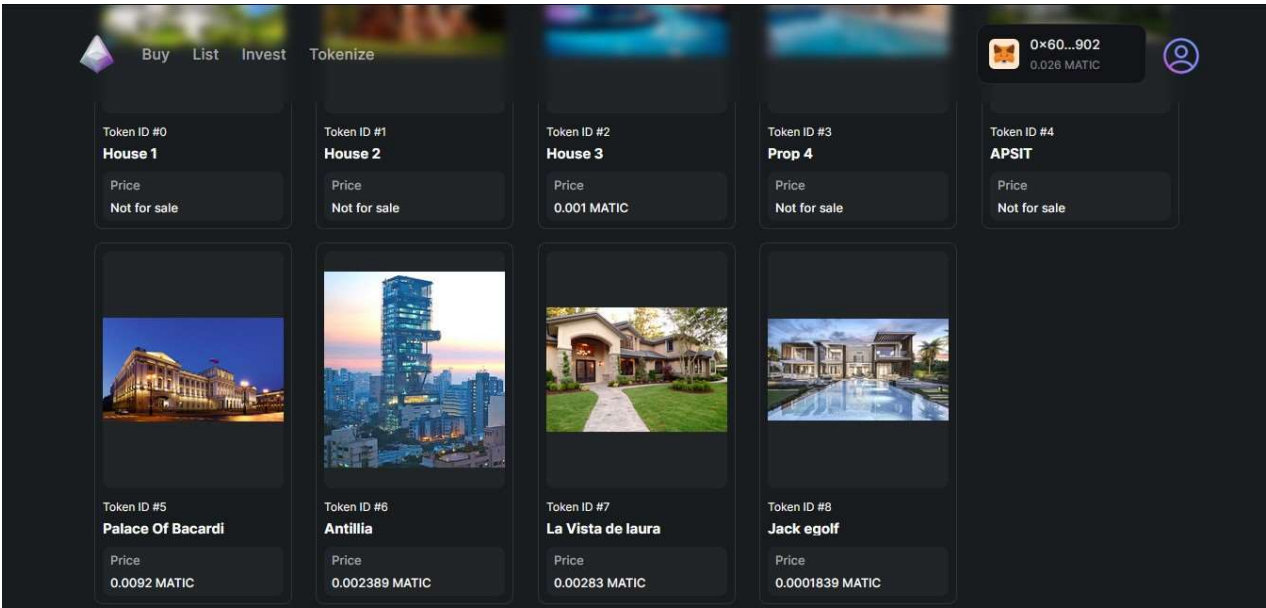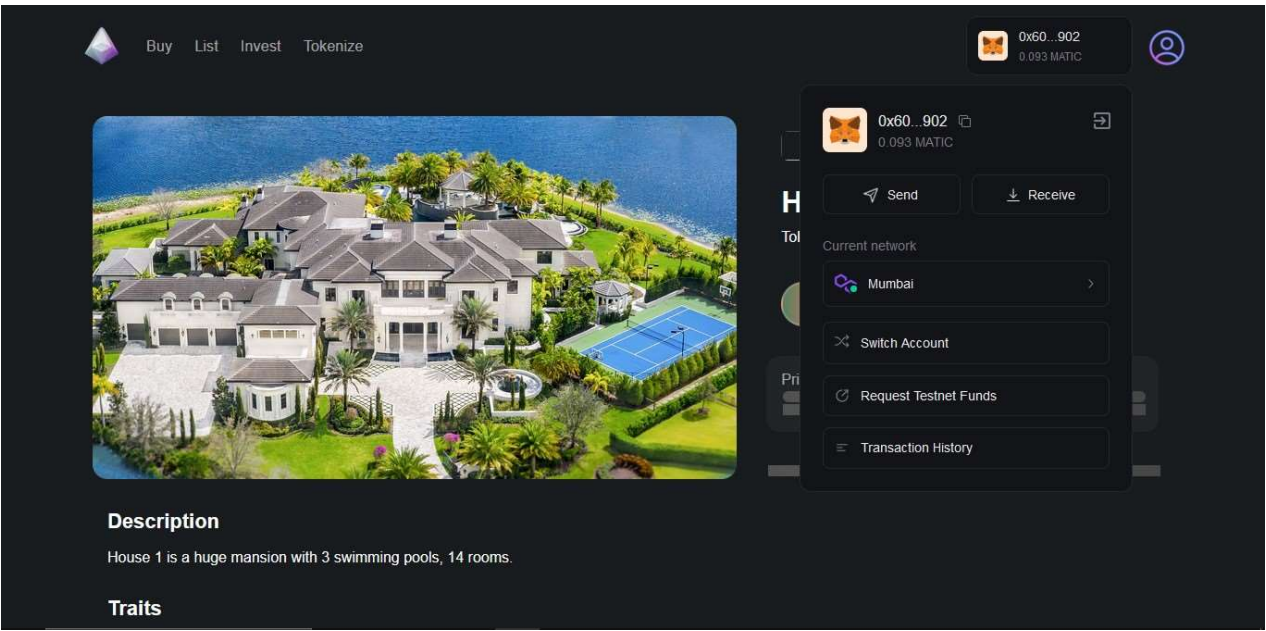
Figure 7.3 – Marketplace

Figure 7.4 – Buying Assest

In Figure 7.3, the marketplace of our DApp, providing users with a comprehensive platform to engage in decentralized buying and listing activities. Figure 7.4 showcases the seamless transaction approval process for a buying process, emphasizing the user-friendly nature of our interface and the ease of executing transactions.
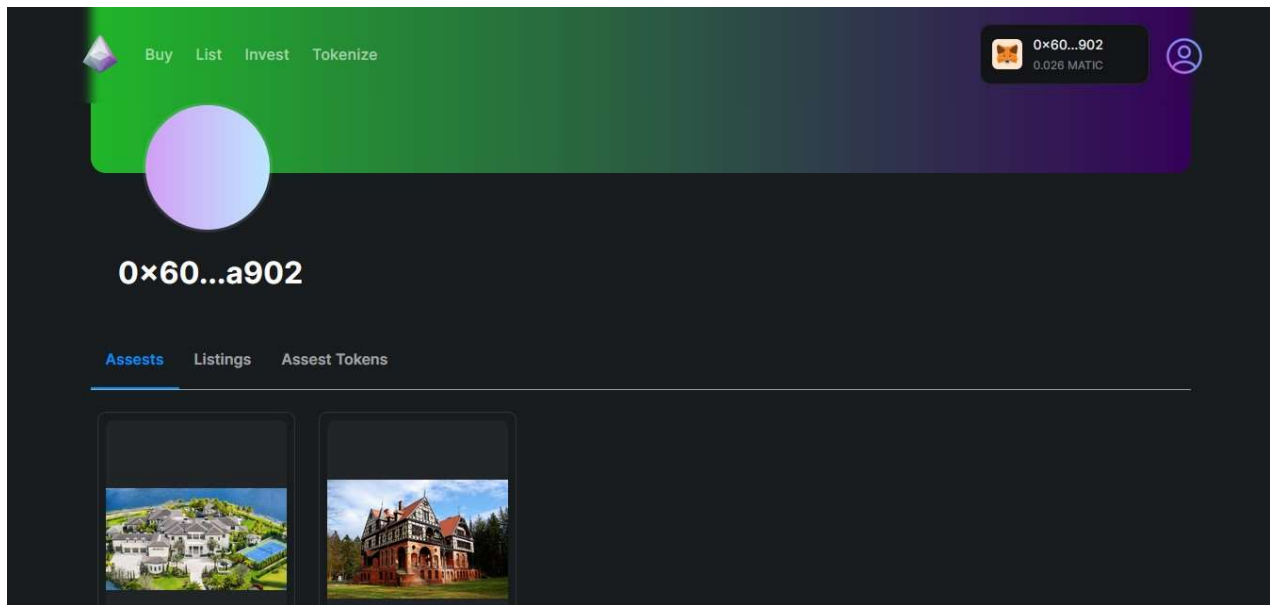
Figure 7.5 – Dashboard

In Figure 7.5 - We present the user dashboard showcasing all their listed properties, offering unparalleled user-friendliness and enabling seamless asset management from a single page. This centralized interface empowers users to efficiently oversee and manage all their assets, simplifying   the   management   process   and   enhancing   overall   efficiency.

CHAPTER 8

Project Plan

- **Gantt Chart**

Figure 8.1 – Gantt Chart

CHAPTER 9

Conclusion

Our project emphasized "Equikey" as a potential solution in real estate, evidenced by our approach which addresses liquidity issues, improves transparency, and streamlines real estate operations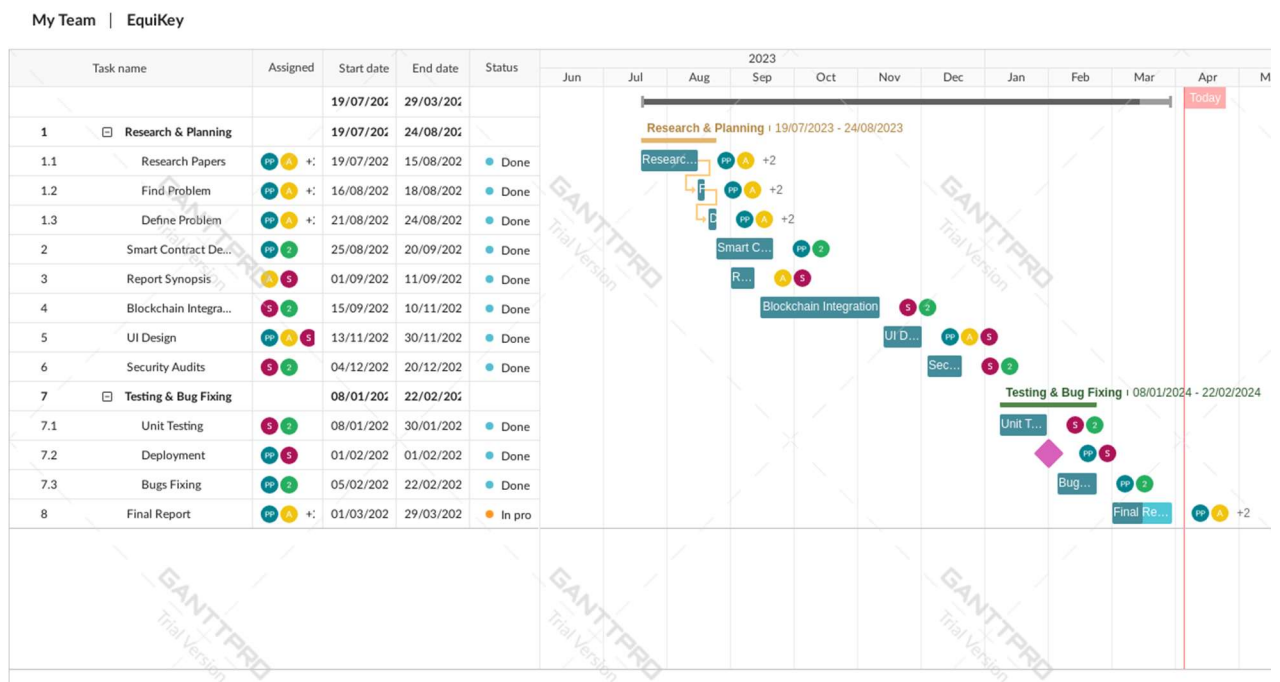.The democratization of real estate investments and increased operational performance have far-reaching societal effects.

Our results are built on the effective implementation of smart contracts, which automate and streamline crucial procedures like property listing, ownership verification, and transfers. Our smart contracts exhibited significant advantages after substantial testing on the Mumbai Polygon testnet.

Smart contracts allowed for a considerable reduction in transaction time by automating activities that previously required time-consuming documentation. This not only improves the efficiency of real estate transactions, but it also reduces the possibility of errors caused by human document handling. Furthermore, the automated nature of smart contracts removes the need for intermediaries, such as brokers and legal entities, resulting in substantial cost savings for users.

Our platform "Equikey" effectively solved the issue of low liquidity in traditional real estate transactions. Our smart contracts boosted liquidity by enabling fractionalization of property ownership via Non-Fungible Tokens (NFTs), making it easier to acquire and sell fractional ownership in real estate assets. This innovation not only broadens market participation, but also gives a means of diversifying real estate ownership for the user allowing them to diversify their portfolio.

CHAPTER 10
Future Scope

1   Regulatory Compliance and Legal Frameworks:

The incorporation of blockchain in real estate faces significant regulatory hurdles. Existing legal frameworks must adapt to accommodate the unique characteristics of blockchain transactions. Standardized standards and regulatory norms are crucial to ensure legal clarity and facilitate a smooth integration process.

2   Interoperability Challenges:

Interoperability difficulties hinder seamless collaboration among diverse stakeholders in real estate transactions.

Extensive research into standardized protocols and communication mechanisms is necessary to harmonize various systems and platforms engaged in real estate transactions.

3   Decentralized Autonomous Organizations (DAOs) and Non-Fungible Tokens (NFTs):

DAOs and NFTs present innovative avenues for clients to access exclusive real estate properties and services.

These emerging technologies offer new possibilities for enhancing accessibility and inclusivity in the real estate market.

4   Scalability and Energy Consumption:

Scalability and energy consumption pose challenges to the widespread adoption of blockchain in real estate. Future research should explore innovative consensus methods and energy-efficient protocols to improve scalability and reduce environmental impact.

5   User Experience and Education:

User experience and education play crucial roles in the effective implementation of blockchain in real estate. Efforts to enhance user understanding and streamline the user interface are essential for driving adoption and maximizing the benefits of blockchain technology in the real estate industry.

References

[1] S. Nakamoto, "Bitcoin: A Peer-to-Peer Electronic Cash System," in Bitcoin, October 2009. https://bitcoin.org/bitcoin.pdf.

[2] F Anniina Saari, Jussi Vimpari, Seppo Junnila, Blockchain in real estate: Recent developments and empirical applications, Land Use Policy, Volume 121, 2022, 106334, ISSN 0264-8377, https://doi.org/10.1016/j.landusepol.2022.106334.

[3] Yadav, A.S., Kushwaha, D.S. Blockchain-based digitization of land record through trust value-based consensus algorithm. Peer-to-Peer Netw. Appl. 14, 3540–3558 (2021). https://doi.org/10.1007/s12083-021-01207-1

[4] "E. Bandara, X. Liang, S. Shetty, R. Mukkamala, A. Rahman and N. W. Keong, "Indy528 — Federated Learning Model Tokenization with Non-Fungible Tokens(NFT) and Model Cards," 2022 IEEE 19th International Conference on Mobile Ad Hoc and Smart Systems (MASS), Denver, CO, USA, 2022, pp. 195-201, doi: 10.1109/MASS56207.2022.00033.

[5] Wouda, H.P., & Opdenakker, R. (2019). Blockchain technology in commercial real estate transactions. Journal of Property Investment & Finance, Vol. 37(6), pp. 561-575. ISSN: 1463-578X. Published online on 16 August 2019. Issue publication date: 20 August 2019.https://doi.org/10.1007/s12083-021-01207-1

[6] T. Ali, A. Nadeem, A. Alzahrani and S. Jan, "A Transparent and Trusted Property Registration System on Permissioned Blockchain," 2019 International Conference on Advances in the Emerging Computing Technologies (AECT), Al Madinah Al Munawwarah, Saudi Arabia, 2020, pp. 1-6, doi: 10.1109/AECT47998.2020.9194222.

[7] Ziakis, Christos. (2022). Blockchain and Artificial Intelligence in Real Estate. 10.1007/978-3-031-06530-9_4.

[8] Huh, J.-H., & Kim, S.-K. (2020). Verification Plan Using Neural Algorithm Blockchain Smart Contract for Secure P2P Real Estate Transactions. Electronics, 9(6), 1052. DOI: 10.3390/electronics9061052.

[9] Avantaggiato, Mirko & Gallo, Pierluigi. (2019). Challenges and Opportunities using MultiChain for Real Estate. 1-5. 10.1109/BlackSeaCom.2019.8812780.

[10] Hoxha, Visar & Sadiku, Sara. (2019). Study of factors influencing the decision to adopt the blockchain technology in real estate transactions in Kosovo. Property Management. 10.1108/PM-01-2019-0002.

[11] Moringiello, Juliet M. and Odinet, Christopher K., Blockchain Real Estate and NFTs (August 3, 2022). 64 William & Mary Law Review 1131 (2023), U Iowa Legal Studies Research Paper No. 2022-16, Widener Law Commonwealth Research Paper, Available at SSRN:
https://ssrn.com/abstract=4180876

[12] Leena S. Alotaibi and Sultan S. Alshamrani, Smart Contract: Security & Privacy, Computer Systems Science & Engineering, (CSSE), Vol.38, No.1, (2021).

[13] A. Gupta, J. Rathod, D. Patel, J. Bothra, S. Shanbhag, and T. Bhalerao, "Tokenization of Real Estate Using Blockchain Technology," in Applied Cryptography and Network Security Workshops, J. Zhou et al. (Eds.), Lecture Notes in Computer Science, vol. 12418, Springer, Cham, 2020.

[14] Toqeer Ali, Adnan Nadeem, Ali Alzahrani, and Salman Jan, "A Transparent & Trusted Property Registration System on Permissioned Blockchain," in Proceedings of the International Conference on Advances in the Emerging Computing Technologies (AECT), 2020.

[15] F. Rizal Batubara, Jolien Ubacht, and Marijn Janssen, "Challenges of blockchain technology adoption for e-government: a systematic literature review," in Proceedings of the 19th Annual International Conference on Digital Government Research: Governance in the Data Age, Association for Computing Machinery, New York, NY, USA, 2018, pp. 1–9. https://doi.org/10.1145/3209281.3209317

[16] "Tokenization of Real Estate: Benefits and Challenges, "LCX,
https://www.lcx.com/tokenization-of-real-estate-benefits-and-challenges, Accessed: May 9, 2023.

Publication

The project titled **'EquiKey: A Blockchain Based Real Estate Solution"** has been submitted and accepted to the Springer Scopus Indexed, **'BIDA 2024'**.

EquiKey: A Blockchain Based Real Estate Solution

Kunj Patel[1], Avadh Pandey[2], Saket Nigam[3], Prince Pal[4], Pranali Patil[5] and Ashvini Gaikwad[6]

[1] Department of Computer Engineering, A. P. Shah Institute of Technology, Mumbai, India
[2] Department of Computer Engineering, A. P. Shah Institute of Technology, Mumbai, India
[3] Department of Computer Engineering, A. P. Shah Institute of Technology, Mumbai, India
[4] Department of Computer Engineering, A. P. Shah Institute of Technology, Mumbai, India
[5] Assistant Professor, A. P. Shah Institute of Technology, Mumbai, India
[6] Assistant Professor, A. P. Shah Institute of Technology, Mumbai, India
lncs@springer.com

Abstract. Traditional real estate processes are often burdened with inherent inefficiencies, including lengthy procedures, high costs, susceptibility to fraud, and time-consuming transactions. In response to these challenges, this study introduces "EquiKey," a decentralized application with the potential to revolutionize the real estate industry. Leveraging blockchain technology, EquiKey offers a swift, cost-effective, secure, and transparent platform for real estate transactions, effectively mitigating fraud and streamlining the conventional process. Key features of EquiKey include the utilization of blockchain's immutability to establish tamper-proof records, ensuring heightened transparency and security. Furthermore, integration of the ERC-721 standard for Non-Fungible Tokens (NFTs) guarantees a unique representation of property ownership, bolstering authenticity and trust in transactions. Smart contracts play a pivotal role in converting real-world assets into NFTs, enhancing liquidity in the marketplace through tokenization. Moreover, EquiKey incorporates Zk-SNARKs (Zero-Knowledge Succinct Non-Interactive Argument of Knowledge) to facilitate ownership verification while safeguarding privacy and security. By addressing liquidity challenges inherent in traditional real estate, EquiKey not only offers a solution but also catalyzes the evolution of a more efficient and secure real estate ecosystem.

Keywords: Blockchain, Real Estate, NFT, zk-snarks, tokenization.

1   Introduction

Blockchain technology which initially emerged as a technology that revolutionized the finance market and introduced crypto, has started to expand beyond its intended scope and is revolutionizing various sectors due to its inherent attributes of safety, privacy, transparency, and decentralization. This research explores the transformative impact that blockchain can exert within the real estate industry through "EquiKey", our blockchain based DApp designed to address the challenges in conventional real estate processes.

Blockchain's widespread influence in real estate is defined by its capacity to transform core processes. One of the most significant examples of this technological transformation is the use of real estate tokenization. Blockchain enables the digital securitization of properties under this novel framework, introducing a revolutionary notion that allows for asset fractionalization. This, in turn, not only expands the availability of real estate investments but also fundamentally alters the traditional ownership structure. Furthermore, the introduction of Non-Fungible Tokens (NFTs) into the EquiKey platform adds another level of intricacy. Using the ERC-721 standard, each property is assigned a unique token, which simplifies the listing process while also improving security and uniqueness in every real estate transaction.

EquiKey, in alignment with these enhancements, uses Zero-Knowledge Succinct Non-

Interactive Arguments of Knowledge (zk-SNARKs) for ownership verification. This cryptographic approach provides an unprecedented level of anonymity in the real estate ownership verification procedure. Property owners can list their assets on the blockchain without revealing critical information, resulting in a careful balance of security and confidentiality. The seamless integration of zk-SNARKs improves the overall trustworthiness of the EquiKey platform by providing a secure method of validating ownership without disclosing confidential information. The size of the non-interactive zero-knowledge arguments can even be reduced to a constant number of group elements if we allow the common reference string to be large[9].

Furthermore, the incorporation of smart contracts into the "EquiKey" ecosystem highlights blockchain's disruptive potential in real estate. Smart contracts automate and streamline critical operations like asset management, project financing, and land registration. Performing various transactions on real estate records in the government organization is a cumbersome task and has many pitfalls. There are a number of problems with the existing land registry systems[11].Smart contracts promote efficiency, transparency, and security by automatically executing predefined rules and circumstances. For example, they can create an immutable ledger of property ownership records, simplifying verification and conflict resolution. Automation and streamlining of contract processes using smart contracts and blockchain technology can effectively reduce fraud while saving time and money. The use of smart contracts offers a crucial development in altering the typical shortcomings of real estate procedures, leading to enhanced efficiency.

This study seeks to shed light on the multifaceted nature and use case of blockchain, NFTs, zk-SNARKs, and smart contracts in the real estate business, with a particular focus on the "EquiKey" platform. The study aims to provide a deeper comprehension of how these technologies collectively reshape traditional practices and foster innovation in the real estate landscape by delving into the intricate details of real estate tokenization, the use of NFTs, the innovative ownership verification provided by zk-SNARKs, and the transformative potential of smart contracts. However, there are still challenges to address, such as regulatory compliance, standardization, and interoperability. Furthermore, the use of blockchain technology in the real estate market calls for coordination among a variety of stakeholders, including real estate agents, investors, regulators, government, and technology providers.

2   Background

The history of blockchain can be traced back to Satoshi Nakamoto's innovative essay "Bitcoin: A Peer-to-Peer Electronic Cash System," which was published in 2008[1]. This book established the notion of a decentralized, distributed ledger that served as the foundation for the innovative cryptocurrency Bitcoin, which debuted in 2009 as the first practical implementation of blockchain technology. As Bitcoin gained popularity, developers saw the greater potential of blockchain beyond digital currencies, which led to the development and implementation of smart contracts, particularly on platforms such as Ethereum in 2015. This increased the scope of blockchain to include programmable and automated agreements. Concurrently, the real estate market underwent a disruptive wave with the introduction of blockchain, initially addressing difficulties inherent in traditional procedures such as long-term transactions, high costs, and susceptibility to fraud.

Notable applications included leveraging blockchain to conduct secure and transparent property transactions. In recent years, the evolution of blockchain in real estate has reached new heights, with innovations such as real estate tokenization, which allows for fractional ownership and enhanced liquidity. Non-fungible Tokens (NFTs) based on blockchain technology have reached the market, representing unique digital assets and adding layers of transparency and authenticity to real estate transactions

The main benefits of tokenization are decentralization from a single source of authority, encryption of data that avoids tampering, and digital proof of ownership. The NFT registers real estate static and dynamic information to be traded in the data marketplace between the different users and stakeholders such as investors, occupiers, insurers, and property managers.[5] The history of Non-Fungible Tokens (NFTs) adds another layer to the blockchain narrative. NFTs, which represent unique digital assets, gained traction in 2017 when the Ethereum blockchain's ERC-721 standard was created. While initially connected with digital art and collectibles, NFTs have found widespread application in the real estate industry. Real estate NFTs began to represent property ownership or specified qualities, introducing a new and secure method of conducting transactions. The incorporation of NFTs into real estate has

reimagined the concept of ownership, offering a visible and verifiable record of property rights. These tokens, which are commonly linked to physical properties via metadata, improve the validity and traceability of real estate holdings. Notably, NFTs facilitate fractional ownership, enabling investors to acquire and exchange fractions of high-value properties.

As blockchain technology advances, developments such as Zero-Knowledge Succinct Non-Interactive Argument of Knowledge (zk-SNARKs) have improved its uses. zk-SNARKs, due to their very short proofs and verification times. This makes them well suited to be used as transaction data, hiding all the private details at the same time they guarantee the integrity and accuracy of the transaction, and be verified on-chain by a smart contract[4]. In the domain of real estate, zk-SNARKs have been used for ownership verification, providing a cryptographic technique for property owners to establish ownership without revealing sensitive information.

To summarize, the history of blockchain, NFTs, and real estate is intertwined with the emergence of decentralized ledgers, smart contracts, and tokenization. From tackling issues in traditional real estate procedures to reinventing ownership structures through NFTs, the combination of these technologies is transforming the industrial landscape, bringing unparalleled levels of efficiency, openness, and accessibility.

3 Existing Systems and its Challenges

Real estate investors have an important role in the growth of the rental market. However, there are often hindrances to investing for residential rental purposes. In order to overcome these barriers, they first need to be identified and understood[3]. Existing real estate systems have long faced numerous obstacles, ranging from time-consuming paperwork to high transaction costs and limited access to global markets. Traditional models frequently suffer from transparency difficulties, long verification processes, and fraud vulnerability, jeopardizing the efficiency and reliability of real estate transactions.

Real estate faces major administrative problems such as high transaction fees, a lack of transparency, fraud and the effects of a middleman including undue influence and commissons[10]. Furthermore, a lack of liquidity, complex regulatory compliance, and inefficiencies in property management have highlighted the importance of transformational solutions. As we explore the landscape of existing blockchain systems, it becomes clear that blockchain has the potential to address these deficiencies, ushering in a new era of openness and efficiency in the real estate market.

1. Lengthy and Paper Intensive Processes:

Traditional real estate systems are sometimes encumbered with excessive paperwork, including countless documents and manual processes. The reliance on physical documents causes transaction delays, creates inefficiencies, and slows down total real estate negotiations. There is also a requirement to keep documents that are prone to physical wear and tear.

2. High Transaction Costs:

The reliance on intermediaries such as brokers, agents, and legal entities incurs significant transaction costs. Commissions, fees, and other expenditures associated with these intermediaries drive up overall transaction costs, making real estate transactions a financially burdensome process.

3. Verification Process:

With current practices, verifying property ownership and doing due diligence might take time. Delays in validating titles, zoning information, and other key facts frequently increase the time required to complete deals, frustrating both buyers and sellers.

4. Limited Liquidity:

Traditional real estate transactions include assets that are not liquid, making it difficult for investors to acquire or sell fractional ownership of buildings. This lack of liquidity inhibits market participation and the ease with which real estate holdings can be diversified. Global real estate (RE) investments surpass the size of the stock market. Despite this, the number of RE investors is significantly fewer due to liquidity and global availability[6].

In the context of traditional real estate difficulties, the limits indicated drove us to look into alternate approaches and frameworks, which led us to blockchain. We looked into novel solutions to problems such as transparency, security, and efficiency. Our project initiative, by design, takes a transformational approach, employing decentralized technology to tackle these difficulties.

This investigation into alternative approaches demonstrates the dedication to transforming the real estate landscape using blockchain, with the goal of increasing transparency, streamlining

processes, and ultimately providing a more robust, efficient, and secure framework for real estate transactions, which inspired the development of our project.

4 Methodology

The primary research methodology implemented was a multiple step sequential process to explore the practical advantages of integration of blockchain technology through our decentralized app in real estate transactions.

The research began with problem identification. This included a thorough examination of the issues and challenges found in traditional real estate transactions and processes. Extensive research and analysis revealed key flaws such as lengthy procedures, high expenses, fraud vulnerability, a lack of transparency, and transaction inefficiencies.

Following that, a thorough literature review was undertaken to get insights into existing studies and practices involving blockchain technology in real estate. This step was useful in assessing the present status of the topic, identifying gaps in the literature, and investigating potential solutions provided by smart contracts and other blockchain technologies.

Following the literature research, the methodology focused on assessing the suitability of various blockchain platforms and technologies for use in real estate applications.

Scalability, compatibility, security, privacy features, and smart contract capabilities were among the factors that were evaluated. The advantages and disadvantages of several blockchain systems in resolving the issues with real estate transactions were contrasted and examined.

EquiKey was created as a decentralized application with the intention of resolving the drawbacks of conventional real estate procedures, based on the conclusions drawn from the research of the literature and the assessment of blockchain platforms. This included creating and putting into use features like transparent governance mechanisms, smart contracts, non-fungible tokens (NFTs), and privacy-enhancing technologies like Zk-SNARKs.

After that, an EquiKey prototype was created and put to the test in scenarios that mimicked real life situations to evaluate its usefulness, functionality, and ability to solve the issues that were found.

A number of restrictions and difficulties arose during the research process. These included technological limitations like blockchain platform scalability problems, regulatory uncertainty around tokenized assets, and challenges in fusing blockchain technology with current real estate systems. Furthermore, issues with user acceptance, trust, and confidence in blockchain-based solutions in the real estate sector were also noted.

To summarise, the method comprised a methodical approach to problem identification, a review of relevant literature, an assessment of blockchain platforms, the development of EquiKey, testing of prototypes, and an evaluation of potential obstacles and constraints. Through the use of this methodical approach, the study sought to overcome the inherent obstacles and constraints while offering insightful information about the real-world benefits of incorporating blockchain technology into real estate transactions.

4.1 Use Case

To evaluate blockchain platforms appropriate for real estate applications, thorough technical research was carried out. Scalability, security features, and consensus processes were assessed, with an emphasis on systems like Ethereum and Hyperledger. The empirical insights also indicated that blockchain could, in some cases, help reduce fraud and increase security and trust compared with centralized digital solutions[2].

The research paper "Blockchain Technology in Real Estate: A Systematic Literature Review"[14] and a website "Tokenization of Real Estate: Benefits and Challenges"[15] collectively identify several challenges within the real estate industry. These include limited interoperability with existing real estate systems, concerns regarding data privacy and security, regulatory uncertainties impacting adoption and scalability, regulatory compliance issues due to the evolving legal framework, lack of liquidity in tokenized real estate markets, scalability issues with smart contract execution, complex legal requirements impacting the implementation of smart contracts, and the lack of standardized processes for real estate transactions.

EquiKey presents innovative solutions to these challenges. It addresses interoperability concerns by seamlessly integrating with conventional real estate processes and systems. Furthermore, EquiKey ensures data privacy and security through the implementation of

privacy-enhancing technologies like Zk-SNARKs. It enhances liquidity in tokenized real estate markets by offering robust trading mechanisms. Moreover, EquiKey guarantees the uniqueness and authenticity of tokenized real estate assets through the use of the ERC-721 standard for NFTs, instilling confidence in investors. It addresses scalability concerns by leveraging advancements in blockchain technology and optimizing smart contract execution. EquiKey ensures seamless integration of smart contracts into real estate transactions through transparent governance mechanisms and legal compliance measures. Lastly, EquiKey offers standardized processes and protocols for real estate transactions, enhancing efficiency and reducing complexities. By aligning EquiKey's advancements with the challenges identified in existing research papers, it demonstrates how EquiKey offers solutions and improvements in the realm of blockchain-based systems in real estate.

To model the integration of blockchain technology at key points in the real estate process, such as property listing, ownership verification, and transfer, realistic use cases were created. We were able to assess the viability, difficulties, and revolutionary potential of blockchain adoption through these scenarios.

Various token standards were reviewed as token standards are critical in defining the capabilities and behaviors of blockchain-based assets. When it comes to blockchain real estate, we discovered that ERC-721 stood out as one of the most prominent token standards. ERC-721, which has been extensively researched and is widely used in the blockchain ecosystem, provides distinct advantages for representing real estate assets. Unlike fungible tokens like ERC-20, ERC-721 tokens are non-fungible, which means that each token is unique and indivisible, making them perfect for embodying unique qualities. Tokens of the ERC 777 standard, which represent fractional ownership of the real estate can be purchased by an investor and these tokens can also be listed on secondary exchanges. The robustness of Smart Contracts can enable the efficient transfer of tokens and seamless distribution of earnings amongst the investors[5]. This ensures a one-of-a-kind depiction of real estate assets, preventing double-spending and enabling detailed ownership tracing. ERC-721's ability to reflect various and complicated ownership structures in real estate, together with its established market acceptance and powerful security features, makes it an attractive alternative for assuring transparency, liquidity, and authenticity in real estate transactions.

4.2   Smart Contracts

Smart contracts are self-executing contracts in which the terms of the agreement are encoded directly into code. They operate on blockchain networks and automatically enforce, execute, or verify contract terms when certain criteria are satisfied. Smart contracts in real estate can help speed processes, remove intermediaries, and increase transaction transparency. Although the concept of smart contracts existed before blockchain technology's testing phase, it was fully implemented after understanding and testing blockchain. Smart contracts were proposed in 1994 and elaborated later, in 1996[12].

Listing:

```
function listRealEstateAsNFT(seller, realEstateDetails,
zkSnarkProof):
    tokenId = generateUniqueId()
    if verifyOwnershipWithZkSnark(seller,
realEstateDetails, zkSnarkProof):
        realEstateNFT = createNFT(tokenId,
realEstateDetails, seller)
        mint(realEstateNFT)
```

A unique token ID is created for the asset that is going to be listed at the beginning of the EquiKey listing process. Throughout the transaction lifecycle, the property is uniquely identified by this token ID. The information supplied by the lister is then rigorously verified using zk-SNARKs, a privacy-preserving cryptographic method. The legitimacy and ownership of the listed property are guaranteed by this validation procedure. EquiKey mints a Non-Fungible Token (NFT) to represent the listed property after verification is successful. This NFT has important information that was supplied by the lister and is contained in metadata. The property is effectively tokenized by minting and deploying the NFT on EquiKey, allowing safe

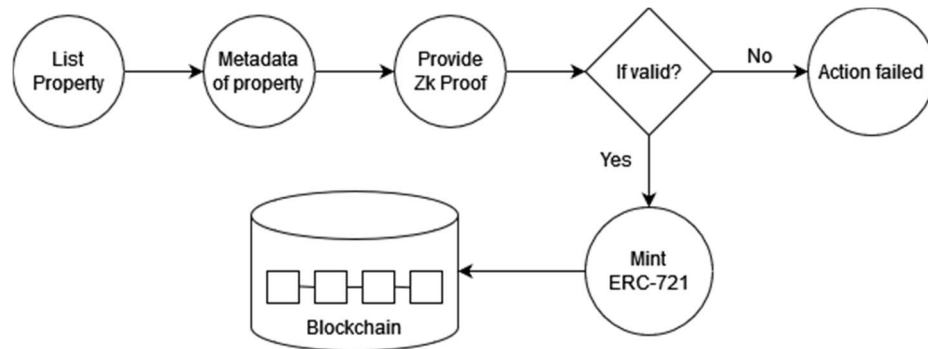and transparent transactions within the decentralized real estate ecosystem.

Fig. 1. Lisiting process on our platform

Fig. 1. outlines the operational process for the "Equikey" platform, a blockchain-based real estate solution. Here's a step-by-step explanation of how the platform functions:

List Property: The process begins with property owners listing their property on the Equikey platform. This involves providing details about the property that will be tokenized, like location, size, valuation, and other significant attributes.

Metadata of Property: Once the property is listed, its metadata is created. This metadata includes all the information necessary to describe the property uniquely and comprehensively. This could encompass ownership history, legal status, and any encumbrances or liens on the property.

Provide ZK Proof: To protect user privacy and validate property ownership without revealing any extraneous information, the platform employs Zero-Knowledge Proofs or ZK Proofs. This process makes sure that private information isn't needlessly posted to the public ledger while maintaining verifiability of the information.

If Valid?: The validation procedure is covered in this step. It ascertains whether the given Zero-Knowledge Proof is adequate to validate the metadata of the property. The procedure proceeds if the ZK Proof is determined to be valid; if not, the action is unsuccessful.

Action Failed: The platform designates an action as unsuccessful if it is unable to validate the proof or the metadata. This can mean that the property owner has to submit the necessary data again or fix any errors in the original submission.

Mint ERC-721: The metadata of the property is used to mint a single, non-fungible ERC-721 token if the ZK Proof is validated successfully. This token can be used for a number of transactions, including sales, transfers, and fractional ownership stakes. It represents ownership of the property on the blockchain.

Blockchain: All transactions involving the ERC-721 tokens issued through the Equikey platform are recorded in the blockchain, which acts as an immutable, decentralized ledger. Because every transaction is permanently and publicly recorded, this guarantees transparency, security, and confidence in the transactions.

Buying

```
function initiatePurchase(buyer, tokenId, payment):
    realEstateNFT = getNFTDetails(tokenId)
    if verifyPaymentAndOwnership(buyer, realEstateNFT,
payment):
        transferOwnership(realEstateNFT, buyer)
```

The unique token id of the NFT is used to locate the NFT and gather its metadata, then when the buyer pays the price the transaction is verified, and as soon as it gets processed the ownership of the NFT or the real estate is transferred to the buyer.
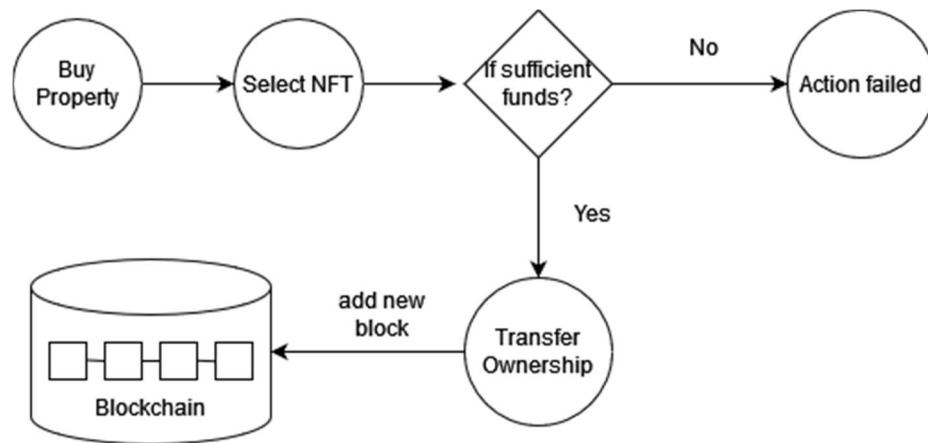
Fig. 2. Buying process on our platform

Fig. 2. outlines the operational process for the "Equikey" platform, a blockchain-based real estate solution. Here's a step-by-step explanation of how the platform functions:

Buy Property: The process begins with the buyer selecting a property among the listed assets in the marketplace which were listed as NFTs.

Select NFT: Once the property is selected, its metadata is loaded and displayed for the buyer to view. This metadata includes all the information necessary to describe the property uniquely and comprehensively. This could encompass ownership history, legal status, and any encumbrances or liens on the property.

If Sufficient Funds: The validation procedure is covered in this step. It ascertains whether the buyer has adequate funds to make the purchase and validates the metadata of the property

Action Failed: The platform designates an action as unsuccessful if it is unable to validate that the buyer has the necessary funds to make the purchase. This can mean that the buyer has to add necessary funds to their wallet or fix any errors in the original submission.

Transfer ownership: The metadata of the property is updated and the ownership of the NFT is transferred if the necessary funds are validated successfully.

Blockchain: All transactions involving the ERC-721 tokens issued through the Equikey platform are recorded in the blockchain, which acts as an immutable, decentralized ledger. Because every transaction is permanently and publicly recorded, this guarantees transparency, security, and confidence in the transactions.

4.3   Modules

Dashboard
The dashboard functions as our project's management center for the users. Users may quickly review all of their belongings, including investments and assets, there. Consider it your primary location for monitoring everything you own. It simplifies things by gathering all the necessary information in one location allowing for quick transactions and serving as a gateway for secure digital asset management.

Wallet Connector
The Wallet Connector serves as a security guard for our platform. It ensures a strong and secure interface between users' wallets and our platform. The connection functions similarly to a private tunnel, ensuring the security of transactions. It allows users to engage in various financial activities with confidence.

This module ensures a secure connection between users' wallets and the platform, facilitating easy transactions and providing a gateway for managing digital assets securely.

Marketplace
The Marketplace allows users to buy and sell various digital items. It functions similarly to a large online store, but only for digital assets-Real estate NFTs. Users may view what's available, track price changes, and quickly buy or sell items. Furthermore, it is not just about buying; users can also list or invest.

4.4   Testing and Deployment

In the deployment and validation phase, our team implemented blockchain based smart contracts, which were thoroughly reviewed and tested and then successfully integrated into the test network of the Mumbai Polygon. This strategic approach enabled testing of functionality, security, and overall availability. The delivery process was a smooth transition from concept to implementation by tailoring the contract to suit the construction of the test network at the Polygon Mumbai test site.

This deployment and validation phase not only demonstrates research results in action but also lays the groundwork to demonstrate the innovative potential of blockchain based smart contracts to transform real estate transactions. The results obtained from this step will include important empirical evidence, improving the reliability and effectiveness of the research.

5   Results

Our research has produced compelling results, including the successful deployment and testing of smart contracts on the Mumbai Polygon testnet. Our success is built on the effective implementation of smart contracts, which automate and streamline crucial procedures like property listing, ownership verification, and transfers. Our smart contracts exhibited significant advantages after substantial testing on the Mumbai Polygon testnet.

Smart contracts allow for a considerable reduction in transaction time by automating activities that previously required time-consuming documentation. This not only improves the efficiency of real estate transactions but also reduces the possibility of errors caused by human document handling. Furthermore, the automated nature of smart contracts removes the need for intermediaries, such as brokers and legal entities, resulting in substantial cost savings for users.

EquiKey shortened processing times by automating crucial tasks like land registration and asset management, which greatly increased transaction efficiency. Its use of zk-SNARKs for ownership verification guaranteed increased security and privacy, and blockchain technology offered clear, unchangeable transaction records that increased stakeholder trust. Smart contracts expedited contract execution and reduced fraud risk, while real estate tokenization and NFT integration increased investment opportunities and streamlined listing procedures.

We have effectively tackled the common issue of low liquidity in conventional real estate transactions with our study. We developed a solution that greatly increased liquidity by enabling the fractionalization of property ownership via Non-Fungible Tokens (NFTs), utilizing smart contracts. The process of purchasing and selling fractional ownership stakes in real estate assets is made significantly easier by this innovative method. Our research opens up a way to diversify real estate ownership portfolios while also improving market participation by introducing this innovation.

Table 1. Comparative Analysis between the traditional transaction methods and our proposed solutions against various aspects

Aspect	Conventional Method	Proposed Method
Transaction Speed	Slow transactions due to manual paperwork and intermediaries.	Faster transactions are facilitated by automated processes.
Costs	High transaction costs with fees for various intermediaries.	Reduced costs as intermediaries are minimized.
Transparency	Limited transparency, often leads to trust issues and disputes.	Enhanced transparency through an immutable blockchain ledger.
Ownership Verification	Time consuming verification process with potential for delays.	Expedited ownership verification using zksnarks.
Liquidity	Low Liquidity, limiting market activity.	Improved liquidity with tokenization, enhancing market activity.
Investing Prospects	Fewer opportunities due to regional laws and	By dividing large real estate projects into

	access.	smaller tokens, Equikey enables regular people to invest in them. Imagine owning a small portion of a massive property.
Counterfeit Property Listings	There are a lot of people making counterfeit documents to scam people.	By preventing fake real estate listings using zk-snarks, our authentication ensures the reliability of property data.
Property History	A lot of inaccuracies in the history of ownership records are the reason for major property disputes.	The unchangeable and precise property histories guaranteed by blockchain technology lower the possibility of false information.

The comparison in Table 1 demonstrates the major benefits that our blockchain-based solutions have over traditional real estate practices. Solutions built on blockchain technology result in quicker transactions, lower costs, more transparency, quicker ownership verification, better liquidity, more investment opportunities, fewer fraudulent property listings, and accurate property histories. These advantages over traditional methods—efficiency, transparency, and security—contribute to the revolutionary potential of blockchain technology in revolutionizing the real estate sector.

Even with these achievements, issues like interoperability and regulatory compliance need to be resolved before widespread adoption can occur[13]. The main challenges faced in blockchain adoption are predominantly presented as technological aspects such as security, scalability and flexibility. The results highlight "EquiKey" having transformational potential in changing traditional real estate operations and add considerably to the ongoing discussion about the incorporation of blockchain technology in the real estate market.

6   Societal Impact

The societal impact of using "Equikey" or other blockchain technologies in real estate activities can be characterized by disruptive developments that span multiple aspects of the sector. By leveraging blockchain's decentralized and transparent nature, our study contributes to a paradigm shift in the real estate sector, fostering efficiency, trust, and inclusivity.

One notable socioeconomic impact is the democratization of access to real estate assets. The usage of blockchain enables fractionalized ownership through the issuing of Non-Fungible Tokens (NFTs), allowing a larger pool of investors to engage in high-value properties. This democratization not only increases market inclusion but also creates opportunities for diverse and accessible real estate holdings.

Furthermore, the adoption of blockchain technology tackles long-standing issues with transparency and security. The immutability of blockchain ensures tamper-proof records, lowering the likelihood of fraudulent activity and improving the overall integrity of property transactions. This increased transparency fosters confidence among stakeholders, including buyers, sellers, and regulatory agencies, resulting in a more strong and dependable real estate ecosystem. The introduction of Blockchain technology will simplify the procedure for registering rights to immovable things, however, it will be able to increase the indisputability of the registered right only if the principle of depositing is fully implemented.

The application of blockchain technology in real estate will have a positive social impact through democratized capital access, enhanced transparency, and streamlined procedures. These significant adjustments contribute to the development of a more approachable, secure, and effective real estate environment, encouraging creativity and adaptability in the face of persistent problems in the sector.

7   Conclusion

Our paper emphasizes "Equikey" as a potential solution in real estate, evidenced by our approach which addresses liquidity issues, improves transparency, and streamlines real estate operations. The societal benefit can be seen in the democratization of real estate investments and greater operational efficiency. The democratization of real estate investments and increased operational performance have far-reaching societal effects.

Looking ahead, the results we obtained offer important insights for future research and development at the crossroads of blockchain technology and real estate. Continued efforts to address regulatory concerns, improve interoperability, and create stakeholder engagement will be critical to the long-term future of blockchain in the real estate market. This study contributes to the ongoing discussion about the adoption of emerging technologies by making a strong argument for blockchain's revolutionary potential in changing existing processes and stimulating innovation in the real estate sector.

7.1   Future Work

The incorporation of our project in real estate, while appealing, faces significant hurdles that demand much future research and action on various levels and scales. Although, economists and international development experts have found that land title security not only stimulates the Real Estate market's land development sector but is the very foundation of a market economy and sustainable economic growth[8]. The biggest barrier is regulatory compliance, as the existing legal framework must comply with the new characteristics of blockchain transactions. Creating standardized standards and regulatory norms becomes critical to ensuring a smooth integration process and legal clarity.

Interoperability difficulties are another major challenge, necessitating extensive research into standardized protocols and communication mechanisms to harmonize the various systems and platforms engaged in real estate transactions. Interoperability is critical for facilitating collaboration among diverse stakeholders, including real estate professionals, investors, regulators, and technology providers. Decentralized Autonomous Organizations (DAOs) and Non-fungible tokens (NFTs) can offer a new way for clients to access exclusive real estate properties and services[7].

In addition to regulatory and interoperability issues, tackling scalability and energy consumption in blockchain networks as it scale has emerged as a major challenge. The growing volume of real estate transactions necessitates the scalability of the project to ensure smooth operation. Future study is needed to look into innovative consensus methods and energy-efficient protocols to improve scalability while reducing environmental effects. Furthermore, user experience and education are critical factors in the effective implementation of our platform in real estate.

References

1. Nakamoto, S., 2009. Bitcoin: A Peer-to-Peer Electronic Cash System. https://bitcoin.org/bitcoin.pdf.
2. Anniina Saari., Jussi Vimpari, Seppo Junnila. Blockchain in real estate: Recent Developments and empirical applications. Land Use Policy, Volume 121 Article number 106334, (2022)
3. Adriana S. C. Pires, Fernando A. F. Ferreira, Marjan S. Jalali, Hsiao-Chen Chang Barriers to Real Estate Investments For Residential Rental Purposes. International Journal of Strategic Property Management, Volume 22 number 3(2018).
4. Pinto, A.M.. An Introduction to the Use of zk-SNARKs in Blockchains. In: Pardalos, P., Kotsireas, I., Guo, Y., Knottenbelt, W. (eds) Mathematical Research for Blockchain Economy. Springer Proceedings in Business and Economics. Springer, Cham (2020)
5. Gupta, A., Rathod, J., Patel, D., Bothra, J., Shanbhag, S., Bhalerao, T. Tokenization of Real Estate Using Blockchain Technology. In: Zhou, J., et al. Applied Cryptography and Network Security Workshops. ACNS 2020. Lecture Notes in Computer Science(), vol 12418. Springer, Cham (2020).
6. S. Latifi, Y. Zhang and L. -C. Cheng, Blockchain-Based Real Estate Market: One Method for Applying Blockchain Technology in Commercial Real Estate Market, IEEE International Conference on Blockchain (Blockchain), Atlanta, GA, USA, pp. 528-535 (2019).
7. Cruz, Gonçalo & Guimarães, Tiago & Santos, Manuel & Machado, José. How Decentralized Autonomous Organizations are Affecting Real Estate.(2023)

8. Palomar, Joyce. Land Tenure Security as a Market Stimulator in China. Duke Journal of Comparative and International Law(2001).

9. Jens Groth., Short Pairing Non-Iteractive Zero-Knowledge Arguments, University College London, LNSC, Vol 6477, (2010).

10. Iftikar Ahmed, Mohammed A. Alqarni, Abdulwahab Ali Almazroi & Laiba Alam, Real Estate Management via a Decentralized Blockchain Platform, Computers, Materialz & Continua 2021, Vol.66, N0.2, (2021).

11. Toqeer Ali, Adnan Nadeem, Ali Alzahrani & Salman Jan, A Transparent & Trusted Property Registration System on Permissioned Blockchain, International Conference on Advances in the Emerging Computing Technologies (AECT), (2020)

12. Leena S. Alotaibi and Sultan S. Alshamrani, Smart Contract: Security & Privacy, Computer Systems Science & Engineering, (CSSE), Vol.38, No.1, (2021).

13. F.Rizal Batubara, Jolien Ubacht, Marijin Janssen,Challenges of Blockchain Technology Adoption for E-Government: A Systematic Literature Review", Annual International Conference on Digital Government Research: Governance in the Data Age, Article No-76, (2018)

14. Anniina Saari, Jussi Vimpari, Seppo Junnila, Blockchain in real estate: Recent developments and empirical applications, Land Use Policy, Volume 121,(2022).

15. Tokenization of Real Estate: Benefits and Callenges, https://www.lcx.com/tokenization-of-real-estate-benefits-and-challenges, last accessed 2023/05/9.