Real Estate Management System with Block-chain

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Ajeenkya DY Patil University, Pune

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CERTIFICATE

This is to certify that the dissertation entitled **"Real Estate Management System with Block-chain"** is a bonafide work of "**Harshal Singh" (2018-B-02022001)** submitted to the School of Engineering, Ajeenkya D Y Patil University, Pune in partial fulfillment of the requirement for the award of the degree of **"*Bachelor of Technology in Mechatronics Engineering*"**.

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This is to certify that the dissertation entitled **"Real Estate Management System with Block-chain"** submitted by **Harshal Singh, URN 2018-B-02022001,** is a record of original work carried out by him/her under my supervision and guidance in partial fulfillment of the requirements of the degree of ***Bachelor of Technology in Mechatronics Engineering*** *at* **School of Engineering**, **Ajeenkya DY Patil University, Pune, Maharashtra-412105**. Neither this dissertation nor any part of it has been submitted earlier for any degree or diploma to any institute or university in India or abroad.

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Declaration of Originality

I, ***Harshal Singh*,** URN ***2018-B-02022001***, hereby declare that this dissertation entitled "***Real Estate Management System with Block-chain***" presents my original work carried out as a bachelor student of School of Engineering, Ajeenkya D Y Patil University, Pune, Maharashtra. To the best of my knowledge, this dissertation contains no material previously published or written by another person, nor any material presented by me for the award of any degree or diploma of Ajeenkya D Y Patil University, Pune or any other institution. Any contribution made to this research by others, with whom I have worked at Ajeenkya D Y Patil University, Pune or elsewhere, is explicitly acknowledged in the dissertation. Works of other authors cited in this dissertation have been duly acknowledged under the sections "Reference" or "Bibliography". I also declare that I 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.

I am fully aware that in case of any non-compliance detected in future, the Academic Council of Ajeenkya D Y Patil University, Pune may withdraw the degree awarded to me on the basis of the present dissertation.

Date:

Place: Lohegaon, Pune

Harshal Singh

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Abstract

Industries all over the globe are undergoing a technological transformation, necessitating the development of solutions that may speed up corporate operations while also increasing safety and transparency. Because of the volume of financial transactions processed, the real-estate business is among many others that would profit from such technology. Real-estate owners' present management approach is reliant on a variety of middlemen, including brokers, agents, and financial service suppliers. This business model leads to shortcomings in the real-estate market, resulting in issues such as lack of transparency, high transaction costs, personal prejudices, tax evasion or under taxation, landlord-tenant disputes, and long transaction times. This thesis looks at the potential for block-chain-based smart-contract technology to be implemented in the real-estate business and how it may help to eliminate inefficiencies. Block-chain is a novel and developing technology that has the potential to be used in a variety of sectors. Previous block-chain research has focused on the technology's possible application in digital money. The goal of this project was to design, create, and validate a block-chain-based smart-contract model for real-estate property management that would solve the shortcomings of present management models while also potentially lowering housing costs by eliminating intermediaries in the management process. To meet the study's goals, a proof of concept (POC) technique was used to demonstrate the notion of employing a block-chain-based smart-contract model to address the flaws in existing real-estate property management platforms. Planning, developing, implementing, and improving the proof of concept were all done in four phases (PDIOI). The POC focuses on developing a Solidity Smart-contract for the Housing Industry based on the Ethereum Model, which can be found at grandmullah.github.io/real-estate. To showcase block-chain transactions, the researcher built the Etoken cryptocurrency, which may be used as a means of trade. For paying the transaction validation cost, the researcher additionally obtained test ethers via the Ethereum Rinkeby faucet. ETokens were transferred from the tenant account to the landlord account using the smart-contract paradigm. Upon successful validation, all transactions were stored in block-chain distributed ledgers, which were visible to all Ethereum-network users, ensuring transaction transparency and integrity. The study said that a block-chain-based model is crucial in any organisation that values previous transactions, such as a financial services organisation, as a generalisation and expansion into other sectors. Research can be expanded to create a totally block-chain-based version of electronic real-estate transaction records, such as land registration or real-estate ownership transfers, as a recommendation for further study.

Index Terms – *Block-chain, Ethereum-network, Real-estate, Bitcoin, Ethereum Etokens, Cryptography, Decentralized network, Smart-contracts***.**

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List of Abbreviations

DLT	Distributed Ledger Technology
EVM	Ethereum Virtual Machine
PDIOI	Plan, Design, Improve, Operate, Implement
POC	Proof of concept

CHAPTER 1

INTRODUCTION

1.0 Introduction

This chapter gives an overview of the basic principles and issues. that underpin this research, with a focus on frictions in deposit claims, middlemen, and enforcement of renters' rights and responsibilities, the conflict between tenants and landlords over rent, and cases of unexplained rent increases, inconsistency in the payment period. It goes on to define the The study's scope, assumptions, importance, and contribution, as well as outline the research objectives, list the research questions, declare the research problem, and define the scope, assumptions, significance, and contribution of the study.

1.1 Background Study

The global technical revolution is increasingly altering corporate practices. As a result, businesses have reengineered their business processes and improved their operational efficiency. The real-estate market is also impacted. The significance of the real-estate business stems from the fact that it counters with housing, which is a crucial service for a country's general well-being. In many cases, real-estate problems can be traced back to market's inefficiencies. Inefficiencies such as an illiquid market, challenges with transparency, high amount of transaction costs, human biases, intermediaries, and sluggish transaction's processes are all examples of inefficiencies.

The entire cost of renting a home is largely determined by market structure and real-estate owners' management strategies. Not full time landlords are choosing to deal with middlemen to bring their rental properties to market due to the present management strategy. This raises the entire leasing rate without providing any additional value to the end-user (Tenant). The tenant is frequently the least well-informed and wealthiest actor in the real-estate market. When taken together, this creates a power imbalance in Tenant's favor. Tenants and property owners agree that the tenant will be permitted to reside and use a specific amount of space in the building. The tenant does this by paying the property owner (landlord or landlady) a set amount of money over a set period of time. Rent is usually paid fortnightly or from month to month in most nations, however shorter and longer payment intervals are sometimes conceivable.

Currently, rent can be paid by bank transfer, credit card, cash, or any other method agreed upon by the owner or agents and the tenant. This method of payment and management has resulted in an increase in leasing fees and a high level of bureaucracy, with cases of minimum balance requirements, transaction expenses, early notifications, and middlemen being widespread. Brokers, dealers, agents, banks, service suppliers, and other intermediaries are currently used in real-estate transactions. It is estimated that block-chain technologies could lead to a massive amount of savings in the real-estate market. It also eliminates the need for parties to reconcile papers because each party keeps an identical, immutable copy of transaction records. Furthermore, block-chain may be used to replace various time-consuming and expensive functions, as well as smart-contracts and automatic payments of rent, deposits, and fees. Block-chain-based registries could allow peer-to-peer asset transfers or payment of rental fees, which will reduce the number of transactions and will make it clearer to understand and read. Transaction costs would also come down to the modest service fee. There is and fixed flat fee that refers to a fixed fee that a client pays to a broker instead of a percentage-based commission. This concept is often used to describe residential area fees charged by the real-estate agents for listing and selling the properties. Here the tenant and landlord are mostly connected through the medium of the agent and that allows the agent to grab an amount of brokerage from the transaction made between the tenant and landlord (Fig 1.1).

Fig. 1.1 Current real-estate transaction process

This system is very slow for a variety of reasons, the most significant of which is the repeated process of authenticating data. Many of the documents must be signed on paper and sent from the agency to the landlord. Manual methods are required for document validation. Because of the large number of signed papers, errors sometimes arise and must be repaired. It's possible that there will be instances of fraud and corruption. Due to the time-consuming process, high transaction amount of money, and scams, all these factors combine to make the process slow and inefficient. The sector's current infrastructure is slow, expensive, and brittle. Transaction charges for the rental payment might add up to a significant portion of the entire rental rate. Entire industries have sprung up to profit off the inefficiencies that occur in the transaction process. The position in less developed markets is frequently more difficult.

With block-chain technology, many of these activities could be eliminated from the current process (Fig 1.2).

Fig. 1.2. Proposed real-estate transaction process

On the market, block-chain is a new and emerging technology. It is a type of information technology that has a variety of applications, such as asset registries, exchanges, and inventories. Block-chain is a decentralized transaction technology that was first designed for the Bitcoin cryptocurrency, however, it might be used in any sector of economics, finance, or money. The technology makes use of ledgers (a distributed database architecture) to store any type of data, and it has the potential to reduce transaction times and make systems more transparent and dependable.

1.2 Problem Statement

Real-estate owners' present management strategy is reliant on a number of middlemen, including brokers, agents, and financial service suppliers. The process of renting a home is fraught with red tape and fees charged by real-estate agents. Tenancy agreements, which are mostly paper-based and hand-signed, lay out the agreed terms such as rental period and from month to month payments payable when a property is rented.

The existing system has flaws such as the excessive number of paper documents necessary, long bank transfer periods, and hefty estate agency fees. According to research, transferring funds between banks can take up to a day or more for bigger sums, resulting in additional fees. While many technologies have been used in the real-estate and housing markets, there is a need for technologies that allow for the immutable and autonomous payment of a rental charge in a transparent, conflict-free manner without the use of a third person.

1.3 Concern of the Study

The study's main goal was to develop a block-chain-based smart-contract model for reducing operational expenses when managing a rental property and, as a result, cutting the rental fee charge. This would be accomplished by eliminating the existing high levels of bureaucracy in the real-estate property management industry.

1.4 Objectives of the Study

1. To investigate the flaws in present real-estate property management approaches.
2. To create a smart-contract approach for real-estate property management based on block-chain technology.
3. To create a smart-contract prototype for real-estate property management based on block-chain technology.
4. To validate and verify the smart-contract model prototype that has been implemented.

1.5 Research Questions

The following questions are addressed by this study:

- What is the best way to design a real-estate model based on a block-chain smart-contract?
- How can a smart-contract prototype based on block-chain technology be implemented in the real-estate industry?
- How can the validated and verified block-chain-based smart-contract model prototype be implemented?

1.6 Research Goal

The following are some of the study's findings::

- Report on the existing real-estate property management system.
- Designing a model for real-estate based on block-chain smart-contract.
- Prototype of a block-chain-based smart-contract implementation model for real-estate bodies.
- Verification and Validation of the functionality of this model.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

This section explains the current real-estate management system and an overview of block-chain technology, also an in-depth look at the Ethereum-network and Smart-contracts. The implementation overview and conceptual framework of the real-estate management system is also been discussed in this chapter.

Jerinas Gresch *et.al* in the paper "International Conference on Business Information Systems" devised a system to verify diplomas, called UZHBS. The idea aimed to eliminate the disadvantages of paper diplomas while also lowering the likelihood of false certificates. Their technique differs from previous research in that they began by formalising seven UZH needs gleaned from stakeholder interviews. Their system's interface shows a window to users, and the architecture is built on two functions. The first function is the front-end, which receives a PDF document from the user, and the second is the back-end, which processes the document. The material's hash is combined with a smart-contract function and sent to the Ethereum Block-chain [1].

Ana Lidia Franzoni *et.al* in the paper "International Conference on Advanced Learning Technologies (ICALT)" made a system for their government called Prenda on the Ethereum Block-chain. The major purpose is to preserve credentials for instructors who have completed teacher training in Mexico. A smart-contract is constructed in this system, which contains a wallet for each teacher's fundamental data. Furthermore, the key information from the courses is kept in a smart-contract and published to the Block-chain. In their trial, 1,518 primary school teachers from six states on Mexico took part and kept their credentials in the Block-chain platform for eacher training [2].

Lucas M Palma *et.al* have discussed in paper “International Journal of Network Management” a prototype for incorporating Block-chain technology into the Brazilian educational system Once students complete their needed coursework, the researchers suggest keeping their academic records in Block-chain utilising smart-contracts. Their proposal's implementation creates a user interface based on three smart-contracts: Authority, Curriculum, and Diploma. Furthermore, the study's prototype operates on the public Ethereum Block-chain, with smart-contracts developed in the Solidity programming language. Future studies should include all academic data for kids from elementary school through graduate school, according to the researchers. The authors claim that their prototype system was the first to use Block-chain technology to issue diploma certificates [3].

Lennart Ante et.al have discussed in the paper “Smartcontracts on the block-chain –A bibliometric analysis and review” have summarized the smart-contract by explaining Smart-contracts are decentralised scripts on block-chains or similar infrastructures that allow for the transparent execution of predetermined procedures. Smart-contracts allow business logic to be automated and assets like money to be programmable, opening up hitherto untapped application possibilities. Smart-contracts already control billions of dollars in value. This report examines 468 papers on smart-contracts and associated 20,188 references, giving an overview and analysis of the present status of smart-contracts research, as well as highlighting conceptual structures and developing trends Six diverse strands of study in the technological, social, economic, and legal fields are discovered using exploratory factor analysis for co-citation analysis: I) block-chain networks' technical foundations, development, and open questions; II) block-chain and smart-contracts for the Internet of Things; III) smart-contract standardisation, verification, and security; IV) block-chain and smart-contracts for disrupting existing processes and industries; V) smart-contract potentials and challenges; and VI) smart-contracts and the law. Using social network analysis, the interrelationships between these groups and individual high-impact publications are displayed. It is possible to gain an organised overview of the key research strands on smart-contracts, their evolution over time, the usefulness of smart-contract platforms in research, and conceptual links between publications and discourses. Starting points for future research are drawn from the findings, providing academics and practitioners with a solid foundation for their work on smart contracts. [4].

Muhamed Turkanovic *et.al*, in the paper “A blockchain-based higher education credit platform” have put their focus on issuing and verification of diplomas. This research differs from the previous one in that their concept includes an EduCTX Blockchain wallet for each student to store their academic information. This student wallet allows them to view their credit report. They also make it possible for Higher Education Institutions (HEIs) to join the EduCTX network. They created their platform on top of the Ark Blockchain infrastructure, with the intention of expanding it to include smart contracts in the future [5].

Matthew B Hoy *et.al* in the paper “Medical reference services quarterly” discussed a possible use for blockchain in libraries. Their concept is to integrate scientific materials with Blockchain to allow secure scientific investigations in libraries. To identify any modifications, the papers are transformed to a hashed document, and a private Bitcoin key is produced for that document. The hash code changes whenever the document is altered or updated. Users can quickly verify changes. Another application of Blockchain technology in libraries is as a tool for managing and reducing duplicate sources. The Blockchain produces a single, unique record that anybody can view but cannot edit [6]

Mahmood A Rashid *et.al* in the paper “Teduchain: A platform for crowdsourcing tertiary education fund using blockchain technology” have devised a new platform called TEduchain. This website lets students gather and manage finances by establishing a contract between them and their sponsors. The author platform was created to assist students with overcoming financial barriers to completion of their studies. To conduct this activity over the Blockchain network, TEduchain provides a user-friendly dashboard that allows students, fundraisers, and sponsors to connect rapidly [7].

Sabine Kolvenbach *et.al* in the paper “Proceedings of 16th European Conference on Computer-Supported Cooperative Work-Panels, Posters and Demos” have talked about quick issuance and rapid verification of documents. The Ethereum Blockchain and smart contracts were used in their study. They used the InterPlanetary File System protocol to link the certificates to the fingerprints in their system and store them [8].

K Palanivel *et.al* in the paper "Blockchain architecture to higher education systems" gave a structure named proof of education transcript system (PETS) using blockchain technology for learning. The smart contract is used to store and exchange learning resources internationally, and the system is constructed on a distributed P2P network. This structure is designed to benefit students by allowing them to select their courses from the organisations or institutions of their choice. When students select a course, they may pay for it using the public ledger. A miner examines the students' final records and provides their certificates once they finish their courses by completing all evaluations and examinations. The sensitive information of the student or learner is saved on a private Blockchain [9]

V. Buterin et.al have discussed in paper "A Next Generation Smart Contract & Decentralized Application Platform", when Satoshi Nakamoto launched the Bitcoin network in January 2009, he did so while simultaneously proposing two novel and untested ideas. The first is "bitcoin," which is a decentralised peer-to-peer internet money with no backing, intrinsic value, or central issuer. So far, the currency unit "bitcoin" has gotten the most attention from the public, both in terms of the political elements of a currency without a central bank and its extraordinary upward and downward price volatility. However, there is another aspect of Satoshi's g rand experiment that is equally important: the concept of a proof-of-work-based blockchain that allows for public consensus on transaction order. Bitcoin can be described as a first-to-file programme if one entity owns 50 BTC and transmits the same 50 BTC to both A and B at the same time, only the transaction that is confirmed first will be processed. There is no intrinsic way of determining from two previous transactions, which has hindered the creation of decentralised digital currency for decades. The blockchain, created by Satoshi Nakamoto, was the first reliable decentralised solution. Now, the focus is quickly shifting to the second half of Bitcoin's technology, the blockchain, and how it may be used for more than simply money [10].

Satoshi Nakamoto et al "A Next Generation Smart Contract and Decentralized Application Platform" the author set the Bitcoin blockchain motion in 2009. Bitcoin is nothing but a decentralized platform used for peer-to-peer online currency which is used to maintain transactions without any central user or intrinsic value". Bitcoin is taking a huge attention of public recently in both the political aspects of the currency without interruption of central bank and it is volatilely taking its price upward and downward. The other main concept is the proof of concept of work based on blockchain technology to allow public agreement example if one entity has 100 BTC at the same time spends the same 100 BTC to A and B , when the transaction is confirmed by both the parties then only the transaction is been processed. There is no other intrinsic way to find out which transaction came earlier. The author's blockchain was the first transactions. Bitcoin can be described as first to first-to-file system example securely without any third party intervention based on trust. In blockchain system blocks are created and then they are connected by using specific values known as hash values that further maintains the transaction. The proof of work of algorithm which is used to control and manage different blocks on various platforms. The Ethereum (public blockchain platform) it is used to implement decentralized application using a virtual contract known as smart contract by using solidity language that defines the way to exchange assets digitally [11].

Fabian Vogelsteller et al Vitalik Buterin "Ethereum Improvement Proposals" the author has given the proof of work that how specific standard allows us to implement a standard API for tokens within our smart contracts. The basic functionality is to transfer tokens and then get approved. The motivation behind the work is standard interface allows different tokens on Ethereum that can be reused by any other applications such as crypto wallets for decentralized exchanges [12].

Satoshi Nakamoto et al "Bitcoin: A Peer-to-Peer Electronic Cash System" the author has proposed a system for any electronic transactions without any third-party intervention. The usual framework of coins (bitcoins) for exchange using digital contracts or signatures that provides a ownership, that is incomplete without double spending. To get a solution on this problem the author proposed a solution to use a network keeping record of the public history of the previous transactions which can be impossible for any attacker to change the data if nodes have the majority of CPU power. Nodes work simultaneously with each other. The messages are not routed on any specific or particular place so they don't need to be identified. Only peer-to-peer online payments would allow us to send electronic cash directly from one person to another without any institute [13].

Harish Sukhwani et al Nan Wang, Kishor S. Trivedi, Andy Rindos “Performance Modelling of Hyperledger Fabric (Permissioned Blockchain Network), the author has presented performance model of Hyperledger Fabric v1.0+ using Stochastic Reward Nets (SRN). From this model we can compute the utilization for validating the model, they setup an HLF network to run the workload using Hyperledger Caliper. From the results, the endorsement process to be completed is affected by the number of different policies and peers. Each transaction in the fabric undergoes three phases – endorsement, ordering, validation. The full system and the subsystems corresponding each phase is been analyzed. All the data from the fabric setup workload to validate the models. The committing peer confirms transactions in parallel for an incoming block, it boosts the performance if committing peer are installed on a machine with CPU. It minimizes the length of the queue at the VSCC validation which allows the system to absorb the rush of blocks arriving. We look at two different scenarios: different peers per organization and validators architecture. The endorsement process is the performance bottleneck, transaction endorsement parallelization can significantly lower the length and raise system’s maximum output. The pipe line architecture improves block validation by about 1% that has no additional advantages. To tackle the largeness in model creation and solution, we will consider a hierarchical modeling approach in future study [14].

2.1 Real-estate Management System

The tenant-focused rental management is committed to building up a safe, secured, and easy to operate the system. We accomplish this by providing high-quality residences at reasonable prices and cultivating genuine connections with our renters. Specifically, their purpose is to provide renters with favourable experiences. Eventually, the goal is to create a positive experience for tenants and landlords in the rental and leasing process.

Real-estate is essential to everything we do; we need it to stay in, work in, and enjoy ourselves. It is not only a vital economic and industrial resource, but also the home of several national and international investment funds. According to the research and studies today, more and more people are shifting towards metropolitan cities and urban revolution continues to grow overall the world, which increases the number of financial transactions and transparency challenges in those transactions. There is an urgent need to use new and new technologies for managing all of such challenges. This thesis explains how block-chain technology fights and solves almost every challenge that is been experienced in the currently running system.

2.2 Existing Model

To explain the necessity for new block-chain technology and smart-contracts in the rental system we need to exhibit inefficiencies in the current running system. According to a World Economic Forum study of CEOs and ICT professionals, 59% of respondents think that by 2025, block-chain technology would be used to hold 15% of global GDP information. In this situation, industry participants have realized that block-chain-based smart-contracts may play a far greater role in real-estate transactions, possibly altering basic real-estate processes like property sales. Listing of a few organizations which are using block-chain technologies in the real-estate sector nowadays.

2.2.1 Republic – Location: New York, NY [15]

Republic allows its customers to invest and return to the opportunities that contribute toward a better future for themselves and others. The services include Commission-free trading and investing applications, a Decentralized ecosystem of gaming applications, and Future real-estate that uses the whole next-level technologies in their day-to-day services.

2.2.2 SafeWire – Location: Columbus, Ohio [16]

SafeWire exists to assure that no wire fraud occurs during any real-estate transaction. Wire fraud in real-estate is a problem that stems from global financial inequity. Often, the criminals are from poor nations throughout the world who believe they are Robin Hood, robbing the affluent to give to the needy. SafeWire will need to favorably alter global financial inequity in sections of the globe where online fraud is created if we are to define success with our purpose and achieve a Fraud Free future. Wire fraud in real-estate isn't glamorous. However, it is a major issue for the traditional real-estate sector. Since 2016, Business Email Compromise (BEC) fraud has cost over $9 billion*. Real-estate Wire Fraud is responsible for 16% of those losses.

2.2.3 Vairt – Location: Cincinnati, Ohio [17]

Vairt is an all-in-one solution for real-estate, property management, and vacation home management working bodies to manage, market, and deliver an exceptional experience, as well as a crowd funding platform for investing in rental income-generating properties, tokenizing, and liquidating real-estate assets via block-chain.

2.2.4 RealT – Location: Aventura, FL [18]

RealT provides the services of Fractional, tokenized real-estate investing where anyone can grow a global real-estate portfolio easily and affordably through the Ethereum block-chain.

2.3 Design of Block-chain-Based Smart-contracts Models

2.3.1 Block-chain Overview

Block-chain is a technology that was created as a form of accounting for virtual currencies Bitcoin. Block-chain is a distributed-ledger-technology (DLT) that is now being used in a wide range of commercial applications. Now a days, the technology is mostly used to verify digital currency transactions, however, it is feasible to digitize code and enter almost any document into the block-chain. As a result, an indelible record is created that cannot be altered. Furthermore, rather than relying on a single centralized authority, the veracity of the document may be checked by the whole community using the block-chain. The world has seen how public crypto-currencies have maintained a high degree of robust security, demonstrating that this new generation of block-chain technology may deliver efficiency and intangible technological advantages akin to what the internet has done.

A block that is the current section of a block-chain, which records some or all of the recently done transactions, exists within the block-chain. A block is added to the block-chain as a permanent database after it is completed. When a block is finished, a new one is produced. The block-chain contains an infinite number of such kind of blocks that are linked to one another (links in a chain) in a correct linear and chronological sequence. Every block carries a hash of the one before it. From the genesis block to the most recently completed block, the block-chain contains comprehensive information about individual user addresses and their balances.

Block-chain transaction mostly works in the given order:

i. **Transaction Initiation:** At the First party creates the transaction that transmits it to the network.

ii. **Transaction Authentication:** The peer network that has nodes receive the message and start the authentication for validity by decrypting and encrypting the digital signature.

iii. **Block Creation:** The transaction which was kept to be updated are taken into action and are updated in the ledger version, which is called a block. Forwarded in the network by one of the nodes.

iv. **Block Validation:** The network's validator nodes get the proposed block and work to validate it in an repetitive process that needs the majority of the network's validator nodes to agree.

v. **Block Chaining:** If all of the transactions are genuine, the newest block is added to the block-chain and the new ledger's current status is broadcast to the network.

Block-chain simply is a chain of blocks that holds a complete list of transaction records like a conventional public ledger. Fig. 2.3.1 is an example of block-chain. Each block is directly connected to the previous block via a reference that is essentially a hash value of the previous block called a parent block. Each and every block’s hash function or hash value is been stored in the Ethereum block-chain. The first block in the block-chain also called as parent block is technically named as the genesis block.

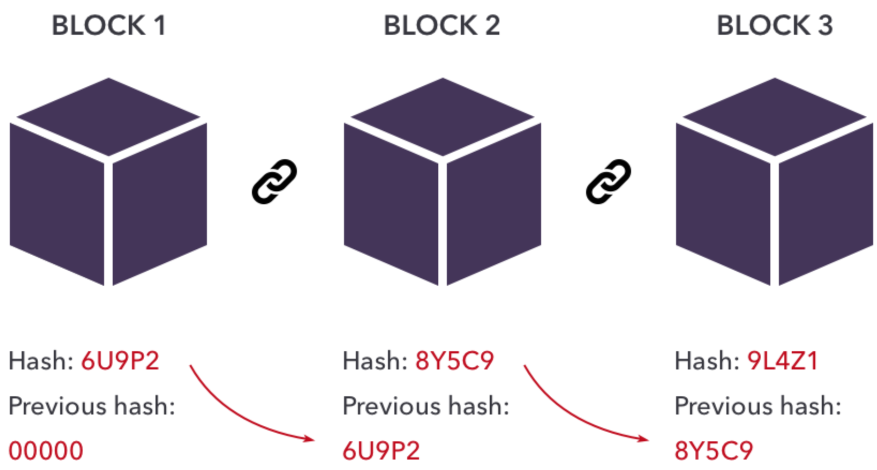

Fig. 2.1 Example of Block-chain and their hash values.

Every Block body is composed of the transaction data that is been provided, verified, and validated by the nodes of the network. The maximum number of transactions to be stored in the block completely depends on the size of the block and the size of the transaction detail. This block-chain technology uses an asymmetric cryptography mechanism to validate the authentication of transactions. A digital signature is generated by the parties which are completely based on asymmetric cryptography because it is been used in an untrustworthy environment.

Cryptocurrency is the main medium or can be called digital currency which is been used to carry all the transactions we can experience in block-chain. A crypto-currency is a digital currency designed to work as a medium of exchange in a block-chain-based transaction. It employs encryption to safeguard and authenticate transactions, as well as to regulate the generation of new cryptocurrency units. Cryptocurrencies are, in essence, restricted entries in a database that no one may update until certain requirements are met. Litecoin, Ripple, Ethereum, and Bitcoin are currently accepted digital currencies. Ethereum ether is employed for mining in this study, while digital mode is Ethereum ETokens are used for real-estate transactions.

In block-chain architecture, all of the transactions are recorded in a public distributed ledger. A distributed ledger is a database that is shared, duplicated, and synced among network participants. The distributed ledger keeps track of transactions between network participants, such as the exchange of goods or data. The network's participants control and agree on alterations to the ledger's records by consensus. There is no central, third-party mediator engaged, such as a financial institution or clearinghouse. The distributed ledger contains a timestamp and a unique cryptographic signature for each entry, giving it an auditable history of all network transactions. In a nutshell, block-chain is a network of computers that each have an identical copy of the database (distributed) and change its state (records) by consensus based on pure mathematics, without the need for a central server or agent to entrust.

A consensus transaction validation is completed before a block-chain transaction are recorded to a distributive ledger. The technique through which the nodes agree on whether a transaction and block are valid or not is known as consensus. Transactions must be verified by the nodes, as previously stated. Nodes are parties who can vote on whether or not a transaction is legitimate. This frequently necessitates processes agreeing on a data value that is required during calculation. It's difficult to achieve a consensus in a dispersed setting. Block-chains are fundamental decentralized systems that are made up of a variety of actors that behave based on their motivations and the information they have access to. When a new transaction is broadcast to the network, nodes can choose whether to incorporate it in their copy of the ledger or ignore it. A consensus is reached when the majority of the participants in the network agree on a single acceptable state. To be functional, cryptocurrency exchanges, smart-contracts, and distributed ledgers based on the block-chain must be validated by 16 the block-chain. These affirmations are based on so-called consensus procedures.

Several methods to reach consensus in the block-chain distributed network are been explained:

i. **Proof of Work (POW):**

This is a protocol aimed at thwarting cyber-attacks such as a distributed denial-of-service (DDoS) assault, which aims to deplete a computer system's resources by sending many bogus requests. Proof of work, commonly known as mining, is a requirement for defining a costly computer calculation that must be done in order to produce a new set of trustless transactions on a block-chain distributed ledger. The mining process confirms a transaction's authenticity, preventing double-spending, and also creates new digital money by compensating miners for completing the prior duty. When the POW method is used to set a transaction, the transactions are packaged together into a block, and miners check that the transactions inside each block are valid. To do so, miners must solve a mathematical riddle known as a proof-of-work problem, with the first miner who solves each block problem receiving a reward. The validated transactions are deposited as a new block in the public block-chain, forming a chain of blocks (Block-chain). Although this algorithm lowers fraud, it consumes a lot of power, making it inefficient for big production networks.

ii. Proof of Stake (POS):

Proof of stake is a low-energy alternative to proof of work. In a Proof-of-Stake (PoS) system, miners must demonstrate that they hold the money in question. People with more currencies are thought to be less inclined to assault the network. Because the single richest individual is guaranteed to be dominant in the network, selection based on account balance is highly unfair. As a result, a variety of methods are presented using a mix of stake size to choose which block to forge next.

iii. Kraft:

This was introduced by Zheng (2016) as a novel consensus mechanism for ensuring that a block is created at a generally consistent speed. High block creation rates are well recognized to jeopardize network security. To overcome this problem, the GHOST (Greedy Heaviest-Observed Sub-Tree) chain selection rule is developed. Instead of using the longest branch strategy, GHOST weights the branches so that miners may pick the best one.

iv. Peer-To-Peer Consensus Algorithm:

Chepurnoy (2016) proposed a consensus approach for peer-to-peer block-chain systems in which anybody who delivers non-interactive proofs of obtaining prior state snapshots based on agreeing to build the block is rewarded. Miners simply have to save outdated block headers instead of complete blocks in such a system.

Three main types of Block-chain is been introduced to the world by Bitcoin:

I. **Public Block-chain-** Everyone who is part of the public block-chain has access to each and every piece of data stored in the block-chain. As its name is public, where no one is in charge and anyone is permitted to participate in reading, writing, and auditing the block-chain. These types of block-chains are open and maintain 100% transparency hence anyone can review anything at a given point of time on a public block-chain. For Example, Bitcoin, Litecoin, and Ethereum.

II. **Private Block-chain-** This type of private property is owned by an individual or a group of individuals called an organization. Only and only those nodes are permitted to access block-chain data those who belong to that organization or the owner of that block-chain. The owner also can provide access to other nodes. Here, the agreement is reached based on the whims of the central in-charge, who has the authority to grant or deny mining rights to anybody.
This makes it centralized again, with numerous rights being exercised and vested in a single 18 central trusted person, but it is cryptographically safe and more cost-effective for the firm.
For Example, Bank-chain.

III. **Consortium Block-chain-** Using private block-chains, this block-chain attempts to remove the exclusive autonomy that is vested in a single entity. It assures that only a small number of pre-selected nodes participate in a consortium block-chain's consensus process. As a result, instead of just one person in command, there would be several people in charge. In essence, a group of firms or persons that represent the network get together and make choices that benefit the whole network. Consortia or federations are the names given to such organizations.

Table. 1 Comparisons among Public, Private, and Consortium Block-chain

Feature	Public Chain	Private Chain	Consortium Chain
Efficiency	**Low**	**High**	**High**
Consensus determination	**All miners**	**One organization**	**A selected set of nodes**
Reading permission	**Open for public**	**Restricted**	**Restricted**
Immutability	**Nearly impossible to tamper**	**Could be tampered**	**Could be tampered**
Centralization	**No**	**Yes**	**Partial**
Consensus process	**Permission less**	**Permissioned**	**Permissioned**

There are a few common features in all types of Block-chain that have been discussed above:

a) **Decentralization:** Most traditional centralized transaction systems need transaction authorization through central trusted parties (such as the central bank), which invariably results in cost and performance bottlenecks at the central servers. A transaction on the block-chain network, on the other hand, maybe completed between any two peers (P2P) without the need for central agency authentication. As a result, the block-chain 19 technology is a useful tool for decentralizing the internet. It also has the ability to make significant changes in industries.

b) **Immutability:** It is almost hard to tamper with the network since each transaction must be validated and recorded in blocks dispersed throughout the network. Other nodes would also validate each broadcasted block, and transactions would be examined. So the main feature we can see here is any kind of forgery in the system can be easily detected.

c) **Anonymity:** With a created address, any user may communicate with the block-chain network. Furthermore, a user might construct a large number of addresses in order to protect his or her identity. There is no longer any central authority in charge of users' personal data. This approach ensures that the transactions on the block-chain are kept private to some extent. Due to inherent constraints that have yet to be explained, block-chain cannot ensure absolute privacy protection.

d) **Auditability:** Users may easily check and track prior records by contacting any node in the distributed network since each transaction on the block-chain is verified and logged with a timestamp. This increases the data stored in the block-chain's traceability and transparency.

2.3.2 Smart-contracts

Smart-contracts are self-executing programs in which the conditions of a deal between two or more parties are put directly into lines of code that execute on the block-chain network. The code, as well as the agreements it contains, are disseminated throughout a decentralized block-chain network. According to Kosba and colleagues (2016), contracts allow for trusted transactions and agreements between multiple, anonymous individuals without the requirement for a central trusted party, legal system, or external authority. Transactions are traceable, transparent, and irrevocable thanks to them. Smart-contracts make it possible to exchange cash, belongings, stocks, asset leases, or anything else of value in a transparent, conflict-free way without the use of a third person. The distinction between traditional contracts and the current smart-contract may be observed in the following diagrams. Auto-executable contract code replaces conventional intermediaries.

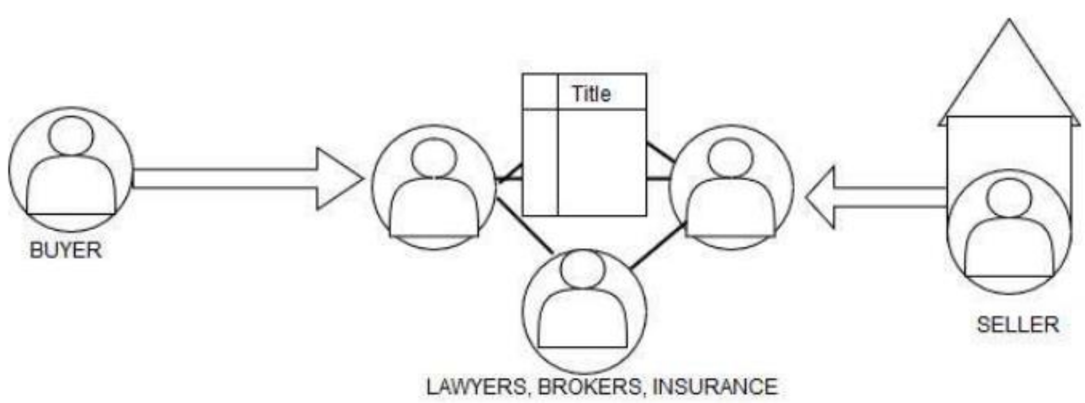

Fig. 2.2 Visualization of traditional real-estate.

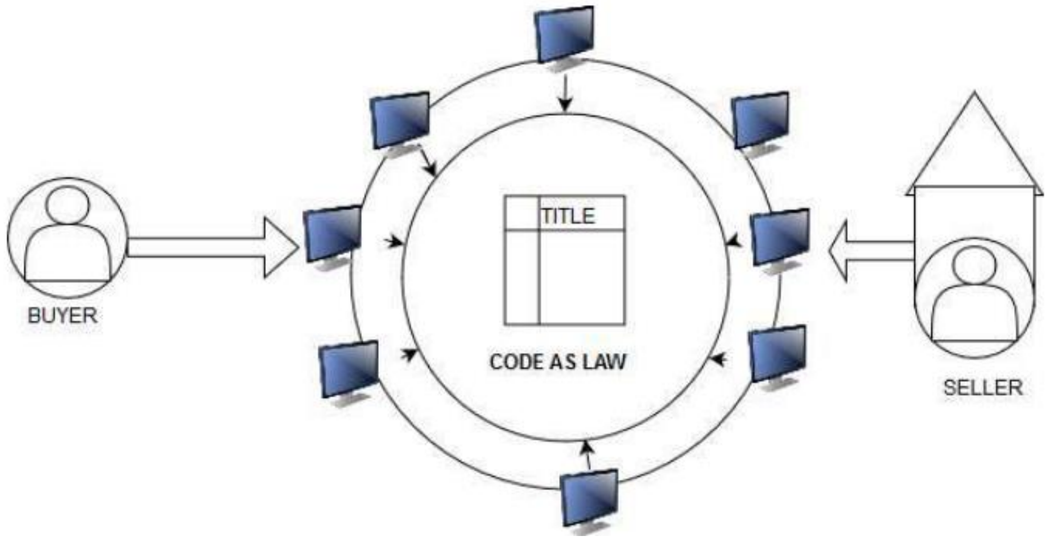

Fig. 2.3 Example working with smart-contract

- **Ethereum Based Solidity Smart-contract**

This study's Ethereum smart-contract is an example of a block-chain-based smart-contract. Ethereum is a block-chain-based open software platform that allows developers to create and deploy decentralized applications. Miners on the Ethereum 21 block-chain labour to earn Ether, a cryptocurrency that powers the network. Application developers utilize Ether to pay for transaction fees and services on the Ethereum-network. A Solidity smart-contract based on Ethereum is a self-contained solidity code that runs on the Ethereum-network. The solidity programming language is used to create the code. The system's currency is ether, transaction fees are paid with this currency. and computations when smart-contracts are executed.

Externally owned accounts and contract accounts are supported by the Ethereum-network. Individuals hold externally owned accounts, which are managed by their private keys, whereas contract accounts are governed by their contract code. Both sorts of accounts are identified by their 20-byte addresses and have a corresponding ether balance. A nonce and a storage field are also stored in the accounts to avoid double spending. Contract accounts can only send messages, whereas externally controlled accounts can send transactions. Only contract accounts are permitted to have associated code that is run when a transaction or communication is received.

2.4 Conceptual Framework

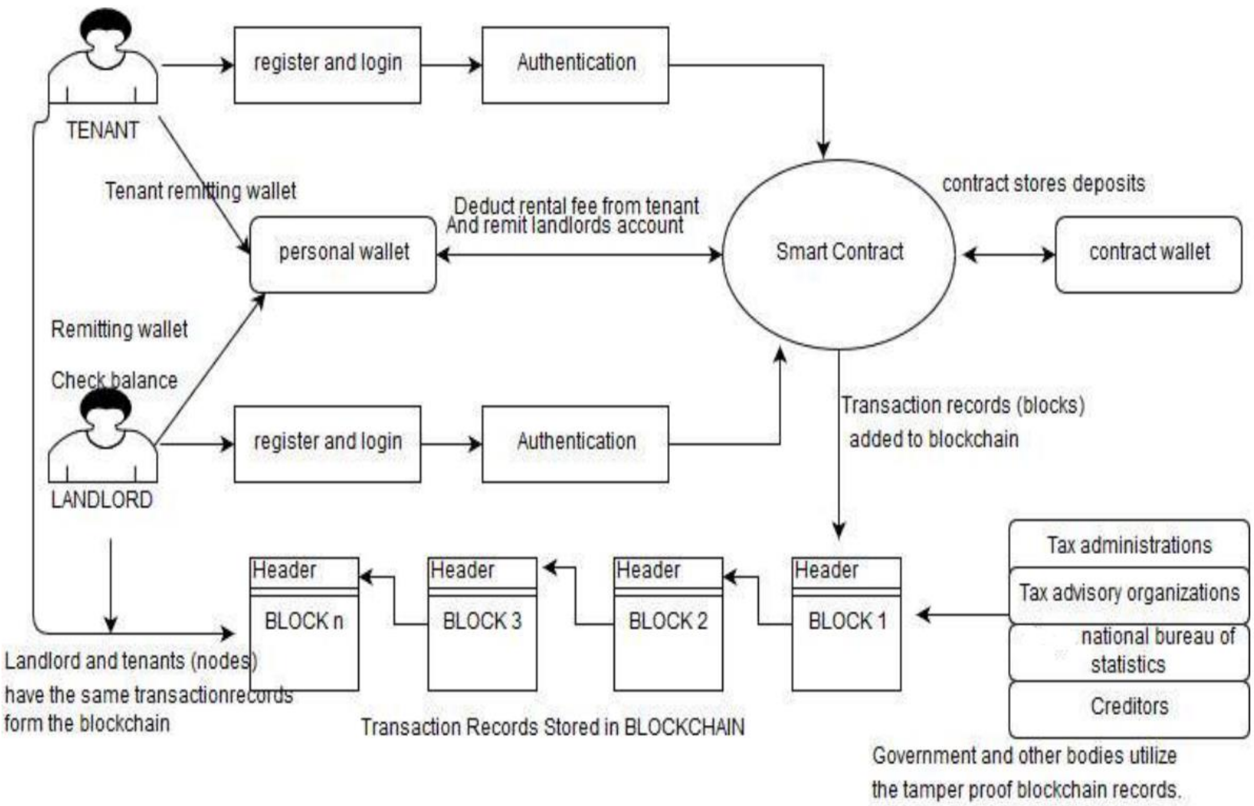

Fig. 2.4 Conceptual Framework

As a result, the Ethereum-based Solidity Smart-contract Model for Housing Market is developed to address the issues that the housing market business faces. The model will include the following modules: a User Registration module for both the tenant and the landlord, a User Login and Authentication module that will restrict access to only approved users, and a User Registration module for both the tenant and the landlord. A chain of transaction blocks, a smart-contract to automate transactions and produce immutable transaction blocks of records, a personal wallet to store individual ethers and a contract walled to keep deposits, and a smart-contract to automate transactions. Because occupancies are private concerns, the model must be highly resilient; it must not disclose any authentication credentials, and it must have an intuitive and easy user interface for non-technical/Amateurish people. The renter will pay the security deposit in ether to the smart-contract that stores the model's logic, As a result, overseas transfers are not subject to lengthy bank processing periods or hefty costs. The funds are frozen until the conclusion of the lease, when the landlord will be able to determine the appropriate deduction amount. In the event of a disagreement, an arbitrator makes the ultimate judgement on the withdrawal split. In addition to the deposit being paid in ether, smart-contracts make it possible to pay the landlord in ether for the rent payments. The smart-contract applies logic to these payments, such as prohibiting rent from being overcharged or moved after the tenancy ends. The user must provide the software access to their account in order for the programme to transfer rent on their behalf.

2.5 Prototype Implementation Overview

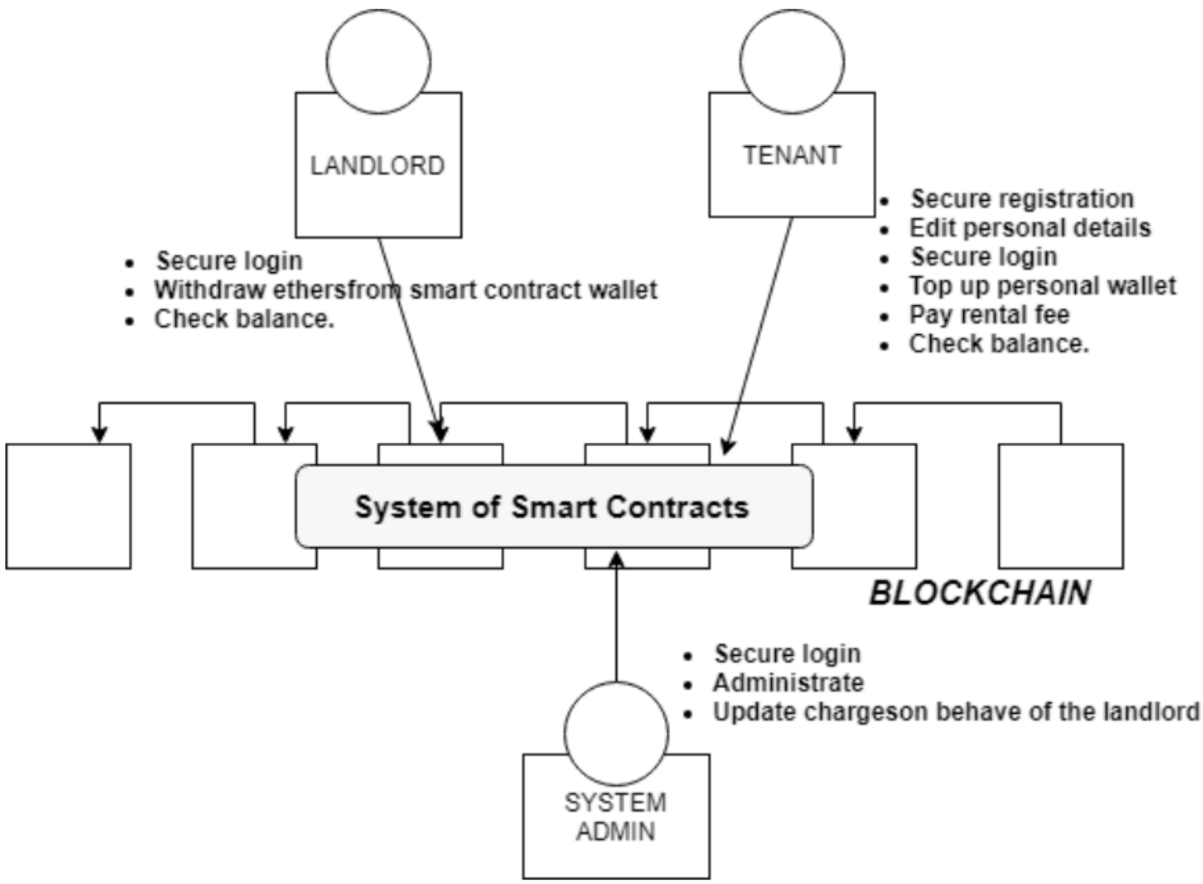

Fig. 2.5 Overview of the prototype implementation with various users and their interactions with the block-chain and the smart-contract system that exists on the block-chain.

To summarise, this chapter reviewed the available literature on real-estate property management models. It also presented a block-chain-based smart-contract architecture for real-estate property management, as well as the theories that support block-chain as a public database of performed transactions.

CHAPTER 3

PROPOSED SYSTEM AND METHODOLOGY

3.0 Introduction

The research approach used in this study is described in this chapter. A systematic approach to solving an issue is known as the research methodology. Its goal is to provide a research work plan. To fulfill the study's goals, a proof of concept (POC) technique was used to demonstrate the notion of employing a block-chain-based smart-contract model to address the flaws in existing real-estate property management platforms. Planning, designing, execution, operation, and improvement were the five phases of the proof of concept (PDIOI). The POC's goal was to create a Solidity Smart-contract based on the Ethereum-network.

3.1 Proof of Concept

Proof of concept (PoC) is the execution of a technique or idea in order to demonstrate its viability or a proof of concept with the goal of demonstrating that a notion or theory has practical potential. The proof of concept technique used in this thesis permitted for the demonstration and verification of smart-contracts' practical potential in real-estate management. The model was designed to be less expensive and complicated than the planned system it mimics, As a result, the researcher was able to better understand and use the model to conduct studies that would not be feasible in a real-world setting due to economic considerations.

PoC is defined as a strategy for avoiding wasting a lot of money (resources) on something that isn't marketable or technologically viable. It will be tough to argue against other project stakeholders if one can provide solid proof that his or her concept is good. This provides for a high possibility of determining the project's worth even before the development process begins.

3.1.1 Procedure for Proof of Concept

A Proof of Concept (POC) might be a non-coding prototype or an MVP (Minimum Viable Product) with a limited feature set and a week zero deadline. This research employed a proof-of-concept strategy to address how the suggested model will support organizational goals, objectives, and other prospective business requirements, as mentioned in section 3.2. This includes explicitly outlining success criteria, documentation for how the proof of concept will be carried out, an assessment component, and a plan for how to proceed if the POC is successful. As seen in Chapter 4, this research used focus groups to create user needs and assessment criteria via user stories.

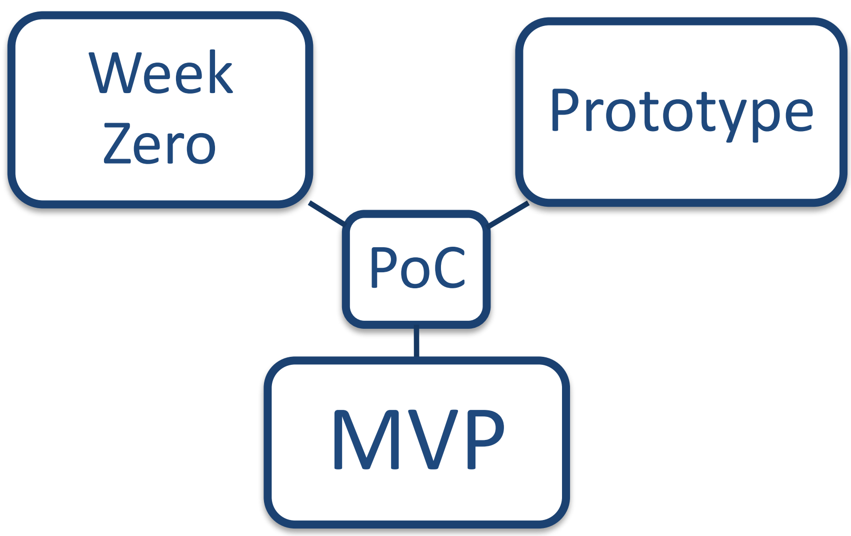

Fig. 3.1 Procedure for Proof of Concept

During Week Zero, this study conducted a literature analysis to demonstrate the necessity for Block-chain-based real-estate management systems, as provided in Chapter 2 and as part of the research's context and rationale in Chapter 1. It demonstrated how smart-contracts on the block-chain may increase manageability or efficiency. Following that, as described in chapter four, explained how to map the goals/problems to a feasible solution. The prototype was designed to be exceedingly basic since the researcher had no intention of utilizing any of the prototypes in this condition in the future. This stage (week Zero) provided a clear theoretical postulate that could be tested.

In this research again, the prototype is needed to affirm and demonstrate the feasibility and practical potential of the proposed idea. This informed and enabled the researcher and other decision-makers to determine how best to develop the product when it moves into full production for a final, market-ready item as pointed in.

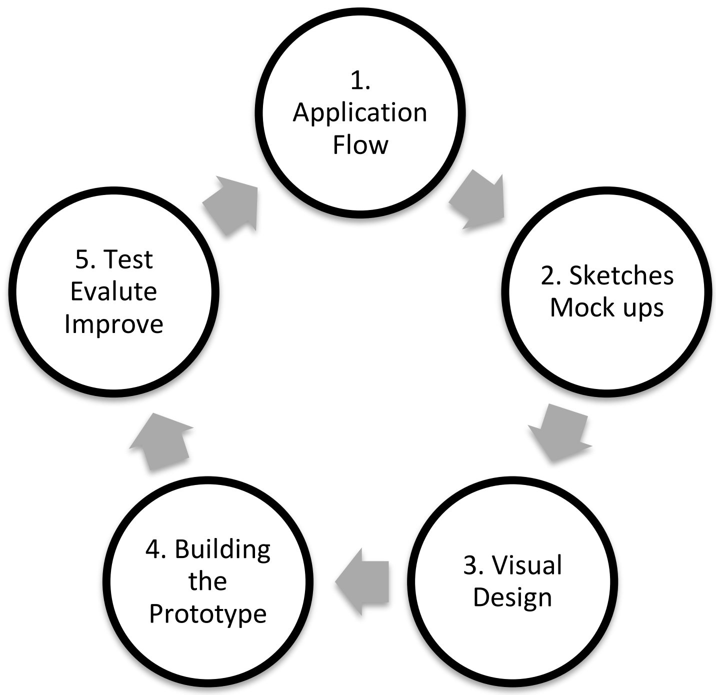

Fig. 3.2 Prototyping Process

Similarly, a minimal viable product (MVP) emerged following successful proof of concept development. The goal at this point was to construct a product with a minimal set of features that could be used to validate the research's core assumptions. With minimum resources, the MVP was employed to establish the suggested model postulate. A proof-of-concept (PoC) has been constructed to demonstrate that the model described is a viable option. A description of how this PoC was built and a discussion of design issues can be found in Chapter 4. There are also explanations of the use cases that have been established for the PoC. The proof of concept has been developed and tested.

3.2 PDIOI Approach

The Planning, Design, Implementation, Operation, and Improvement approach was utilized for this study. Huawei's PDIOI approach is used to implement Enterprise Engineering Projects (IEEP). This technique was ideal since it assisted in increasing agility, speeding up processes, and reducing and resolving complications throughout the implementation of the PoC artifact.

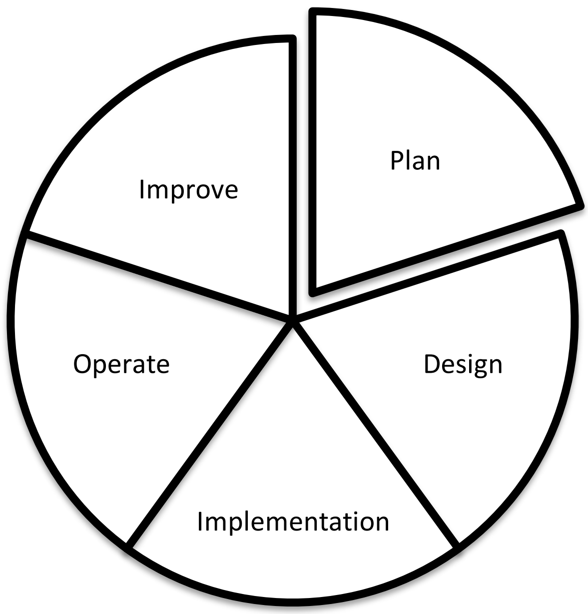

Fig. 3.3 PDIOI

I. **Planning:** The planning stage of the suggested model is the first step. The context, needs, and objectives of the model are examined, as well as the technology roadmap, as provided in section 4.2. It looked at the proposed model from a macro perspective, with the goal of establishing a framework for the entire study and determining the general direction, which has a direct impact on model outcomes. It also establishes the model scope, which is required for the allocation of budgets and resources. It establishes roles and duties for linking research and applicable systems. The study design's guiding concepts are articulated, giving direction and a foundation for future work. In general, this phase grasps the research's overall context, creating a good external environment for efficient progress.

II. **Design:** Designs based on the model criteria and guidelines given in the planning phase are realised using technical approaches in the design phase. As indicated in section 3.2.1, the design process follows the modular design approach, with hierarchical architecture applied in each module. Device selection, technology roadmap, model functionality, and performance standards are all determined by it. The model and technology selection efforts are only getting started.

III. **Implementation:** The model was constructed during the implementation stage, and the other components were added in accordance with the design specifications. Infrastructure to back it up.

IV. **Operation:** During the operating phase, the researcher kept a close eye on the model's performance and vital signs in order to enhance service quality, minimize interruptions, mitigate outages, and ensure high availability, dependability, and security. It provides a streamlined structure and operational tools for dealing with issues and avoiding costly downtime and disruption. Upgrades, transfers, additions, and adjustments were also possible, all while eliminating model operation flaws.

V. **Improve:** The goal of the model optimization phase was to boost model performance, security, and reliability as well as the user experience As a result, the created model was able to satisfy the service requirements. Hardware optimization, software optimization, expansion, and maintenance are all examples of optimization modernization of technologies

3.2.1 Smart-contracts Design

To function properly, every non-trivial Dapp will require more than one contract. It's impossible to construct a safe and scalable smart-contract backend without spreading data and functionality across numerous servers. As a result, the model's planned architecture as a smart-contract system is founded on the design premise of having multiple sorts of contracts for different types of jobs.

A model is known as "The Five Types Model" is used to categorize the contracts, albeit not all of the five categories are employed in this PoC.

The five different models are mentioned below:

1. **Database Contracts**

   These Contracts are simply used to store data. They just require methods that enable other contracts to write to, update, and retrieve data, as well as a basic method of determining caller permissions.

2. **Controller Contracts**

   A contract for regulating database contracts is one step above in the layer of abstraction. These agreements are based on storage agreements. Both controllers and databases can be replaced by other, comparable contracts that share the same public API in a flexible system. Advanced controllers can perform batch reads and writes, as well as read from and write to numerous databases instead of just one. They have the ability to act on various database contracts as well.

3. **Contract Managing Contracts(CMCs)**

   These contracts are required to govern and manage the activities of other contracts as well as their existence. Their primary responsibility is to maintain track of all of the system's contracts/components, manage communication between contracts and other components, and facilitate modular design. Keeping this functionality apart from typical business logic is a smart idea, and it provides a number of advantages for the system.

4. **Application Logic Contracts**

   An application logic contract is one that uses controllers to accomplish application-specific code tasks. In general, an ALC is a contract that makes use of controllers and other contracts to accomplish application-specific activities.

5. **Utility Contracts**

   These contracts are often used to do a specific task and can be called by other contracts without limitation. It entails certain minor, general operations that may be outsourced into highly specialised utility contracts. It might be a contract that hashes strings using an algorithm, generates random integers, or does something else entirely. They usually don't require much storage and have few, if any, dependencies.

The model design proposes the following contracts.

Table. 2 Model Design

EToken	A contract that generates tokens for use in the proof-of-concept. Etokens are used to calculate gas costs and rental fees.
Interface	The RPC is managed by this composite contract, which also connects all other contracts.
Migrations	Migrations are JavaScript files that aid in the deployment of Ethereum contracts. These files are in charge of staging deployment tasks and are created with the expectation that deployment requirements would vary over time.
TenantInfoDb	Tenant information is stored in a database contract. Personal information and addresses are among the items maintained for each renter. For each Tenant, a Tenant-struct is produced that has the corresponding data as well as a next and prev-attribute that can be used to iterate through them using a doubly-linked list.
CMC	CMC stands for contract-managing-contract and comprises a collection of different contracts. All other contracts must be CMC-connected or inherit from the CmcEnabled class.
Tenant	Application logic contract for managing Tenant requests such as obtaining and making payments, altering the consent-level for a certain home description-Admin tuple, and so on.

Landlord	Landlord requests are handled using an application logic contract. Adding new room features, making a payment, or verifying that a given feature has been uploaded are examples of these.
Contract Supplier	Contracts from Cmc are obtained using this interface.

3.2.2 Model Design Constructs

Modules were created from the real-estate model. The parts were arranged according to the tasks that needed to be completed. The functional components of the model are listed below.

i. **The Smart-contract -** To create an Ethereum smart-contract, follow these steps. The computer language Solidity was utilized. It's a general-purpose programming language with a contract (class) and methods for defining it. The primary goal of Solidity is to send and receive digital tokens as well as to store states.

ii. **Ethereum Wallets -** Three types of Ethereum wallets were built to properly represent the study objectives: one for the renter, one for the landlord, and one for the contract.

iii. **Dapp -** Dapps are used by front-end users to connect to the block-chain using Smart-contracts (Front End - Smart-contract - Block-chain). The Ethereum Truffle development framework was utilized.

3.2.3 Overview of Smart-contract Model Design

The accompanying overview of the system of smart-contracts for the Real-estate Management PoC figure was useful in managing the model throughout its full life cycle, from building up a framework to drawing up specific plans to executing and concluding the project. It explains what the system is and what it is capable of. Although, for the purpose of clarity and relevancy, not all smart-contracts are included in the PoC.

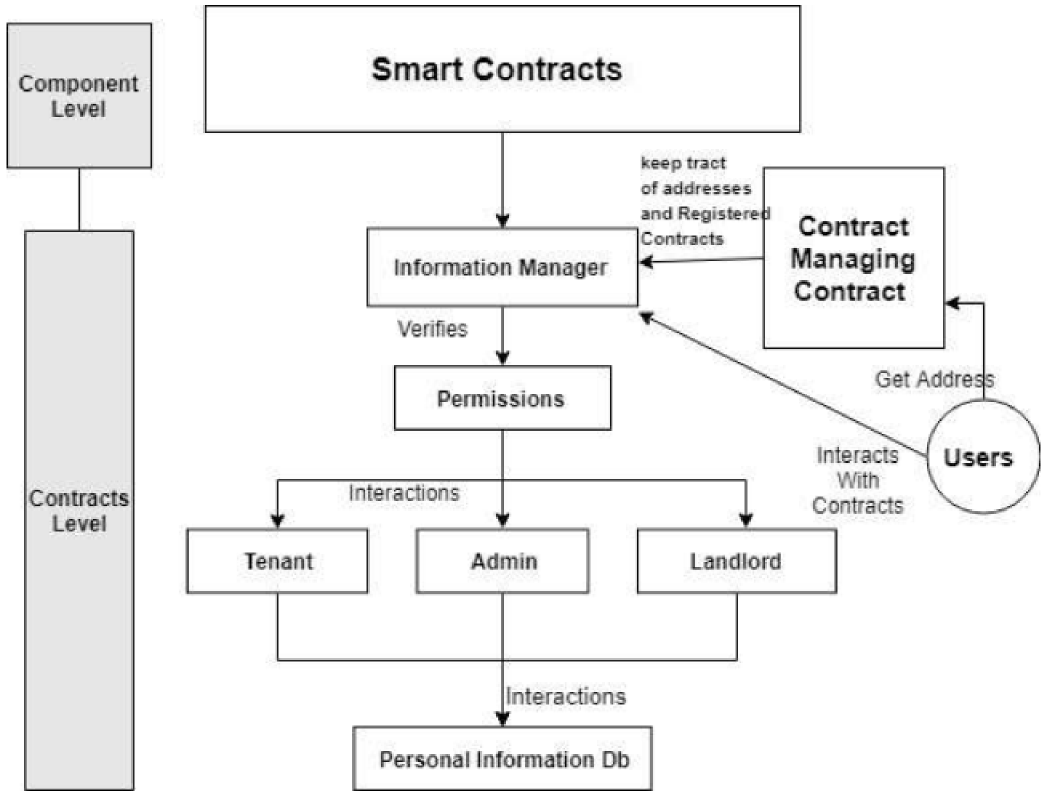

Fig. 3.4 Overview of Smart-contract Model.

3.3 Model Evaluation

The model evaluation approach was based on the idea that a research's purposes, goals, or targets are determined at the outset, and that the evaluation process will be used to determine whether the goals have been met and, if not, why not questions will be used to correct any missing functionalities. The prototype was assessed utilizing goal-based assessment techniques, with the main goal of determining if the prototype achieves the established technical goals.

3.3.1 Description of Evaluation Criteria

"Functionality, completeness, consistency, correctness, performance, dependability, usability, fit with the organization, and other important quality qualities" were used to evaluate the artifact (model). The artifact was assessed using all criteria due to the novelty of block-chain technology, the breadth of the thesis, and the extension of the PoC. Only when the technology is really novel and alternative approaches are unavailable may a descriptive assessment be employed.

Because the Block-chain-based Real-estate Model meets these characteristics, it was assessed using two descriptive assessment methodologies.

i. **Informed** argument to develop a persuasive argument for the artifact's value, leverage facts from the knowledge base, such as other studies.

ii. **Scenarios** to show the artifact's utility, a thorough scenario was created.

3.3.2 Selection Criteria for Model Testing

Purposive sampling was used to pick the agencies for model testing, ensuring that only those agencies that use the IT service were included in the research to assess the model's appropriateness. Purposive sampling (also known as judgement, selective, or subjective sampling) is a sampling approach in which the researcher chooses individuals of the population to participate in the study based on his or her own judgement. Purposive sampling was utilised in this study to guarantee that all agencies that have embraced IT-based services were included in the sample frame.

3.4 Observations

The research technique and methods utilized in confirming the viability of the suggested concept were discussed in the preceding section, which was centered on attaining the study's objectives and appropriately addressing the research questions. It explained the POC (proof of concept) and PDIOI (Planning, Design, Implementation, Operation, and Improvement) approaches.

CHAPTER 4

RESULTS AND DISCUSSION

4.0 Introduction

This chapter summarises the study's findings in accordance with the research goals outlined in section 1.3. A study on existing real-estate property management models is offered, as well as a prototype of a block-chain-based smart-contract implementation model to aid real-estate crews and a verification report on the operation of the real-estate block-chain smart-contract model prototype.

4.1 Design of Block-chain Based Smart-contracts Model for Real-estate

The design of a block-chain-based smart-contract paradigm for real-estate is given in this section. This relates to the achievement of the study's second research aim. To offer functional requirements for the PoC and model objectives, the three separate user archetypes are outlined first, along with user stories. There are also more details on the PoC, such as quality attributes and how to build up a smart-contract system using a block-chain. Following that, a diagram of prototype interactions on the block-chain is displayed, as well as interactions between smart-contracts. The proposed solution to the given problem makes use of block-chain technology's decentralised, trustless, and immutable qualities, as well as smart-contract permissions. It should be emphasised, however, that this solution has not fixed any security or privacy issues outside of the block-chain. In the model debates, some of the biggest off-chain challenges are highlighted.

4.1.1 Model Functional Requirements

This thesis' implementation is restricted to three archetypical users: Admin, Tenant, and Landlord. User stories from a focused group were developed to describe the many functional needs that users have on the application, as illustrated in the table below. Following that, the various user kinds are further specified. The user stories and criteria were simplified to the absolute minimum while the proof of concept was kept at a usable and secure level.

Table. 3 Defining Functional Requirements of the Model

Admin	▪ Identifying in a cryptographical manner upon accessing tenant information, so that no unauthorized entities can access it.
Landlord	▪ Should be able to access the records of the tenants and the payments. ▪ Verifying the tenant side identity. ▪ Keep records over a collection of the rent amount. ▪ Adjusting the rent level. ▪ Should be able to collect rent from smart-contract each month according to requirements. ▪ Identifying in a cryptographical manner upon accessing tenant information, so that no unauthorized entities can access it.
Tenant	▪ Should be able to create and edit accounts through the registration process. ▪ Identifying in a cryptographical manner upon accessing tenant information, so that no unauthorized entities can access it. ▪ Sharing information with Landlord and Admin should be at ease. ▪ Rental payment should be carried in the form of cryptocurrencies. ▪ Bills for Gas, Electricity, and Telephone should be shared through Smart-contracts. ▪ Should be able to check account balance and expected payment dates.

The model was created utilizing open source technologies in order to realize the notion. In interactive functionalities, the model was built with the light server, truffle framework, nodeJS, NPM, and web3 JSON RPC(s). The user stories listed above may be summarised in the table below to provide a functional overview of the model.

Table 4 Model Functional Overview

The Model Functionality	How to realize
1. User Registration	Before using any of the model's features, all users must first register with the model. This is to record the user's personal information as well as their authentication credentials.
2. User authentication	Before allowing them to use any of the system functionalities, the suggested model required that all users be registered. Those who have registered must log in using their account addresses and passwords.
3. User de-registration	When a tenancy contract expires, the tenant's information is transferred from an active account to a repository.
4. Rental fee payment	The approach enables Ethereum-based rental payments. This proof-of-concept makes use of newly produced crypto coins to enable infinite testing.
5. Transaction record management	The model enables the transaction to be recorded on the block-chain.
6. Report generation	Users can produce reports on transactions using the model.

4.1.2 Users Overview and Interaction with Block-chain

Tenants, administrators, landlords, and hosting service suppliers (EVM, Github, and Metamask) are among the participants in the block-chain-based model for real-estate administration PoC.

a) **Tenants** are assumed to be private persons or group of people that rents and occupies a house, office, or anything like that.

b) **The Lanlord** is assumed to be a person or group that owns a house, apartment, condominium, or real-estate which is rented or leased to an individual or business.

c) **System administrator**, is a person who is in charge of the maintenance, configuration, and reliable running of computer systems, particularly multi-user computers like servers. The system administrator's goal is to make sure that the computers they administer have enough uptime, performance, resources, and security to suit the demands of the users while staying within a budget.

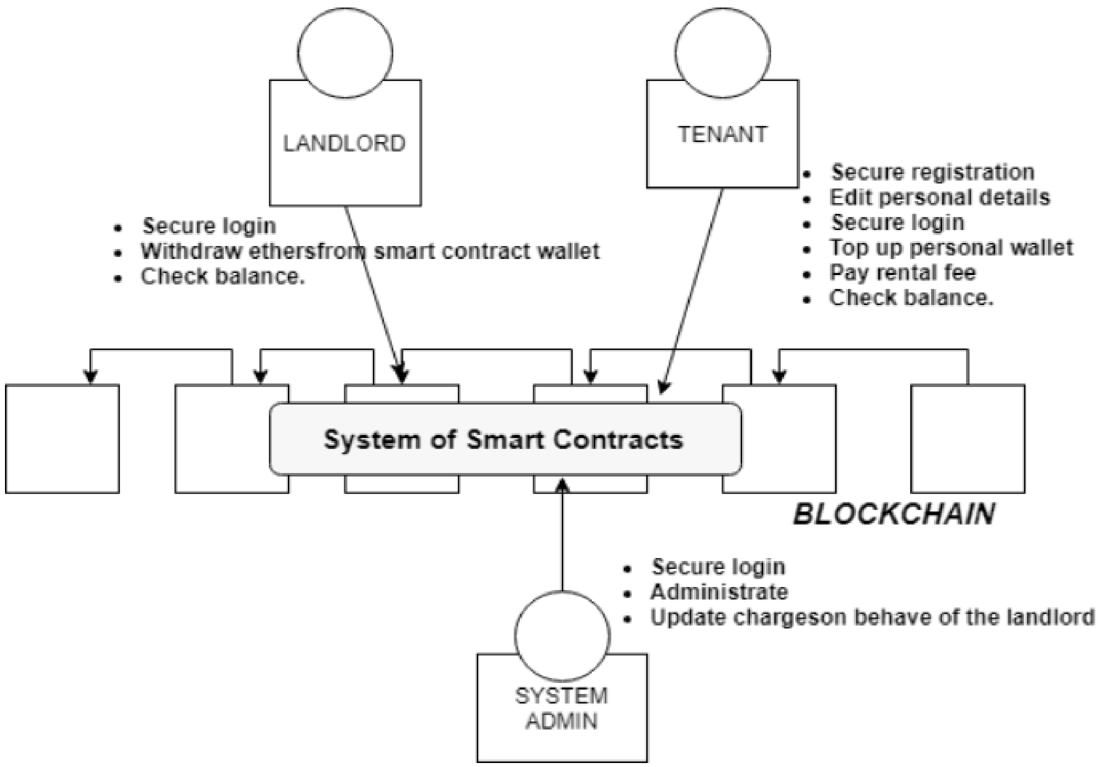

Fig. 4.1 Overview of different users and their interaction with block-chain

There are some criteria that apply to the entire system rather than just one user. Some of them are partially detailed in the user stories, but they are expressly written below for completeness and are applicable to users who are not in the system.

R1. A non-registered person must be unable to join the model network.

R2. Only those who are authorized to connect to the network should be able to do so.

R3. Immutable traceability must be embedded into the model, such that it is feasible to see:

i. All rental fee payment is captured in block-chain.
ii. Account balance before and after the transaction.
iii. Old transactions are to be displayed.

Immutable traceability requires a history of changes to the rental cost and payment, as well as making it extremely difficult, if not impossible, to change it after the fact.

R4. Smart-contracts must be interchangeable without requiring the removal of the complete model or the changing of addresses for contracts that interact with humans.

4.1.3 The Model Starting-Up Activities

The command truffle init is run from the command line in the project directory to start the basic truffle project. After this procedure is performed, the following components are added to the project structure: The Contracts Directory contains Solidity contracts, the Migrations Directory contains scriptable deployment files, and the Test Directory contains test files for testing your application and contracts, and truffle.config.js is a Truffle configuration file. The validators are configured, the block-chain is established, and transactions may commence in the order depicted in the diagram below.

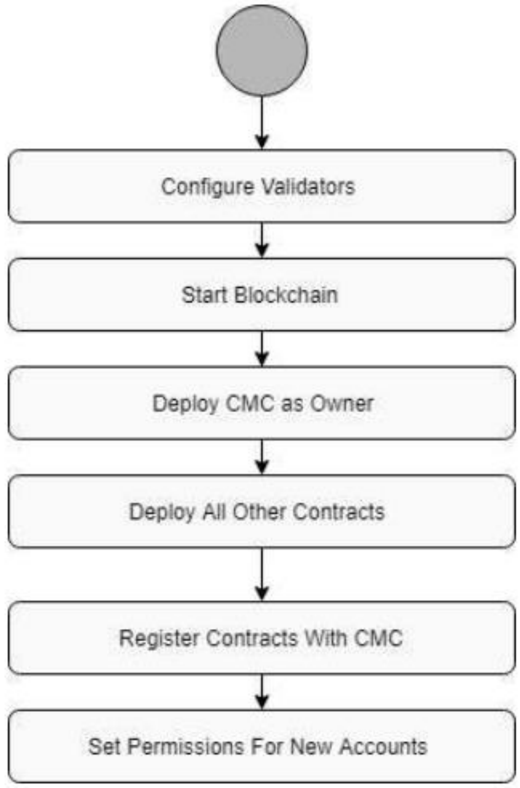

Fig 4.2 How starting activities work for the model

4.1.4 Truffle Framework

The proof-of-concept approach isn't complete without smart-contracts. A block-chain is also required, as well as a key management mechanism. Additionally, a distributed or centralised consensus on who is permitted to join the network as a Tenant or Landlord must be created. Due to its efficient consensus mechanism compared to the accessible alternative, the specifics of the consensus algorithms and the underlying reasoning for the selected block-chain Truffle platform were utilised (parity). As a result, the concerns around an adequate consensus process have been resolved. Truffle is a development environment, testing framework, and asset pipeline for Ethereum Virtual Machine (EVM)-based block-chains that aims to make life simpler for developers. In the Ethereum ecosystem, it has become one of the most extensively used IDEs and frameworks. It is used by developers to create and deploy Dapps for testing reasons, and it has a number of features that appeal to consumers with a Web 3.0 development background. With Mocha and Chai automated contract testing, it features built-in smart-contract compilation, linking, deployment, and binary management. It's also known as Scriptable deployment & migrations framework and Configurable build pipeline with support for bespoke build procedures.

- **Truffle Framework Environment Setup**

The following requirements and software must be set in order to utilise truffle framework. NodeJS, Web3, Node Packet Manager NPM, and light server are among them.

a) NodeJS v8.9.4

Node.js is a cross-platform, open-source JavaScript run-time environment that allows you to run JavaScript code outside of a browser. The V8 JavaScript runtime engine is used by both JavaScript and Node.js. This engine turns JavaScript code into machine code that is quicker. Node.js is lightweight and efficient because it employs an event-driven, non-blocking I/O architecture.

b) The Node Package Manager (npm)

npm is a package manager for the JavaScript programming language that was created by Isaac Z. It is built entirely in JavaScript. It's the default package manager for Node.js, which is a JavaScript runtime environment. It consists of a command-line client, commonly known as npm, and the npm registry, an online database of public and paid-for private packages. The client may access the registry, and the npm website can be used to browse and search for available packages. npm is in charge of the package management and the registry.

c) Lite Server

Single Page Apps are supported by Lite-server, a lightweight development web server (SPAs). Lite-server is a modified wrapper for Browser Sync that makes serving Single Page Applications straightforward (SPAs). It's a lightweight development-only node server that serves a web app, opens it in the browser, refreshes when html or JavaScript changes, injects CSS updates through sockets, and offers a fallback page if a route isn't found. Browser Sync is a lightweight development server that is extremely fast. It provides static content, detects changes, reloads the browser, and allows for a variety of modifications. Browser Sync is used by Lite-server, which allows for configuration overrides through a project's own bs-config.json or bsconfig.js file.

d) Metamask

Metamask is a browser extension that enables Ethereum transactions on ordinary websites. It's a browser extension that lets you visit the dispersed web of the future. It enables the execution of Ethereum Dapps in a browser without the need for a complete Ethereum node. This aids Ethereum adoption by bridging the gap between Ethereum user interfaces, such as Mist browsers or Dapps, and ordinary web browsers like as Chrome. MetaMask injects a JavaScript library named web3.js into the namespace of each website your browser opens, according to metamask (2018). MetaMask also allows users to designate which Ethereum node these requests should be sent to. The ability to send queries to nodes other than the user's computer is significant since it implies that individuals may use Ethereum without having to download a node with a 10+GB block-chain on their machines. Chrome, Firefox, Opera, and the new Brave browser all support the MetaMask add-on (Coin, 2018). This study downloads MetaMask on the Chrome browser in order to utilise it.

e) Web3

Web3.js is a set of libraries that allow you to communicate with a local or distant Ethereum node over HTTP or RPC. It's for Ethereum's block-chain as well as smart-contracts. The whisper protocol for p2p and broadcast communication, the swarm protocol for decentralised file storage, and web3-utils assistance functions for Dapp development are also included. Web3.js uses the JSON RPC (Remote Procedure Call) protocol to communicate with the Ethereum Block-chain. As illustrated below, Web3.js supports JSON RPC queries to an individual Ethereum node in order to read and send data to the network.

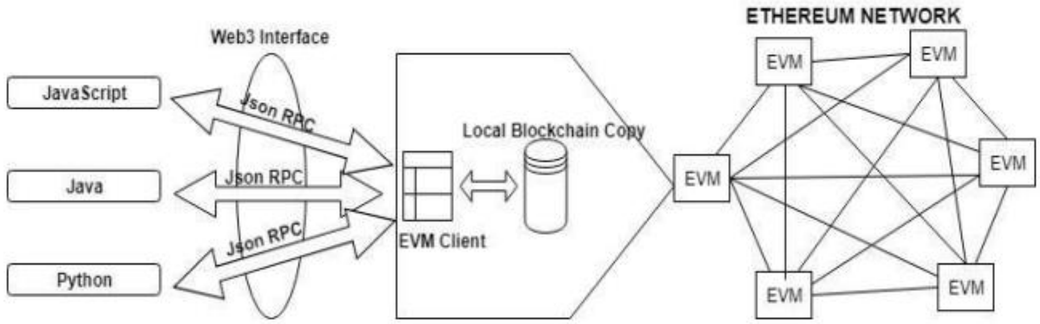

Fig. 4.3 Interaction with local Ethereum node

4.2 Development of Block-chain-Based Smart-contracts Model for Real-estate

This section shows how the researcher met the study's third research aim, which required him to create a block-chain-based smart-contract model for real-estate.

4.2.1 User Registration and Authentication

To register, you must first create a new user account, which is a database record that describes how you will authenticate your identity. This allows model Participants to sign up in a timely way, saving time that would otherwise be spent manually going through illegible or erroneous paperwork. To authenticate you, you must provide proof that your identity matches that of your user account.

i. User Registration

The registration procedure is the model's entrance point, and it caters to two categories of system users: tenants and landlords. In order to establish their identity, registered users often furnish the system with certain credentials (such as their address and password). This is done as part of the sign-in procedure. Real-estate crew systems would frequently enable any user to register simply by selecting a register function and entering these credentials for the first time. Registered users have access to additional features not available to unregistered users. Tenants must register by submitting their information and creating an eight-character password throughout the registration procedure.

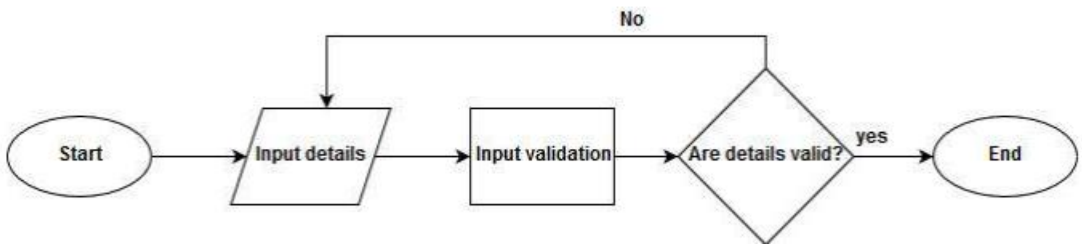

Fig. 4.4 User Registration Process

ii. User Authentication

The user authentication procedure establishes proof that the user's identity matches the one stated in the user account. This assures that system users are cryptographically recognised, preventing unauthorised entities from accessing the network.

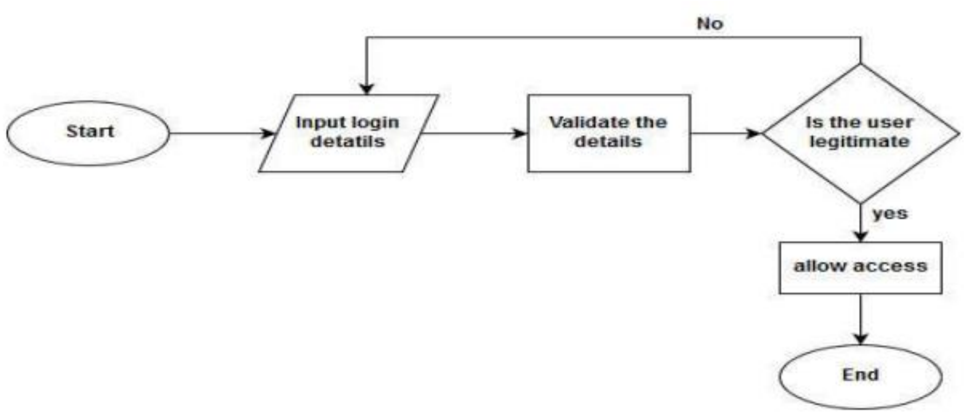

Fig. 4.5 User Authentication Process

4.2.2 Development of Rental Payment Mode

A rental charge is a payment given for the temporary use of another person's good, facility, equipment, service, or property. In this study, it refers to a tenant's payment of a certain sum at predetermined periods in exchange for the right to inhabit or use another's property. A gross lease is one in which the tenant pays a set from month to month rent and the landlord covers all of the property costs that the owner incurs on a regular basis. The renters are considered to be paying a gross lease in this study.

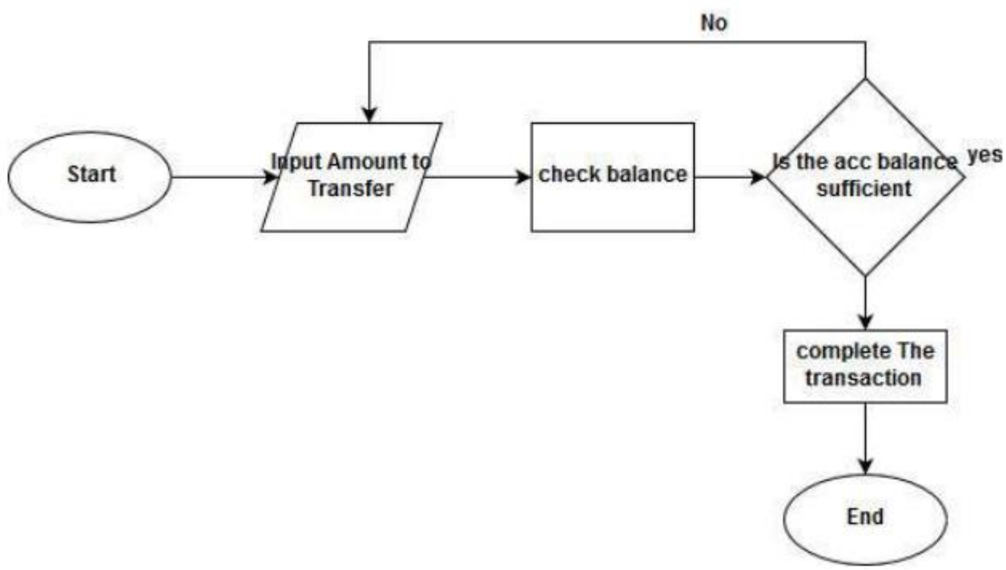

Fig. 4.6 Rental Payment Structure

4.2.3 Deployment of Smart-contracts to Block-chain Network.

A project is deployed to an Ethereum Test Network (testnet), which replicates Ethereum, before it is launched on the Ethereum block-chain. The Testnet is a platform for putting smart-contract innovations to the test. It's essentially an Ethereum clone that lets you to deploy and test smart-contracts without paying real money. This allows developers to test the waters before investing real money. On a testnet, ether and tokens are simple to get and have no real-world value. kovan, Rinkeby, and ropsten are the three testnets currently in operation, and each performs identically to the production block-chain (where actual Ether and tokens reside). The Rinkeby test network was chosen because of its effective consensus process. The Geth team created Rinkeby, a block-chain based on proof-of-authority. In Rinkeby, test ethers cannot be mined; instead, they must be requested through the faucet. Its decision is justified by the convenience and ease with which test ethers may be obtained, as well as the efficiency of the consensus procedure. To deploy a project, you must first download the Rinkeby node, which contains all of the time transactions. MetaMask may be used to transmit Ether and tokens when it has been downloaded successfully. Switching from Ethereum's main network to Rinkeby is similarly simple. One's balances and transaction history should update in MetaMask to reflect the selected network. It's worth mentioning that Ethereum addresses and private keys are valid on all testnets. As a result, it's crucial not to transmit Ether or tokens from the Ethereum mainnet to a testnet address. The block-chain-based smart-contracts concept for real-estate was shown by running a PoC on a Rinkeby testnet based Transaction after successful deployment. This was done following the successful deployment and completion of the proof-of-concept project.

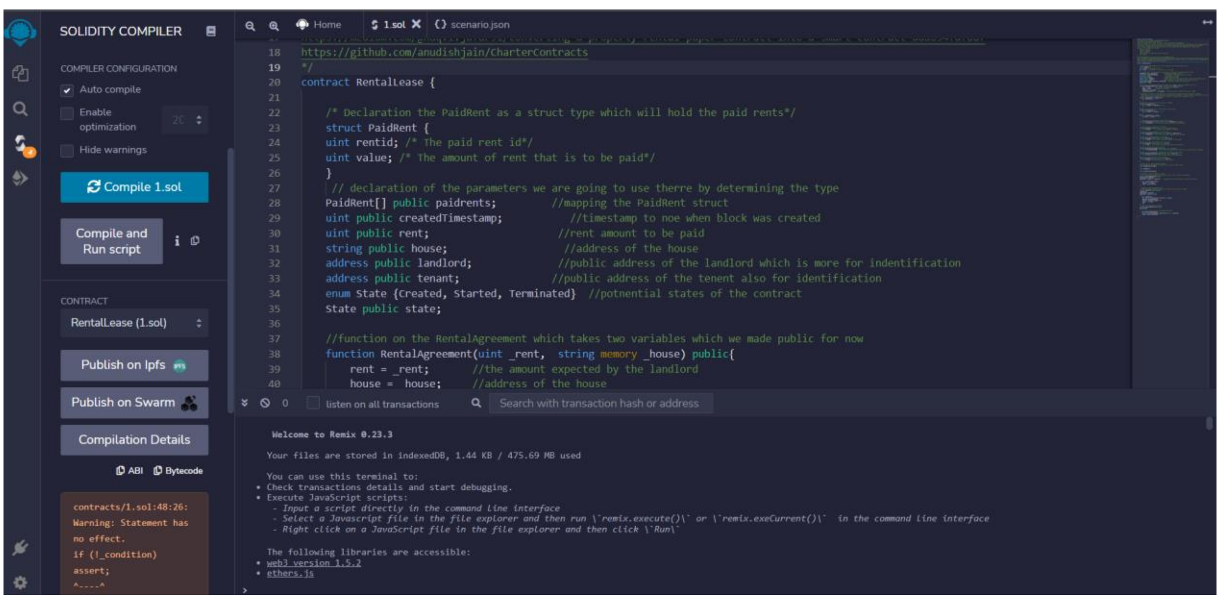

Fig 4.7 Compiling the solidity

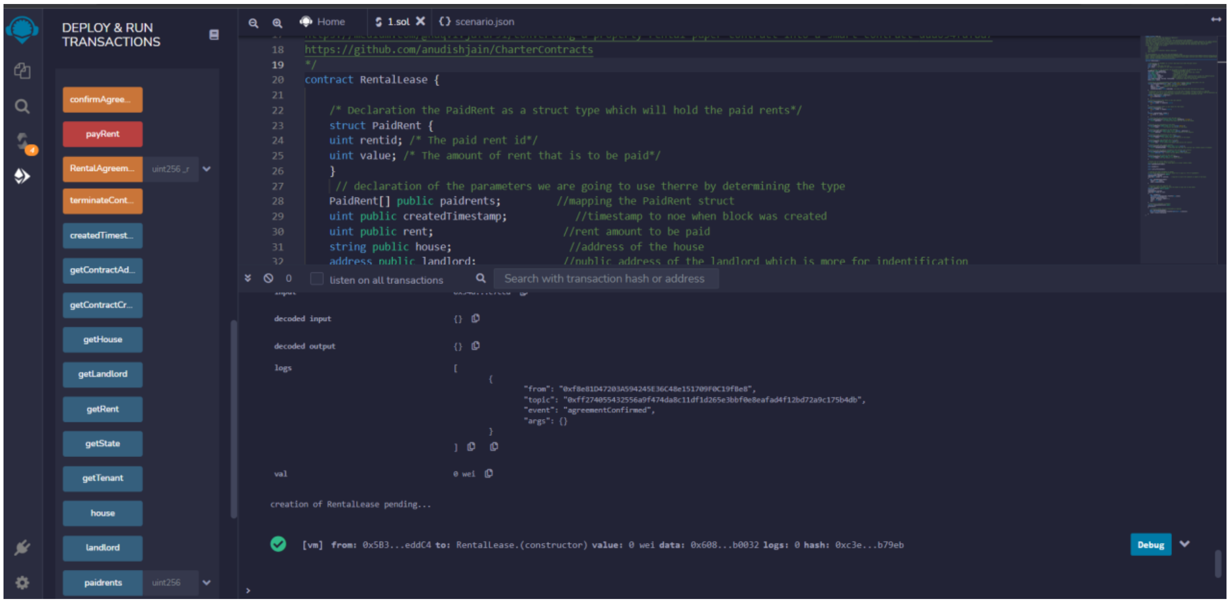

Fig 4.8 Deployed to our testnet

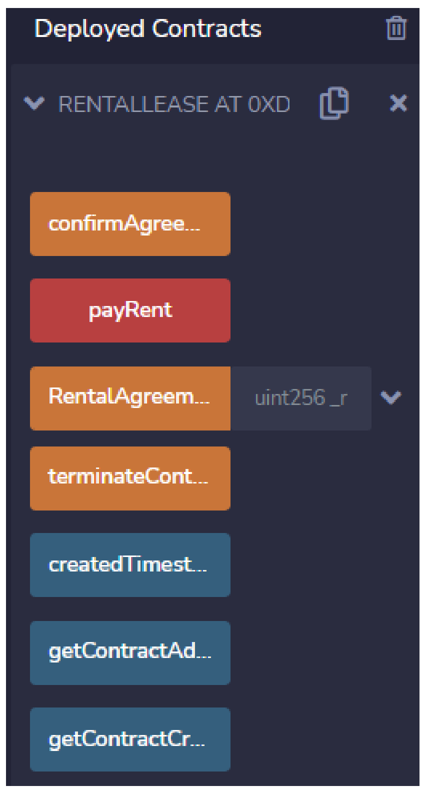

Fig 4.9 All contract function has been created

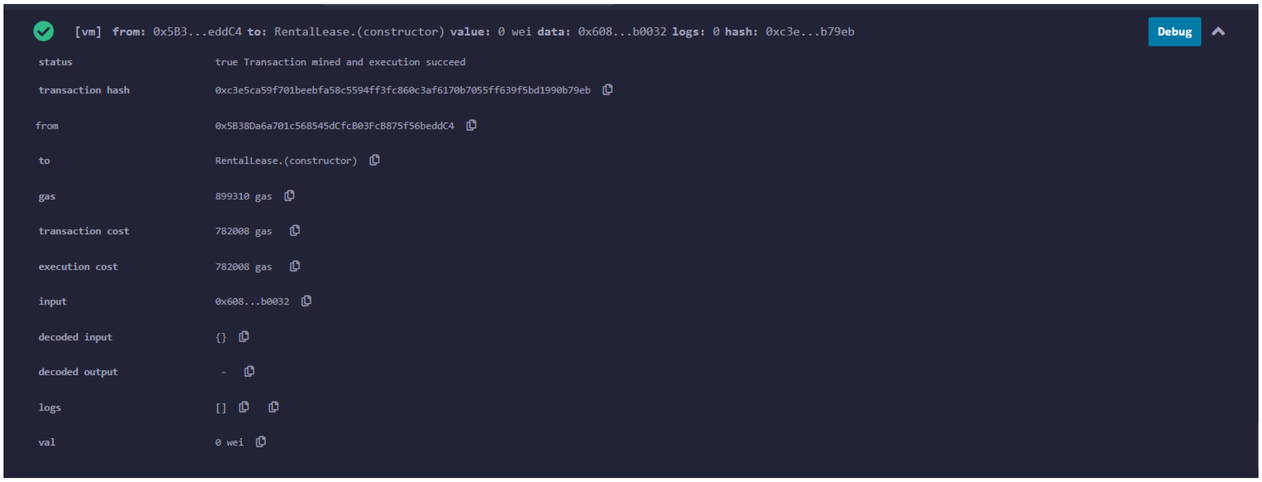

Fig 4.10 Terminal that shows every transaction requirement

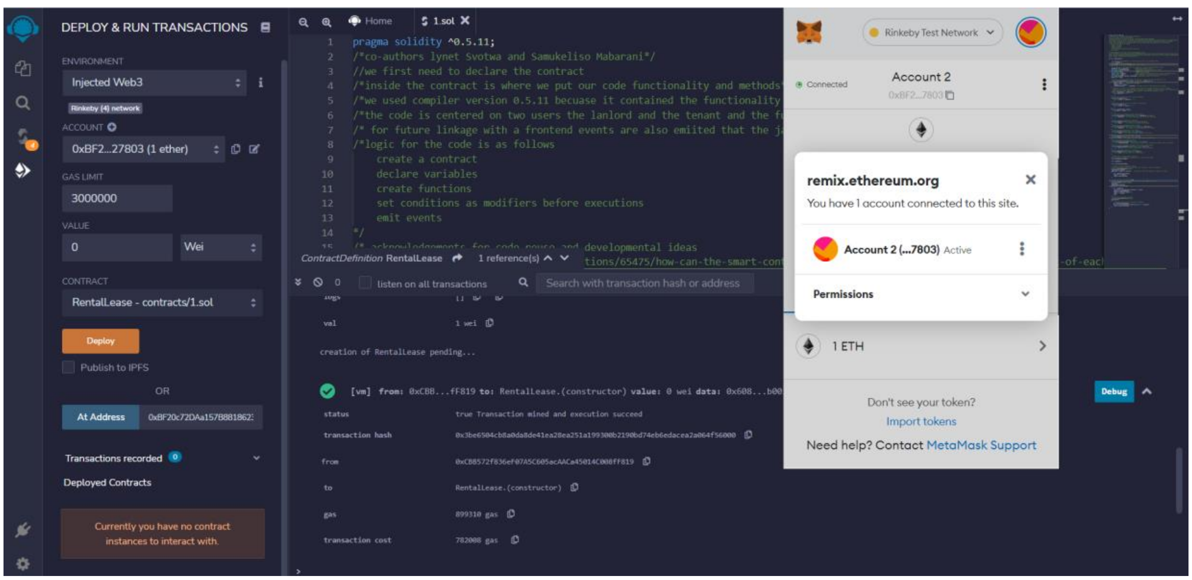

Fig 4.11 Connecting our injected web3(metamask) wallet to remix ide

4.2 Observations

The artefact and the thinking behind it are a compelling justification for the use of such an application in the real-estate business, given the considerations made to functionality, completeness, and performance in terms of security, immutability, and privacy.

CHAPTER 5

CONCLUSION AND FUTURE SCOPE

5.0 Introduction

In this chapter, a proof-of-concept model was created to act as a totally decentralised electronic block-chain-based real-estate management plan. A system of smart-contracts was built utilising the Solidity programming language in conjunction with public block-chain architecture and standard cryptography tools to establish a peer-to-peer network safe enough to hold transaction records and personal information. The generated artefact was then assessed against established design research criteria and found to meet all of the criteria. Despite the fact that the assessment requirements were met, it is vital to note that no security claims outside of the PoC may be made based on this thesis, as stated in the study's scope. The study's findings, additional research areas, and suggestions are listed below.

5.1 Summary

The existing management practises in the real-estate market have inefficiencies and flaws, which prompted this study. This study looks into block-chain technology as a possible solution. Each rental transaction record is bundled into a block with a unique header, and each block is identifiable by its block Txhash (transaction hash) and other information /block-chain characteristics, as detailed in Chapter 2. Each rental transaction record is bundled into a block with a unique header, and each block is identifiable by its block Txhash (transaction hash) and other information /block-chain characteristics, as detailed in Chapter 2. A block header is hashed repeatedly by miners by changing the nonce value as part of a routine mining practise. They want to develop a proof of work through this effort, which will allow miners to be paid for their contributions to keeping the block-chain system functioning and maintaining consistency. It has been established that housing transactions are recorded on a distributed ledger, resulting in increased transparency. Anyone may check that the system is operating properly thanks to public verifiability. Everything is saved and authorised in a decentralised manner, assuring transaction integrity and reliability. Various parties can make use of these records. Payment of rent fees directly to the landlord's account decreases transaction costs, indicating that this approach meets the user's needs and the study's goals.

The ideas presented in the thesis, as well as the design of the application and the thinking surrounding it, have all been answered by the concepts summarised in the thesis, as well as the architecture of the application and the rationale behind it. In this part, the conclusion for each of the objectives is offered.

5.2 Conclusions

Although the goal of this research was to tackle a specific problem in the real-estate management industry, it is impossible to ignore the potential spillover effects it may have on other industries. It's essentially a paradigm that allows users to register information, conduct safe cryptocurrency transactions, and then share it with certain partners on a distributed network in a highly regulated manner. Consider a collection of banks, and potentially even other regulated companies, that rely heavily on customer and transaction information. Basically, any firm or organisation that provides financial services, such as an internet supplier or a mobile phone operator, falls under this category. By law, they are all required to know personal information about their clients or their previous transactions. Let's now apply the notion of the Point of Contact to this issue. Using slightly modified smart-contracts, a client registers or carries and encrypts information on the block-chain. When a bank or other entity need access to such information, they simply send a request to the consumer, who can accept or refuse it. When a bank or other entity need access to such information, they simply send a request to the consumer, who can accept or refuse it. What distinguishes it from a traditional centralised server is that it has immutable traceability, and, more crucially, users may have the power and right to dispute how firms use their personal information or transaction history. Information sales would have to be consensual on a far higher level than they are now in most systems. Another use case may be in a huge corporation, where information sharing and transaction history are critical but difficult to achieve when dealing with secret or sensitive data.

5.3 Challenges Faced During the Study

i. Changes and updates: updating the Solidity environment, dependencies, and development tools on a regular basis while maintaining backward compatibility was a major problem.

ii. The Dark Web and the Black Market: Since its inception, Bitcoin has been linked to the shadowy worlds of the black market and the dark web. Because this is the public's first encounter with block-chain technology, a relationship has developed between Bitcoin, altcoins, and the technology that underpins them. Users associated the suggested paradigm with these concerns during the investigation.

5.4 Future Scope

Ethereum and other digital currencies should have a legal framework established by the government. Although many governments are considering developing their own Bitcoin-like cryptocurrency, as evidenced by the literature, the process should entail sensitising citizens and financial institutions. This will lessen potential customers' opposition to the real-estate management concept based on block-chain smart-contracts.

References

[1] Lucas M Palma, Martín AG Vigil, Fernando L Pereira, and Jean E Martina. Block-chain and smart-contracts for higher education registry in brazil. International Journal of Network Management, 29(3):e2061, 2019.

[2] Ana Lidia Franzoni, Cristina Cárdenas, and Alejandro Almazan. Using block-chain to store teachers' certification in basic education in mexico. In 2019 IEEE 19th International Conference on Advanced Learning Technologies (ICALT), volume 2161, pages 217–218. IEEE, 2019.

[3] Lucas M Palma, Martín AG Vigil, Fernando L Pereira, and Jean E Martina. Block-chain and smart-contracts for higher education registry in brazil. International Journal of Network Management, 29(3):e2061, 2019.

[4] Ante, Lennart, "Smart-contracts on the block-chain – A bibliometric analysis and review"(22 Oct, 2020). Available at : https://www.sciencedirect.com/science/article/abs/pii/S0736585320301787?via%3Dihub

[5] Muhamed Turkanović, Marko Hölbl, Kristjan Košič, Marjan Heričko, and Aida Kamišalić. Eductx: A blockchain-based higher education credit platform. IEEE access, 6:5112–5127, 2018.

[6] Matthew B Hoy. An introduction to the blockchain and its implications for libraries and medicine. Medical reference services quarterly, 36(3):273–279, 2017

[7] Mahmood A Rashid, Krishneel Deo, Divnesh Prasad, Kunal Singh, Sarvesh Chand, and Mansour Assaf. Teduchain: A platform for crowdsourcing tertiary education fund using blockchain technology. arXiv preprint arXiv:1901.06327, 2019.

[8] Sabine Kolvenbach, Rudolf Ruland, Wolfgang Gräther, and Wolfgang Prinz. Blockchain 4 education. In Proceedings of 16th European Conference on Computer-Supported Cooperative Work-Panels, Posters and Demos. European Society for Socially Embedded Technologies (EUSSET), 2018.

[9] K Palanivel. Blockchain architecture to higher education systems.

[10] V. Buterin, Ethereum Foundation, A Next Generation Smart Contract & Decentralized Application Platform, 2015.

[11] Satoshi Nakamoto "A Next Generation Smart Contract and Decentralized Application Platform" https://www.researchgate.net/publication/348863176_A_Next-Generation_Smart_Contract_and_Decentralized_blockchain_Platform_A_case_study_on_Ethiopia, January-June, 2020.

[12] Fabian Vogelsteller, Vitalik Buterin "Ethereum Improvement Proposals", https://eips.ethereum.org/EIPS/eip-20, 19 Nov 2015

[13] Satoshi Nakamoto "Bitcoin: A Peer-to-Peer Electronic Cash System", https://bitcoin.org/bitcoin.pdf

[14] Harish Sukhwani , Nan Wang , Kishor S. Trivedi, Andy Rindos " Performance Modeling of Hyperledger Fabric (Permissioned Blockchain Network), https://ieeexplore.ieee.org/document/8548070 , 29 November 2018

[15] https://www.linkedin.com/company/republic.co/

[16] https://www.linkedin.com/company/safewirefraudfree/

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