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Land Registry Traceability System Based on Blockchain Technology

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Dedication

بسم الله الرحمن الرحيم

Every time I complete an important step in my life, I pause to look back and remember all those who shared both the joyful and difficult moments with me. Those who helped me without asking for anything in return, supported me unconditionally, and loved me without measure. These are the people to whom my happiness is deeply connected—people who stand by me through tears and triumph alike.

I dedicate this humble act as a token of my gratitude and respect:

To my dear parents.
To my teachers and all those to whom I owe a debt.
To my brothers and sister.
To all my family.

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Finally, I thank my family and friends for their unwavering support and motivation, which helped me remain focused and committed to completing this work.

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List of Acronyms

ABI Application Binary Interface

BFT Byzantine Fault Tolerance

CSS Cascading Style Sheets

DApp Decentralized Application

DB Database

DPoS Delegated Proof of Stake

ETH Ethereum

Ganache Personal Ethereum blockchain for testing

HTML HyperText Markup Language

HTTPS Hypertext Transfer Protocol Secure

IDE Integrated Development Environment

JS JavaScript

PBFT Practical Byzantine Fault Tolerance

PHP Hypertext Preprocessor

PoS Proof of Stake

PoW Proof of Work

RDBMS Relational Database Management System

RPC Remote Procedure Call

SQL Structured Query Language

SOL Solidity

SSL Secure Sockets Layer

Truffle Ethereum development framework

UI User Interface

UX User Experience

VS Code Visual Studio Code

General Introduction

Land ownership and registration are crucial components of property management in any country, directly influencing individual rights, investment, urban development, and economic growth. However, traditional land registration systems often face challenges such as bureaucracy, delays, fraud, and lack of transparency, which erode public trust in relevant institutions.

In response to these issues, blockchain technology has emerged as a promising solution due to its inherent characteristics of transparency, immutability, and decentralization, making it well-suited for securely recording and tracing property ownership. This project presents the development of a digital land registry and traceability system based on blockchain, integrated with a MySQL database for centralized administrative management. The system is designed with government as the main authority and is modeled on the Algerian land registration context.

The first chapter introduces the problem and project motivations; the second chapter provides the theoretical foundation and reviews relevant studies and global implementations; the third chapter (not detailed here) focuses on technical design and implementation using HTML, PHP, MySQL, Web3.js, and MetaMask; and the fourth chapter discusses the results, system benefits, challenges encountered, and future recommendations.

Ultimately, this project aims to lay the groundwork for a transparent and secure real estate registration platform that protects ownership rights and reduces the risk of tampering or data loss through the integration of modern technologies with practical land administration needs.

Chapter 1
Land Registry Systems

1.1 Introduction

Employees in land registry offices face numerous challenges during the land registration process. Bureaucratic complexity, reliance on paper documents, and lengthy administrative procedures cause delays in transactions and increase disputes over ownership. The absence of a unified and accurate system complicates the tracking of property ownership, leading to errors, document fraud, and risks to property rights. Given these challenges, land registration plays a crucial role in protecting property rights, ensuring transparency in real estate transactions, and supporting investment and urban planning [3]. With the advancement of information technology, digital transformation has become essential to improving the efficiency of land registration [7]. Utilizing modern technologies such as blockchain and artificial intelligence can expedite processes, reduce errors, and provide secure and easy access to property records [8], paving the way for a more organized and sustainable future for land registry systems.

1.2 Land registry

1.2.1 Definition of Land Registry Systems

Land registration is a legal and administrative process through which property transactions related to land are officially recorded by a designated government authority. This process often requires the payment of specific fees, following the laws and regulations in place. The primary objective of land registration is to document land ownership and related rights, helping to protect property, simplify real estate transactions, and prevent illegal actions [3]. The land registry contains accurate information about the location, full description of the property, and any rights attached to or affecting it. It also identifies the people involved in these rights, providing a clear legal reference for real estate deals and resolving disputes. The type of information recorded and the level of legal protection provided by land registration vary depending on the laws and regulations of each jurisdiction [3].

1.2.2 History of Land Registration Systems

The land registration system in Algeria has evolved through various historical stages, influenced by the political and legal changes the country has experienced. During the Ottoman Era (1518–1830), land transactions were managed according to Islamic law, with contracts and property rights documented by judges and legal scribes using manual records and oral testimonies. In the French Colonial Period (1830–1962), the colonial administration introduced a personal registration system [7] that recorded property transactions based on the owner's name rather than the land itself, creating complications in tracking and clarifying ownership. After independence in 1962, Algeria inherited this system, and during the Post-Independence Era (1962–1975), it continued to face challenges such as the absence of a unified and accurate method for documenting property rights and transactions. A significant change occurred with the 1975 Land Law Reform (Order No. 75-74, November 12, 1975), which introduced the real folio system (*système du livre foncier*), focusing on registering properties based on the land itself rather than the owner's identity. This shift simplified ownership tracking and helped reduce legal disputes [7].

1.3 Types of Land Registration Systems

1.3.1 Personal registration system

This system focuses on registering property rights based on the names of the owners. Real estate transactions are recorded in registers organized alphabetically by the names of individuals, without assigning a separate file for each property. This system is considered less accurate, as it may lead to difficulties in tracking the property's history and overlaps in ownership, making it complex to obtain complete information about a specific property [3][7].

1.3.2 Eye registration system (Title Registration System)

This system focuses on the property itself as an independent unit. Each property is given a dedicated file in the land registry containing all related details, including its location, boundaries, area, and any rights or transactions associated with it. This system is more accurate and reliable, making it easier to track ownership history and reducing potential disputes [3][7].

1.4 Land Registry in Algeria

1.4.1 Legal Framework

The land registration system in Algeria is based on Order No. 75-74 issued on November 12, 1975, concerning the preparation of a general land survey and the establishment of a modern land registry. This system follows the real registration approach, where each property is registered as an independent unit. A dedicated property file includes all essential details such as location, boundaries, area, and associated rights [7]. The main goal of this system is to ensure the protection of property rights, reduce disputes, and simplify real estate transactions [3].

1.4.2 Key Authorities

The Land Registry Office is the main authority responsible for managing the land registry. It oversees the registration of property rights and the issuance of property records, operating under the supervision of the Ministry of Finance [3]. The Land Survey Department is responsible for conducting the national land survey and precisely determining the boundaries of each property, forming the basis for accurate property registration [7]. The Court Clerk and Property Courts intervene in property disputes and handle the registration of judicial decisions related to ownership when necessary [3].

1.4.3 Challenges

The process of land registration in Algeria faces several challenges, including delays in land surveys, which slow down property registration and create legal complications for owners [3]. Additionally, bureaucratic hurdles and complex procedures make the registration process lengthy and cumbersome [3]. The lack of digitalization further exacerbates these issues, as reliance on paper-based records increases the risk of data loss or damage and slows down administrative operations [3][7]. Moreover, limited public awareness about the importance of legal property registration leaves many citizens vulnerable to ownership disputes. In response, the Algerian government is actively working to address these challenges by promoting the digitalization of land records, simplifying administrative procedures, and raising public awareness to enhance property rights protection and foster real estate market development [7].

1.5 Components of a Land Registry Systemc

A land registry system is a structured framework designed to record and manage information related to land ownership and property rights [3]. It consists of several key components that ensure transparency, security, and efficiency in land transactions.

1.5.1 Land Records and Stored Information

A land registry serves as a comprehensive record-keeping system for properties, documenting essential details such as ownership information, including the registered owner(s) of the land. It also maintains a description of the property, covering its location, boundaries, size, and classification [3]. Additionally, the registry tracks the transaction history, recording past sales, transfers, and ownership changes. Legal rights and restrictions, such as easements, mortgages, liens, and zoning regulations, are also documented [3]. Furthermore, the registry includes survey and mapping data, providing accurate geographic and cadastral maps that define land parcels precisely [7].

1.5.2 Key Stakeholders

Maintaining and managing the land registry system is a shared responsibility among several key parties to ensure its accuracy, efficiency, and legal validity. Government authorities, especially the Land Registry Office (Cadastre Office), play a central role in recording property ownership data, ensuring transparency and security in land transactions. Other government agencies, such as cadastral and legal departments, oversee registration processes and enforce regulations. Property owners and buyers rely on the registry to prove ownership and secure their legal rights. Surveyors and engineers are responsible for measuring and mapping land accurately to keep reliable property records, which serve as the foundation for land registration. Lawyers and notaries help facilitate property transactions by verifying documents and ensuring compliance with legal requirements. Additionally, financial institutions, such as banks and lenders, check land records before approving loans or mortgages to confirm clear and verified ownership. Collaboration among these stakeholders, with the Land Registry Office at the center, helps keep the system accurate, up-to-date, and legally valid, ensuring that land ownership is protected and preventing disputes or unauthorized transactions [3][7].

1.5.3 Role of Technology in Land Registration

Technology plays a key role in modernizing land registration systems by improving efficiency, accuracy, and security. Important advancements include digital land records, which replace paper-based systems with digital databases, making information more accessible and reducing the risk of data loss. Blockchain technology offers a decentralized and tamper-proof system that increases transparency and prevents fraud [8]. Geographic Information Systems (GIS) allow for accurate mapping and clear visualization of land boundaries. Online registration platforms enable citizens to access land records, submit applications, and complete transactions remotely, making the process more convenient. Automation and artificial intelligence help verify documents, detect fraud, and simplify land registration procedures. By adopting these technologies, governments can reduce administrative delays, minimize corruption, and build public trust in the land registry system [3][7].

1.6 Challenges in Land Registry Systems

Land registry systems play a vital role in securing property rights, but they face several challenges that affect their efficiency. Bureaucracy and inefficiency caused by manual processes and excessive paperwork [3][7] lead to delays and discourage property registration. Lack of digitalization makes paper-based records vulnerable to loss, forgery, and restricted access to land information. Legal complexity, due to changing laws and multiple authorities, creates inconsistencies and ownership disputes. Corruption and fraud further worsen the situation, as weak governance allows illegal transactions and document forgery. Land disputes and incomplete surveys result in boundary conflicts and ownership issues [3][7]. Additionally, limited public awareness of registration procedures, along with high costs and legal difficulties, prevents many landowners from complying with the process. To address these challenges, governments can digitize land records to improve security and efficiency, use blockchain and GIS to prevent fraud and increase accuracy [7][8], simplify legal frameworks to make property registration easier, and launch public awareness programs to encourage legal ownership. By implementing these solutions, land registry systems can become more transparent, efficient, and secure.

1.7 Innovations and Modern Developments

1.7.1 Use of Geographic Information Systems (GIS)

GIS plays a crucial role in improving land registration by providing detailed and accurate property maps. It helps in defining property boundaries and documenting ownership more efficiently. In Algeria, GIS has been applied to support sustainable agricultural land development [7] by collecting and analyzing geographic data. This allows better land planning and expansion, ensuring optimal land use.

1.7.2 Digital Transformation and Its Impact on Land Registration

The shift towards digital land registration aims to improve efficiency and transparency [3][7] in managing property records. This includes digitizing land records, reducing reliance on paper documents, and minimizing risks of data loss or fraud. In Algeria, digital transformation has become essential to protect properties from fraud and unauthorized claims while enabling online services. Despite challenges such as bureaucracy and complex procedures, authorities are working to integrate new technologies into land surveying and registration [7][8], making transactions more transparent and accessible.
By adopting these modern innovations, land registration systems can achieve greater accuracy, reduce disputes, and make property information more accessible to citizens and investors alike.

1.8 Digitalization of Land Registry Worldwide

The digitalization of land registries is transforming property management globally, enhancing transparency, security, and efficiency.

1.8.1 Case studies of digital land registries

Ghana has developed a blockchain-based framework to address land acquisition challenges. This system aims to streamline property transactions, prevent fraud, and establish an immutable record of ownership. In December 2020, Afghanistan's Ministry of Urban Development and Land implemented a new digital land registry for informal urban settlements. This initiative addresses secure land rights, a critical issue contributing to conflict in the country. In Georgia, the National Agency of Public Registry integrated blockchain [8] technology into its land titling project. This integration enhances the security and transparency of property records, providing a reliable platform for land registration.

1.8.2 Case studies of digital land registries

- **Blockchain Technology:** Blockchain offers a tamper-proof, decentralized ledger for recording land transactions. Its immutable nature ensures that property records are secure and transparent, reducing the risk of fraud and disputes [8].

- **Artificial Intelligence (AI):** AI enhances land registry systems by analyzing variables such as location and amenities to provide accurate property valuations. Machine learning algorithms can detect anomalies, aiding in fraud prevention and ensuring data integrity [8].

- **Integration of AI and Blockchain:** Combining AI with blockchain technology creates a robust land registration system. Blockchain ensures data security and transparency, while AI offers insights and efficiencies in property management [8].

These technological advancements are revolutionizing land registration processes, making them more secure, transparent, and efficient.

1.9 Conclusion

The challenges of land registration, such as bureaucratic complexity and reliance on paper documents, are major obstacles for both employees and citizens. These difficulties cause delays in transactions and increase disputes, highlighting the need for innovative solutions to improve the efficiency of land registry systems. In this context, digital transformation is a necessary step to overcome these challenges and ensure accurate and reliable property registration. Technologies like blockchain and artificial intelligence can speed up processes, reduce errors, and enhance security and transparency in property management. Adopting these solutions not only improves the experience of employees and citizens but also paves the way for a more organized and sustainable real estate market in the future.

Chapter 2
Blockchain Technology

2.1 Introduction

In an era where technology is advancing at an unprecedented pace, the way we store, share, and secure information is undergoing a profound transformation. The digital world has long relied on centralized systems, which are often vulnerable to manipulation, inefficiencies, and breaches. However, as the demand for trust, security, and transparency increases, a new paradigm emergesone that challenges traditional structures and redefines how data is managed. At the heart of this transformation lies blockchain, a revolutionary concept that operates beyond conventional limitations. It is not merely a technology but a shift in the very foundations of digital trust. By eliminating intermediaries, ensuring tamper-proof records, and enhancing transparency, blockchain introduces a decentralized approach where control is no longer confined to a single entity. With its core principles of decentralization, security, transparency, and immutability, it promises to reshape industries in ways previously unimaginable. But what makes this technology so powerful? How does it extend beyond cryptocurrencies into finance, supply chains, identity management, and even land registry systems? The answers lie in the intricate mechanisms that drive blockchains unmatched reliability. As we dive deeper, the impact and potential of this innovation become clearer, unveiling a future where trust is no longer a questionbut a certainty.

2.2 Blockchain

2.2.1 Blockchain Definition

Blockchain technology is a decentralized digital system used to record and verify transactions in a secure and transparent way. Data is stored in linked blocks, where each block contains a set of transactions and is connected to the previous one using advanced encryption techniques. This makes it difficult to modify data without the approval of all participants in the network. The idea of blockchain first appeared in 1991 by researchers [1] Stuart Haber and Scott Stornetta. They proposed a digital system based on a chain of encrypted blocks to create a timestamp for digital documents, providing strong protection when storing them. In 2008, blockchain technology was applied practically with the launch of Bitcoin, the first decentralized digital currency. It was used to record financial transactions securely and transparently without the need for a central authority. Blockchain technology is now used in many fields, including digital currencies, supply chains, smart contracts, and healthcare, offering innovative solutions to traditional challenges in these sectors.

2.2.2 Blockchain Features

Blockchain technology has several features that make it a reliable and secure system. First, decentralization means that data is not stored on a central server but is distributed across a network of nodes. This prevents any single entity from having full control over the system and enhances transparency [3][7]. Second, security is a key advantage, as advanced encryption techniques make it difficult to tamper with or hack the stored information. Additionally, transparency allows all participants in the network to access an updated record of all transactions, which builds trust among users. Moreover, timestamping ensures that data is recorded in a specific order, making it easier to track all registered operations. Finally, blockchain features immutability, meaning that once a transaction is recorded, it cannot be changed without modifying all subsequent blocks, making the data permanent and resistant to manipulation [7]. Thanks to these features, blockchain has become a powerful tool used in various fields, including digital currencies, smart contracts, and supply chains [7].

2.3 Blockchain Components and Structure

2.3.1 Blocks and Transactions

In a blockchain system, blocks and transactions are two essential components that ensure the network operates securely and efficiently. A block is the fundamental unit for storing data, containing a set of verified transactions added to the network. Each block includes a unique hash that identifies it, along with the hash of the previous block, linking all blocks in a continuous chronological sequence. This structure makes it impossible to modify a block without affecting all subsequent blocks, ensuring security and data integrity [1][18]. On the other hand, transactions represent operations executed within the network, such as the transfer of assets or data between users. Each transaction contains details like the sender and receiver addresses, the value of the transferred asset, and a timestamp indicating when it was executed [18]. Before a transaction is added to a new block, it must be verified using consensus mechanisms like Proof of Work (PoW) or Proof of Stake (PoS). Once validated, the transaction is included in a block, which is then permanently added to the chain, enhancing transparency and security within the system [7].

2.3.2 Hash Functions and Merkle Trees

In a blockchain system, hash functions and Merkle trees play a crucial role in ensuring data security and efficient verification. Hash functions are mathematical algorithms that convert any input data into a fixed-length string of characters known as a hash. These functions have key properties, such as fixed length, meaning the output remains the same size regardless of input data size; uniqueness, where even a small change in the input produces a completely different hash [1][18]; and irreversibility, making it impossible to retrieve the original data from the generated hash. In blockchain, hash functions are used to create unique identifiers for blocks and transactions, ensuring data integrity and preventing tampering [1]. On the other hand, Merkle trees are hierarchical data structures that summarize large sets of transactions or data and enable efficient verification. These trees consist of multiple levels, where the leaves represent hashes of individual transactions, intermediate nodes are calculated by combining and hashing child nodes, and the root, known as the "Merkle root," serves as the final hash representing the entire tree. This structure allows quick validation of transactions without needing to examine the entire record, saving time and resources while making blockchain more efficient and secure [18].

2.3.3 Smart Contracts

In a blockchain system, smart contracts are self-executing programs stored on the network that automatically run when predefined conditions are met, enabling agreements between parties without the need for traditional intermediaries. These contracts are written using encrypted algorithms that define rules and conditions, and they are stored on the blockchain to ensure immutability and prevent tampering [5][18]. Smart contracts are widely applied in various fields, such as financial services, where they facilitate decentralized finance (DeFi) activities like lending and borrowing without central authorities [5]. They also enhance transparency in supply chain management by enabling product tracking and origin verification, which helps reduce fraud [4]. Additionally, smart contracts support secure and transparent electronic voting systems, preventing manipulation and increasing trust in electoral processes [5][13]. Despite these benefits, smart contracts face legal and regulatory challenges, as their decentralized nature requires a reevaluation of existing legal frameworks to ensure compatibility and safety. Developing suitable legislation is essential for the effective and secure adoption of smart contracts across industries [6].

2.4 Consensus Mechanisms in Blockchain

2.4.1 Proof of Work (PoW)

In blockchain systems, Proof of Work (PoW) is one of the fundamental consensus algorithms that ensures the validity of transactions and the security of the decentralized network. This mechanism relies on the participation of "miners," who use high computing power to solve complex mathematical problems. When a miner successfully solves these problems, they are allowed to add a new block to the blockchain and receive a reward in digital currency [1][9]. PoW provides a high level of security, as modifying any block requires recalculating all previous blocks, making attacks costly and difficult to execute. However, this mechanism has some drawbacks, the most notable being high energy consumption, as mining operations require massive amounts of electricity, raising environmental concerns [3]. Additionally, the high cost of mining can lead to the concentration of mining operations in the hands of a few large miners, which may weaken the principle of decentralization in the network [9]. Despite these challenges, PoW remains one of the most widely used consensus mechanisms in blockchain networks, ensuring the reliability and security of recorded transactions.

2.4.2 Proof of Stake (PoS)

Consensus mechanisms are essential components that ensure the validity of transactions and the security of decentralized networks. Among these mechanisms, Proof of Stake (PoS) is an advanced alternative to Proof of Work (PoW). PoS selects validators based on the amount of cryptocurrency they own and are willing to "stake" as collateral, making it more energy-efficient than PoW since it does not require complex computations. One of the key advantages of this mechanism is its significant reduction in energy consumption [9][10], making it an environmentally sustainable option [3]. It also allows more individuals to participate in the validation process without requiring large investments in mining equipment. However, PoS has some drawbacks, such as the potential for centralization, where power may become concentrated in the hands of individuals or entities that hold large amounts of cryptocurrency, possibly weakening decentralization [10]. Additionally, the system may be vulnerable to attacks like the "Nothing at Stake" problem, where validators can vote on multiple chain versions without incurring any significant cost [10]. Besides PoW and PoS, other mechanisms such as Practical Byzantine Fault Tolerance (PBFT) exist. PBFT is used in private or permissioned networks to ensure consensus even in the presence of some malicious nodes [12].

2.4.3 Other Consensus Algorithms (DPoS, PBFT, etc.)

Various consensus mechanisms are used in blockchain networks to ensure transaction security and operational efficiency. Among these mechanisms are Delegated Proof of Stake (DPoS) and Practical Byzantine Fault Tolerance (PBFT), along with other specialized models [12][13]. DPoS allows users to vote for a limited group of delegates responsible for validating transactions and producing new blocks. This mechanism is known for its speed and efficiency but may introduce a degree of centralization due to the restricted number of selected validators. On the other hand, PBFT aims to achieve consensus even in the presence of malicious or unreliable nodes by relying on message exchange among trusted nodes. It is often used in private networks where the number of participants is limited, enabling fast and reliable transactions. Additionally, other mechanisms exist, such as Proof of Authority (PoA), which relies on known validators instead of mining or staking, making it suitable for private networks, and Proof of Capacity (PoC), which utilizes available storage space instead of complex computations, reducing energy consumption [10]. Byzantine Fault Tolerance (BFT) also helps ensure network operation even when some nodes are uncooperative or malfunctioning [12]. Each of these mechanisms has its own advantages and drawbacks, and the choice depends on the specific needs and objectives of the network.

2.5 Types of Blockchain

2.5.1 Public Blockchain

Public blockchain networks are open-source systems that allow anyone to join and participate without restrictions. They are fully decentralized, meaning each participant holds a complete copy of the transaction ledger [13]. These networks are primarily used in cryptocurrencies like Bitcoin and Ethereum, as well as in electronic voting systems to ensure transparency and prevent fraud [14]. Additionally, they facilitate smart contracts, enabling automatic execution of agreements between parties without the need for intermediaries [15]. Public blockchains offer high transparency, as all transactions are visible to everyone, enhancing trust among users. They also provide strong security through encryption technologies, making data manipulation or hacking extremely difficult [16]. Furthermore, the absence of a central authority increases network stability. However, these networks have some drawbacks, such as high energy consumption in systems that rely on mining, as well as privacy concerns, since all data is publicly accessible, which may not be suitable for certain users [17]. Additionally, transaction processing speeds can be slower compared to centralized systems. Overall, public blockchains are ideal for applications requiring transparency and decentralization but may not be the best choice for those needing higher privacy or faster transaction processing.

2.5.2 Private Blockchain

Private blockchain networks are closed systems managed by a specific organization or group, with controlled access based on certain restrictions [5]. This makes them ideal for environments requiring high security and privacy, such as financial institutions and large corporations. These networks are used in various fields, including supply chain management for tracking products and ensuring quality, financial services to speed up settlements and reduce errors, and healthcare for securely storing medical records and sharing them with authorized entities [19]. Private blockchains offer centralized control, allowing organizations to manage the network and determine who can participate. They also provide high privacy to protect sensitive data and greater efficiency in transactions due to the limited number of participants. However, their centralized nature may conflict with the core principle of decentralization in blockchain technology. Additionally, they require trust in the controlling entity, which can be a challenge in some cases. Furthermore, they may be less secure than public blockchains since fewer participants can make them more vulnerable to attacks if strong security measures are not implemented [3]. Overall, private blockchains are a suitable choice for applications that require centralized control and high privacy but may lack some of the transparency and decentralization benefits offered by public networks.

2.5.3 Consortium Blockchain

Consortium blockchain, also known as federated blockchain, is a type of blockchain network jointly managed by a specific group of institutions or organizations, where these entities collaborate to govern the network and make related decisions. These networks are used in various fields, such as banking and payments, where a group of banks can form a consortium to manage a shared blockchain network for transaction validation. They are also utilized in research to exchange data and findings, as well as in food supply chain tracking to ensure product safety. Consortium blockchains provide a collaborative environment between institutions while maintaining a certain level of decentralization. However, they may face challenges related to reduced transparency, as a compromised node within the consortium could pose security risks. Additionally, the operational efficiency of the network may be affected by the governance rules imposed on the blockchain [22].

2.6 Application of Blockchain in Various Sectors

2.6.1 Promoting Transparency

Using blockchain in land registry systems significantly enhances transparency by providing a secure, immutable, and publicly verifiable record of property transactions. Traditional land registry systems often suffer from issues like fraud, unauthorized alterations, and lack of accessibility. By implementing blockchain, all property-related transactions are recorded in a decentralized ledger that cannot be modified or tampered with, ensuring data integrity and reliability. This transparency helps prevent disputes over ownership, reduces corruption, and allows for easy verification of property records by relevant authorities and stakeholders [7]. Furthermore, blockchain enables real-time access to transaction history, making property transfers more efficient and reducing the need for intermediaries. This system is particularly beneficial in countries where land disputes are common, as it provides an indisputable and tamper-proof record of land ownership, ultimately increasing trust in the registry process [3].

2.6.2 Preventing Forgery and Fraud

Adopting blockchain in land registry systems plays a crucial role in preventing forgery and fraud by providing a secure and tamper-proof record of property ownership and related transactions. Traditional registration systems face risks such as document forgery, unauthorized modifications, and fraudulent claims. Blockchain technology eliminates these risks by ensuring that once a transaction is recorded, it becomes permanent and cannot be altered or deleted. Additionally, each entry in the blockchain is cryptographically secured, making it nearly impossible to forge ownership documents or manipulate historical records [13][14]. Furthermore, smart contracts can be integrated to automate property transfers and verify legal compliance, reducing human intervention, which is often a source of corruption. By implementing blockchain in land registry systems, governments and stakeholders can significantly reduce fraud cases, enhance security, and build trust in real estate transactions [15][16].

2.6.3 Improving Efficiency Through Smart Contracts

Adopting blockchain in land registry systems significantly enhances efficiency through the use of smart contracts, which automate the process of property registration and ownership transfer. In traditional systems, real estate transactions require extensive paperwork, multiple approvals, and human intervention, leading to long delays and increased costs. With smart contracts, transactions are executed automatically once predefined conditions are met, reducing the need for intermediaries such as lawyers and notaries. This speeds up the process and lowers costs [7]. Additionally, smart contracts ensure that transactions comply with legal requirements, minimizing human errors and potential disputes. Furthermore, these contracts provide a high level of transparency and security, as all data is stored on the blockchain in a tamper-proof manner, contributing to a more efficient and reliable land registry system [19][20].

2.7 Application of Blockchain in Various Sectors

2.7.1 Finance and Cryptocurrencies

Blockchain is one of the most impactful technologies in the finance and cryptocurrency sector, providing a high level of security, transparency, and decentralization in financial transactions. Its emergence has led to the creation of digital currencies like Bitcoin and Ethereum, allowing individuals to conduct transactions without the need for financial intermediaries such as banks. This technology also helps accelerate payment processes and reduce costs associated with financial transfers, especially in international transactions that traditionally require long processing times and high fees [22]. Additionally, financial institutions leverage blockchain to enhance operational efficiency in areas such as digital identity management, regulatory compliance, and fraud prevention through immutable records. Smart contracts further automate financial processes, ensuring that agreements are executed automatically when predefined conditions are met, thereby increasing security and reliability in the modern digital financial system [23][24].

2.7.2 Supply Chain Management

Many companies rely on blockchain technology to enhance supply chain management by providing transparency and tracking products at every stage of production and distribution. This approach helps reduce errors, detect fraud or counterfeiting, and ensure product authenticity, especially in industries that require high precision, such as pharmaceuticals and food production. By recording all data on an immutable network, businesses and consumers can easily verify the origin of raw materials, shipping routes, and storage conditions, strengthening trust among stakeholders. Additionally, smart contracts automate various supply chain processes, such as automatic payments upon goods delivery or verifying compliance with specific standards, reducing the need for intermediaries and improving overall operational efficiency [25][26][27][28].

2.7.3 Healthcare and Identity Management

Blockchain technology contributes to the advancement of the healthcare sector and identity management by providing secure and tamper-proof health records, ensuring data accuracy and easy access for authorized entities. This improves the quality of medical care, as doctors can quickly access patient history without relying on complex traditional systems. Additionally, blockchain plays a vital role in protecting personal data by allowing patients to control who can access their medical information, enhancing privacy and security. Moreover, this technology is used in digital identity management systems to reduce the risk of fraud and identity theft, as information is securely and permanently recorded. This facilitates verification processes in government, financial, and educational services without the need for traditional intermediaries [31][32].

2.8 Challenges and Limitations of Blockchain Technology

Despite the many benefits that blockchain technology offers, it faces several challenges that limit its widespread adoption [37]. Scalability is one of the major obstacles, as some blockchain networks, like Bitcoin, require long processing times due to the consensus mechanisms they use. Energy consumption is another challenge, especially in systems that rely on Proof of Work (PoW), which demands enormous amounts of power for complex computations. Additionally, legal and regulatory barriers remain a concern, as governments struggle to establish clear frameworks to regulate blockchain use, particularly in financial and real estate sectors. Security risks also exist, such as cyberattacks targeting digital wallets and smart contracts. Furthermore, users often find blockchain technology difficult to understand and interact with, which may hinder its adoption among individuals and businesses unfamiliar with the technology [36][37].

2.9 Conclusion

Blockchain technology has proven its ability to revolutionize data management and transactions across various sectors, combining transparency, security, efficiency, and decentralization to offer more reliable solutions. By eliminating the need for intermediaries, blockchain enhances financial operations, strengthens supply chains, and provides a secure environment for digital identity management and land registry systems. Despite challenges such as scalability and high energy consumption, ongoing advancements and innovations, including smart contracts and alternative consensus mechanisms, continue to improve its efficiency. As governments and businesses increasingly adopt blockchain, it becomes clear that this technology is not just a passing trend but a foundation for a more secure and trustworthy digital future.

Chapter 3
System Design

3.1 Introduction

After completing the study of the current system and analyzing its various functional and organizational aspects, we are now able to move to the design phase, which represents a key step in the software development life cycle [15]. This phase allows us to translate the results of the analysis into visual models that help build an accurate vision of the future system, and serves as a solid foundation for the development team to implement the application effectively and with high quality. In this context, we adopted the Unified Modeling Language (UML), as it provides powerful tools to represent the systems components and interactions in an organized and abstract way. The importance of these diagrams lies in their ability to simplify the understanding of the systems structure and behavior, while also defining the relationships between users and the system, as well as the internal interactions between its components. This chapter presents the key design models used to define the architecture and behavior of our Blockchain-based Land Registry Traceability System. It begins with the architectural system design, followed by use case diagrams that illustrate user roles and interactions [16][17]. Then, it provides sequence diagrams describing the flow of operations, and finally, class diagrams representing the structural relationships between data entities. These models collectively lay the groundwork for a secure, functional, and scalable implementation of the system [18][19].

3.2 Architectural System Design

The architectural design represents a high-level overview of the system's components and how they interact with one another. Its purpose is to provide a conceptual understanding of how the blockchain-based land registry system is structured in layers, from user interaction to data validation and storage. This diagram is essential in this chapter as it establishes the foundation upon which all detailed design models (such as use case, sequence, and class diagrams) are built. It visually communicates the division of responsibilities across the different parts of the system including the user interface, backend services, relational database, and blockchain layer and highlights how they work together to ensure traceability, transparency, and security of property registration operations [15].

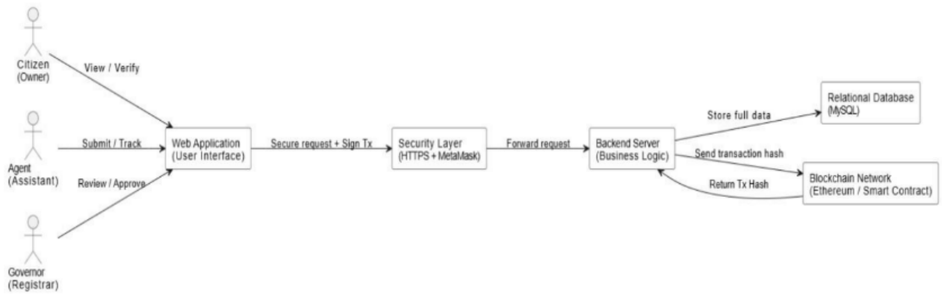

Figure 3.1: Architectural System Design

3.2.1 Users

The system involves three main user types: the citizen (property owner), the agent (assistant), and the governor (registrar). The citizen interacts with the system to view or verify property information. The agent is responsible for entering property and ownership data and submitting registration requests. The governor reviews and decides on these requests. All users access the system through a unified web interface, with different permissions depending on their roles.

3.2.2 Web Application

This is the graphical interface that allows all users to interact directly with system functions such as submitting or reviewing requests.

3.2.3 Security Layer (HTTPS + MetaMask)

This layer ensures secure communication between users and the system through HTTPS. MetaMask is used to digitally sign transactions before they are submitted to the blockchain, ensuring that agents and governors are authenticated and authorized.

3.2.4 Backend Server

This component handles data processing and validation, stores full records in the MySQL database, and sends hashed transaction data to the blockchain.

3.2.5 Relational Database (MySQL)

Used to store all detailed and editable data such as users, property records, and transactions.

3.2.6 Blockchain Network

Stores only the hash of important transactions to guarantee traceability and prevent tampering. The blockchain returns a transaction hash that is stored in the database as proof of record. This layered structure sets the stage for the detailed modeling of the systems functionality, which will be explored in the following sections through use case, sequence, and class diagrams.

3.3 Use Case Diagram

A Use Case Diagram is one of the key diagrams in the Unified Modeling Language (UML). It provides a high-level visual representation of the interactions between users (actors) and the system. The purpose of a use case diagram is to identify what the system should do from the users perspective, focusing on the functionality the system offers and how external users interact with it [16][17].

In our project, the use case diagram was used to clearly define the roles of the citizen, agent, and governor, and to illustrate the specific actions available to each user through the web application. This helps ensure that all functional requirements are captured accurately and provides a solid foundation for developing sequence diagrams and other behavioral models that follow.

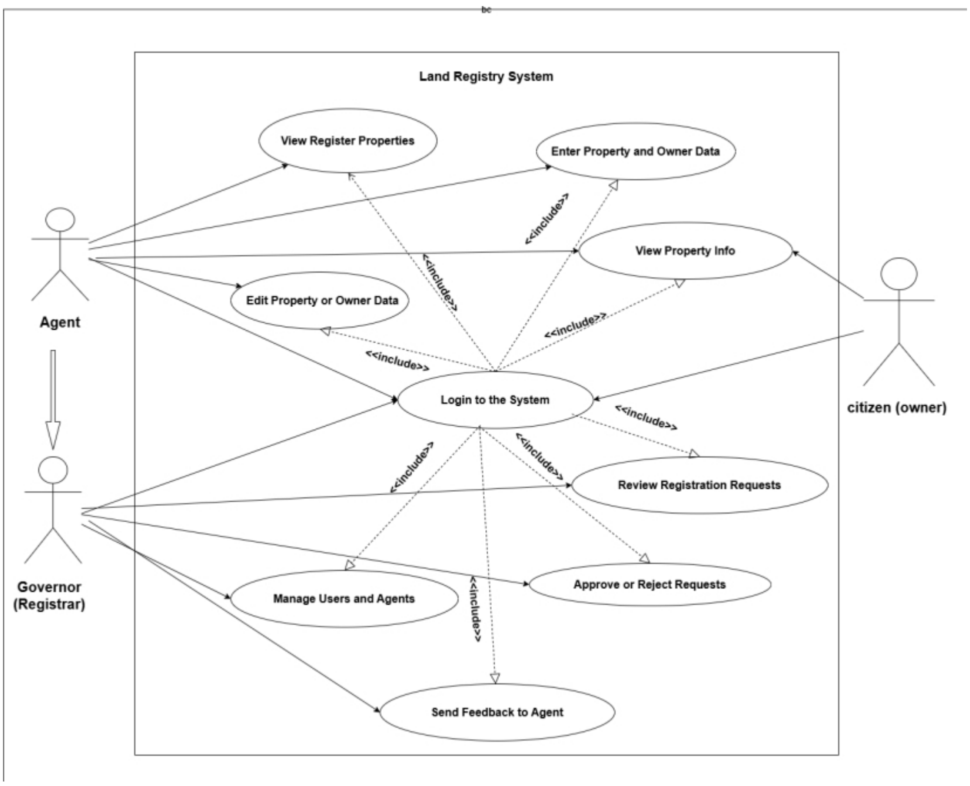

Figure 3.2: UML Use Case Diagram of User Roles and Interactions

All users must first log into the system to access their authorized functionalities.

The citizen (owner) is a simple user who has no privileges to modify or submit data. After logging into the system, the citizen can only access the functionality of viewing their property information, ensuring transparency and the ability to verify the accuracy of their ownership records.

The agent plays the role of the field officer responsible for entering primary data into the system. Once authenticated, the agent can input property and owner information, modify it when necessary, and view the registered properties. However, the agent does not have the authority to approve or reject submissions; instead, they forward requests to the governor for review.

The governor (registrar) represents the core administrative authority in the system and holds full privileges. Upon logging in, the governor can view all property information and registration requests, review submissions, and make the final decision to approve or reject them. Additionally, the governor can manage user accountsparticularly agentsby adding or removing them from the system, and can also send feedback or instructions. This confirms that the governor is not merely a reviewer but the systems top decision-maker, responsible for overseeing the entire registration process and ensuring its legitimacy.

After defining user roles and system functionalities through the use case diagram, the next section presents sequence diagrams that describe the step-by-step interaction between system components during core operations, focusing on the flow of data and messages exchanged between the user, backend, database, and blockchain.

3.4 Sequence Diagram

A Sequence Diagram is one of the most important behavioral diagrams in the Unified Modeling Language (UML). It illustrates how objects or components in a system interact with each other over time through the exchange of messages. This diagram emphasizes the chronological sequence of operations, showing how a process flows step-by-step from the initiating actor to the internal components and back.

Sequence diagrams are especially useful for visualizing the logic of complex use cases and for identifying the communication between the user interface, backend logic, database, and external services such as blockchain networks.

In this chapter, we used sequence diagrams to describe two key processes in our system: property registration and property ownership transfer, both of which involve critical interactions between the user, backend, and blockchain to ensure security and traceability.

3.4.1 Sequence Diagram Property Registration Process

This section presents the sequence diagram for the first-time property registration process. It details the chronological interaction between the agent, the system backend, the blockchain network, and the relational database. The objective is to ensure that all new property entries are verified, securely recorded on the blockchain, and consistently stored in the systems internal database. This sequence guarantees the integrity, traceability, and authenticity of the property registration operation.

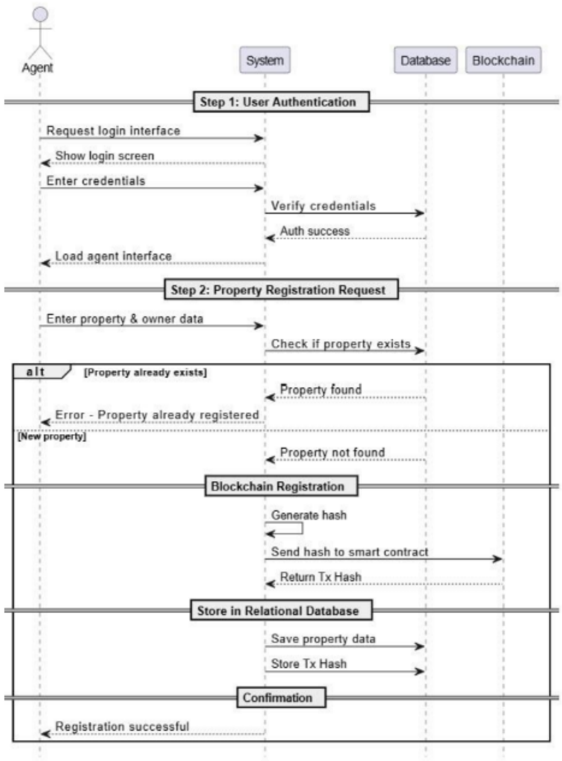

Figure 3.3: UML Sequence Diagram of Property Registration Process

This diagram outlines the sequential interaction between the Agent, the System, the Database, and the Blockchain during the property registration process.

After login, the agent submits new property and owner data through the web interface. The system first checks whether the property already exists in the database. If it does, the process is stopped, and an error message is returned. If the property is new, the system generates a hash of the data and sends it to the blockchain to create a verifiable transaction.

Once the blockchain confirms the transaction and returns a transaction hash, the system stores both the property data and the hash in the relational database. A confirmation is then sent back to the agent, completing the process with secure, traceable registration.

3.4.2 Sequence Diagram Ownership Transfer Process

This section presents the event sequence for the property ownership transfer process in the blockchain-based land registry traceability system. The goal of this sequence diagram is to demonstrate how ownership is transferred from the current owner to a new one, ensuring data integrity and transaction traceability via blockchain.

The diagram focuses on the agents interaction with the system when entering new ownership data and associating it with an already registered property. It illustrates the verification steps, blockchain registration, and database update, all of which contribute to a secure and transparent transfer process. In this sequence, the agent begins by entering

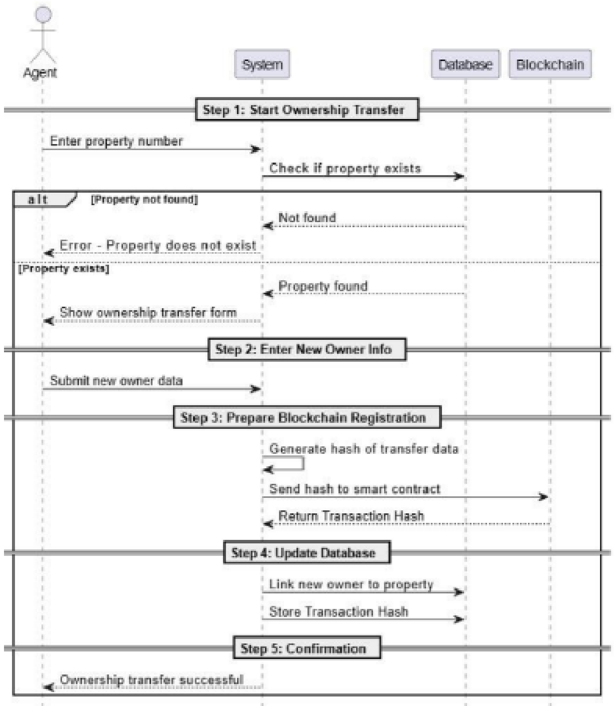

Figure 3.4: UML Sequence Diagram of Ownership Transfer Process

the property number. The system checks whether the property exists in the database. If not, the process is halted. If the property is found, a form is displayed to input the new owner's information.

Once the data is submitted, the system generates a hash for the ownership transfer and sends it to the blockchain. After receiving the transaction hash, the system updates the database by linking the new owner to the property and storing the transaction hash.

Finally, a confirmation is sent to the agent with transaction details, ensuring the security, traceability, and integrity of the ownership transfer process.

After illustrating the temporal flow of core system interactions, we now move on to the structural representation of the system through the Class Diagram, which highlights the relationships between the main data entities.

3.5 Class Diagram

A Class Diagram is a structural diagram in the Unified Modeling Language (UML) that represents the static structure of a system. It describes the systems classes, their attributes, operations (methods), and the relationships between objects.

Class diagrams are used to model the data structure and logical architecture of a system. They help developers understand how entities (such as users, properties, and transactions) relate to one another, making them essential for database design and object-oriented programming.

In the context of our Blockchain-based Land Registry Traceability System, the class diagram is used to represent the core data entitiessuch as users, owners, properties, and transactionsand their associations. This model forms the foundation for implementing consistent data handling and interaction logic in the system. This class diagram rep-

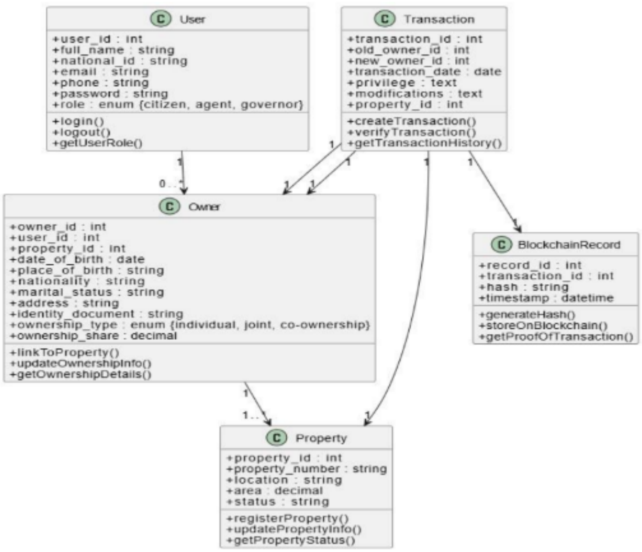

Figure 3.5: UML Class Diagram Core Data Entities and System Structure

resents the structural design of the system, highlighting the core entities that form the database of the blockchain-based land registry traceability system. It includes five main classes: `User`, `Owner`, `Property`, `Transaction`, and `BlockchainRecord`. The `User` class represents all system users (citizen, agent, governor), containing identification and role-related information. The `Owner` class defines the legal property owners, including personal and ownership data, and is directly linked to a user. The `Property` class describes the technical and administrative attributes of a property and is associated with an owner. The `Transaction` class models ownership transfer operations, detailing the old and new owners, the related property, and any associated privileges or modifications. Finally, the `BlockchainRecord` class stores the transaction data recorded on the blockchain, such as the hash and timestamp, to enhance traceability and authenticity. Multiplicity indicators define the relationships between these classes, reflecting how the components of the system are structurally connected to support integration between the traditional database and the blockchain, ensuring secure and verifiable property information.

3.6 Conclusion

Through this chapter, we have laid out the essential design diagrams that form the conceptual blueprint of our Land Registry Traceability System based on Blockchain technology. By leveraging the expressive power of UML diagrams, we were able to clearly model the system's structure, the roles of different users, and the dynamic interactions between its components.

These visual representations not only provide a shared understanding among stakeholders but also serve as a reference for the development phase, ensuring coherence between analysis and implementation. The adoption of blockchain principles in the design reinforces the systems objectives of transparency, security, and immutability.

Thus, this design phase acts as a critical bridge, transforming theoretical insights into a structured plan ready for development, marking a significant step forward toward building a reliable and modern land registration system.

Chapter 4
System Implementation and User Interface (UI)

4.1 Introduction

After analyzing the current land registration process and proposing a blockchain-based solution in the previous chapters, this chapter presents the practical implementation of the system. It translates the theoretical designs such as system architecture [9], database schema, and smart contract structure [5] into a functional working prototype. The implementation process involved selecting and using a variety of development tools and technologies that support both traditional web application development and blockchain integration. These tools include PHP, MySQL, HTML, CSS, JavaScript, Web3.js [8], MetaMask [10], Solidity [5], Ganache, and Truffle [9]. This chapter is structured to highlight, first, the key tools and technologies used in building the system [7][9], and then to demonstrate the actual user interfaces developed for the three types of users: citizens, agents, and land registrars. These interfaces allow each user to perform their respective tasks, such as property registration, ownership transfer, or verification of blockchain records [3]. The goal of this chapter is to show how the design elements from Chapter 3 were implemented in practice to produce a secure, user-friendly, and decentralized land registry system [1][2][3].

4.2 The Purpose of the Implementation

The purpose of implementing this system is to transform the proposed design into a working prototype that addresses real-world problems in traditional land registry processes. The system aims to provide a secure and decentralized environment for storing property records, ensuring that every land-related transaction is transparent, verifiable, and resistant to tampering. Beyond benefiting citizens by protecting their ownership rights, the system is also designed to assist government employees such as agents and registrars by simplifying administrative procedures, reducing paperwork, and minimizing the risk of human error or data loss. By allowing records to be stored and tracked on the blockchain, the system provides an efficient tool for managing land data, improving institutional trust and speeding up operations.

Moreover, the traceability offered by the blockchain component helps in preventing disputes related to land ownership by offering clear historical data of every transaction. Although the system has not yet been deployed or tested in a real land registration office, its implementation demonstrates the feasibility and potential of adopting blockchain-based solutions in the public sector for land governance [2][4][6][7].

4.3 Tools and Technologies Used

4.3.1 Development Tools

Visual Studio Code (VS Code)

Visual Studio Code (VS Code) is a free and open-source source-code editor developed by Microsoft. It is a lightweight but powerful tool used across major operating systems such as Windows, macOS, and Linux. VS Code supports a wide range of programming languages including PHP, JavaScript, Python, and Solidity, making it a versatile environment for web and blockchain development. Key features include syntax highlighting, intelligent code completion (IntelliSense), debugging tools, integrated Git support, and a vast marketplace of extensions that allow developers to customize their workspace. In this project, VS Code was used as the primary development environment to write and manage the backend code (PHP), frontend interface (HTML/CSS/JavaScript), and smart contracts (Solidity), providing an efficient and unified workspace throughout the system's development [20].

Figure 4.1: Visual Studio Code

Truffle

Truffle is a development framework for Ethereum that provides a suite of tools for writing, compiling, testing, and deploying smart contracts. It simplifies the development process by offering automated migrations, built-in testing with Mocha and Chai, and integration with Ethereum clients. Truffle also provides a configurable environment for managing multiple networks and contracts, which is essential for building decentralized applications (DApps) on Ethereum. In this project, Truffle was used to compile and deploy the smart contract (*LandRegistry*) to the local blockchain (Ganache), ensuring that the contract logic was correctly implemented and testable before integration with the user interface [9].

Figure 4.2: Truffle

Ganache

Ganache is a personal blockchain for Ethereum development that allows developers to deploy contracts, develop applications, and run tests in a controlled environment. It simulates a full Ethereum node and provides a local blockchain instance with predefined accounts and private keys, enabling fast and predictable testing. Ganache supports both a desktop interface (Ganache UI) and a command-line version (ganache-cli), making it flexible for different development workflows [21].

In this project, Ganache was used to create a local Ethereum blockchain environment, allowing for the safe deployment and testing of the `LandRegistry` smart contract before integrating it with the web interface and storing property data on the blockchain.

Figure 4.3: Ganache

MetaMask

MetaMask is a crypto wallet and gateway to blockchain applications, available as a browser extension and mobile app. It allows users to manage their Ethereum accounts, store and send cryptocurrencies, and interact with decentralized applications (DApps) directly from the browser. MetaMask injects a Web3 provider into websites, enabling seamless communication between the browser and the Ethereum blockchain. It also provides security features such as password protection, seed phrases, and transaction signing [10].

In this project, MetaMask was used to connect the web interface with the blockchain, allowing users (such as land officers) to digitally sign and send transactions when registering or transferring property. It played a key role in securely authorizing blockchain operations from the browser.

Figure 4.4: MetaMask

Solidity

Solidity is a statically-typed programming language designed specifically for writing smart contracts on blockchain platforms such as Ethereum. It allows developers to implement self-executing contracts with predefined rules and conditions that run on the decentralized Ethereum Virtual Machine (EVM). Solidity supports inheritance, libraries, and complex user-defined types, making it the standard language for creating decentralized applications (DApps) [8].

In this project, Solidity was used to develop the `LandRegistry` smart contract, which manages property registration, ownership transfers, and ensures the integrity and traceability of land records on the blockchain.

Figure 4.5: Solidity

4.4 User Interface (UI) Design and Implementation

4.4.1 User Interface (UI) Design and Implementation

The user interface (UI) is a critical component of the land registry system, as it serves as the primary point of interaction between users and the underlying blockchain-based platform. A well-designed UI enhances usability, facilitates efficient data entry, and ensures smooth navigation for different user roles, such as citizens and land officers.

In this project, the UI was developed with a focus on simplicity, clarity, and responsiveness, using `HTML`, `CSS`, and `JavaScript` to create an accessible and intuitive environment [22]. The design also integrates seamlessly with MetaMask to enable secure blockchain transactions directly from the web interface [10].

4.4.2 Login Interface

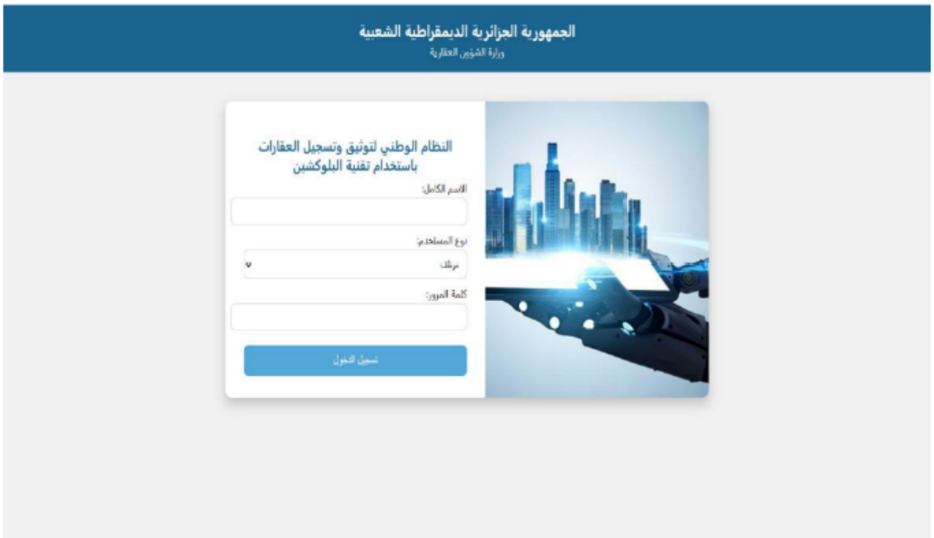

Figure 4.6: User Login Interface

The login interface is the initial access point to the system, designed to authenticate users based on their role. It offers a streamlined process where citizens can access their property-related information by simply entering their full name without the need for a password, ensuring ease of access and inclusivity. In contrast, employees such as agents and land administrators must provide both their full name and a password. This distinction enhances the security of administrative operations and prevents unauthorized access to sensitive actions like property registration or ownership transfer.

The system uses a role-selection dropdown and conditional input validation to direct users to their respective dashboards. This design ensures both usability for citizens and security for internal operations, forming a clear gateway into the blockchain-based property registration platform.

4.4.3 Agent interface

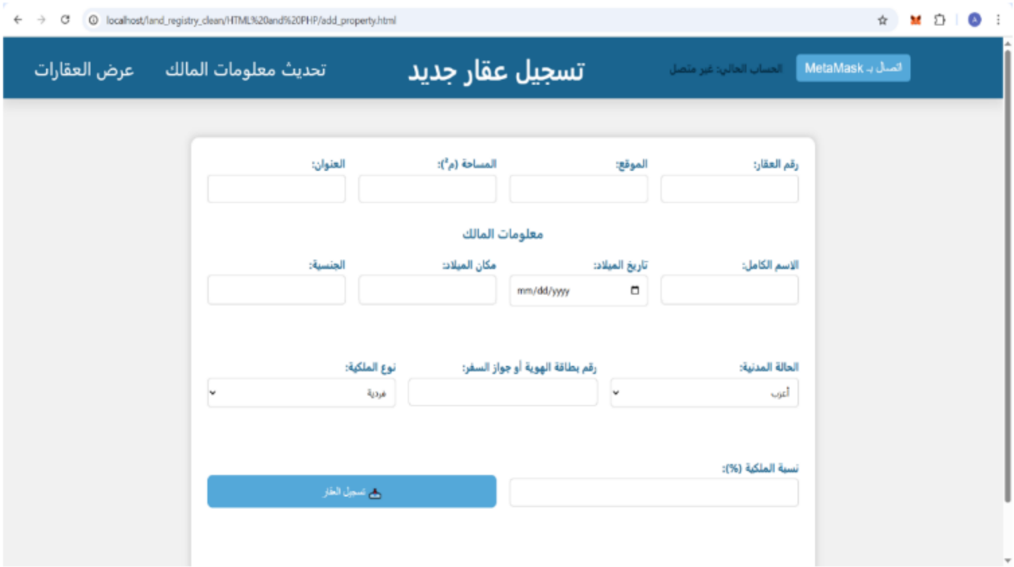

Figure 4.7: Agent interface

The New Property Registration interface features a simple and well-organized design that allows for easy input of property and owner information. At the top of the page, a horizontal navigation bar is displayed with the title “Register New Property” centered, along with links to other pages such as “View Properties” and “Update Owner Information,” facilitating smooth navigation between sections. In the upper-right corner, there is a “Connect to MetaMask” button dedicated to connecting the user’s wallet, alongside a display of the current connection status.

In the center of the page, a clearly structured form is presented, divided into two sections: the first section is for property details such as property number, location, area, and address; the second section contains owner information, including full name, date and place of birth, nationality, marital status, ID or passport number, type of ownership, and ownership percentage. At the bottom of the form, a blue “Register Property” button appears for submitting the data. The interface uses clear fonts, consistent formatting, and a logical arrangement of fields to enhance ease of use.

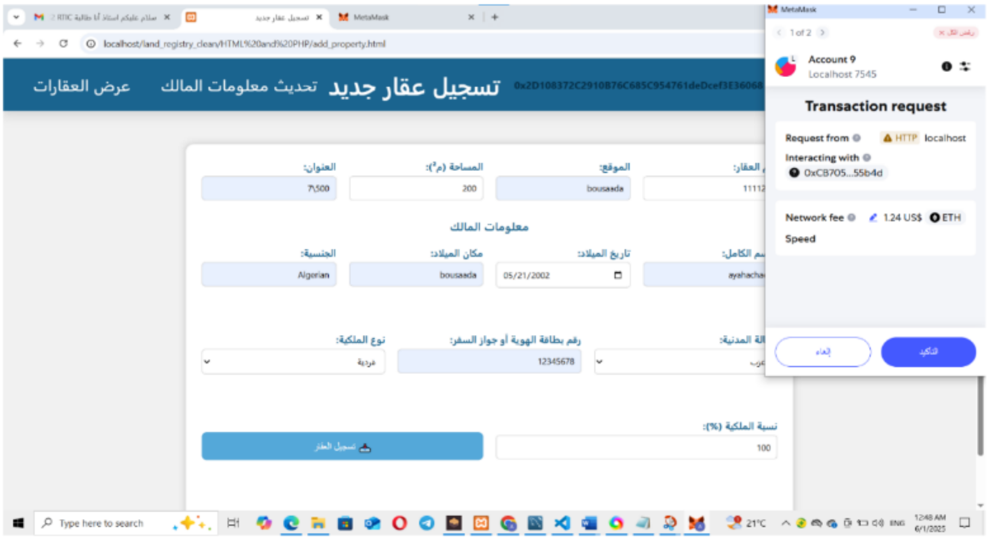

Figure 4.8: Property Registration Interface

4.4.4 Property Registration Interface

This interface is responsible for the actual registration of property data onto the blockchain. Once the user accesses the page, a "Connect to MetaMask" button is available, allowing the user to connect their wallet. After a successful connection, the current wallet address is displayed, confirming the link between the application and the blockchain account.

The user is then able to fill in the required property and ownership information through the structured form provided. Upon clicking the "Register Property" button, a MetaMask pop-up window appears prompting the user to confirm the blockchain transaction. After the user confirms the operation through MetaMask, the system processes the request and displays a success message, indicating that the property has been registered successfully and the transaction has been recorded on the blockchain.

4.4.5 Property Listing Interface

This interface allows the agent to search and view registered property information after it has been successfully recorded in both the blockchain and the database. The design includes a search field where the agent can enter the property number. Once the number is submitted, the interface retrieves and displays the corresponding details from two sources: the local database and the blockchain network. This dual display provides a clear comparison and ensures transparency and data integrity. The interface helps agents quickly verify the validity of a registration and track any inconsistencies if they exist, making it a crucial tool for ensuring system traceability.

Figure 4.9: Property Listing Interface

4.4.6 Owner Information Update Interface (Property Ownership Transfer)

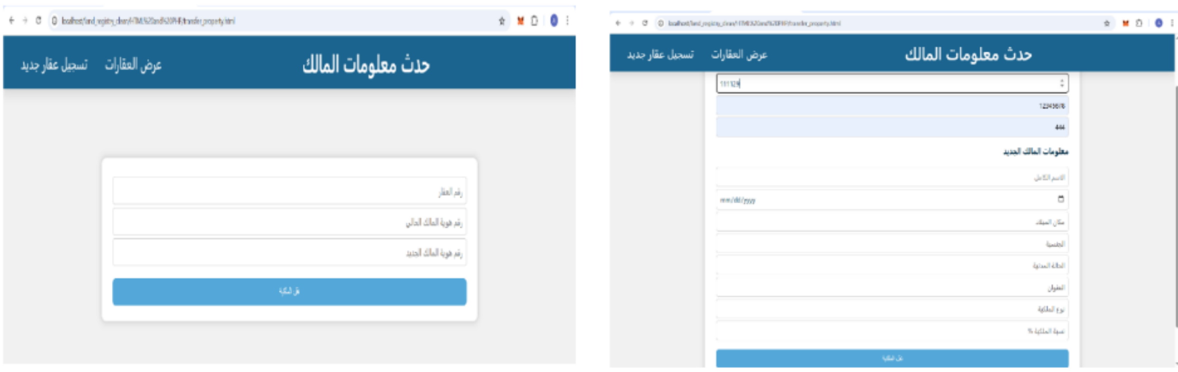

Figure 4.10: Owner Information Update Interface

This interface is tailored for use by the agent, providing a structured layout that includes input fields for entering the property number, the current owner's identity number, and the new owner's identity number. If the entered new owner is not already registered in the system, the interface dynamically displays additional input fields to allow the agent to enter the required personal details of the new owner. This dynamic and responsive design helps facilitate the accurate recording of ownership transfers while keeping the interface intuitive and organized for agent use.

4.4.7 MetaMask Wallet Connection

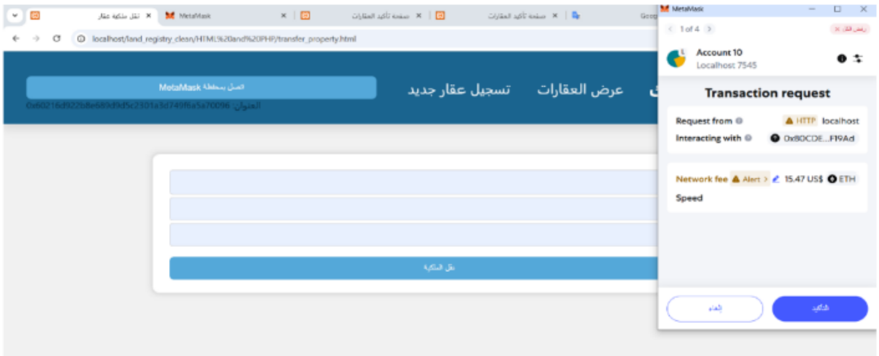

Figure 4.11: Connecting to MetaMask Wallet Interface

This interface begins by establishing a secure connection with the user's MetaMask wallet. The wallet must be connected and authorized to sign blockchain transactions. Once connected, the wallet address appears in the navigation bar to ensure transparency and identity verification. This step is essential before transferring ownership, as the wallet will be used to sign and confirm the transaction on the blockchain.

4.4.8 Governor Interface

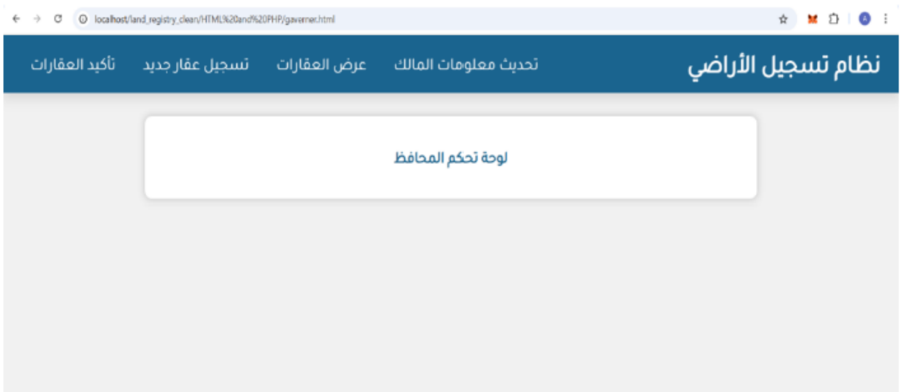

Figure 4.12: Governor Interface

The Governor Interface offers an organized and professional design, displaying a navigation bar at the top that includes various core functionalities such as updating owner information, viewing properties, registering new properties, and confirming property ownership. At the center of the page, a clear label indicates that the user is currently on the Governor Control Panel.

The governor has full authority over the system, inheriting all the functionalities available to the agent, including viewing and managing property and owner records. Additionally, the primary function of the governor is to confirm property registrations, which is why there is a dedicated section in the navigation bar labeled “Confirm Properties”. This feature ensures that property records are validated at the highest administrative level, reinforcing the reliability and trust in the land registration system.

4.4.9 Confirmation of Registered Properties

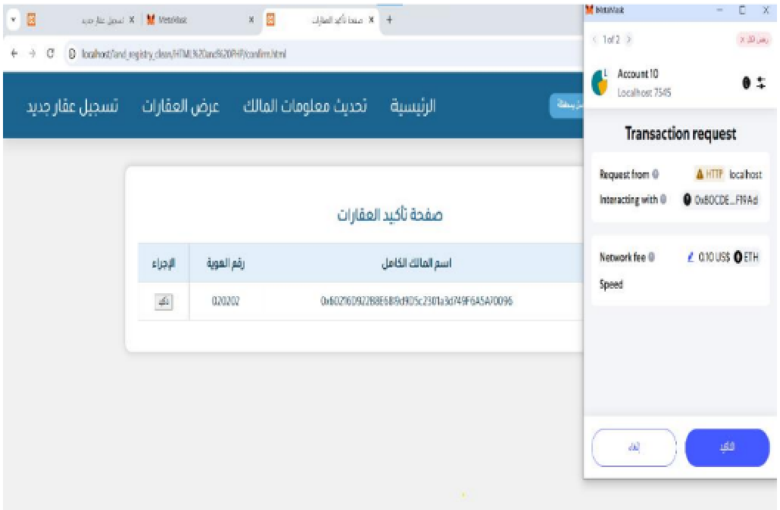

Figure 4.13: Confirmation of Registered Properties Interface

This interface allows the governor to review and approve newly registered properties before they are officially validated in the system. The table displays key information such as the property number, the owner’s full name, and their identity number. Each row includes an "Approve" button under the "Action" column, enabling the governor to manually verify and authorize the registration. This step is essential to ensure administrative accuracy and legal validity, making it a crucial part of the land registry workflow. Once the governor confirms the transaction, the property data is sent to the blockchain network using MetaMask, where it is officially and immutably recorded. Upon successful completion, the property is automatically removed from the table to indicate that it has been approved, and a success message is displayed to notify the user.

4.4.10 Property Information Display Interface (Citizen Interface)

The citizen interface is user-friendly, allowing the user to simply enter the property number to retrieve its information. The interface features a clean and organized design centered on the page, where the “Property Card” is displayed within a neat white-bordered container. The card is divided into two main sections: “Property Information” and “Owner Information,” presenting the data in a clear and structured manner. At the bottom of the card, there are functional buttons, including a “Print” button with a printer icon, and a “Download PDF” button for easily exporting the data.

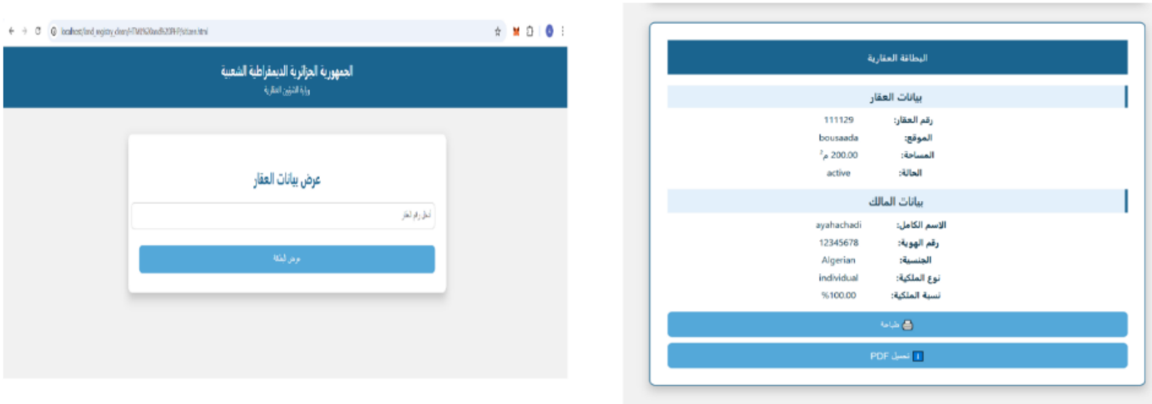

Figure 4.14: Citizen Interface

4.4.11 Conclusion

In conclusion, the design and implementation of the user interfaces play a fundamental role in ensuring the usability, accessibility, and effectiveness of the land registry system. Each interface was carefully developed to serve a specific user type—whether citizen, agent, or governor— providing a seamless and intuitive experience tailored to their responsibilities. The use of blockchain technology, integrated through MetaMask wallet interaction, reinforces the transparency and security of the system, particularly in property registration and ownership transfer operations. Through these interfaces, users can interact with the system efficiently while ensuring that property records are accurately stored in both the centralized database and the blockchain. This chapter highlighted how thoughtful interface design contributes significantly to the systems overall functionality, trust, and traceability.

General Conclusion

This project aimed to design and implement a secure, transparent, and reliable land registration and traceability system using blockchain technology [3]. Through the study and development phases, we demonstrated how the integration of smart contracts [5], decentralized records [1], and centralized databases can significantly improve the efficiency and trustworthiness of property management systems [7]. The proposed system ensures immutability of records, prevents unauthorized tampering, and provides real-time verification of ownership data all while maintaining compatibility with governmental oversight structures [10].

The implementation showed that blockchain is not only a theoretical solution but a practical one that can be adapted to local contexts, such as the Algerian land registry [11]. By combining technologies like MetaMask, Web3.js, PHP, and MySQL, the project succeeded in creating a prototype that reflects the real-world needs of land administration. Furthermore, the systems ability to document transactions and ownership history contributes to better transparency, reduced corruption, and greater protection of land rights [7].

While the results are promising, the project also revealed some challenges, such as integration complexity, user accessibility, and the need for legal and institutional alignment for full deployment. Future improvements could focus on enhancing scalability, user interface design, and aligning with national land registration regulations.

In conclusion, this project contributes to the growing field of blockchain-based governance and provides a solid foundation for transforming traditional land registration systems into more secure, modern, and efficient platforms [11][12].

Bibliography

[1] Nakamoto, S. (2008). Bitcoin: A Peer-to-Peer Electronic Cash System.

[2] Zyskind, G., Nathan, O., Pentland, A. (2015). Decentralizing privacy: Using blockchain to protect personal data.

[3] World Bank Group. (2018). Blockchain and Land Titles.

[4] FAO and ITU. (2020). E-agriculture in action: Blockchain for agriculture Opportunities and challenges.

[5] Christidis, K., Devetsikiotis, M. (2016). Blockchains and Smart Contracts for the Internet of Things. *IEEE Communications Magazine*.

[6] Lemieux, V. L. (2016). Trusting records: Is Blockchain technology the answer? *Records Management Journal*.

[7] Aliyu, A., et al. (2021). Blockchain Technology for Land Registration: A Systematic Review.

[8] Ethereum Documentation. Available at: `https://ethereum.org`

[9] Truffle Suite Documentation. Available at: `https://trufflesuite.com`

[10] MetaMask Documentation. Available at: `https://docs.metamask.io`

[11] Lantmäteriet. (2018). The Swedish Land Registrys Blockchain Pilot.

[12] Bitfury Group. Blockchain-based Land-Titling Project in Republic of Georgia.

[13] Kshetri, N. (2017). Can Blockchain Strengthen the Internet of Things? *IT Professional*.

[14] Implementation results and system testing data from the student's own project.

[15] Sommerville, I. (2015). *Software Engineering* (10th ed.). Pearson Education.

[16] Fowler, M. (2003). *UML Distilled: A Brief Guide to the Standard Object Modeling Language* (3rd ed.). Addison-Wesley.

[17] Object Management Group (OMG). (2017). OMG Unified Modeling Language (OMG UML), Version 2.5. Available at: `https://www.omg.org/spec/UML`

[18] Narayanan, A., Bonneau, J., Felten, E., Miller, A., Goldfeder, S. (2016). *Bitcoin and Cryptocurrency Technologies*. Princeton University Press.

[19] Merkow, M. S., Breithaupt, J. (2014). *Information Security: Principles and Practices*.

[20] Microsoft. (n.d.). Visual Studio Code Documentation. Available at: `https://code.visualstudio.com/docs`

[21] Ganache Documentation. Available at: `https://trufflesuite.com/ganache`

[22] Mozilla Developer Network (MDN). Available at: `https://developer.mozilla.org`

[23] Tapscott, D., Tapscott, A. (2016). *Blockchain Revolution: How the Technology Behind Bitcoin and Other Cryptocurrencies is Changing the World*. Penguin.

[24] Peters, G. W., Panayi, E. (2016). Understanding Modern Banking Ledgers through Blockchain Technologies: Future of Transaction Processing and Smart Contracts on the Internet of Money. In *Banking Beyond Banks and Money* (pp. 239278). Springer.

[25] Chen, Y., Bellavitis, C. (2020). Blockchain disruption and decentralized finance: The rise of decentralized business models. *Journal of Business Venturing Insights*, 13, e00151.

[26] Saberi, S., Kouhizadeh, M., Sarkis, J., Shen, L. (2019). Blockchain technology and its relationships to sustainable supply chain management. *International Journal of Production Research*, 57(7), 21172135.

[27] Francisco, K., Swanson, D. (2018). The Supply Chain Has No Clothes: Technology Adoption of Blockchain for Supply Chain Transparency. *Logistics*, 2(1), 2.

[28] Kshetri, N. (2018). Blockchains roles in meeting key supply chain management objectives. *International Journal of Information Management*, 39, 8089.

[29] Tian, F. (2017). A supply chain traceability system for food safety based on HACCP, blockchain Internet of Things. *2017 International Conference on Service Systems and Service Management*.

[30] Agbo, C. C., Mahmoud, Q. H., Eklund, J. M. (2019). Blockchain technology in healthcare: A systematic review. *Healthcare*, 7(2), 56.

[31] Roehrs, A., da Costa, C. A., da Rosa Righi, R., de Oliveira, K. S. F. (2019). Personal health records: A systematic literature review. *Journal of Biomedical Informatics*, 92, 103122.

[32] Tobin, A., Reed, D. (2016). The inevitable rise of self-sovereign identity. Sovrin Foundation.

[33] Croman, K., et al. (2016). On Scaling Decentralized Blockchains.

[34] Vranken, H. (2017). Sustainability of Bitcoin and blockchain. *Current Opinion in Environmental Sustainability*, 28, 19.

[35] Zohar, A. (2015). Bitcoin: under the hood. *Communications of the ACM*, 58(9), 104113.

[36] Atzei, N., Bartoletti, M., Cimoli, T. (2017). A survey of attacks on Ethereum smart contracts. *International Conference on Principles of Security and Trust*.

[37] Swan, M. (2015). *Blockchain: Blueprint for a New Economy*. O'Reilly Media, Inc.