Avrupa Bilim ve Teknoloji Dergisi
Sayı 54, S. 7-13, Aralık 2024

Araştırma Makalesi

www.ejosat.com ISSN:2148-2683

European Journal of Science and Technology
No. 54, pp. 7-13, December 2024

Research Article

A Novel Blockchain-Based Application for Real Estate Management System

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(İlk Geliş Tarihi 13 Mart 2023 ve Kabul Tarihi 27 Aralık 2023)

(**DOI:** 10.5281/zenodo.14175526)

ATIF/REFERENCE: Uslu, H., Samet, R. & Ozkan-Okay, M. (2024). A Novel Blockchain-Based Application for Real Estate Managemenet System. *European Journal of Science and Technology*, (54), 7-13.

Abstract

Traditionally, real estate management systems are based on a centralized approach where a single entity controls and manages all aspects of a real estate. However, centralized systems can compromise data security and integrity when issues arise. With the emergence of blockchain technology, it is now possible to create decentralized systems using smart contracts to automate various tasks and reduce the need for intermediaries. In this study, a real estate management system leveraging smart contracts and the decentralized structure of blockchain to facilitate the buying and selling of real estates has been developed. The developed application has successfully completed real estate transactions, and transaction information data has been recorded on the blockchain. The benefits of using a decentralized system, such as reducing transaction costs and increasing security, have been observed. This application not only reduces the physically conducted processes in a real estate transaction but also brings transparency to the real estate buying and selling process, contributing to the solving of trust issues between buyers and sellers in property transfers.

Keywords: Real estate systems, notary, blockchain, smart contract

Gayrimenkul Yönetim Sistemleri için Blok Zinciri Tabanlı Yeni Bir Uygulama

Öz

Gayrimenkul yönetim sistemleri, geleneksel olarak, tek bir varlığın bir mülkün tüm yönlerini kontrol ettiği ve yönettiği merkezi bir yaklaşıma dayanmaktadır. Ancak, veri yönetiminin merkeziyetçi yaklaşım ile yapılması, sistemde herhangi bir sorunla karşılaşıldığında veri güvenliğini ve bütünlüğünü ihlal etmektedir. Bununla birlikte, blok zinciri teknolojisinin ortaya çıkışıyla, çeşitli görevleri otomatikleştirmek ve aracılara olan ihtiyacı azaltmak için akıllı sözleşmeler kullanan merkezi olmayan sistemler oluşturmak artık mümkündür. Bu çalışmada, mülklerin satın alınmasını ve satılmasını kolaylaştırmak için akıllı sözleşmelerden ve blok zincirinin merkeziyetçi olmayan yapısından yararlanan bir gayrimenkul yönetim sistemi geliştirilmiştir. Geliştirilen uygulama ile gayrimenkul alış satış işlemi tamamlanmış ve işlem bilgileri blok zinciri üzerine kaydedilmiştir. Azalan işlem maliyetleri ve iyileştirilmiş güvenlik gibi merkezi olmayan bir sistem kullanmanın faydaları ortaya koyulmuştur. Bu uygulama, bir gayrimenkul satış işlemindeki fiziki olarak yapılan işlemleri azaltmasının yanı sıra, gayrimenkul alım satım sürecine şeffaflık getirmiştir ve mülk devrinde alıcı/satıcı arasındaki güven probleminin çözümüne de katkı sağlamıştır.

Anahtar Kelimeler: Gayrimenkul yönetim sistemleri, noter, block zinciri, akıllı sözleşmeler

1. Introduction

In our daily lives, there are many situations that involve official processes, such as banking transactions, real estate buying and selling, and legal procedures, and we often encounter difficulties in these situations. Among these scenarios, real estate management stands out as one of the most complex and challenging processes, requiring comprehensive documentation and paperwork. However, with the development of technology, numerous applications have emerged to simplify our daily routines and official procedures. Notably, the emergence of blockchain technology and smart contracts has revolutionized the real estate sector [1-5]. The integration of smart contracts into real estate management systems has simplified the entire process, making it more transparent, secure, and efficient. In this study, an application and method that utilize blockchain technology and smart contracts to facilitate and contribute to this challenging process have been developed.

A smart contract is a self-executing computer program that automatically enforces, verifies, and executes the terms of an agreement between two or more parties [6]. It is a computer code that runs on a blockchain network, which is a decentralized digital ledger that transparently and securely records and stores transactions [7]. Smart contracts are designed to automate various business processes, eliminate the need for intermediaries, reduce transaction costs, and enhance the security and efficiency of transactions [8]. For example, in the context of real estate, a smart contract can automate the process of buying or selling a property. The contract can be programmed to release payment to the seller automatically when the buyer transfers the money to an escrow account. This eliminates the need for intermediaries such as banks or lawyers, reducing transaction costs and the time required to complete the transaction.

Blockchain technology is a distributed data storage mechanism where data is kept in blocks that contain the hash information of the previous block, and this information is used to create its own hash and store the data in an encrypted form [9-11]. In centralized systems, data is always stored on a single node in the network, whereas in decentralized systems, data is stored on all nodes included in the network (Figure 1). With blockchain technology, data is stored on all nodes of the blockchain network rather than in a central database. This feature ensures that if there is an error or data corruption in any node, data in other nodes can be used. Additionally, since the data is stored in encrypted blocks, and each block in the blockchain is created using the hash information of the previous block, it is impossible to change any data within a block. Therefore, it is impossible for malicious individuals to alter the data stored in the blockchain. Furthermore, the consensus mechanism algorithms used to add data to the blockchain network ensure that the data in the network is always correct. The timestamp of each block in the blockchain network cannot be changed, which enhances the reliability of the data and provides convenience during the tracking of transactions [12-15]. Due to these features of blockchain technology, it has found applications in many aspects of our daily lives. Research has been conducted on its use in real estate transactions, and some countries have started implementing it.

Despite technological advancements in real estate management systems, several challenges still exist. One of these challenges is that real estate transfers are not yet fully online and are often carried out physically through notaries. Another issue is the issue of trust between buyers and sellers. In the case of a sale, problems may arise, such as the seller reporting a lower sale price than the agreed-upon price and receiving the remaining amount from the buyer in cash to avoid paying income tax. In recent years, banks have developed applications to mitigate the trust issue between buyers and sellers. In such cases, banks open a real estate sales account, blocking the buyer's funds until the transfer is completed and then transferring the funds to the seller's account. However, the low penalty charged to both the buyer and seller in case of withdrawal and the possibility of either party having the right to withdraw can be detrimental to both parties. Additionally, there is also the risk of sellers accepting deposits from multiple buyers, and there is no application available to control and keep track of this situation. To address these issues, a blockchain-based notary application using smart contracts has been designed.

This system differs in several ways from previous systems developed in this field. Tan and Nguyen [16] noted that real estate transactions consume significant time and involve substantial fees to intermediary institutions. They proposed the RETT (Real Estate Transaction Trace) system to reform the existing system. In this study, data is stored using two separate data storage technologies: blockchain and a central database. While using a central database alongside blockchain technology can enhance performance, it may compromise data accuracy and reliability. Mital et al. [17] highlighted that real estate transactions are often inefficient in India and in many parts of the world, with the potential threat of data loss, alteration, or fraud due to a lack of synchronized communication between institutions in this process. The proposed system addresses the need for the seller to communicate with other institutions in an encrypted manner during real estate transactions for security purposes. Latifi et al. [18] introduced a blockchain-based system for real estate transactions to ensure data security, prevent potential fraud, expedite transactions, eliminate intermediary institutions, and safeguard the value of real estate held on the blockchain network against inflation. Mendi et al. [19] suggested a blockchain-based land registry system to provide secure data. However, the proposed study highlights a deficiency in the system due to the lack of shared information about when and to whom the real estate was sold, which is available in the blockchain.

One significant difference in the proposed system is its ability to retrieve the transaction history of real estate from the blockchain, including information on previous owners, purchase dates, and sale prices. Moreover, the system administers and controls user views over a single blockchain network. To prevent sellers from avoiding taxes by reporting a lower sale price than the agreed price, the system verifies the consistency between the agreed-upon and transferred amounts. Additionally, in cases of shared ownership, real estate can be sold directly without requiring the signatures of other heirs. The most recent contribution is that the deed fee is no longer unfairly charged only to the buyer; with our system, this unfairness is prevented.

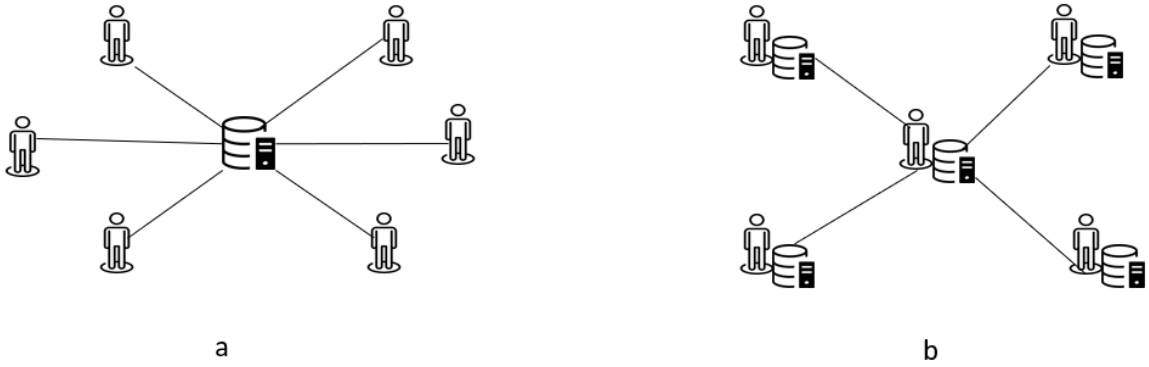

Figure 1(a) The centralized blockchain system (b) The decentralized blockchain system

The main stages of this developed application are listed below:

- The seller can list their real estate they want to sell on the blockchain-based system. However, before this stage, the system determines whether the real estate is suitable for sale by making a query through the municipality web service.
- If the real estate is suitable for sale, the system adds the advertisement information to the blockchain as a block.
- Buyers can send offers to the seller through the advertisements on the blockchain.
- In the case that the seller accepts the most suitable offer among the received offers, the other offers in the system become inactive and are kept waiting. A preliminary agreement is defined between the buyer and the seller through the system.
- The records of the preliminary agreement, written on the blockchain, are submitted to the system administrator for approval. If the system administrator approves the money transfer to the system account, the real estate transfer takes place.

The content of the study is as follows: In Section 2, the architecture of the developed application is explained. In Section 3, a case study of the developed application is given in detail. The evaluation of the developed application is provided in Section 4. The final section discusses the results, contributions of the study, and future work.

2. Architecture of the Proposed Application

Alongside a literature review, the operation of the current system in Turkey has been thoroughly researched. This research involved analyzing the creation of real estate sales advertisements, the negotiation process between buyers and sellers, and the preparation of necessary documents before proceeding to notary offices. Additionally, the procedures carried out within the notary offices have been examined. Technological research has been conducted to explore the management of this process through a blockchain-based system. As a result of our research, the Ethereum platform has emerged as the most commonly used blockchain platform. Subsequently, studies have been conducted to develop a notary application based on the Ethereum blockchain platform.

The proposed application's architecture comprises three main layers: data, service, and user interface (Figure 2).

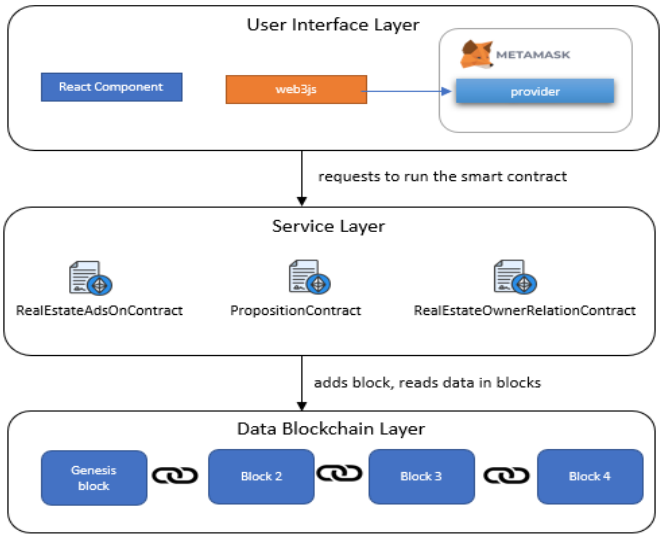

Figure 2. Architecture of the proposed application

2.1. Data Layer: In the data layer, transaction data is added to the blockchain in an encrypted form. All blocks, except for the first block in the blockchain, contain the hash information of the previous block. The first block in the blockchain, known as the genesis block, does not contain this hash value. Hash information within blocks is generated by hash functions using the data from the previous block and the block itself. By keeping data encrypted and distributed across multiple nodes, data security and integrity are ensured.

2.2. Service Layer: Smart contracts are utilized in the service layer to add blocks to the Ethereum-based blockchain in the data layer. Smart contracts consist of code blocks written in Solidity and run on the Ethereum blockchain. They govern agreements between parties and manage users' property data. Furthermore, smart contracts within the system validate the data added by users to ensure its compliance with the system's requirements, thereby preventing the addition of incorrect data and fraudulent transactions. Smart contracts are translated into bytecode and executed on the Ethereum Virtual Machine (EVM). Each smart contract is assigned a unique address, with Ethereum using the Keccak-256 hash function to calculate these addresses. Hash functions produce a unique and fixed-length encrypted output for every given input. Even a slight change in the input will result in a significantly different encrypted output. Predicting or computing the encrypted data from the hash function outputs is impossible. Smart contract addresses on the Ethereum blockchain are created using these hash functions, ensuring that the same address cannot exist in another smart contract.

2.3. User Interface Layer: Web3.0 is utilized in the user interface layer to access the blockchain network through smart contract addresses. To access the interface, which is developed using Web3.0 and React, users need to connect to the Ethereum network with their MetaMask accounts. MetaMask is a cryptocurrency wallet that links to the Ethereum blockchain network, allowing users to access the blockchain without downloading all the blockchain data [20, 21]. This enables users with limited storage space to access the blockchain data easily. Users must provide approval through MetaMask to perform actions such as advertising, accepting, or rejecting an offer. Web3 uses the user's account information and transaction data to execute the smart contract on the network.

The proposed architecture has been developed by drawing inspiration from software architecture examples in centralized applications. While relational databases are commonly employed in the data layer of centralized systems, our proposed application stores data using blockchain technology. Smart contracts are used to access and add to the blockchain in the service layer. Similar to centralized applications, the service layer is positioned between the view layer and the data layer in the proposed architecture.

3. Case Study: A Smart Contract Application

Smart contracts are the most important component of the system. In the developed system, the user profile is divided into two categories: system users and application administrators. Role information of users and the operations they can perform based on their role are carried out through smart contracts developed for the system.

Users with the role of application administrator are third-party users located in the notary office. Although one of the main principles of blockchain technology is to remove the authority for transactions, the decision was made to ignore this principle in the initial version of the application by adding an admin user role to the system. This was done to transfer the data from the existing centralized system to the blockchain network and to be able to verify that users are performing the correct operations and provide live assistance when needed. Users with the role of application administrator can add real estate data to the system and associate the accounts of users who own real estate with the real estate data in the system. Real estates that will be added to the blockchain through smart contracts can be added to an individual as well as to shared ownership. Smart contracts were designed considering that system users cannot perform operations that can be performed by the admin role.

Users with the system user role can view their real estates in the system and can put them up for sale, even if they are jointly owned real estates. They can see the offers they receive for the real estates they have put up for sale and can accept or reject them. They can also view the listed real estates and their historical data on the blockchain network. The sequence diagram of the proposed system is given in Figure 3.

With the designed system, users with the system user role can carry out real estate sales that are manually conducted through the system. The determination of the fair value and tax debt query is checked by the system by accessing the municipality web service after getting ads query by the seller. The reason for checking these operations is that there is no such control in the real estate ads on the existing ad sites, and the buyer can only access this information after spending a certain amount of time talking to the seller. This process is carried out by the system before getting an ad query to ensure that there is no obstacle to the sale of real estates on the system. The designed smart contracts are based on the blockchain and create an ad based on the debt and fair value of real estate information obtained from the municipality web services. If this obtained information is proper to create an ad, the system will add the block data to the blockchain. The reliability of the system will be increased by obtaining the necessary information from the blockchain-based municipality web service. By means of this, the problems that buyers experience in the initial stages will be solved.

One of the most important reasons for using blockchain technology in real estate buying and selling systems is to eliminate the trust problem between the buyer and the seller. This is because it is possible for the seller to make agreements with multiple buyers before the sales process begins. To solve this problem, when the seller accepts the buyer's offer, the ads in which users can make offers are removed from the list and locked for the buyer. With the smart contracts developed for the system, it is prevented that another buyer can send an offer to the locked ads.

Ads that are locked for the buyer are subject to the approval of the system administrator. The system administrator expects the buyer to send the real estate sales price and deed fees to the system account, and only the deed fees to the seller's system account. Once the transfer is complete, it receives verbal confirmation from the buyer and seller before approving the necessary money

transfers on the blockchain. Verbal confirmation by the system administrator is a system requirement for users specific to the first version to get used to the system, and it can be removed later. After receiving verbal confirmation from the buyer and seller, the real estate transfer is performed on the blockchain with the approval of the system administrator. By this context, the agreements of the buyer and the seller and the amounts to be transferred are controlled through the system, and the transactions that require trust between the buyer and the seller are left to the responsibility of the system.

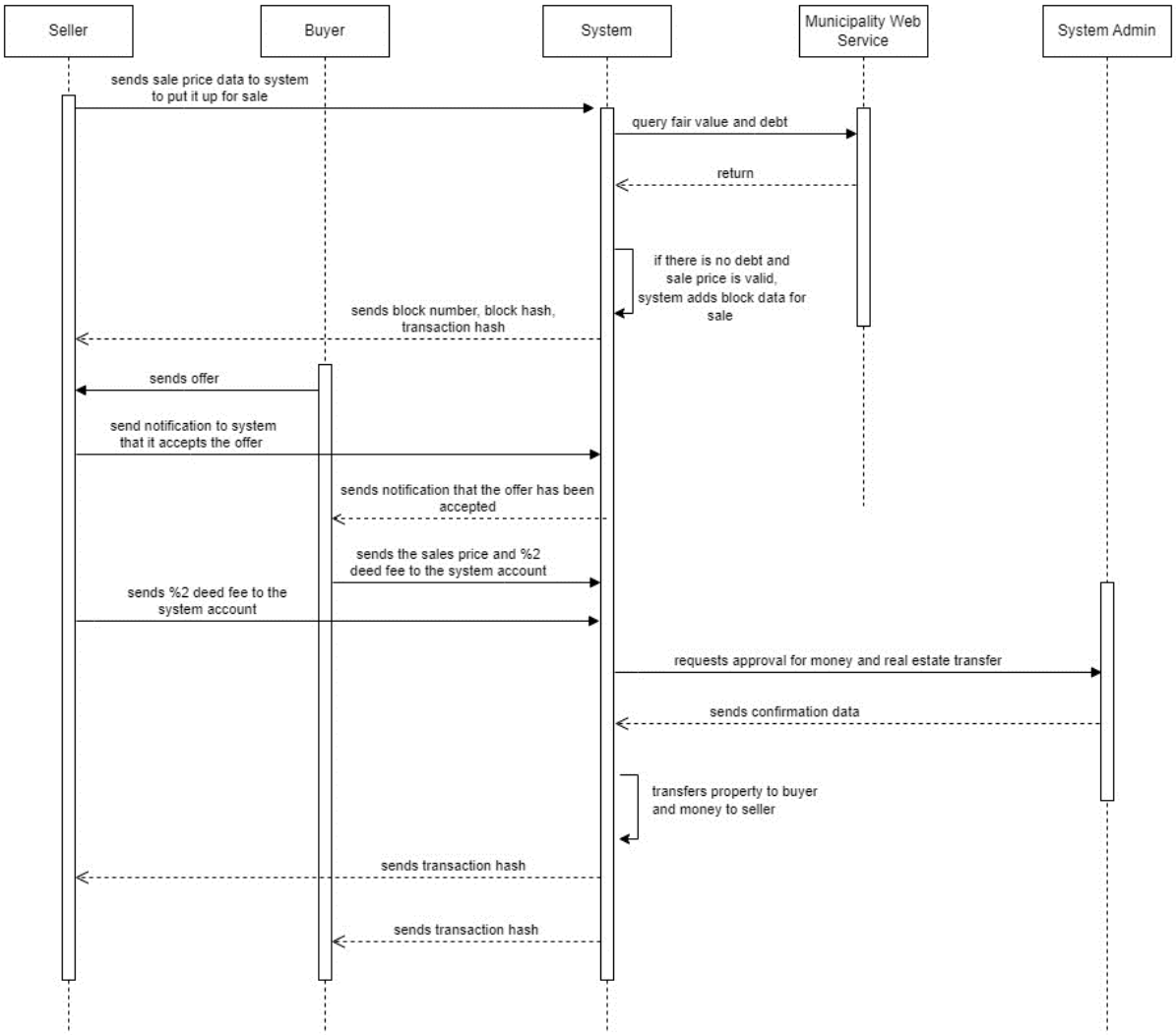

Figure 3. Sequence diagram of the proposed system

The cost calculated for real estate sales conducted through the blockchain-based notary application is provided in Table 1.

Table 1. The cost of a real estate sales transaction in the proposed system

Transaction Name	**Gas Fee**	**ETH**	**≈ TL**
Creating add	220494	0.0044	170
Sending offer	252306	0.0050	190
Confirming offer	85412	0.0017	65
Confirming the money transfer	57298	0.0012	45
Completing real estate transfer	104306	0.0021	85

The steps of a real estate buying and selling transaction made with the recommended application are outlined in Table 1. These steps involve creating an advertisement for a real estate sale, sending an offer to the seller, approving the buyer's offer, confirming the

money transfer made by the system administrator to the system account of the buyer and seller, and completing the real estate sale. The costs of these transactions are calculated based on the amount of gas expended to execute a transaction on the Ethereum blockchain, the amount of ETH, and the TL equivalent of these transactions. It has been determined that real estate sales conducted through the proposed application are more cost-effective compared to current systems. The measurement parameter for this outcome includes the commissions paid to intermediaries such as lawyers and real estate agents, as well as the fees associated with transfer transactions at notary offices in current systems.

4. Discussion and Evaluation

In this study, a blockchain-based notary application has been developed with the aim of conducting real estate transactions more securely and efficiently. The developed application securely and transparently stores data related to the transactions carried out during the buying and selling process on the blockchain. To prevent unauthorized users from adding real estate and shareholders in the system, the execution of smart contracts used for adding real estate and shareholders in the system has been restricted for everyone. Thanks to these features, the developed application can provide better results than those found in existing studies in the literature in terms of both security and transaction costs. In this context, a comparison of existing studies and the developed application is given in Table 2.

Table 2. Comparison of the proposed application with the common studies in the literature

	Mendi et al..2020 [19]	**Tan and Nguyen 2022 [16]**	**Mukne et al. 2019 [22]**	**Proposed Application**
Security	Metamask	Metamask	Github	Metamask
Blockchain Platform	Hyperledger Fabric	Ethereum	Hyperledger	Ethereum
Fair Price Control	✓	-	-	✓
No relational database, Just blockchain	✓	-	✓	✓
Co-ownership property sale	-	-	-	✓
Prevent the seller from agreeing with other buyers	-	-	-	✓

The developed application has been compared to studies in the literature [Table 2]. In research conducted within the literature, it has been observed that Ethereum and Hyperledger Fabric blockchains are more commonly used in blockchain-based notary applications. Ethereum blockchain is public, whereas the Hyperledger blockchain is classified as a permissioned blockchain. Since a public blockchain is more suitable for an application where all citizens will have access, the recommended application employs the Ethereum blockchain. For the blockchain-based notary application recommended by Mukne and others, authentication is required with a GitHub account. However, for such an application, authentication should be based on national identity information or application-specific account information (e.g., Metamask). The use of the Tan and Nygue blockchain, along with a relational database, has compromised the security and encryption of all data used in the application. In the recommended application, data is securely stored and encrypted solely on the blockchain. Finally, it has been noted in other studies within the literature that there are no constraints added to smart contracts to prevent shared sales and sellers from making agreements with other buyers.

The proposed system ensures that highly important land registry information is stored on a blockchain, ensuring the immutability of the data. In real estate transactions, the process is autonomously advanced through smart contracts within the application, eliminating the need for intermediaries and making buying and selling more reliable. Transactions conducted via smart contracts cannot be reversed or removed from the system once executed. Consequently, any potential software vulnerability in smart contracts could affect parties for a certain period due to erroneous transactions, which could be considered a drawback of the system. To implement the proposed system in the real world, legal regulations by the government are necessary, and the work should be conducted under government oversight. For future developments, protocol discussions with the necessary government institutions will be conducted to test the developed system in real-world scenarios.

5. Conclusion

In real estate buying and selling, there are many official procedures that come with various challenging processes. However, the emergence of blockchain technology and smart contracts has led to significant advancements in the real estate sector. The integration of smart contracts into real estate management systems has made it possible to simplify the entire process and make it more transparent, secure, and efficient.

Despite the significant technological advancements in real estate management systems, there are still several issues that we encounter. To address these problems, a blockchain-based real estate application using smart contracts has been proposed. One notable feature of this system, distinct from other studies in the literature, is its ability to provide information about who bought the real estates from the blockchain, along with their historical data such as the date and sale price. Additionally, advertisement information and information that require oversight by the system administrator are managed through a single system. To prevent sellers from evading taxes by selling at a lower price than the real value, the system checks for consistency between the agreed amount and the transferred amount. In the case of co-owned real estates, they can be sold directly without the need for the signatures of other owners. The last distinction is that with this system guaranties that both the buyer and the seller share the title deed fee.

In the future, there are plans to further develop this system, allowing for automatic real estate transfers to the buyer and the transfer of funds to the seller without the need for the system administrator's approval once the buying-selling process is complete. Additionally, there is an aim to test this system in the real world by collaborating with government institutions.

References

[1] Dijkstra, M. (2017). Blockchain: Towards Disruption in the Real Estate Sector: An exploration on the impact of blockchain technology in the real estate management process.

[2] Wouda, H. P., & Opdenakker, R. (2019). Blockchain technology in commercial real estate transactions. Journal of property investment & Finance.

[3] Ahmad, I., Alqarni, M. A., Almazroi, A. A., & Alam, L. (2021). Real estate management via a decentralized blockchain platform. Comput. Mater. Contin, 66(2), 1813-1822.

[4] Karamitsos, I., Papadaki, M., & Al Barghuthi, N. B. (2018). Design of the blockchain smart contract: A use case for real estate. Journal of Information Security, 9(3), 177-190.

[5] Mohanta, B. K., Panda, S. S., & Jena, D. (2018, July). An overview of smart contract and use cases in blockchain technology. In 2018 9th international conference on computing, communication and networking technologies (ICCCNT) (pp. 1-4). IEEE.

[6] Zou, W., Lo, D., Kochhar, P. S., Le, X. B. D., Xia, X., Feng, Y., ... & Xu, B. (2019). Smart contract development: Challenges and opportunities. IEEE Transactions on Software Engineering, 47(10), 2084-2106.

[7] Ren, M., Yin, Z., Ma, F., Xu, Z., Jiang, Y., Sun, C., ... & Cai, Y. (2021, July). Empirical evaluation of smart contract testing: What is the best choice?. In Proceedings of the 30th ACM SIGSOFT International Symposium on Software Testing and Analysis (pp. 566-579).

[8] Wang, S., Yuan, Y., Wang, X., Li, J., Qin, R., & Wang, F. Y. (2018, June). An overview of smart contract: architecture, applications, and future trends. In 2018 IEEE Intelligent Vehicles Symposium (IV) (pp. 108-113). IEEE.

[9] Ammous, S. (2016). Blockchain technology: What is it good for?. Available at SSRN 2832751.

[10] Di Pierro, M. (2017). What is the blockchain?. Computing in Science & Engineering, 19(5), 92-95.

[11] Fauziah, Z., Latifah, H., Omar, X., Khoirunisa, A., & Millah, S. (2020). Application of blockchain technology in smart contracts: a systematic literature review. Aptisi Transactions on Technopreneurship (ATT), 2(2), 160-166.

[12] Golosova, J., & Romanovs, A. (2018, November). The advantages and disadvantages of the blockchain technology. In 2018 IEEE 6th workshop on advances in information, electronic and electrical engineering (AIEEE) (pp. 1-6). IEEE.

[13] Niranjanamurthy, M., Nithya, B. N., & Jagannatha, S. J. C. C. (2019). Analysis of Blockchain technology: pros, cons and SWOT. Cluster Computing, 22, 14743-14757.

[14] Sarmah, S. S. (2018). Understanding blockchain technology. Computer Science and Engineering, 8(2), 23-29.

[15] Ali, O., Jaradat, A., Kulakli, A., & Abuhalimeh, A. (2021). A comparative study: Blockchain technology utilization benefits, challenges and functionalities. Ieee Access, 9, 12730-12749.

[16] Tan, V. K. and T. Nguyen (2022). The Real Estate Transaction Trace System Model Based on Ethereum Blockchain Platform. 2022 14th International Conference on Computer and Automation Engineering (ICCAE), IEEE.

[17] Mittal, A., Sharma, B., & Ranjan, P. (2020, November). Real Estate Management System based on Blockchain. In 2020 IEEE 7th Uttar Pradesh Section International Conference on Electrical, Electronics and Computer Engineering (UPCON) (pp. 1-6). IEEE.

[18] Latifi, S., Zhang, Y., & Cheng, L. C. (2019, July). Blockchain-based real estate market: One method for applying blockchain technology in commercial real estate market. In 2019 IEEE International Conference on Blockchain (Blockchain) (pp. 528-535). IEEE.

[19] MENDİ, A. F. Ankara'da Blokzincir Tabanlı Arazi Kayıt Sistemi Kullanımı. Avrupa Bilim ve Teknoloji Dergisi, (29), 193-199.

[20] Lee, W. M., & Lee, W. M. (2019). Using the metamask chrome extension. *Beginning Ethereum Smart Contracts Programming: With Examples in Python, Solidity, and JavaScript*, 93-126.

[21] Beştaş, M., Taş, R., Akin, E., Ozkan-Okay, M., Aslan, Ö., & Aktug, S. S. (2023). A Novel Blockchain-Based Scientific Publishing System. Sustainability, 15(4), 3354.

[22] Mukne, H., Pai, P., Raut, S., & Ambawade, D. (2019). Land record management using hyperledger fabric and ipfs. 2019 10th International Conference on Computing, Communication and Networking Technologies (ICCCNT).