BlockEstate: Revolutionizing Real Estate Transactions through Hyperledger-based Blockchain Technology

Laviza Falak Naz
Department of Software Engineering, NED University of Engineering & Technology, Pakistan
lavizaniazi2001@gmail.com

Rohail Qamar
Department of Computer Science & Information Technology, NED University of Engineering & Technology, Pakistan
rohailqamar@cloud.neduet.edu.pk (corresponding author)

Raheela Asif
Department of Software Engineering, NED University of Engineering & Technology, Pakistan
rahmed@cloud.neduet.edu.pk

Saad Ahmed
Department of Computer Science, IQRA University, Pakistan
saadahmed@iqra.edu.pk

Muhammad Imran
Department of Computer Science & Information Technology, NED University of Engineering & Technology, Pakistan
hmimran@neduet.edu.pk

Received: 19 February 2024 | Revised: 19 March 2024 | Accepted: 24 March 2024

 DOI: https://doi.org/10.48084/etasr.7105

ABSTRACT

This study introduces BlockEstate, an innovative platform to revolutionize real estate transactions through the application of Hyperledger blockchain technology. BlockEstate presents novel contributions in the form of a pioneering compensation request mechanism and a sophisticated chaincode for real estate transaction management. These advancements address long-standing challenges in traditional real estate transactions by leveraging the decentralization, immutability, and transparency of blockchain technology. By ensuring secure and transparent financial transactions and automating property ownership conveyances, BlockEstate sets a new standard for efficiency and safety in the real estate industry. This study comprehensively investigates the design, functionality, and impact of BlockEstate, highlighting its unique contributions and potential to transform the real estate market.

Keywords-blockchain; real estate; hyperledger; chaincode; property ownership management; pay order; decentralization; transaction security; financial transparency; smart contracts; digital tokenization; property token

I. INTRODUCTION

The real estate sector is going through a transformative period driven by the emergence of blockchain technology. Traditional real estate transactions have long been affected by inefficiencies, lack of transparency, and security concerns. In response to these challenges, BlockEstate emerges as a groundbreaking platform built on the hyperledger blockchain architecture. This study presents BlockEstate's innovative contributions, notably its revolutionary compensation request mechanism and sophisticated chaincode for property ownership management. By harnessing the inherent benefits of blockchain technology, including decentralization and transparency, BlockEstate aims to streamline real estate transactions while

certifying the security and integrity of financial exchanges. This study performs a thorough investigation of the BlockEstate's architecture, functionality, and potential impact on the real estate industry. The emergence of blockchain technology has sparked a new era of innovation that has not gone unnoticed in the real estate sector. Long cycles, the absence of straightforwardness, and a critical gamble of extortion are among the issues that affect customary real estate transactions [1]. These problems require a strong framework to guarantee security and simplicity while smoothing out transactions. BlockEstate is altering real estate transactions by exploiting the inherent benefits of blockchain, including permanence, decentralization, and straightforwardness [2]. The proposed framework utilizes a chaincode to follow property ownership, which is supported by another compensation request framework that makes property conveyances safer and more effective.

The advent of blockchain technology, a decentralized and immutable ledger system, has ignited a paradigm shift across various industries, including real estate. Blockchain, fundamentally altering conventional transactional frameworks, promises enhanced security, transparency, and efficiency. In this context, the Hyperledger framework stands out as a robust platform for implementing blockchain solutions tailored to specific industry needs. By leveraging Hyperledger's modular architecture and permission network model, organizations can develop secure and scalable blockchain applications, addressing the inherent challenges of traditional systems. The design of BlockEstate provides a far-reaching answer to the current failures in the real estate market. It guarantees that all exchanges are noticeable and irreversible by permitting a decentralized record framework. Chaincode is used to follow property possession, whereas the compensation request framework ascertais straightforward and protected monetary exchanges between buyers and dealers [3].

Continuing academic and industry studies have shown an increasing interest in the utilization of blockchain in real estate transactions [4]. Some investigations have underscored the true capacity of blockchain to handle massive challenges in real estate transactions, such as extortion, lack of straightforwardness, and shortcomings [5]. The qualities of blockchain, especially its decentralized nature and sealed record, have been cited as essential for improving the dependability and effectiveness of real estate transactions [6]. Earlier blockchain applications in the real estate sector have mostly focused on digitizing property records and smoothing out title handovers [7]. However, these frameworks need complete answers for the exchange of executives and monetary security, which are pivotal in real estate transactions. Savvy contracts have been acquainted with automated exchange methods [8]. However, the intricacy of real estate transactions, which expand over legal, monetary, and administrative issues, requires a more customized framework [9].

The BlockEstate framework, which utilizes the secluded and versatile construction of Huperledger, represents a significant step in this area [10]. Due to Hyperledger's adaptability for private exchanges and adaptable agreement techniques, it is appropriate for real estate transactions where security and proficiency are essential [11]. In contrast to regular agreements, the chaincode for ownership provides a more complex and versatile arrangement in the field of real estate transactions [12]. In addition, BlockEstate's compensation request component fills a huge need in the existing blockchain real estate frameworks [13]. Although previous models provided a protected record of property data, most of them missed the intricacies of real estate monetary exchanges. The BlockEstate mediation ledger concept not only ensures the security of financial transactions, but also provides transparency [14]. Recent studies have underscored the growing interest in utilizing blockchain technology in various sectors, including real estate. In particular, the Hyperledger framework has attracted significant attention because of its suitability for developing blockchain applications tailored to specific industry requirements.

II. BLOCKESTATE ARCHITECTURE

BlockEstate is a pioneering real estate transaction framework based on the strength of the versatile Hyperledger blockchain system [15]. BlockEstate is specifically designed to adapt to the subtleties and complexity of real estate transactions, offering a safe, transparent, and effective solution [16]. The decentralized record at the core of BlockEstate's design enables the permanent recording of property exchanges, improving security, privacy, and straightforwardness. Unlike public blockchains, Hyperledger offers a permission network environment, which is essential for safeguarding the privacy of real estate transactions. It makes it possible to set up private channels, allowing specific data to be shared only with authorized parties, which is crucial when dealing with sensitive information in real estate transactions.

A. Network Structure

The BlockEstate structure consists of numerous hubs, each of them addressing a particular role in the real estate market, such as buyers, merchants, monetary establishments, and administrative associations [17]. These hubs participate in the agreement cycle, guaranteeing the authenticity and realness of the exchange. Additionally, the design incorporates savvy contracts or chaincode to automate exchange methods and implement BlockEstate business rules [18].

B. Chaincode for Property Ownership

BlockEstate's structure consists of numerous hubs, each one addressing a particular player in the housing market, such as purchasers, merchants, monetary establishments, and administrative associations [19]. These hubs participate in the agreement cycle, verifying the authenticity and realness of the transaction. The design also contains savvy contracts or chaincode, which automate exchange methods and implement the BlockEstate business rules [20]. Figure 1 illustrates the architecture of BlockEstate, a revolutionary real estate transaction platform built on the Hyperledger blockchain framework. The diagram presents its decentralized network structure, comprised of various nodes representing key stakeholders in the real estate market, such as buyers, sellers, financial institutions, and regulatory agencies. These nodes interact within the permission network, ensuring transaction authenticity and integrity. Additionally, the diagram highlights

the role of smart contracts or chaincode in automating transaction processes and enforcing business rules within the BlockEstate ecosystem. Figure 1 provides a comprehensive visualization of the platform's architecture, emphasizing its ability to address the complexities of real estate transactions while leveraging the benefits of blockchain technology.

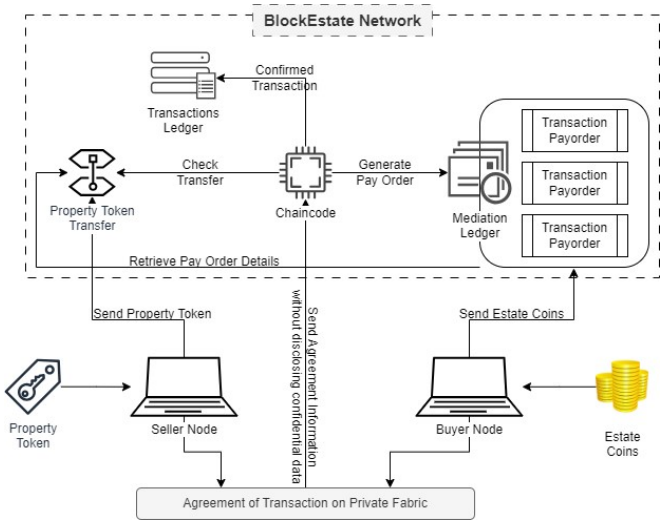

Fig. 1. BlockEstate architecture diagram.

III. PAY REQUEST MECHANISM

The BlockEstate pay request mechanism is a creative procedure for managing monetary transactions in the real estate market. This procedure is basic to keep up with monetary security and simplicity in real estate transactions.

A. Functionality

When a property exchange begins, the purchaser's cash is not transferred directly to the dealer. All things considered are recorded as a compensation request in an intervention record. The buyer and the seller are the only people who have access to the transaction information in this ledger, which is accessible to all network peers. However, this ledger does not allow access to private data.

B. Security and Transparency

The intervention record fills in as a protected store box for money exchange. It captures all transaction information while ensuring that private data is kept secret. This technique protects the money and guarantees straightforwardness for all sides that participate in the transaction [21].

C. Automated Affirmation and Reversion

The chaincode is basic to the compensation request method. The chaincode consequently approves the compensation request in the intervention record and disseminates the money to the dealer upon the exchange of the property token from the merchant to the purchaser. This part certifies that the progression of installments depends on the effective exchange of property ownership [22]. The pay order is canceled and the funds are returned to the buyer if the property token is not transferred within the specified time frame. This element offers a level of monetary security, protecting the two parts. Figure 2 presents the transaction flow within the BlockEstate framework, illustrating the sequence of events during a typical real estate transaction. The diagram begins with the initiation of a property transaction by a buyer, followed by the generation of a pay order in the mediation ledger to secure the transaction funds. Upon confirmation of the pay order, the property token is transferred from the seller to the buyer, triggering the release of funds from the mediation ledger to the seller. The diagram highlights the automated confirmation and reversion processes facilitated by the platform's chaincode, establishing the security and transparency of the transaction.

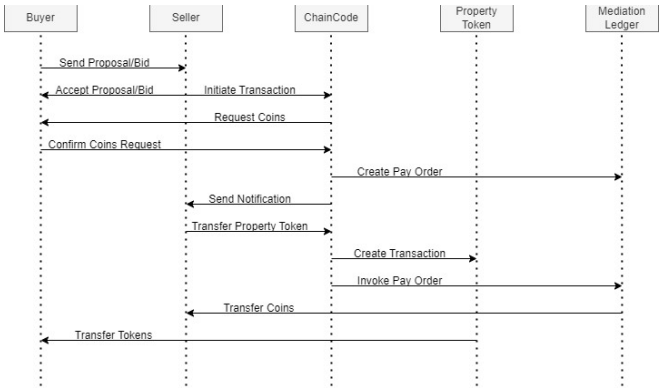

Fig. 2. BlockEstate transaction flow diagram.

The BlockEstate design, upheld by the Hyperledger structure and its original compensation request component, set another norm in real estate transactions. The blend of these innovations addresses a large number of the current land challenges, providing a framework that is more productive, safe, straightforward, and easy to use [23].

IV. CHAINCODE FUNCTIONALITY

The chaincode, a basic part of BlockEstate's design, acts as its conditional spine. An assortment of programmable directions run on the Hyperledger blockchain to oversee and work with real estate transactions.

A. Technical Implementation

The chaincode in BlockEstate is written in a high-level programming language, supported by the Hyperledger texture structure, such as Go or JavaScript. This programming style empowers the advancement of mind-boggling business rationale to oversee numerous components of property transactions [24-25]. The guidelines for validating transactions, executing pay orders, and transferring property ownership are embedded in the chaincode.

B. Transaction Interaction Automation

Chaincode smooths out the buyer-vendor transaction. Chaincode checks the accessibility and responsibility for a property token when an exchange is sent. Then, it administers the compensation request framework, guaranteeing that money is securely kept in the intercession record until all deal details are fulfilled [26].

C. Ensuring Consistency and Security

Chaincode ascertains that all exchanges comply with the predefined principles and limitations [27]. It also plays an important role in ensuring exchange security by preventing unapproved access and deceitful movement.

ALGORITHM 1: BLOCKESTATE CHAINCODE

```
Initialize Chaincode
Initialize ledger state

// Handler for various chaincode invocations
Invoke Function

// Create a new property record
CreateProperty(property details).
Validate property details, store property in
ledger and return success or error message.

// Transfer property ownership
TransferProperty(property ID, new owner).
Retrieve property from the ledger, verify
ownership and transfer conditions.
Update property record with the new owner,
return success or error message.

// Create a pay order for a property
// transaction
CreatePayOrder(buyer, seller, amount).
Validate transaction details, create and store
pay order in ledger.
Lock transaction amount in mediation ledger
and return success or error message.

// Confirm a pay order upon successful
// property transfer
ConfirmPayOrder(pay order ID)
Retrieve pay order from ledger, verify
property transfer completion.
Update pay order status, transfer funds from
mediation ledger to seller, return success or
error message.
```

V. CASE STUDY/APPLICATION EXAMPLE

An imaginary contextual analysis was proposed to investigate the execution and advantages of BlockEstate, while also examining its scalability, performance, reliability, and security implications [28].

A. Background

Consider the following situation: a purchaser, Alice, wants to buy a home from a seller, Bob, using the BlockEstate platform in a metropolitan area. As the transaction unfolds, BlockEstate demonstrates its ability to handle a surge in activity without compromising performance or reliability. The platform's architecture, backed by the Hyperledger framework, ensures that the transaction process remains secure and transparent throughout. Furthermore, BlockEstate's scalability becomes evident as it effortlessly manages multiple transactions concurrently, showcasing its potential to accommodate future growth in real estate transactions. The reliability of the platform is underscored, as it consistently executes smart contracts and manages property ownership transfers without downtime or errors. Additionally, stringent security measures, such as data encryption and access control, protect sensitive information exchanged during the transaction.

B. Initiation of Transaction

Alice begins the transaction on the BlockEstate framework. The chaincode produces a compensation request due to her sign of interest, protecting the transaction sum in the intervention record. Then Bob transfers Alice's property token through the BlockEstate platform. The chaincode approves the exchange and confirms the compensation request. Bob gets the money from the intercession record [29].

C. Efficiency and Security Benefits

This contextual analysis features BlockEstate's productivity and security benefits. The transaction system is improved, reducing the time and complexity associated with common property exchanges. In addition, the chaincode and pay request instrument confirm the security of cash and the simplicity of the transaction [26]. Figure 3 portrays the practical application of the BlockEstate framework in the real estate market through a conceptual case study. The transaction process involves the transfer of a property token and the confirmation of a pay order, facilitated by the platform's chaincode. Figure 3 demonstrates the efficiency and security benefits of utilizing BlockEstate in real estate transactions, highlighting its potential to streamline the buying and selling process while ensuring transparency and trust between parties. In general, the figure provides a tangible example of how BlockEstate can revolutionize the real estate market. BlockEstate manifests that the use of blockchain technology in real estate transactions significantly enhances security and privacy. However, these developments require a comprehensive examination to mitigate the associated risks [30].

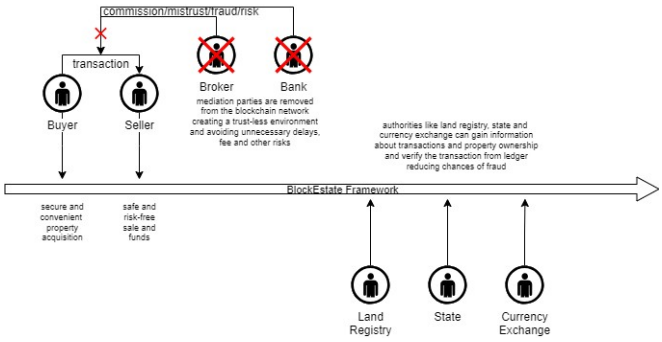

Fig. 3. Application of BlockEstate framework in the real estate market.

D. Data Encryption and Access Control

Important data, such as individual buyer and merchant data and property token particulars, are encrypted. Advanced encryption algorithms can be applied to protect data both in transit and at rest thanks to the Hyperledger framework. In addition, access control measures are deployed to reassure that the main approved clients approach specific information, subsequently safeguarding the data.

E. Smart Agreement Security

BlockEstate's chaincode or smart agreements avoid weaknesses that might be mishandled [31]. The convention incorporates normal reviews and moves up to protect the chaincode's trustworthiness and security, thus defending the framework from potential breaks or deceitful action.

F. Regulatory Compliance

BlockEstate is planned to conform to existing property and information insurance rules [32]. The framework follows administrative prerequisites for information security, such as GDPR, and property regulations to certify the protection of property deliveries.

VI. CHALLENGES AND LIMITATIONS

Despite the innovative approach and advanced technology of BlockEstate, some inherent barriers and constraints must be acknowledged and addressed.

A. Technical Complexity

The utilization of blockchain technology in the real estate sector presents significant technical challenges. The development and maintenance of the BlockEstate platform requires substantial technical expertise, particularly in blockchain technology and smart contract programming. Implementing and managing a complex system like BlockEstate requires a skilled team capable of navigating intricate cryptographic protocols, consensus mechanisms, and distributed ledger technologies. Furthermore, ensuring the interoperability and compatibility of BlockEstate with existing real estate systems and processes adds another layer of technical complexity [33].

B. Adoption and Integration

The adoption of blockchain technology poses a formidable challenge in the traditionally conservative real estate market. Integrating BlockEstate with established real estate workflows and systems may encounter resistance from stakeholders accustomed to conventional methods. Additionally, ascertaining seamless integration with regulatory frameworks and compliance standards adds complexity to the adoption process. Overcoming skepticism and fostering trust among industry participants will be crucial for the widespread acceptance and utilization of BlockEstate [34].

C. Scalability and Performance

Scalability and performance are perennial concerns associated with blockchain technologies, and BlockEstate is no exception. As the platform scales to accommodate a growing volume of transactions and users, it must demonstrate the ability to maintain speed, efficiency, and reliability. Scalability challenges arise from the inherent design of blockchain networks, including issues such as transaction throughput, network congestion, and resource consumption. Confirming that BlockEstate can handle increased transactional demands without compromising performance will be essential for its long-term viability and success. In addition, optimizing resource utilization and improving network efficiency will be ongoing objectives to effectively address scalability concerns [35].

D. Regulatory and Legal Challenges

Navigating regulatory frameworks and compliance requirements presents significant hurdles for BlockEstate. The real estate sector is subject to a myriad of laws, regulations, and jurisdictional nuances that govern real estate transactions, data privacy, and financial transactions. Compliance with regulatory mandates such as Know Your Customer (KYC), Anti-Money Laundering (AML), and data protection regulations poses additional challenges for BlockEstate. Establishing that the platform adheres to legal requirements while maintaining user privacy and data security requires meticulous attention to detail and ongoing monitoring of regulatory developments. Failure to adequately address regulatory concerns could result in legal liabilities, reputational damage, and operational disruptions [36].

E. Market Acceptance and Trust

Building trust and gaining acceptance within the real estate industry and among potential users is a critical but challenging endeavor for BlockEstate. Overcoming skepticism and dispelling misconceptions about the reliability, security, and suitability of blockchain technology for real estate transactions requires concerted efforts in education, outreach, and transparency. Establishing a successful transaction record, addressing concerns related to data privacy and security, and fostering a community of satisfied users will be instrumental in building trust and credibility for BlockEstate. Moreover, collaborating with industry stakeholders, regulatory bodies, and professional associations to promote awareness and understanding of BlockEstate's capabilities and benefits will be essential for driving adoption and market acceptance.

VII. CONCLUSION

BlockEstate is a major step in the utilization of blockchain innovation for real estate transactions. Using the Hyperledger foundation and introducing a novel order-pay system, BlockEstate addresses significant issues in the real estate market, such as transaction inefficiencies, lack of transparency, and security concerns. The design of the framework and the chaincode capabilities increase the productivity, security, and straightforwardness of real estate transactions [36]. While there are limits and obstacles, for example, specialized intricacy and versatility issues, the expected advantages of BlockEstate in reforming real estate transactions are obvious. Inferences highlight its importance in advancing blockchain technology adoption in real estate transactions, emphasizing the transformative potential of platforms like BlockEstate to address long-standing challenges and ushering in a new era of efficiency, transparency, and security in real estate transactions. As blockchain innovation evolves, new frameworks such as BlockEstate are likely to outperform the current requirements and create new standards in the real estate market. In conclusion, BlockEstate represents a significant advancement in the utilization of blockchain technology for real estate transactions. By introducing novel features, like the compensation request mechanism and advanced chaincode for property ownership management, BlockEstate addresses critical shortcomings in traditional real estate transactions. Although challenges involving technical complexity and scalability remain, the potential benefits of BlockEstate in

revolutionizing real estate transactions are undeniable. As blockchain technology continues to evolve, platforms like BlockEstate are poised to redefine the standards of efficiency, security, and transparency in the real estate market, leading to a more innovative and inclusive landscape.

REFERENCES

[1] A. Saari, J. Vimpari, and S. Junnila, "Blockchain in real estate: Recent developments and empirical applications," *Land Use Policy*, vol. 121, Oct. 2022, Art. no. 106334, https://doi.org/10.1016/j.landusepol.2022.106334.

[2] R. M. Garcia-Teruel, "Legal challenges and opportunities of blockchain technology in the real estate sector," *Journal of Property, Planning and Environmental Law*, vol. 12, no. 2, pp. 129–145, Jan. 2020, https://doi.org/10.1108/JPPEL-07-2019-0039.

[3] F. Ullah and F. Al-Turjman, "A conceptual framework for blockchain smart contract adoption to manage real estate deals in smart cities," *Neural Computing and Applications*, vol. 35, no. 7, pp. 5033–5054, Mar. 2023, https://doi.org/10.1007/s00521-021-05800-6.

[4] T. P. Podshivalov, "Improving implementation of the Blockchain technology in real estate registration," *The Journal of High Technology Management Research*, vol. 33, no. 2, Nov. 2022, Art. no. 100440, https://doi.org/10.1016/j.hitech.2022.100440.

[5] K. Rajeshkumar, C. Ananth, and N. Mohananthini, "Blockchain-Assisted Homomorphic Encryption Approach for Skin Lesion Diagnosis using Optimal Deep Learning Model," *Engineering, Technology & Applied Science Research*, vol. 13, no. 3, pp. 10978–10983, Jun. 2023, https://doi.org/10.48084/etasr.5594.

[6] H. P. Wouda and R. Opdenakker, "Blockchain technology in commercial real estate transactions," *Journal of Property Investment & Finance*, vol. 37, no. 6, pp. 570–579, Jan. 2019, https://doi.org/10.1108/JPIF-06-2019-0085.

[7] S. Latifi, Y. Zhang, and L. C. Cheng, "Blockchain-Based Real Estate Market: One Method for Applying Blockchain Technology in Commercial Real Estate Market," in *2019 IEEE International Conference on Blockchain (Blockchain)*, Atlanta, GA, USA, Jul. 2019, pp. 528–535, https://doi.org/10.1109/Blockchain.2019.00002.

[8] S. H. Said, M. A. Dida, E. M. Kosia, and R. S. Sinde, "A Blockchain-based Conceptual Model to Address Educational Certificate Verification Challenges in Tanzania," *Engineering, Technology & Applied Science Research*, vol. 13, no. 5, pp. 11691–11704, Oct. 2023, https://doi.org/10.48084/etasr.6170.

[9] O. Konashevych, "Constraints and benefits of the blockchain use for real estate and property rights," *Journal of Property, Planning and Environmental Law*, vol. 12, no. 2, pp. 109–127, Jan. 2020, https://doi.org/10.1108/JPPEL-12-2019-0061.

[10] J. Veuger, "Dutch blockchain, real estate and land registration," *Journal of Property, Planning and Environmental Law*, vol. 12, no. 2, pp. 93–108, Jan. 2020, https://doi.org/10.1108/JPPEL-11-2019-0053.

[11] S. Jeong and B. Ahn, "Implementation of real estate contract system using zero knowledge proof algorithm based blockchain," *The Journal of Supercomputing*, vol. 77, no. 10, pp. 11881–11893, Oct. 2021, https://doi.org/10.1007/s11227-021-03728-1.

[12] S. S. Taher, S. Y. Ameen, and J. A. Ahmed, "Advanced Fraud Detection in Blockchain Transactions: An Ensemble Learning and Explainable AI Approach," *Engineering, Technology & Applied Science Research*, vol. 14, no. 1, pp. 12822–12830, Feb. 2024, https://doi.org/10.48084/etasr.6641.

[13] A. Mittal, B. Sharma, and P. Ranjan, "Real Estate Management System based on Blockchain," in *2020 IEEE 7th Uttar Pradesh Section International Conference on Electrical, Electronics and Computer Engineering (UPCON)*, Prayagraj, India, Nov. 2020, pp. 1–6, https://doi.org/10.1109/UPCON50219.2020.9376540.

[14] A. Gupta, J. Rathod, D. Patel, J. Bothra, S. Shanbhag, and T. Bhalerao, "Tokenization of Real Estate Using Blockchain Technology," in *Applied Cryptography and Network Security Workshops*, Rome, Italy, 2020, pp. 77–90, https://doi.org/10.1007/978-3-030-61638-0_5.

[15] J. H. Huh and S. K. Kim, "Verification Plan Using Neural Algorithm Blockchain Smart Contract for Secure P2P Real Estate Transactions," *Electronics*, vol. 9, no. 6, Jun. 2020, Art. no. 1052, https://doi.org/10.3390/electronics9061052.

[16] E. Pankratov, V. Grigoryev, and O. Pankratov, "The blockchain technology in real estate sector: Experience and prospects," *IOP Conference Series: Materials Science and Engineering*, vol. 869, no. 6, Mar. 2020, Art no. 062010, https://doi.org/10.1088/1757-899X/869/6/062010.

[17] D. Bhanushali, A. Koul, S. Sharma, and B. Shaikh, "BlockChain to Prevent Fraudulent Activities: Buying and Selling Property Using BlockChain," in *2020 International Conference on Inventive Computation Technologies (ICICT)*, Feb. 2020, pp. 705–709, https://doi.org/10.1109/ICICT48043.2020.9112478.

[18] F. Ferreira Santana, M. M. da Silva, and F. G. da Cunha, "Blockchain for Real Estate: A Systematic Literature Review," in *Proceedings of the International Conference on Information Systems Development (ISD)*, Valencia, Spain, 2021.

[19] V. Hoxha and S. Sadiku, "Study of factors influencing the decision to adopt the blockchain technology in real estate transactions in Kosovo," *Property Management*, vol. 37, no. 5, pp. 684–700, Jan. 2019, https://doi.org/10.1108/PM-01-2019-0002.

[20] G. Sladić, B. Milosavljević, S. Nikolić, D. Sladić, and A. Radulović, "A Blockchain Solution for Securing Real Property Transactions: A Case Study for Serbia," *ISPRS International Journal of Geo-Information*, vol. 10, no. 1, Jan. 2021, Art. no. 35, https://doi.org/10.3390/ijgi10010035.

[21] A. Mashatan, V. Lemieux, S. H. (Mark) Lee, P. Szufel, and Z. Roberts, "Usurping Double-Ending Fraud in Real Estate Transactions via Blockchain Technology," *Journal of Database Management (JDM)*, vol. 32, no. 1, pp. 27–48, Jan. 2021, https://doi.org/10.4018/JDM.2021010102.

[22] J. Harris and E. Nikbakht, "Blockchain Applications in Real Estate," in *The Emerald Handbook of Blockchain for Business*, H. Kent Baker, E. Nikbakht, and S. Stein Smith, Eds. Emerald Publishing Limited, 2021, pp. 311–323.

[23] J. Veuger, "A Database Exploring Blockchain and Real Estate," in *Disruptive Technology, Legal Innovation, and the Future of Real Estate*, A. Lehavi and R. Levine-Schnur, Eds. Cham, Switzerland: Springer International Publishing, 2020, pp. 3–25.

[24] A. Saull, A. Baum, and F. Braesemann, "Can digital technologies speed up real estate transactions?," *Journal of Property Investment & Finance*, vol. 38, no. 4, pp. 349–361, Jan. 2020, https://doi.org/10.1108/JPIF-09-2019-0131.

[25] E. Lindholm, "Blockchain evolution: adoption, knowledge and barriers of blockchain technology in the Finnish real estate industry," M.S. thesis, Aalto University, Espoo, Finland, 2021.

[26] M. Li, L. Shen, and G. Q. Huang, "Blockchain-enabled workflow operating system for logistics resources sharing in E-commerce logistics real estate service," *Computers & Industrial Engineering*, vol. 135, pp. 950–969, Sep. 2019, https://doi.org/10.1016/j.cie.2019.07.003.

[27] J. Hutson, G. Banerjee, N. Kshetri, K. Odenwald, and J. Ratican, "Architecting the Metaverse: Blockchain and the Financial and Legal Regulatory Challenges of Virtual Real Estate," *Journal of Intelligent Learning Systems and Applications*, vol. 15, Feb. 2023, https://doi.org/10.4236/jilsa.2023.151001.

[28] N. A. Alsharif, S. Mishra, and M. Alshehri, "IDS in IoT using Machine Learning and Blockchain," *Engineering, Technology & Applied Science Research*, vol. 13, no. 4, pp. 11197–11203, Aug. 2023, https://doi.org/10.48084/etasr.5992.

[29] K. Bhatia, J. Vij, H. Kumar, Y. Sharma, and A. Sharma, "Exploration of Blockchain Based Solution for Real-Estate," *International Journal of Scientific Research in Computer Science, Engineering and Information Technology*, vol. 5, no. 2, pp. 957–962, Apr. 2019, https://doi.org/10.32628/CSEIT1952263.

[30] P. Kothari, A. Bharambe, R. Motwani, and A. Rathi, "Smart Contract for Real Estate Using Blockchain," Apr. 2020, https://doi.org/10.2139/ssrn.3565497

[31] A. Baum, "Tokenization—The Future of Real Estate Investment?," *The Journal of Portfolio Management*, vol. 47, no. 10, pp. 41–61, Jun. 2021, https://doi.org/10.3905/jpm.2021.1.260.

[32] J. M. Moringiello and C. K. Odinet, "Blockchain Real Estate and NFTs," MSc Thesis, William & Mary Law School, Williamsburg, Virginia, 2023.

[33] J. L. Tilbury, E. De La Rey, and K. Van Der Schyff, "Business Process Models of Blockchain and South African Real Estate Transactions," in *2019 International Conference on Advances in Big Data, Computing and Data Communication Systems (icABCD)*, Winterton, South Africa, Aug. 2019, pp. 1–7, https://doi.org/10.1109/ICABCD.2019.8851014.

[34] A. Jain, B. Chitroda, A. Dixit, and H. Dalvi, "Blockchain-Powered Real Estate System," in *Advanced Computing Technologies and Applications*, Singapore, 2020, pp. 609–620, https://doi.org/10.1007/978-981-15-3242-9_58.

[35] D. Yacob, "Blockchain : An Application on the Commercial Real Estate Leasing Market," M.S. Thesis, KTH Royal Institute of Technology, Stockholm, Sweden, 2021.

[36] M. Shuaib, S. Alam, and S. M. Daud, "Improving the Authenticity of Real Estate Land Transaction Data Using Blockchain-Based Security Scheme," in *Advances in Cyber Security*, Singapore, 2021, pp. 3–10, https://doi.org/10.1007/978-981-33-6835-4_1.