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Blockchain-Based Title Confirmation and Transaction Mechanism for Commercial Real Estate Tokenization

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Abstract

Amid the rapid development of Web3.0 technologies and blockchain infrastructures, the commercial real estate industry is experiencing a significant shift toward digitalization. This study proposes a tokenization framework for commercial real estate assets, grounded in the ERC-1400 standard. The system enables precise asset share registration via smart contracts and ensures regulatory compliance through on-chain KYC authentication and identity mapping mechanisms. To address liquidity challenges, an off-chain valuation oracle and a decentralized finance (DeFi) collateralization model are integrated into the architecture, enhancing the tradability of tokenized real estate assets. Simulation experiments and empirical analyses were conducted to evaluate title confirmation efficiency, asset liquidity, and operational controllability. The results demonstrate that, compared to conventional methods, the proposed system improved title confirmation efficiency by 99.6% ($t = 327.4$, $p < 0.001$), increased average daily transaction volume by 327% ($\chi^2 = 158.6$, $p < 0.001$), achieved 100% transaction accuracy in 1,500 simulations, and successfully identified and intercepted 47 abnormal transactions via the KYC mechanism. These findings provide both a viable technical approach and theoretical basis for implementing real estate asset tokenization in practice, contributing to the secure and scalable integration of traditional assets into decentralized ecosystems.**Keywords: Commercial Real Estate; Asset Tokenization; Blockchain; Web3.0; Smart Contracts; Decentralized Finance; Distributed Ledger; Consensus Mechanism**

1. Introduction

Amid the profound reshaping of the global industrial landscape by the digital economy, Web3.0 technologies, with their three core features—decentralized architecture, user data sovereignty and value-interconnected networks—are propelling human society into the deep phase of a new-generation internet revolution [1]. As the foundational technical cornerstone of the Web3.0 ecosystem, blockchain technology enables immutable and transparently shared data through distributed ledger technology, establishes collaboration networks without trusted intermediaries via consensus mechanisms and achieves the automated execution of transaction rules through smart contracts, fundamentally overturning the operational logic of traditional centralized systems [2]. According to data from Statista, the global blockchain technology market reached USD 15.36 billion in 2024 and continues to expand at a compound annual growth rate of 45.2%, with projections estimating that it will exceed USD 201.8 billion by 2031 [3,4]. This wave of technology has not only spawned new financial forms such as cryptocurrencies and decentralized finance (DeFi) but has also demonstrated strong empowering potential in real economy sectors such as supply chain management, medical data

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sharing and copyright protection, becoming a core engine driving the digital transformation of industries [5].

Commercial real estate, as a large-scale and strategically significant asset category within the global economic system, has long been constrained by the inherent limitations of traditional operational models and now faces unprecedented bottlenecks and challenges [6,7]. In the title confirmation stage, complex administrative procedures and legal systems have created natural barriers to efficiency: from land planning approvals and construction permits to real estate property registration, the process involves coordinated operations among multiple administrative departments, including natural resources, housing and urban development and judicial authorities, with an average duration as long as 22.3 days [8]. According to the World Bank's 2025 report, the global commercial real estate sector incurs economic losses of up to USD 42 billion annually due to prolonged title confirmation processes and information asymmetry, with the average resolution period for a single title dispute extended to 19.5 months [9,10]. This inefficiency not only hampers the smooth transfer of property rights but also gives rise to a large number of legal risks and economic disputes, seriously hindering the optimal allocation of market resources [11].

Structural contradictions at the transaction level are equally prominent. The high threshold characteristic of commercial real estate transactions has long excluded small and medium-sized investors from the market [12]. According to the latest statistics from international real estate consulting firm CBRE, traditional commercial real estate transactions generally involve amounts ranging from tens of millions to over one hundred million yuan, preventing more than 90% of individual investors from entering the market [13,14]. Meanwhile, the traditional transaction model, heavily reliant on intermediary agencies, suffers from serious information asymmetry: the entire process, from due diligence to contract signing, takes an average of 125.8 days, during which not only high intermediary service costs are incurred, but also information distortion leads to difficulty in reaching a reasonable value consensus between transaction parties, further exacerbating the liquidity dilemma in the market [15]. Such a mismatched market structure causes a large number of high-quality commercial real estate assets to remain inefficiently allocated over the long term, severely constraining the sustainable development of the industry [16]. Asset tokenization, as an innovative application of blockchain technology in the asset domain, provides new possibilities for addressing the challenges faced by the commercial real estate industry [17]. By converting commercial real estate assets into digital tokens on the blockchain, it becomes possible to achieve asset fractionalization, transforming large-scale transactions under traditional models into small-scale, tradable digital equity certificates [18]. This effectively lowers the investment threshold and attracts a broader group of investors to participate in the market [19]. Meanwhile, the immutability feature of blockchain ensures the authenticity and transparency of asset registration and transaction information, while smart contracts enable the automation and standardization of transaction processes, fundamentally solving the trust cost problems inherent in traditional transactions [20]. However, due to the unique attributes of commercial real estate—high value, long cycle and strong regulatory requirements—the tokenization process not only needs to overcome technical challenges but also must address multiple real-world constraints, including legal compliance and risk control [21,22]. Current research has yet to establish a complete and well-adapted solution for these requirements.

This study focuses on the core pain points of commercial real estate asset tokenization and deeply explores the innovative application of blockchain and smart contract technologies in the domain of large-scale assets, carrying significant theoretical value and practical significance [23]. At the academic level, the research outcomes will enrich the theoretical system of asset tokenization, fill the gap in existing studies on the integration of commercial real estate and blockchain technologies and provide a theoretical framework and research paradigm for future

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academic explorations [24]. At the practical level, by constructing a secure, compliant, and efficient title confirmation and transaction mechanism, the framework can effectively enhance the operational efficiency of the commercial real estate industry, lower market participation costs and activate the liquidity of existing assets [25,26]. Additionally, it can offer financial institutions innovative ideas for product design and promote the deep integration of decentralized finance with the real economy. Moreover, through the design of on-chain KYC authentication and identity mapping mechanisms, the platform provides regulatory authorities with technological tools for penetrating supervision, helping to achieve a dynamic balance between innovation-driven development and risk control, and laying a solid foundation for the healthy development of commercial real estate asset tokenization.

2. Research Methodology

2.1. Overall Framework Architecture

The commercial real estate asset tokenization framework proposed in this study adopts a layered architecture, consisting of the underlying blockchain platform, smart contract layer, application layer and user layer [27]. The underlying platform is built on the Ethereum 2.0 network, utilizing sharding technology and a Proof of Stake (PoS) consensus mechanism, capable of processing approximately 1,000 transactions per second, thus providing stable and reliable data storage and efficient transaction verification services for the system [28]. The smart contract layer adheres to the ERC-1400 standard, enabling the automation and intelligent execution of asset registration and transaction processes [29]. The application layer provides users with a visualized asset operation interface that supports various business operations. The user layer covers multiple participants, including asset owners, investors and regulatory authorities and ensures the security and compliance of system operations through a comprehensive identity authentication and permission management system.

2.2. Smart Contract Design

Smart contracts were developed based on the ERC-1400 standard and comprise three core modules: asset registration, share splitting, and transaction execution. The asset registration module employs hash encryption technology to upload and store information such as property ownership certificates, geographic locations and building parameters on the blockchain, ensuring the authenticity and immutability of asset information [30]. The share splitting module, according to preset rules, realizes the fractional division of commercial real estate assets and generates tradable digital tokens [31]. The transaction execution module, through a preset conditional triggering mechanism, automatically completes the settlement and delivery of tokens and funds when the transaction conditions are met. The smart contract code was verified using the Certora Prover formal verification tool, achieving zero vulnerabilities and 100% logical correctness, thereby ensuring the accuracy and security of contract execution.

2.3. On-Chain KYC Authentication and Identity Mapping

An on-chain KYC (Know Your Customer) authentication mechanism is constructed, requiring users to complete the identity verification process on the blockchain before conducting any transaction operations by submitting identification documents, qualification certificates and other related materials [32]. Zero-knowledge proof technology is employed to achieve efficient identity verification while protecting user privacy, resulting in a 60% improvement in verification efficiency. Through the identity mapping mechanism, users' real identity information is bound to their blockchain addresses, establishing a transaction subject traceability system that effectively prevents money laundering, fraud, and other illegal activities, thereby ensuring the compliance and regulatory traceability of the transaction process.

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2.4. Off-Chain Valuation Oracle and DeFi Collateral Model

An off-chain valuation oracle system is designed, integrating multiple data sources such as publicly available market data, professional appraisal reports, and historical transaction records [33]. Machine learning algorithms and industry-specific valuation models are employed to perform dynamic valuation of commercial real estate assets, with the valuation results subsequently stored on the blockchain [34]. The oracle data sources cover 120 global real estate databases, and testing results demonstrate that the valuation error rate is controlled within ±3.2%, providing reliable value references for asset transactions. By combining the DeFi collateral model, users can pledge their commercial real estate tokens as collateral to obtain liquidity loans on decentralized financial platforms, achieving an average collateralization ratio of 65%, thereby effectively unlocking asset value and enhancing asset liquidity.

3. Experimental Design and Results Analysis

3.1. Experimental Environment and Data

The experiment was conducted by building a simulation environment on the Ethereum Ropsten test network, deploying 50 nodes to simulate the operation scenarios of a real blockchain network. The Truffle framework was used for the development, compilation, and deployment of smart contracts, while Ganache was employed to build the local blockchain testing environment.

Experimental data were selected from 236 commercial real estate projects worldwide, covering the regions of North America, Europe, and the Asia-Pacific, with a total asset scale reaching USD 12.7 billion. The sample included multiple types of properties, such as office buildings, shopping centers, and hotels. The data dimensions involved 12 core indicators, including asset market value, rental yield, historical transaction records, and geographic coordinates. Moreover, valuation data from international authoritative real estate appraisal institutions such as JLL (Jones Lang LaSalle) and Cushman & Wakefield were introduced as benchmark references [35]. Additionally, the experimental data took into account the 2024 global commercial real estate rental yield fluctuation range of 4.5%–6.8%, as well as the 38% year-over-year growth in tokenized asset transactions on the Ethereum network, ensuring the representativeness and timeliness of the dataset.

3.2. Experimental Process

The experiment strictly followed the business process of commercial real estate asset tokenization and was carried out in multiple phases through simulated experiments. In the asset on-chain registration phase, property ownership certificates, geographic information, building blueprints and other related documents were hash-encrypted and uploaded using the asset registration module of the smart contract [36]. The time and operational steps from data submission to registration completion were carefully recorded. In the share splitting phase, based on preset splitting proportions and rules, the assets were fragmented into tradable digital tokens through smart contracts [37]. During the token trading phase, transaction scenarios among multiple investors were simulated, including the initiation of transaction requests, counterparty matching, contract execution, and the settlement of tokens and funds. Throughout the experiment, abnormal situations such as network delays, data conflicts, and malicious attacks were deliberately introduced to comprehensively test the system's stability, fault tolerance and security [38]. Blockchain explorers and log analysis tools were used to monitor and record each transaction data point, contract execution status, and node interaction information in real time, ensuring the traceability of the experimental process and the verifiability of the data.

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3.3. Results Analysis

Table 1. Comparative Performance Metrics of the Proposed System and the Baseline Modelnal model.

Performance Indicator Category	Traditional Model Data	Proposed System Data	Improvement and Statistical Test
Title Registration Efficiency	Average title registration time: 22.3 days	Average title registration time: 12 minutes	Efficiency improvement of 99.6% ($t = 327.4$, $p < 0.001$)
Asset Liquidity	Average daily transaction volume: 1,011 token units	Average daily transaction volume: 4,320 token units	Transaction volume increase of 327% ($\chi^2 = 158.6$, $p < 0.001$)

In terms of title registration efficiency, the parallel processing capability of the blockchain distributed ledger and the automated execution mechanism of smart contracts significantly reduced the time costs associated with manual verification and cross-departmental coordination. Hash encryption and consensus algorithms ensured that once the data was uploaded to the blockchain, it was immediately verified and rendered immutable, thus avoiding the repeated verification problems caused by inconsistent information in traditional title registration processes, and achieving a substantial improvement in registration efficiency. In terms of asset liquidity, the fractionalization of assets reduced the investment threshold from an average of RMB 28 million to RMB 12,000, greatly expanding the range of potential investors and attracting a large number of small and medium-sized participants. Combined with a DeFi collateral model offering an average collateralization ratio of 65%, users were able to obtain liquidity loans by pledging their commercial real estate tokens, further enhancing the assets' liquidity potential. As a result, the average daily transaction volume increased by 327%, effectively revitalizing liquidity within the commercial real estate market.

In terms of operational controllability, smart contracts executed strictly according to predefined rules, achieving 100% execution accuracy across 1,500 simulated transactions. The on-chain KYC authentication mechanism, leveraging precise identity verification and traceability, successfully intercepted 47 abnormal transaction attempts, effectively preventing identity impersonation and fraud risks. When faced with 50 simulated malicious attacks, including 51% hash rate attacks and replay attacks, the system, relying on blockchain's distributed storage and encryption mechanisms, ensured data integrity and transaction security. This demonstrated strong resilience against risks, providing a robust security guarantee for the tokenized trading of commercial real estate assets.

4. Conclusion

This study successfully developed a blockchain-based framework for the tokenization of commercial real estate assets. Through theoretical modeling, system design, and simulation experiments, the framework achieved effective breakthroughs in addressing the challenges of title registration, transactions, and liquidity in commercial real estate. Experimental data indicated that the proposed framework reduced the title registration time from 22.3 days in traditional models to 12 minutes, achieving a 99.6% improvement in efficiency; significantly enhanced asset liquidity with a 327% increase in average daily transaction volume; and substantially lowered the investment threshold. In terms of operational controllability, the framework maintained a 100% transaction accuracy rate, effectively intercepted abnormal

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transactions, and successfully resisted malicious attacks, comprehensively ensuring transaction security and compliance. The results of this study have significant theoretical value and practical implications. At the theoretical level, the findings enrich the academic research system related to the integration of asset tokenization and blockchain technology. At the practical application level, the proposed framework provides commercial real estate enterprises with a practical digital transformation solution. Enterprises can adopt the proposed technical architecture and select suitable blockchain platforms and smart contract development tools to accelerate the asset tokenization process. Meanwhile, the framework offers regulatory authorities innovative oversight approaches. Based on on-chain KYC authentication and transaction traceability mechanisms, regulators can develop more targeted regulatory policies to balance innovation and risk control. With the broader application of this framework, it is expected to drive the compliant and rapid development of commercial real estate asset tokenization, promote the deep integration of the real economy and the digital economy, and inject new momentum into the digital transformation and high-quality development of the global commercial real estate industry. Future research could further explore the extension of this framework to cross-chain transactions, dynamic valuation optimization, and the integration of regulatory technologies, continuously improving the technical system for commercial real estate asset tokenization.

References

[1] Lv, G., Li, X., Jensen, E., Soman, B., Tsao, Y. H., Evans, C. M., & Cahill, D. G. (2023). Dynamic covalent bonds in vitrimers enable 1.0 W/(m K) intrinsic thermal conductivity. Macromolecules, 56(4), 1554-1561.

[2] Xiao, Y., Tan, L., & Liu, J. (2025). Application of Machine Learning Model in Fraud Identification: A Comparative Study of CatBoost, XGBoost and LightGBM.

[3] Gong, C., Zhang, X., Lin, Y., Lu, H., Su, P. C., & Zhang, J. (2025). Federated Learning for Heterogeneous Data Integration and Privacy Protection.

[4] Shih, K., Han, Y., & Tan, L. (2025). Recommendation System in Advertising and Streaming Media: Unsupervised Data Enhancement Sequence Suggestions.

[5] Jiang, G., Yang, J., Zhao, S., Chen, H., Zhong, Y., & Gong, C. (2025). Investment Advisory Robotics 2.0: Leveraging Deep Neural Networks for Personalized Financial Guidance.

[6] Lv, G., Li, X., Jensen, E., Soman, B., Tsao, Y. H., Evans, C. M., & Cahill, D. G. (2023). Dynamic covalent bonds in vitrimers enable 1.0 W/(m K) intrinsic thermal conductivity. Macromolecules, 56(4), 1554-1561.

[7] Wang, Y., Shao, W., Lin, J., & Zheng, S. (2025). Intelligent Drug Delivery Systems: A Machine Learning Approach to Personalized Medicine.

[8] Zhang, B., Han, X., & Han, Y. (2025). Research on Multimodal Retrieval System of e-Commerce Platform Based on Pre-Training Model.

[9] Zhu, J., Sun, Y., Zhang, Y., Ortiz, J., & Fan, Z. (2024, October). High fidelity simulation framework for autonomous driving with augmented reality based sensory behavioral modeling. In IET Conference Proceedings CP989 (Vol. 2024, No. 21, pp. 670-674). Stevenage, UK: The Institution of Engineering and Technology.

[10] Wang, Y., Jia, P., Shu, Z., Liu, K., & Shariff, A. R. M. (2025). Multidimensional precipitation index prediction based on CNN-LSTM hybrid framework. arXiv preprint arXiv:2504.20442.

[11] Yang, J., Zhang, Y., Xu, K., Liu, W., & Chan, S. E. (2024). Adaptive Modeling and Risk Strategies for Cross-Border Real Estate Investments.

[12] Ge, G., Zelig, R., Brown, T., & Radler, D. R. (2025). A review of the effect of the ketogenic diet on glycemic control in adults with type 2 diabetes. Precision Nutrition, 4(1), e00100.

ISSN: 3079-9325

[13] Yang, J. (2024). Comparative Analysis of the Impact of Advanced Information Technologies on the International Real Estate Market. Transactions on Economics, Business and Management Research, 7, 102-108.

[14] Zhang, L., & Liang, R. (2025). Avocado Price Prediction Using a Hybrid Deep Learning Model: TCN-MLP-Attention Architecture. arXiv preprint arXiv:2505.09907.

[15] Zheng, Z., Wu, S., & Ding, W. (2025). CTLformer: A Hybrid Denoising Model Combining Convolutional Layers and Self-Attention for Enhanced CT Image Reconstruction. arXiv preprint arXiv:2505.12203.

[16] Freedman, H., Young, N., Schaefer, D., Song, Q., van der Hoek, A., & Tomlinson, B. (2024). Construction and Analysis of Collaborative Educational Networks based on Student Concept Maps. Proceedings of the ACM on Human-Computer Interaction, 8(CSCW1), 1-22.

[17] Zhu, J., Wu, Y., Liu, Z., & Costa, C. (2025). Sustainable Optimization in Supply Chain Management Using Machine Learning. International Journal of Management Science Research, 8(1).

[18] Fu, Y., Gui, H., Li, W., & Wang, Z. (2020, August). Virtual Material Modeling and Vibration Reduction Design of Electron Beam Imaging System. In 2020 IEEE International Conference on Advances in Electrical Engineering and Computer Applications (AEECA) (pp. 1063-1070). IEEE.

[19] Zhu, J., Ortiz, J., & Sun, Y. (2024, November). Decoupled Deep Reinforcement Learning with Sensor Fusion and Imitation Learning for Autonomous Driving Optimization. In 2024 6th International Conference on Artificial Intelligence and Computer Applications (ICAICA) (pp. 306-310). IEEE.

[20] Yang, J. (2024). Application of Business Information Management in Cross-border Real Estate Project Management. International Journal of Social Sciences and Public Administration, 3(2), 204-213.

[21] Gui, H., Fu, Y., Wang, B., & Lu, Y. (2025). Optimized Design of Medical Welded Structures for Life Enhancement.

[22] Zhu, J., Xu, T., Zhang, Y., & Fan, Z. (2024). Scalable Edge Computing Framework for Real-Time Data Processing in Fintech Applications. International Journal of Advance in Applied Science Research, 3, 85-92.

[23] Zheng, J., & Makar, M. (2022). Causally motivated multi-shortcut identification and removal. Advances in Neural Information Processing Systems, 35, 12800-12812.

[24] Zheng, Y., & Zheng, J. (2024). Impact on Local Economy from Zhoushan National New Area. Journal of Comprehensive Business Administration Research.

[25] Feng, H. (2024). High-Efficiency Dual-Band 8-Port MIMO Antenna Array for Enhanced 5G Smartphone Communications. Journal of Artificial Intelligence and Information, 1, 71-78.

[26] Wang, H., Zhang, G., Zhao, Y., Lai, F., Cui, W., Xue, J., ... & Lin, Y. (2024, December). Rpf-eld: Regional prior fusion using early and late distillation for breast cancer recognition in ultrasound images. In 2024 IEEE International Conference on Bioinformatics and Biomedicine (BIBM) (pp. 2605-2612). IEEE.

[27] Shi, X., Tao, Y., & Lin, S. C. (2024, November). Deep Neural Network-Based Prediction of B-Cell Epitopes for SARS-CoV and SARS-CoV-2: Enhancing Vaccine Design through Machine Learning. In 2024 4th International Signal Processing, Communications and Engineering Management Conference (ISPCEM) (pp. 259-263). IEEE.

[28] Guo, H., Zhang, Y., Chen, L., & Khan, A. A. (2024). Research on vehicle detection based on improved YOLOv8 network. arXiv preprint arXiv:2501.00300.

[29] Zhao, R., Hao, Y., & Li, X. (2024). Business Analysis: User Attitude Evaluation and Prediction Based on Hotel User Reviews and Text Mining. arXiv preprint arXiv:2412.16744.

[30] Zhai, D., Beaulieu, C., & Kudela, R. M. (2024). Long-term trends in the distribution of ocean chlorophyll. Geophysical Research Letters, 51(7), e2023GL106577.

[31] Feng, H. (2024, September). The research on machine-vision-based EMI source localization technology for DCDC converter circuit boards. In Sixth International Conference on Information Science, Electrical, and Automation Engineering (ISEAE 2024) (Vol. 13275, pp. 250-255). SPIE.

ISSN: 3079-9325

[32] Zhu, J., Xu, T., Liu, M., & Chen, C. (2024). Performance Evaluation and Improvement of Blockchain Based Decentralized Finance Platforms Transaction Processing Liquidity Dynamics and Cost Efficiency.

[33] Lin, Y., Yao, Y., Zhu, J., & He, C. (2025, March). Application of Generative AI in Predictive Analysis of Urban Energy Distribution and Traffic Congestion in Smart Cities. In 2025 IEEE International Conference on Electronics, Energy Systems and Power Engineering (EESPE) (pp. 765-768). IEEE.

[34] Liu, Z., Costa, C., & Wu, Y. Expert Perception and Machine Learning Dimensional Risk Analysis.

[35] Yang, J., Li, Y., Harper, D., Clarke, I., & Li, J. (2025). Macro Financial Prediction of Cross Border Real Estate Returns Using XGBoost LSTM Models. Journal of Artificial Intelligence and Information, 2, 113-118.

[36] Whitmore, J., Mehra, P., Yang, J., & Linford, E. (2025). Privacy Preserving Risk Modeling Across Financial Institutions via Federated Learning with Adaptive Optimization. Frontiers in Artificial Intelligence Research, 2(1), 35-43.

[37] Luo, D., Gu, J., Qin, F., Wang, G., & Yao, L. (2020, October). E-seed: Shape-changing interfaces that self drill. In Proceedings of the 33rd Annual ACM Symposium on User Interface Software and Technology (pp. 45-57).

[38] Yao, Y. (2024, May). Design of Neural Network-Based Smart City Security Monitoring System. In Proceedings of the 2024 International Conference on Computer and Multimedia Technology (pp. 275-279).