EXPLORING THE POTENTIAL OF BLOCKCHAIN TECHNOLOGY IN PROPERTY MANAGEMENT

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DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at UTAR or other institutions.

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ABSTRACT

As Malaysia's property management sector undergoes digital transformation under Construction 4.0, adopting blockchain technology is essential to improve transparency, security, and efficiency. Although blockchain has proven benefits globally, its adoption in property management remains unclear. Existing literature often focuses on isolated applications such as property transactions and rental management. This study addresses that gap by exploring blockchain's potential to integrate and transform the entire property management lifecycle, while also identifying inefficiencies and adoption challenges. The literature review identified 28 inefficiencies and 24 blockchain potentials across six key aspects, which were land administration, property transactions, leasing and renting, property administration, property financialization, and property maintenance. Additionally, 21 adoption challenges were categorized into five main areas, which were legal and regulatory, cost and liquidity, security and privacy, technical limitations, and institutional challenges. A quantitative research methodology was used, and an online questionnaire was distributed among property developers in the Klang Valley, yielding 119 valid responses. Data were analysed using Cronbach's Alpha, Arithmetic Mean, Mann-Whitney U, Kruskal-Wallis, and Spearman's Correlation tests. This study's Arithmetic Mean results reveal maintenance inefficiencies and lack of transparency as the most pressing issues, with blockchain's strongest potential in transparent asset tracking and predictive maintenance. The critical implementation challenges are technical limitations and security concerns, particularly interoperability and privacy protection difficulties. Mann-Whitney U test shows the public sector has greater awareness of these inefficiencies and potentials and views legal, cybersecurity, and smart contract challenges as more severe. Kruskal-Wallis analyses found significant differences across age, experience, job position, and company size, highlighting the complexity of blockchain integration in property management. Spearman's correlations emphasized transparency and predictive maintenance as potential priorities, while digital identity and immutability posed major adoption challenges. These findings underscore the need for a strategic approach to blockchain adoption and provide recommendations for stakeholders and policymakers to navigate this transformative landscape.

Keywords: Blockchain, Property Management, Real Estate Management, Smart Contract, Tokenisation

Subject Area: TH3301-3411 Maintenance and repair

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LIST OF SYMBOLS / ABBREVIATIONS

AI	Artificial Intelligence
GDPR	General Data Protection Regulation
ICT	Information and Communication Technologies
ID	Identification
IoT	Internet of Things
IPFS	InterPlanetary File System
KYC	Know Your Customer
MIPFM	Malaysian Institute of Property and Facility Managers
MLS	Multiple Listing Service
NFT	Non-fungible Token
PKI	Public Key Infrastructure
PoS	Proof of Stake
PoW	Proof of Work
PRH	Public Rental Housing
REHDA	Real Estate and Housing Developers' Association
REITs	Real Estate Investment Trusts
SDGs	Sustainable Development Goals
SPSS	Statistical Package for the Social Sciences
US$	United States Dollar

e	margin of error
n	sample size
p	the proportion of the population with attributes understudy
q	1-p
z	z-scores of the desired confidence level

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CHAPTER 1

INTRODUCTION

1.1 General Introduction

This chapter outlines an overview of the study, which includes its background, problem statement, aim, and objectives. It also includes the research methodology, research scope, and chapter outline.

1.2 Background of the Study

In Malaysia, the property management sector is a crucial component of the construction industry, which is undergoing a transformative phase known as Construction 4.0. This transformation involves the integration of advanced technologies such as big data, artificial intelligence (AI), the Internet of Things (IoT), and blockchain to enhance productivity, efficiency, and sustainability (CIDB Malaysia, 2020). Projections suggested that the global property market is on track to reach an impressive value of US$637.80 trillion by 2024 (Statista, 2023). Property is deemed to be one of the safest investment options, offering comparatively higher returns than other alternatives. However, like other businesses, the property sector faces several inefficiencies, including the involvement of third parties for verification, associated monetary and time costs related to administration, access and verification of records, the use of commission-based agents, transparency issues concerning property ownership, and a dependence on centralized systems that are susceptible to security breaches (Ahmad *et al.*, 2021).

Blockchain technology offers a decentralized, secure, and transparent ledger system with the potential to address inefficiencies in property management and revolutionize its processes. By providing immutable records and facilitating automated transactions through smart contracts, blockchain addresses these key inefficiencies. For instance, Sweden has implemented a blockchain-based land registry system, where property ownership and transaction records are stored on a distributed ledger, ensuring transparency, security, and efficient transfer of ownership (Proskurovska and Dörry, 2018).

This system has proven effective in streamlining property transactions and reducing administrative burdens.

However, despite Malaysia's commitment to digital transformation, as evidenced by initiatives like the Malaysia Digital Economy Blueprint, the adoption of blockchain technology in property management remains limited (Economic Planning Unit, 2021). This gap highlights the urgent need to explore how blockchain technology can be effectively adopted into the property management sector in Malaysia to address the challenges faced by the industry. Thus, this study dedicates its focus to blockchain technology implementation in property management.

1.3 Problem Statement

The integration of blockchain technology has gained significant momentum for its potential to revolutionize various aspects of the property management sector. The characteristics of blockchain, which are decentralization, transparency, immutability, and security, have made blockchain an attractive solution for addressing the challenges faced in property management processes (Bhanushali *et al.*, 2020; Konashevych, 2020a).

Despite the extensive literature on blockchain's potential, most studies focused on single aspects or specific applications rather than a comprehensive integration. For example, Kalyuzhnova (2018) and Ali et al. (2020) have demonstrated the benefits of blockchain in property transactions by simplifying and securing the transfer of property titles with less fraud. In addition to transactional aspects, blockchain's role in land administration has been highlighted. Researchers have explored the implementation of blockchain-based land registry systems, emphasizing their potential to provide tamper-proof records of ownership and reduce disputes (Gupta, Das and Nandi, 2019; Krishnapriya and Sarath, 2020; Yadav *et al.*, 2023; Zein and Twinomurinzi, 2023). Additionally, studies by Konashevych (2020a) and Kshetri (2022) have also examined the application of blockchain in protecting property rights, particularly in developing countries.

Another emerging trend in the literature is the application of blockchain in rental and lease management. Many scholars have studied the use of blockchain to automate various processes related to leasing (Keith,

Fadzil and Zainal-Abidin, 2021; Saari, Junnila and Vimpari, 2022; Jain *et al.*, 2024). Moreover, a case study on the applications of blockchain technology in rental management systems within Malaysia is being conducted by Ying and Wong (2024).

However, there is a lack of research investigating the comprehensive integration of blockchain technology across the entire property management lifecycle. The current body of research on blockchain in property management is fragmented, focusing primarily on specific applications such as property transactions, land registration, and rental agreements. However, these studies do not address the comprehensive integration of blockchain technology across all stages of the property management lifecycle, from acquisition to maintenance and disposition, particularly in the context of Malaysia. Therefore, the aim of this research is to bridge the gap by examining the potential of blockchain technology for comprehensive integration across the entire property management lifecycle in Malaysia. This study seeks to identify inefficiencies in property management practices to better evaluate the potential applications of blockchain technology. Additionally, it will explore the challenges posed by adopting blockchain in the sector. By doing so, the findings will provide valuable insights for stakeholders, policymakers, and developers in enhancing all the stages of property management by adopting blockchain technology.

1.4 Aim

The aim of this study is to investigate the potential of adopting blockchain technology into property management in Malaysia.

1.5 Objectives

Three objectives are established to achieve the aim of this research.

I. To identify inefficiencies faced in property management practice.
II. To identify the potential of adopting blockchain technology in property management.
III. To discover the challenges of implementing blockchain technology in property management.

1.6 Research Methodology

This study adopted a quantitative approach by distributing questionnaires to property developers. The questionnaire was generated using Google Forms and sent via email and other social media platforms such as LinkedIn. A total of 123 responses were initially collected. However, 3 responses were excluded because the respondents were interns without sufficient industry experience, resulting in 119 valid responses. The data collected were analyzed using the Cronbach's Alpha Reliability Test, along with Arithmetic Mean, Mann-Whitney U Test, Kruskal-Wallis Test, and Spearman Correlation Test.

1.7 Research Scope

This research is focused on developers within Klang Valley, Malaysia, without setting any restrictions on the type and size of organisations.

1.8 Chapter Outline

Chapter 1 introduces the research, outlining the background of the study, the problem statement, the aims and objectives, the scope, and a chapter summary. Chapter 2 provides a comprehensive review of existing literature, focusing on the potential of blockchain technology in property management through an analysis of previous studies.

In Chapter 3, the research methods are discussed, including the rationale for the chosen approach, the implementation strategy, the data collection process, and the analytical techniques used to meet the research aims and objectives. Chapter 4 interprets the data obtained from the questionnaire survey, analyses the results in connection with the research, and works toward achieving the primary goal. Finally, Chapter 5 summarizes the accomplishments of the objectives and the contributions of this research, while also addressing the limitations encountered and offering recommendations for future research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter presents a comprehensive literature review on the potential of blockchain technology in property management in Malaysia. The chapter begins by defining property management and the challenges faced in this domain. This is followed by a discussion of blockchain technology, including its definition and distinguishing features. Following that. it explores the potential of blockchain in property management. The chapter also examines the challenges associated with the integration of blockchain in the property management context. Finally, the chapter concludes with the key points discussed.

2.2 Property Management

A systematic discussion regarding the definition, concept, and property management life cycle is explained in the next subsections.

2.2.1 Definition and Concept

Property management involved organizing an efficient system to maximize income from a property while ensuring its upkeep and maintenance to prevent deterioration and wastage. Over time, the scope of property management had expanded significantly. Read and Carswell (2019) noted that it now included financial planning, market studies, deal-making, project assessment, and efforts to be socially and environmentally responsible. Węgrzyn and Najbar (2020) suggested that modern property management extended beyond traditional duties, focusing on creating value for all parties, clarifying roles, improving services, and resolving conflicts, aiming to enhance property value by maintaining tenant satisfaction and smooth operations.

Bello, Khamis and Ibrahim (2020) viewed property management as a comprehensive process combining various tasks to ensure properties operated efficiently, generated income, and remained sustainable. This encompassed

both maintaining the physical building and making strategic financial decisions regarding the property and its tenants.

Additionally, She, Aini and Zyed (2022) categorized property management tasks into six main areas which were tenant management, maintenance, building oversight, community engagement, financial handling, and administrative work. This breakdown helped property managers evaluate their performance and identify areas for improvement.

2.2.2 Property Management Lifecycle

The property management lifecycle was a comprehensive process involving various stages. Each stage played an essential role in maximizing property value, ensuring operational efficiency, and meeting both stakeholder and community needs. The lifecycle was typically broken down into acquisition, planning, design, construction, operation, and disposition stages.

2.2.2.1 Acquisition Stage

The acquisition phase was the starting point for any property management project, as it involved identifying and acquiring properties that aligned with specific investment or community goals. This stage typically included conducting market research, performing feasibility studies, and negotiating acquisition deals. For investors, the goal was to purchase properties that offered potential for high returns, whereas municipalities focused on securing properties that would serve community needs (Munawar *et al.*, 2020). Proper due diligence in this phase was critical for setting the stage for the rest of the lifecycle, ensuring that the property was suitable for development or rental and aligned with the long-term strategy of the organization. Acquisition decisions were influenced by various factors, including market conditions, location, and the property's condition. Proper evaluation of these elements helped mitigate future risks and set realistic goals for the property's use (Van Den Beemt-Tjeerdsma and Veuger, 2016). Additionally, the financial stability and capacity of the purchaser to invest in further stages of the lifecycle played a key role in the success of this stage.

2.2.2.2 Planning and Design Stage

After acquisition, the planning and design phase focused on developing detailed plans for how the property would be utilized or developed. This included conducting thorough market analysis, determining zoning requirements, and creating architectural designs (Vladimirova, Kallaur and Bareshenkova, 2018). For real estate projects, this stage was crucial for aligning the property's design with market needs and regulatory frameworks. It also included decisions about the integration of digital technologies, such as Building Information Modelling (BIM), which enhanced communication and collaboration among stakeholders and optimized design outcomes (Bilge and Yaman, 2021). For municipalities, the planning process included aligning the property project with community objectives, ensuring that it fulfilled local policy goals (Van Den Beemt-Tjeerdsma and Veuger, 2016). Effective planning in this phase minimized the risk of delays during the construction stage and ensured that the project met both functional and regulatory requirements.

2.2.2.3 Construction Stage

The construction phase involved turning the designs into reality. This stage was heavily dependent on project management practices to ensure that the project stayed within budget, was completed on time, and met quality standards. Cost management, time management, and quality control were key components of successful project execution (Vladimirova, Kallaur and Bareshenkova, 2018). During this stage, the integration of BIM continued to be critical for tracking and managing data throughout the construction process, enabling real-time collaboration and reducing the likelihood of costly errors (Bilge and Yaman, 2021). A major challenge during construction was coordinating multiple stakeholders, such as contractors, suppliers, and local authorities, to ensure the smooth execution of the project. Effective communication and collaboration among all parties involved were necessary to minimize risks and delays during the construction phase (Munawar *et al.*, 2020).

2.2.2.4 Operation and Maintenance Stage

Once construction was complete, the property entered the operational phase, where it had to be managed to ensure it met its intended use and retained its value over time. This phase included tenant management, routine maintenance, and facility management (Manchana, 2022). The property had to be maintained according to established standards, ensuring tenant satisfaction and extending the life of the asset. This involved preventive maintenance, repair work, and upgrading facilities to meet changing needs. Effective tenant management was also critical during this phase, as maintaining good tenant relationships and addressing issues promptly reduced turnover and enhanced the property's value (Munawar *et al.*, 2020). The integration of smart technologies for monitoring and maintaining the property improved efficiency, reduced costs, and enhanced service delivery, contributing to long-term sustainability (Manchana, 2022).

2.2.2.5 Financial and Risk Management

Financial management throughout the property lifecycle was crucial for ensuring profitability and maintaining financial health. This included budgeting, rent collection, and expense management to ensure positive cash flow and compliance with financial regulations (Munawar *et al.*, 2020). The role of financial management was not limited to operational costs, but it also encompassed strategic investment decisions and ensuring the property generated a favourable return on investment. Alongside financial management, risk management was also key to maintaining the value of the property and protecting the interests of stakeholders. This included addressing risks related to insurance, compliance with safety regulations, and disaster preparedness (Bilge and Yaman, 2021). Integrating big data analytics and other technological tools enhanced financial strategies, improved forecasting, and assisted with informed decision-making (Munawar *et al.*, 2020).

2.2.2.6 Disposition Stage

The disposition stage marked the end of a property's lifecycle in terms of ownership or utilization. At this stage, the property might have been sold, leased, or repurposed for other uses. Deciding on the best timing and method

for disposal required careful market analysis, assessing property value, and aligning with long-term strategic goals (Van Den Beemt-Tjeerdsma and Veuger, 2016). The goal was to maximize the value of the property at the time of disposal, ensuring that the investment generated the best possible returns.

2.2.2.7 Post-Disposal and Review

After a property had been disposed of, post-disposal management involved ensuring that all administrative tasks were completed. This included finalizing financial accounts, handling any remaining tenant issues, and evaluating the asset's performance over its lifecycle. The continuous review process was vital for identifying lessons learned and applying this knowledge to improve future property management strategies (Bilge and Yaman, 2021). Regular assessments helped ensure that properties continued to meet their objectives and provided valuable insights for optimizing future real estate decisions.

2.3 Blockchain Technology

The overview of blockchain technology regarding its definition and features was provided in the next subsections.

2.3.1 Definition

Blockchain technology had emerged as a revolutionary approach to digital transactions and data management, offering a decentralized solution to the challenge of double-spending (Nijland and Veuger, 2019; Akoguhi and Bhavsingh, 2023). At its core, blockchain had operated as a distributed ledger, where transactions, whether financial or informational, were securely recorded across a network of participants (Ahmad *et al.*, 2021)

Blockchain had functioned as a digital ledger that organized transaction records into blocks, with each block cryptographically linked to the previous one (Shuaib et al., 2022). This distributed ledger system operated on a peer-to-peer network, where transaction validation was decentralized and achieved through consensus mechanisms among network nodes, rather than relying on a central authority (Kalyuzhnova, 2018; Konashevych, 2020a).

2.3.2 Features

Blockchain technology had been characterized by a suite of revolutionary features that collectively had redefined how transactions were conducted, and data integrity was ensured in digital environments. These features not only had underpinned the functionality of blockchain but also had differentiated it from centralized systems, offering benefits across various industries, including property management.

2.3.2.1 Decentralisation

According to Shabbir (2021), blockchain had operated on a decentralized network where control and decision-making were distributed among multiple nodes. Each participant in the network had retained a copy of the entire blockchain, eliminating the need for a central authority or intermediary to validate transactions. Decentralization had enhanced security by reducing the risk of a single point of failure and had made the system more resilient against attacks and censorship.

This feature not only had improved the transparency and trustworthiness of transactions but also had enabled greater inclusivity and accessibility, as anyone with an internet connection could have participated in the blockchain network (Konashevych, 2020a). In sectors such as banking and governance, decentralization had offered the potential to democratize access to financial services and decision-making processes.

2.3.2.2 Consensus Mechanism

Consensus mechanisms had enabled blockchain networks to achieve agreement on the validity of transactions and the state of the ledger without relying on a central authority. Different consensus protocols, such as Proof of Work (PoW) and Proof of Stake (PoS), had offered varying approaches to validating transactions and securing the network (Mahmudnia, Arashpour and Yang, 2022)

PoW, used by Bitcoin, had required participants to solve complex mathematical puzzles to validate transactions and create new blocks, ensuring network security through computational effort. PoS, on the other hand, had

selected validators based on their stake in the network, promoting energy efficiency and scalability (Shabbir, 2021).

2.3.2.3 Transparency

Transparency had been inherent in blockchain technology due to its public ledger system, where all transactions were recorded and accessible to network participants. Each transaction had been timestamped and linked to previous transactions, providing a complete audit trail of asset ownership and transaction history (Ali *et al.*, 2020).

This transparency had reduced the risk of fraud and corruption by enabling stakeholders to verify the authenticity of transactions independently. In industries like property management, blockchain's transparency could have streamlined processes, mitigated disputes, and enhanced accountability (Kalyuzhnova, 2018).

2.3.2.4 Immutability

Immutability had been a foundational characteristic of blockchain, ensuring that once data was recorded, it could not be altered or deleted without the consensus of the network participants. Each block had contained a cryptographic hash of the previous block, creating a chain that linked each transaction back to its origin. This feature had guaranteed the integrity and permanence of data stored on the blockchain, making it highly resistant to tampering and fraud (Thota, 2019).

The immutability of blockchain not only had enhanced security but also had fostered trust among users by providing a transparent and tamper-proof ledger of transactions (Cunha and Silva, 2023). This property was particularly beneficial in industries such as finance, supply chain management, and healthcare, where maintaining accurate and unalterable records was critical.

2.3.2.5 Smart Contract (Autonomous)

Smart contracts had been self-executing agreements with predefined rules written in code. These contracts had automatically enforced terms and conditions when specified conditions were met, eliminating the need for

intermediaries and reducing transaction costs (Morena *et al.*, 2020; Celik, Abraham and Attaran, 2024).

Blockchain-based smart contracts had enabled programmable transactions across various industries, including finance, insurance, and supply chain management. They had streamlined business processes, automated compliance, and enhanced operational efficiency by executing actions automatically based on predefined triggers (Akoguhi and Bhavsingh, 2023).

2.3.2.6 Cryptocurrency and Tokens

Cryptocurrencies had been digital assets used as a medium of exchange within blockchain networks. These assets had been secured by cryptographic techniques and distributed ledger technology, preventing double-spending and ensuring transactional integrity (Pirgmann, 2023).

Tokens, a form of digital asset, had represented ownership or access rights within a blockchain ecosystem. They could have represented physical assets like property or commodities, tokenized assets, and facilitated complex transactions through smart contracts (Avci and Erzurumlu, 2023). Tokens had enabled fractional ownership, liquidity, and asset transferability, expanding blockchain's utility beyond financial transactions.

2.4 Inefficiencies in Property Management

Property management had encountered various inefficiencies globally. In China, the management of public rental housing (PRH) had faced issues due to the abundant supply of PRH in the short term (Luo, Heijden and Boelhouwer, 2020). These inefficiencies had encompassed building repair, service charge collection, sinking fund management, house-buyer relationships, vandalism, and community living promotion in low-cost housing (Wang, Ling and Shi, 2021). Similarly, in Malaysia, homeowners in medium-cost residential buildings encountered inefficiencies with management commitment towards organizing activities, addressing residents' reports or complaints, and solving issues (Musa *et al.*, 2020).

Moreover, the sustainability and management of properties, such as Waqf properties in Malaysia, have been impeded by inefficiencies like insufficient funds, suboptimal performance by managers, unregistered land,

outdated data, and ownership rights issues (Yusoff *et al.*, 2021). Inefficiencies in high-rise residential buildings include issues related to property management transparency, security, safety, professionalism, and maintenance during design and construction stages (Sia *et al.*, 2018). Moreover, the study on sustainable management practices of green features in office properties in Lagos, Nigeria, had indicated that property managers were yet to fully adopt sustainable resource management practices (Fateye *et al.*, 2023). Tenant complaints also represent a significant inefficiency in property management, necessitating immediate resolution to maintain tenant satisfaction levels (Yusop, Azmi and Azlan, 2022).

In conclusion, while property management faces a wide range of global inefficiencies, specific issues have been identified in areas such as land administration, property transactions, leasing and renting, property administration, property financialization, and property maintenance, as outlined in Table 2.1.

Table 2.1: Inefficiencies in Property Management

No.	Inefficiencies	Previous Studies
	Land Administration	
1	Fragmented Institutional Structures and Historical Complexities	Akotia, Opoku and Hafiz (2017); Antonio et al. (2021); Ugonabo, Egolum, and Sado (2023)
2	Administrative Inefficiencies and Corruption	Agegnehu et al. (2021); Ho et al. (2018); Sakib, Islam, and Shishir (2022); Ugonabo, Egolum, and Sado (2023)
3	Insufficient Historical Land Records	Agegnehu et al. (2021); Antonio et al. (2021); Daniel and Speranza's (2020) ; Sakib, Islam, and Shishir (2022)
4	Land Tenure Disputes and Resolution Mechanisms	Agegnehu et al. (2021); Asaaga (2021); Effossou, Cho, and Ramoelo (2022); Ho et al. (2018); Ogbu and Iruobe (2018); Oyedeji (2021)
5	Discrimination and Inequitable Land Ownership	Antonio et al. (2021); Effossou, Cho, and Ramoelo (2022); Sakib, Islam, and Shishir (2022)
6	Governance and Compliance Challenges	Effossou, Cho, and Ramoelo (2022); Ho et al. (2018); Ugonabo, Egolum, and Sado (2023)
	Property Transaction	
7	High Transaction Costs	Dobrucká, Maštálka, and Šilhánková (2024); Guerriero (2023); Kisiała and Rącka (2021); Palm and Bohman (2023)
8	Susceptibility to Fraud and Reliance on Intermediaries	Guerriero (2023); Kisala (2021); Mashatan et al. (2021); Palm and Bohman (2023)
9	Lack of Transparency	Guerriero (2023); Kisiała and Rącka (2021); Palm and Bohman (2023)
10	Slow Processing Times	Palm and Bohman (2023); Wisniewski and Wiśniewski (2024)
11	Inefficiencies in Property Rights Enforcement	Dobrucká, Maštálka, and Šilhánková (2024); Guerriero (2023); Kisiała and Rącka (2021); Rao et al. (2024); Wisniewski and Wiśniewski (2024)

Table 2.1 (Continued)

No.	Inefficiencies	Previous Studies
	Leasing And Renting	
12	Inefficiencies and High Transaction Costs	Guan and Jang (2023); Junaid et al. (2024); Júnior et al. (2019)
13	Transparency and Trust Issues	Guan and Jang (2023); Junaid et al. (2024); Júnior et al. (2019)
14	Intermediaries' Conflicts of Interest	Guan and Jang (2023); Junaid et al. (2024); Júnior et al. (2019)
15	Security Concerns in Rental Transactions	Guan and Jang (2023); Junaid et al. (2024); Júnior et al. (2019)
	Property Administration (Cont'd)	
16	Lack of Transparency and Verification Issues	Aihie (2020); Garcia-Teruel (2020); Hahn and Oluwatofumi (2021); Sia et al. (2018); Soundararaj, Pettit, and Lock (2022); Wouda and Opdenakker (2019)
17	Fragmented Data Storage and Management	Borgentorp, Kaartinen, and Junnila (2023); Hahn and Oluwatofumi (2021); Jasimin et al. (2023); Soundararaj, Pettit, and Lock (2022); Wouda and Opdenakker (2019)
18	Complex Decision-Making and Record-Keeping Challenges	Aihie (2020); Borgentorp, Kaartinen, and Junnila (2023); Jasimin et al. (2023); Wouda and Opdenakker (2019); Sia et al. (2018)
	Property Financialization	
19	Illiquidity and High Entry Barriers	Anggun Andini and Falianty (2022); Banerjee et al. (2022)
20	Lack of Transparency	Anggun Andini and Falianty (2022); Banerjee et al. (2022); Kaldor (2022)
21	Speculative Investments and Rising Property Prices	Anggun Andini and Falianty (2022); Banerjee et al. (2022); Kaldor (2022)
22	Market Volatility and Distortions	Anggun Andini and Falianty (2022); Christophers (2019); Zekri and Razali (2019)

Table 2.1 (Continued)

No.	Inefficiencies	Previous Studies
	Property Maintenance	
23	Inadequate Maintenance by Responsible Bodies	Aihie (2020); Borgentorp, Kaartinen, and Junnila (2023); Janhunen, Leskinen, and Junnila (2020); Musa et al. (2020); Rajedran and Haja Maideen (2023); Sari (2023); Wouda and Opdenakker (2019)
24	Deterioration of Buildings Over Time	Au-Yong et al. (2021); Bikam (2019); Borgentorp, Kaartinen, and Junnila (2023); Janhunen, Leskinen, and Junnila (2020); McAleavey, O'Gorman and Clair (2025); Musa et al. (2020); Rajedran and Haja Maideen (2023)
25	Lack of Awareness Among Residents	Bikam (2019); Janhunen, Leskinen, and Junnila (2020); Kadhim and Altaie (2023); Musa et al. (2020); Rajedran and Haja Maideen (2023); Saari, Junnila, and Vimpari (2022)
26	Professionalism and Transparency Issues	Borgentorp, Kaartinen, and Junnila (2023); Musa et al. (2020); Rajedran and Haja Maideen (2023); Sari (2023); Wouda and Opdenakker (2019)
27	Transition of Maintenance and Management Responsibilities	Borgentorp, Kaartinen, and Junnila (2023); Musa et al. (2020); Rajedran and Haja Maideen (2023); Sari (2023); Wouda and Opdenakker (2019)
28	Ensuring Utility, Health, Safety, and Environmental Significance	Bikam (2019); Janhunen, Leskinen, and Junnila (2020); Musa et al. (2020); Rajedran and Haja Maideen (2023); Sari (2023)

2.4.1 Land Administration

Land administration is a cornerstone of sustainable development, influencing the stability of economic, social equity, and environmental stewardship. However, the system has historically faced numerous inefficiencies, particularly in regions like Sub-Saharan Africa, where colonial legacies and institutional weaknesses have compounded inefficiencies (Antonio *et al.*, 2021). This section explores the multifaceted inefficiencies of land administration.

2.4.1.1 Fragmented Institutional Structures and Historical Complexities

Fragmented systems and historical complexities posed significant inefficiencies to land administration in Sub-Saharan Africa. Colonial legacies created dual governance frameworks, blending customary and statutory systems (Antonio *et al.*, 2021). These frameworks often conflicted, causing confusion among stakeholders regarding their rights and responsibilities (Ugonabo, Egolum and Sado, 2023). In Nigeria, overlapping systems hindered the implementation of unified policies. This led to inefficiencies and a lack of clarity for stakeholders.

Historical land tenure arrangements poorly reflected local realities, adding to institutional confusion. Many colonial-era laws remained unchanged and failed to address modern needs (Akotia, Opoku and Hafiz, 2017; Antonio *et al.*, 2021). These outdated systems delayed equitable land distribution and sustainable resource management. Stakeholders often struggled to navigate their roles within this fragmented framework, exacerbating inefficiencies in land governance.

2.4.1.2 Administrative Inefficiencies and Corruption

Outdated administrative systems undermined land administration efficiency. Many countries relied on manual, paper-based processes, leading to delays in land registration (Sakib, Islam and Shishir, 2022). For instance, in Bangladesh, registration took up to 245 days, discouraging formal registrations. These delays pushed many transactions into informal channels, which lacked transparency and security. In Nigeria, heavy procedures and inefficiencies

increased costs and delayed processes, creating barriers to formal ownership (Ugonabo, Egolum and Sado, 2023).

Reliance on outdated systems also created opportunities for corruption. Bribery and fraudulent practices eroded trust in land administration (Agegnehu *et al.*, 2021). Influential individuals often manipulated policies to their advantage, exploiting marginalized groups (Ho *et al.*, 2018). These practices perpetuated inefficiency and mistrust, further eroding public confidence in governance systems.

2.4.1.3 Insufficient Historical Land Records

The absence of comprehensive land records exacerbated land administration inefficiencies. In many African countries, less than 30% of land parcels were formally documented. In Nigeria, only 3% of the land was covered by title deeds (Antonio *et al.*, 2021; Sakib, Islam and Shishir, 2022). This lack of documentation caused uncertainty about ownership and tenure security. Vulnerable populations were particularly at risk of exploitation and land grabbing.

Insufficient records hindered sustainable land-use policies. Communities without documented boundaries faced frequent disputes (Daniel and Speranza, 2020). Competing claims often escalated conflicts and undermined trust (Agegnehu *et al.*, 2021). This documentation gap created systemic issues that impeded development and stability in land governance.

2.4.1.4 Land Tenure Disputes and Resolution Mechanisms

Land tenure disputes stemmed from overlapping customary and statutory systems. These conflicts created uncertainty regarding land (Ho *et al.*, 2018; Ogbu and Iruobe, 2018). Mechanisms to resolve these disputes, such as courts and informal negotiations, were often slow and ineffective. For example, Ethiopia used both formal and informal methods to resolve disputes, though their success varied (Agegnehu *et al.*, 2021; Oyedeji, 2021).

Current systems enjoyed social legitimacy and were often preferred for conflict resolution. However, these systems lacked clear documentation and long-term reliability (Asaaga, 2021). Growing land scarcity and commodification escalated disputes and marginalization. These unresolved

conflicts complicated efforts to achieve collaborative management and sustainable development (Effossou, Cho and Ramoelo, 2022).

2.4.1.5 Discrimination and Inequitable Land Ownership

Discrimination and inequitable land ownership perpetuated historical injustices in governance. Marginalized groups, such as women and ethnic minorities, were excluded from land ownership. This exclusion was due to systemic biases in statutory and customary laws (Antonio *et al.*, 2021). Formal land systems often favored wealthy individuals, exacerbating cycles of poverty and inequality (Sakib, Islam and Shishir, 2022).

Customary rights, which were often ignored, further deepened these inequities. Women and marginalized groups were frequently denied formal ownership opportunities. This exclusion restricted their participation in economic activities and broader societal development (Antonio *et al.*, 2021). Corporate land acquisitions also led to conflicts, highlighting systemic failures to protect vulnerable communities (Effossou, Cho and Ramoelo, 2022).

2.4.1.6 Governance and Compliance Challenges

Governance and compliance issues created inefficiencies in land administration. Political inertia and selective enforcement of policies hindered meaningful reform (Ugonabo, Egolum and Sado, 2023). Weak monitoring frameworks and inadequate stakeholder engagement fostered inconsistency. These issues created an environment resistant to change (Ho *et al.*, 2018).

In South Comoé, the interaction between statutory and customary systems led to conflicts and inefficiencies. Policies perceived as selectively enforced diminished public trust. This erosion of trust escalated tensions over resources, further complicating governance (Effossou, Cho and Ramoelo, 2022). Addressing governance failures was critical to establishing equitable and sustainable land systems.

2.4.2 Property Transaction

Inefficiencies in property transactions had historically undermined market efficiency and accessibility. Key issues such as high transaction costs, susceptibility to fraud, lack of transparency, slow processing times, and

inefficiencies in property rights enforcement had persisted in the sector. These inefficiencies often stemmed from systemic inefficiencies, socio-economic disparities, and reliance on traditional processes.

2.4.2.1 High Transaction Costs

High transaction costs were a universal inefficiency in property transactions, significantly affecting market efficiency and accessibility. The capital-intensive nature of the real estate sector, combined with the volatility of asset values, contributed to elevated transaction costs (Palm and Bohman, 2023). Accurate property valuations, complicated by the heterogeneous nature of real estate assets, often required external audits, which escalated expenses (Guerriero, 2023). In markets where property values fluctuated significantly, particularly in socio-economically challenged areas, the costs associated with extensive market analysis and property valuation were substantial (Kisiała and Rącka, 2021).

These high costs deterred potential buyers and sellers, leading to market inefficiencies. Substantial transaction costs excluded buyers who valued properties higher than current owners, resulting in resource misallocation and reduced market fluidity (Guerriero, 2023). Additionally, municipalities often managed real estate intuitively, failing to leverage economies of scale or best practices, further exacerbating high transaction costs (Dobrucká, Maštálka and Šilhánková, 2024).

2.4.2.2 Susceptibility to Fraud and Reliance on Intermediaries

The real estate market was particularly vulnerable to fraud due to high levels of asymmetric information between buyers, sellers, and investors. The complexity of property valuations created opportunities for misrepresentation and fraudulent activities (Palm and Bohman, 2023). In such environments, high transaction costs led parties to rely on intermediaries, such as real estate agents and brokers, to facilitate transfers. However, this reliance often introduced vulnerabilities, as intermediaries occasionally exploited their positions, increasing fraud risks in markets lacking oversight (Guerriero, 2023).

Urban poverty further correlated with heightened fraud risks, as areas with concentrated poverty often experienced insufficient regulatory oversight

(Kisala, 2021). Fraud practices, such as double ending, where agents represented both sides of a transaction, led to collusion that disadvantaged one party and inflated costs for buyers and sellers (Mashatan *et al.*, 2021).

2.4.2.3 Lack of Transparency

The lack of transparency significantly affected trust and efficiency in property transactions. The absence of liquid market information on property prices deterred investors and complicated decision-making (Palm and Bohman, 2023). Buyers often struggled to ascertain the true value of properties, leading to mistrust and hesitancy to engage in transactions. Weak property rights and poorly enforced regulations compounded the issue, making it difficult to verify ownership and transaction history (Guerriero, 2023).

In poverty-stricken areas, socio-economic conditions exacerbated disparities in information availability, further hindering informed decision-making (Kisiała and Rącka, 2021). These conditions often resulted in market inefficiencies and mistrust.

2.4.2.4 Slow Processing Times

Slow processing times were a notable inefficiency in property transactions, often resulting from bureaucratic complexities and thorough due diligence requirements. The auditing and documentation processes necessary for legal and regulatory compliance caused delays (Palm and Bohman, 2023). These inefficiencies were more pronounced in areas with high poverty and social challenges, where additional regulatory checks were required (Kisiała and Rącka, 2021).

The need for extensive documentation and approvals further delayed transactions, reducing market fluidity. Inefficient management practices and complex bureaucratic frameworks hindered timely transaction completions (Wisniewski and Wiśniewski, 2024).

2.4.2.5 Inefficiencies in Property Rights Enforcement

The enforcement of property rights was crucial for maintaining market stability, yet inefficiencies in this area complicated property transactions. Weak property rights could lead to significant enforcement challenges,

creating disincentives for investment (Guerriero, 2023). When property rights were inadequately protected, original owners might struggle to reclaim their property from unauthorized takers, complicating transactions and deterring potential investors.

Socio-economic challenges in urban areas could lead to disputes and uncertainties regarding property rights (Kisiała and Rącka, 2021). A lack of comprehensive management strategies could imply challenges in enforcing property rights, as municipalities might not have clear strategies for managing their assets (Dobrucká, Maštálka and Šilhánková, 2024). A well-defined legal framework was necessary to uphold property rights and facilitate smoother transactions, as the risk of disputes and inefficiencies in property rights enforcement remained high (Rao *et al.*, 2024; Wisniewski and Wiśniewski, 2024).

2.4.3 Leasing and Renting

Leasing and renting processes were central to property management, offering flexibility to tenants and income to property owners. However, these processes often faced inefficiencies in management, high transaction costs, lack of transparency, security concerns, and conflicts of interest involving intermediaries.

2.4.3.1 Inefficiencies and High Transaction Costs

One of the most significant inefficiencies in lease and rental management was the inefficiency of current systems, which led to high transaction costs. Guan and Jang (2023) highlighted that the operational dynamics of the real estate sector were inherently complex, involving multiple parties and outdated processes. These inefficiencies resulted in delays and inflated costs for both landlords and tenants. The reliance on intermediaries, such as brokers, further exacerbated the issue by adding additional fees, which burdened stakeholders and reduced the affordability of rental housing. Similarly, Júnior et al. (2019) identified the decentralized and fragmented management of lease agreements as a key contributor to inefficiencies. For example, nearly 18.9% of assets at São Paulo remained in use under expired contracts due to poor tracking systems. This lack of coordination often resulted in unskilled personnel

handling negotiations, further increasing transaction costs and reducing performance measurement.

Junaid et al. (2024) provided additional evidence of inefficiencies, noting that current lease and mortgage management systems relied heavily on manual processes that involved multiple departments. These processes were prone to errors, information duplication, and data inconsistencies, often taking months to complete a single transaction. Zeff et al. (2024) added that formal approval processes, such as those for leasing water rights, involved substantial transaction costs due to regulatory and legal evaluations. These costs, combined with lengthy approval periods, discouraged market activity and reduced allocation efficiency. Collectively, these studies demonstrated that inefficiencies and high transaction costs were systemic issues in lease and rental management, driven by outdated practices and fragmented systems.

2.4.3.2 Transparency and Trust Issues

Transparency was a cornerstone of effective lease and rental management, yet it remained a persistent challenge in current systems. Guan and Jang (2023) emphasized that the existing rental market suffered from a lack of transparency, making it difficult for tenants and landlords to access accurate information about housing conditions, market prices, or lease terms. This information asymmetry created distrust between parties, as tenants struggled to verify the authenticity of property details, while landlords found it difficult to assess tenants' reliability. Júnior et al. (2019) similarly highlighted the lack of integrated systems for tracking contracts, which resulted in poorly maintained or unavailable historical data. This lack of transparency hindered effective management and oversight, particularly in public administration, where inconsistent implementation of access-to-information laws limited accountability.

Junaid et al. (2024) further underscored the risks associated with opacity in current systems, noting that it increased the likelihood of fraud and corruption. Without clear and accessible records, it became difficult to trace changes in ownership or verify the legitimacy of transactions, deterring potential investors and stakeholders. Zeff et al. (2024) added that in contexts like water leasing, the lack of transparency in formal processes created distrust

among participants, as they were often unable to fully understand the terms or potential impacts of agreements. These transparency issues not only undermined trust but also contributed to transaction uncertainty and disputes, weakening the overall stability of the rental market.

2.4.3.3 Intermediaries' Conflicts of Interest

The involvement of intermediaries in lease and rental management often created conflicts of interest that further complicated the process. Guan and Jang (2023) noted that intermediaries, such as brokers and agents, frequently controlled transaction data, which led to biased recommendations and a lack of transparency. These intermediaries often prioritized their financial gain over the interests of landlords and tenants, exacerbating trust issues and increasing transaction costs. Júnior et al. (2019) highlighted similar concerns, observing that the decentralized management of leasing services by various agencies often resulted in conflicting priorities. This fragmentation made it difficult to coordinate efforts and ensure that the interests of all stakeholders were aligned.

Junaid et al. (2024) provided additional evidence of the negative impact of intermediaries, noting that middlemen often exploited inefficiencies by demanding high fees for facilitating transactions. These practices reduced the affordability of rental housing and contributed to the underutilization of assets, which had broader economic implications. Zeff et al. (2024) added that formal leasing processes often involved attorneys and regulatory bodies, whose involvement increased transaction costs and created additional barriers for participants. These conflicts of interest undermined the fairness and efficiency of lease and rental management systems, making it difficult to build trust and ensure equitable outcomes for all parties involved.

2.4.3.4 Security Concerns in Rental Transactions

Security concerns were another critical challenge in lease and rental management, as current systems were vulnerable to fraud and data breaches. Guan and Jang (2023) highlighted that the reliance on intermediaries and manual processes compromised the integrity of transactions, increasing the risk of personal information leakage and fraudulent activities. For example, tenants faced identity theft, while landlords risked financial losses due to

fraudulent applications or non-payment of rent. Júnior et al. (2019) similarly noted that the absence of centralized systems for tracking contract expirations created legal insecurity, reducing the negotiating power of lessees and increasing the likelihood of disputes.

Junaid et al. (2024) emphasized that while digitization had improved efficiency in some areas, centralized databases remained vulnerable to unauthorized access and manipulation. Issues such as double spending, where a property was leased or mortgaged multiple times to different parties persisted, creating uncertainty for stakeholders. Zeff et al. (2024) suggested that informal leasing frameworks, which compensated potentially impacted parties upfront, mitigated some security risks. However, current systems still lacked adequate safeguards to protect sensitive data and ensure the legitimacy of transactions. These vulnerabilities eroded trust in the rental market and increased the risk and cost of transactions, further complicating lease and rental management.

2.4.4 Property Administration

Property administration was essential for effective real estate management, encompassing the oversight and operation of properties. However, various challenges, including lack of transparency, fragmented data management, and inefficient decision-making processes, significantly hindered its effectiveness and efficiency.

2.4.4.1 Lack of Transparency and Verification Issues

One of the most significant challenges in property administration was the lack of transparency and reliability in verification processes. Outdated methods and reliance on current practices made it difficult to ensure the accuracy of property transactions, leading to mistrust among stakeholders (Hahn and Oluwatofumi, 2021). This issue was particularly pronounced in regions with high levels of corruption, such as Nigeria, where weak institutions and poor governance discouraged investors and property owners from engaging with the system (Aihie, 2020). Inefficiencies in market transparency further complicated the process, making property transactions slow and unreliable (Wouda and Opdenakker, 2019).

In many cases, the authenticity of official property documents was questionable, especially in areas where corruption dominated (Garcia-Teruel, 2020). The absence of real-time data and reliance on intermediaries further complicated the verification of ownership and transaction history, creating additional barriers for stakeholders (Soundararaj, Pettit and Lock, 2022). These challenges were not limited to transactions alone; they extended to property management, where residents often failed to recognize inefficiencies until facilities deteriorated, reflecting a lack of transparency in day-to-day operations (Sia *et al.*, 2018)Together, these issues highlighted the systemic lack of trust and accountability in property administration.

2.4.4.2 Fragmented Data Storage and Management

The way property data was stored and managed in current systems presented critical inefficiencies. Property records were often fragmented, stored in different formats, or managed across multiple systems that did not integrate well, making it difficult to retrieve or analyse information (Wouda and Opdenakker, 2019). In many cases, property data was still managed offline or through outdated software, which increased the risk of errors and inefficiencies (Jasimin *et al.*, 2023). This lack of integration not only slowed down administrative processes but also increased the likelihood of fraud and data loss.

In regions like Nigeria, the lack of technical expertise and proper data management systems further exacerbated these issues, leaving property information incomplete or inaccessible (Hahn and Oluwatofumi, 2021). Similarly, Soundararaj, Pettit and Lock (2022) noted that property data was often spread across disparate systems, making it challenging to analyze or use effectively. Managing diverse data types, such as tenant information, financial records, and maintenance logs, in unstructured formats created additional inefficiencies and increased the risk of errors (Borgentorp, Kaartinen and Junnila, 2023). Poor organization in property management systems also led to inefficiencies in maintenance and administration, as seen in many developing regions (Sia *et al.*, 2018). These challenges demonstrated how methods of storing and managing property data were unreliable and hindered effective property administration.

2.4.4.3 Complex Decision-Making and Record-Keeping Challenges

Decision-making in property administration was often slow and inefficient due to outdated practices and poor record-keeping. Fragmented data and manual processes made it difficult to make informed decisions, particularly during critical stages such as property transactions or maintenance planning (Wouda and Opdenakker, 2019). The involvement of multiple stakeholders in decision-making processes further complicated matters, often leading to miscommunication and delays (Jasimin *et al.*, 2023). Poor record-keeping practices exacerbated these challenges, making it difficult to track the history of property management activities or resolve disputes effectively (Borgentorp, Kaartinen and Junnila, 2023).

Payment processes were another area where property administration struggled. Collecting and managing maintenance fees was often a slow and cumbersome process, creating cash flow problems for property managers and owners (Jasimin *et al.*, 2023). Manual payment systems frequently led to delays and disputes, further complicating financial management (Aihie, 2020). Poor fund allocation and a lack of transparency in financial processes also contributed to dissatisfaction among residents and stakeholders (Sia *et al.*, 2018). These inefficiencies highlighted how these systems made it difficult to manage payments, maintain accurate records, and make timely decisions, ultimately reducing the efficiency of property administration.

2.4.5 Property Financialization

Property financialization referred to the transformation of real estate into financial assets, significantly influencing the dynamics of property markets. However, this process was fraught with challenges, including illiquidity, lack of transparency, speculative investments, and market volatility, all of which could hinder investor participation and exacerbate inequalities in access to housing.

2.4.5.1 Illiquidity and High Entry Barriers

Illiquidity in property markets represented a significant challenge that hindered investor participation, particularly for individuals lacking sufficient financial resources. The inability to quickly buy or sell assets in these markets

meant that investors often faced long holding periods, making real estate a less attractive option compared to other, more liquid investments. Banerjee et al. (2022) noted that the costs associated with securing property rights further complicated entry, creating financial burdens that discouraged potential investors and limited their ability to capitalize on property market opportunities. These entry barriers disproportionately affected low-income individuals and smaller investors, who found it nearly impossible to compete with wealthier counterparts or institutional investors.

Additionally, high entry barriers were often compounded by regulatory complexities that increased the difficulty of navigating property markets. Anggun Andini and Falianty (2022) highlighted that substantial capital requirements and bureaucratic hurdles created an environment where only financially literate individuals or entities could effectively engage in property transactions. This regulatory landscape not only restricted access but also contributed to market inefficiencies as fewer participants led to reduced competition. Consequently, the combination of illiquidity and stringent entry requirements inhibited new investments and perpetuated existing inequalities within the real estate market, thereby stalling economic mobility for disadvantaged groups.

2.4.5.2 Lack of Transparency

The lack of transparency in property markets significantly undermined investor confidence and complicated investment decisions. As highlighted by Kaldor (2022), the opacity surrounding property titles and ownership rights created an atmosphere of uncertainty that deterred potential investors. Investors were often wary of hidden risks associated with unclear property titles or disputed ownership, which led to costly legal battles and financial losses. Banerjee et al. (2022) further emphasized that inadequate transparency impeded access to credit, as lenders were less willing to extend loans when ownership rights were murky. This uncertainty affected individual financial decisions and discouraged broader participation in the property market, as potential investors sought more stable and predictable environments for their investments.

Moreover, the implications of limited transparency extended beyond individual transactions to overall market dynamics. Anggun Andini and Falianty, (2022) suggested that the lack of accessible property data prevented investors from conducting thorough due diligence, leading to poorly informed investment decisions and potential market distortions. In regions where property records were fragmented or poorly managed, investors found it challenging to assess the true value of properties, further contributing to market inefficiencies. This opacity fostered an environment where fraud was more likely to occur, as the lack of oversight allowed unscrupulous actors to exploit gaps in the system. Ultimately, the lack of transparency in property markets restricted investment opportunities and undermined the integrity of the market as a whole.

2.4.5.3 Speculative Investments and Rising Property Prices

Speculative investments acted as a prominent driver of inflated property prices, particularly in urban markets where demand often outstripped supply. Banerjee et al. (2022) observed that speculative demand created bubbles, distorting the true value of properties and making homeownership increasingly unaffordable for low-income individuals. This inflation in property prices exacerbated housing insecurity and pushed vulnerable populations further away from stable living conditions. As speculative investments prioritized short-term gains for investors, essential community needs often became secondary, resulting in socio-economic divides that limited access to affordable housing for those who needed it most.

In addition, Kaldor (2022) suggested that speculative behavior disrupted local economies by attracting investment that did not contribute to sustainable development. When property investors focused on maximizing profits rather than considering the broader implications of their investments, the consequence was an increasing disparity between housing costs and incomes, particularly in cities grappling with affordability crises. This raised critical questions about the ethics of financial practices that prioritized returns for investors over the welfare of residents. As housing prices continued to rise due to speculation, the gap between affluent property owners and low-income renters widened, leading to urban displacement and community fragmentation

(Anggun Andini and Falianty, 2022). Addressing the influence of speculative investments on housing prices was essential for fostering equitable and inclusive cities.

2.4.5.4 Market Volatility and Distortions

Market volatility represented a significant deterrent to investment as noted by (Christophers, 2019), especially in the property sector, as sudden fluctuations in prices created an unstable financial environment. Anggun Andini and Falianty (2022) pointed out that external factors, such as interest rate changes and global economic conditions, led to erratic property values that deterred long-term commitments from investors. Such volatility created an atmosphere of uncertainty where potential investors often chose to abstain from the market altogether, opting instead for safer investment avenues. As a result, the property market suffered from decreased liquidity and diminished interest, leading to further price destabilization and economic inefficiency.

The interplay of market distortions, driven in part by speculation and external shocks, complicated the investment landscape and resulted in misaligned capital allocation. Zekri and Razali (2019) noted that distorted market conditions often led to imbalances between supply and demand, further straining affordability for potential homebuyers. When property values did not reflect true market dynamics, it complicated the ability of individuals to make informed purchasing decisions, which exacerbated housing crises, especially in low-income urban areas. Ultimately, addressing market volatility and its associated distortions was crucial for creating a more stable and predictable property market that could accommodate diverse investors and enhance housing access for all.

2.4.6 Property Maintenance

Property maintenance was a critical component of effective real estate management, ensuring that buildings and facilities remain safe, functional, and appealing to occupants. However, numerous challenges, including inadequate maintenance practices, lack of awareness among residents, and insufficient professionalism, significantly hindered the efficiency and effectiveness of property management systems.

2.4.6.1 Inadequate Maintenance by Responsible Bodies

Inadequate maintenance by responsible bodies remained a critical inefficiency, reflecting systemic inefficiencies in property management. Musa et al. (2020) highlighted that property managers often lacked the professionalism and expertise required to maintain facilities effectively, which led to neglected properties and dissatisfaction among residents. This issue was compounded by the reliance on outdated manual processes and resulted in inefficiencies, frequent breakdowns, and delays in addressing maintenance needs (Rajedran and Haja Maideen, 2023). These operational shortcomings were indicative of deeper structural problems, such as insufficient resources, poor oversight, and a lack of strategic planning. Aihie (2020) further emphasized that in Nigeria, financial constraints and limited technological expertise exacerbated these issues, leaving properties vulnerable to neglect and creating significant maintenance backlogs.

Governance failures further aggravated the problem. Sari (2023) stressed the importance of clearly defined responsibilities and enforcement mechanisms to ensure accountability among property managers. However, Janhunen, Leskinen and Junnila (2020) observed that even in technologically advanced contexts, unreliable service suppliers often failed to meet professional standards, undermining maintenance efforts. Borgentorp, Kaartinen and Junnila (2023) added that property owners and investors frequently prioritized short-term cost savings over long-term benefits, such as adopting smart technologies that could enhance building performance and reduce maintenance inefficiencies. Municipal infrastructure also faced logistical challenges, with inadequate support and lack of transparency resulting in significant maintenance delays (Bikam, 2019). These findings collectively underscored the systemic nature of maintenance inefficiencies that required structural reforms to address effectively.

2.4.6.2 Deterioration of Buildings Over Time

The natural deterioration of buildings was inevitable, but its pace and severity were often worsened by insufficient investment in preventive maintenance(McAleavey, O’Gorman and Clair, 2025). Musa et al. (2020) argued that neglecting regular upkeep accelerated wear and tear, turning

buildings into liabilities that required costly repairs. Rajedran and Haja Maideen (2023) highlighted the absence of preventive and predictive maintenance programs, which increased safety risks and inflated long-term repair costs. Borgentorp, Kaartinen and Junnila (2023) reported that outdated systems in Europe's building stock contributed to faster physical deterioration, with 75% of buildings being energy inefficient. This inefficiency not only accelerated the decline of building infrastructure but also increased operational costs, highlighting the need for modernization. Janhunen, Leskinen and Junnila (2020) suggested that integrating smart technologies, such as energy-efficient systems, could mitigate deterioration by reducing operating costs and improving building performance. However, the adoption of such technologies remained limited in property maintenance due to financial and technical barriers, particularly in regions where resources were scarce, or stakeholders were resistant to change.

The financial and safety implications of delayed maintenance were severe. Bikam (2019) noted that postponing maintenance could lead to repair costs rising exponentially, with estimates suggesting that costs could increase up to 18 times higher if initial upkeep was neglected. Au-Yong et al. (2021) emphasized that delayed repairs compromised safety and reduced the usability of infrastructure, which had cascading effects on the quality of life for residents. Beyond financial costs, neglected buildings posed risks to occupants and contributed to urban decay, as deteriorating structures became unsafe and unsightly.

2.4.6.3 Lack of Awareness Among Residents

A significant challenge in property maintenance was the lack of awareness among residents regarding their responsibilities (Kadhim and Altaie, 2023). Musa et al. (2020) observed that many homeowners failed to pay maintenance charges, which led to unpaid debts and deteriorating living conditions. This lack of awareness was often rooted in poor communication between property managers and residents, as Rajedran and Haja Maideen (2023) highlighted that miscommunication left residents uninformed about maintenance schedules or their roles in property upkeep. This disconnects fostered disengagement, where residents failed to recognize how their actions or inactions contributed

to the overall condition of their properties. This lack of engagement not only complicated maintenance efforts but also created a culture of apathy, where residents viewed maintenance as solely the responsibility of property managers.

The broader implications of this lack of awareness were significant. Bikam (2019) noted that residents often failed to understand how inadequate maintenance affected their daily lives, such as through increased costs, safety risks, and reduced property value. Janhunen, Leskinen and Junnila (2020) as well as Borgentorp, Kaartinen and Junnila (2023) suggested that tools like the Smart Readiness Indicator (SRI) could be adapted to educate residents about their responsibilities, particularly in property maintenance systems. However, such tools were rarely implemented, leaving a gap in resident education. Saari, Junnila and Vimpari (2022) advocated for public education campaigns on governance principles to foster a culture of proactive maintenance and community engagement. These findings highlighted the need for targeted awareness initiatives to empower residents and promote shared responsibility in property upkeep. Without such efforts, the disconnect between residents and property managers would continue to undermine the effectiveness of maintenance systems.

2.4.6.4 Professionalism and Transparency Issues

A lack of professionalism and transparency in property management was another critical challenge. Musa et al. (2020) highlighted gaps in communication and accountability among property managers, which fostered mistrust and dissatisfaction among residents. Rajedran and Haja Maideen (2023) criticized the inefficiencies of manual maintenance approaches, noting that their lack of transparency complicated efforts to address maintenance issues effectively. These challenges were often rooted in weak ethical standards and poor governance structures, where unclear communication and accountability created opportunities for mismanagement and corruption. For example, maintenance funds were often misallocated or misused, which exacerbated the problem and eroded trust between residents and property managers.

The absence of professionalism also undermined the adoption of modern maintenance practices. Janhunen, Leskinen and Junnila (2020) as well as Borgentorp, Kaartinen and Junnila (2023) emphasized that unreliable service suppliers often failed to meet the standards required for managing smart building systems, which further complicated maintenance efforts. Wouda and Opdenakker (2019) highlighted the lack of structured data management systems, which made it difficult to track maintenance activities and hold managers accountable. Sari (2023) linked transparency to good governance principles, arguing that regular reporting and adherence to guidelines could build trust and improve maintenance practices. These findings collectively emphasized the need for professional training, ethical standards, and clear communication to foster trust and ensure effective maintenance practices.

2.4.6.5 Transition of Maintenance and Management Responsibilities

The transition of maintenance and management responsibilities presented significant inefficiency, particularly in adapting to modern systems. Musa et al. (2020) noted that effective property management required collaboration between managers and residents, but unclear roles and responsibilities often led to confusion and inefficiencies. Rajedran and Haja Maideen (2023) highlighted the difficulties of transitioning to computerized maintenance management systems (CMMS), which required proper training and follow-up. Without adequate preparation, these transitions often resulted in service delays and gaps in accountability, which further complicated maintenance efforts.

Borgentorp, Kaartinen and Junnila (2023) emphasized that transitions demanded new skills and knowledge, particularly for managing smart systems. However, the lack of capacity-building initiatives often left service suppliers and property managers ill-equipped to handle these changes. Sari (2023) suggested that clear protocols and accountability measures were essential for smooth transitions, while Wouda and Opdenakker (2019) highlighted the potential of blockchain technology to streamline data management and clarify responsibilities. Despite these potential solutions, logistical challenges and resistance to change remained significant barriers, complicating efforts to modernize maintenance practices. These findings suggested that successful

transitions required not only technological upgrades but also a cultural shift toward embracing innovation and collaboration.

2.4.6.6 Ensuring Utility, Health, Safety, and Environmental Significance

Ensuring utility, health, safety, and environmental significance was a fundamental inefficiency in property maintenance. Musa et al. (2020) highlighted that property managers were often unable to provide essential services, such as cleaning, safety measures, and regular maintenance, due to resource constraints. Rajedran and Haja Maideen (2023) noted that the lack of preventive maintenance programs increased safety risks and undermined the sustainability of property management systems. These gaps left many properties vulnerable to hazards, particularly in regions where regulatory oversight was weak or inconsistent.

Environmental and health considerations were also frequently neglected. Janhunen, Leskinen and Junnila (2020) emphasized that outdated systems in buildings contributed to energy inefficiency and poor occupant well-being. Bikam (2019) highlighted the risks of neglecting safety and environmental standards, such as increased accident rates and property damage. Sari (2023) linked these challenges to weak governance, noting that the lack of enforcement mechanisms allowed property managers to bypass regulations. These findings underscored the need for stronger regulatory frameworks and sustainable practices to address the utility, health, safety, and environmental challenges in property maintenance. Achieving this required not only technological advancements but also a cultural shift toward prioritizing long-term safety and environmental goals over short-term cost savings.

2.5 Potential of Blockchain Technology

Property management had faced many problems due to outdated, manual processes that often lack of clarity, security, and efficiency. These challenges created inefficiencies in areas such as land administration, property transactions, leasing, renting, property financialization, and maintenance. Blockchain technology emerged as a promising solution by offering a decentralized, secure, and transparent system. It had the potential to simplify and improve various aspects of property management, making the property management industry more efficient. Table 2.2 lists and tabulates the potential applications of blockchain technology in property management, as supported by prior studies.

Table 2.2: Potential Application of Blockchain Technology in Property Management

No.	Potential Application	Previous Studies
	Land Adminstration	
1	Land Title Management and Record-Keeping	Banerjee et al. (2022); Thakur et al. (2020)
2	Enhancing Transparency in Land Transactions	Ameyaw and Vries (2020); Junaid et al. (2024)
3	Securing Land Ownership Tracking	Aborujilah, Yatim, and Al-Othmani (2021); Christine et al. (2022)
4	Revolutionizing Land Registration Processes	Mann et al. (2022); Thamrin et al. (2021)
	Property Transaction	
5	Enhancing Security and Transparency in Property Records	Akoguhi and Bhavsingh (2023); Amadi-Echendu (2021); Cu et al. (2023); Gutierrez and Xu (2022); Shaikh et al. (2024)
6	Streamlining Property Transactions Through Automation	Amadi-Echendu (2021); Bhanushali et al. (2020); Cu et al. (2023); Shaikh et al. (2024)
7	Reducing Intermediaries and Transaction Costs	Akoguhi and Bhavsingh (2023); Gutierrez and Xu (2022); Naz et al. (2024)
	Leasing And Renting	
8	Enhancing Transparency and Decentralization in Rental Markets	Chen, Ye, and Lin (2019); Guan and Jang (2023); Kim and Huh (2020)
9	Enhance Trust and Streamline Rental Transactions	Jain et al. (2024); Shanker (2019)
10	Secure And Transparent Rental Records	Madhura and Mahalakshmi (2022); Yu et al. (2021)
	Property Administration	
11	Secure User Authentication and Authorization	Kalyuzhnova (2018); Konashevych (2020a); Wouda and Opdenakker (2019)
12	Tamper-Resistant Data Storage	Akoguhi and Bhavsingh (2023); Wouda and Opdenakker (2019); Konashevych (2020a); Saari, Junnila, and Vimpari (2022)
13	Decentralized Governance and Record-Keeping	Konashevych (2020a); Saari, Junnila, and Vimpari (2022); Wouda and Opdenakker (2019)
14	Automate Payments in Property Management	Celik, Abraham, and Attaran (2024); Nijland and Veuger (2019); Sigalov et al. (2021)

Table 2.2 (Continued)

No.	Potential Application	Previous Studies
	Property Financialization	
15	Tokenization and Fractional Ownership	Joshi and Choudhury (2022); Smith et al. (2019)
16	Improved Liquidity and Market Efficiency	Chen, Ye, and Lin (2019); Huang, Li and Yang (2024); Saari, Junnila, and Vimpari (2022); Smith et al. (2019)
17	Innovative Property Investment Instruments	Gururaja et al. (2024); Pirgmann (2023); Smith et al. (2019)
18	Property Valuation and Market Analysis	Joshi and Choudhury (2022); Pirgmann (2023); Sanjeeva et al. (2023)
19	Stakeholder Collaboration and Coordination	Joshi and Choudhury (2022); Sanjeeva et al. (2023)
20	Societal Implications and Housing Affordability	Hoxha and Sadiku (2019); Nijland and Veuger (2019); Saari, Junnila, and Vimpari (2022); Shaikh et al. (2024); Smith et al. (2019); Wouda and Opdenakker (2019)
	Property Maintenance	
21	Data Management and Transparency	Collins and Lindkvist (2022); Jaskula and Papadonikolaki (2021); Rahman et al. (2023); Sia et al. (2018)
22	Automated Maintenance and Smart Contracts	Collins and Lindkvist (2022); Rahman et al. (2023)
23	Asset Tracking and Supply Chain Management	Aliti et al. (2023); Osho and Olaniyi (2024); Sharma, Isah, and Rana (2024)
24	Predictive Maintenance and Optimization	Jaskula and Papadonikolaki (2021); Rahman et al. (2023); Sia et al. (2018)

2.5.1 Land Administration

The inefficiencies of land registration systems, such as manual processes, centralized design, and insufficient historical records, have led to studies on blockchain technology as a fundamental tool for land management (Ali *et al.*, 2020). The unique features of blockchain, including decentralization, transparency, and immutability, had made it a potential solution to address the inefficiencies of existing land registration systems.

One of the key potential of blockchain technology has been in land title management and record-keeping. Thakur et al. (2020) highlighted how blockchain could facilitate the implementation of secure land titling in India, which enhancing transparency and traceability of land ownership. They emphasized that the adoption of blockchain-based land titling systems could contribute to achieving the Sustainable Development Goals (SDGs), particularly SDG 1 (No Poverty), SDG 5 (Gender Equality), and SDG 16 (Peace, Justice, and Strong Institutions). By providing secure, transparent, and tamper-proof records, blockchain could protect property rights for vulnerable populations particularly women who often faced discrimination in land ownership. Additionally, the reduction of disputes and fraud in land transactions through blockchain could contribute to more peaceful and just institutions, aligning with SDG 16.

Building on this, Banerjee et al. (2022) discussed the development of a blockchain and InterPlanetary File System (IPFS)-based reliable land registry system that could eliminate fraudulent activities and establish a decentralized database to address the shortcomings of land registration systems. While Thakur et al. (2020) focused on the broader societal impact, Banerjee et al. (2022) provided a more technical approach which demonstrated the feasibility of integrating blockchain with IFPS to enhance data storage and retrieval. Both studies highlighted blockchain's potential to revolutionize land administration but in different perspectives which were social impact versus technical innovation.

The decentralized and distributed nature of blockchain technology had also useful for transparent land transactions. Junaid et al. (2024) highlighted the value of utilizing blockchain for transparent land lease and mortgage management, ensuring data integrity and immutability of land

records. This approach was particularly relevant in regions where land transaction processes are plagued by corruption and lack of transparency. The study by Junaid et al. (2024) also supported the findings of Ameyaw and Vries (2020), who presented a four-dimensional framework analysis from the Ghanaian land perspective. Their research showcased how blockchain technology could enhance transparency in land administration processes by improving record-keeping, transaction verification, and dispute resolution. While both studies emphasized transparency, Junaid et al. (2024) focused more on the transactional aspect, whereas Ameyaw and Vries (2020) offered a holistic view that included dispute resolution.

In addition to enhancing transparency, the security features of blockchain such as decentralization, immutability, and traceability had made it a suitable technology for secure land ownership tracking. Christine et al. (2022) proposed a proof-of-authority permissioned blockchain framework for digitizing and tracking land ownership registration in Indonesia in order to enhance the transparency and efficiency of land ownership tracking systems. Similarly, Aborujilah, Yatim and Al-Othmani (2021) introduced a blockchain-based adoption framework for an authentic land registry system in Malaysia. This framework highlighted the potential of blockchain to improve transparency and integration in land registration processes. According to the comparative analysis of these two frameworks, Christine et al. (2022) prioritized a more controlled environment with a permissioned blockchain, whereas Aborujilah, Yatim and Al-Othmani (2021) considered broader integration challenge. including privacy and compliance. However, both frameworks aimed to enhance transparency and security of land ownership transactions.

The potential of blockchain technology to revolutionize land registration processes had been widely explored. Mann et al. (2022) discussed the high level of security provided by blockchain and its potential to facilitate trade without the need for intermediaries. This study indicated land holding systems was a promising area for blockchain integration. However, the need for governance and compliance to ensure the successful implementation of blockchain-based land registration systems was reinforced by Thamrin et al. (2021). They presented a blockchain-based land certificate management

system in Indonesia. This system demonstrated how blockchain could streamline land registration processes through an integrated conceptual framework that enhanced efficiency, reduced bureaucratic delays, and improved data integrity. The two studies complemented each other by balancing the technical feasibility with the broader institutional requirements necessary for successful implementation.

By leveraging the unique features of blockchain, such as decentralization, immutability, and transparency, stakeholders in the property and land administration sectors were able to streamline processes, reduce fraud, and increase trust in land transactions. Furthermore, ongoing research and pilot projects in diverse geographical contexts had been crucial in refining blockchain applications and ensuring their adaptability to different land administration systems.

2.5.2 Property Transaction

Blockchain technology had offered a promising solution to address the longstanding inefficiencies in property transaction processes (Akoguhi and Bhavsingh, 2023). At the core of blockchain's potential in property transactions was its ability to create a secure and transparent digital record of ownership. By establishing a distributed ledger for each individual property, blockchain could record the complete history of ownership transfers and transactions and replacing the current paper-based title deed system (Amadi-Echendu, 2021). The decentralized and encrypted nature of blockchain had enhanced the security and transparency of property ownership record by reducing the risk of fraud or forgery (Amadi-Echendu, 2021; Gutierrez and Xu, 2022). Additionally, the decentralized nature of blockchain had ensured that the entire history of a property's ownership and transactions was visible to all stakeholders, improving the credibility and auditability of the records (Cu *et al.*, 2023; Shaikh *et al.*, 2024). Additionally, the immutable nature of blockchain had prevented unauthorized alterations hence significantly reducing the risk of irregularities in property ownership information (Amadi-Echendu, 2021; Gutierrez and Xu, 2022).

Moreover, blockchain had the potential to streamline property transaction processes by automating many of the verification and validation

processes currently done manually. For example, blockchain could automate the verification of ID numbers and residential addresses, reducing processing time and errors (Amadi-Echendu, 2021). This automation had significantly streamlined the property transaction process and thus reduced complex burdens. Moreover, the potential of blockchain-based continuous timestamp tracking systems had enhanced the "believability" of property ownership data and further improved transparency and auditability while reducing information asymmetry among stakeholders (Bhanushali *et al.*, 2020; Cu *et al.*, 2023; Shaikh *et al.*, 2024).

Furthermore, one of the key benefits of blockchain in property transactions had been the reduction of intermediaries. Blockchain and smart contracts had minimized the need for brokers, lawyers, and other third parties, as transactions could be executed directly between the buyer and seller in a secure and transparent manner (Gutierrez and Xu, 2022; Naz *et al.*, 2024). This reduction in intermediaries had led to lower transaction costs and faster processing times. Additionally, blockchain-based transactions had minimized the need for government intervention and bureaucratic processes, as ownership transfers could be recorded immutably on the blockchain (Gutierrez and Xu, 2022; Akoguhi and Bhavsingh, 2023).

In short, blockchain technology had presented significant opportunities to transform the property transaction process by addressing many of the inefficiencies. Through its decentralized, immutable, and automated features, blockchain could create a more trustworthy and streamlined environment for property ownership and transactions with reduced fraud and bureaucratic delays.

2.5.3 Leasing And Renting

Researchers had explored the use of blockchain to address these inefficiencies by enhancing transparency and decentralization in the housing rental market. For instance, Guan and Jang (2023) proposed a decentralized action model that leveraged blockchain to improve the rental experience by enabling transparent and secure transactions. Similarly, Chen, Ye and Lin (2019) had developed a blockchain-based housing rental system that enabled direct peer-to-peer sharing of listing information without Intermediaries, Landlords could display

their property details and rental terms directly to prospective tenants, while tenants could browse available listings and interact with landlords without the interference of third parties. This enhanced transparency empowered both landlords and tenants, allowing them to make more informed decisions and negotiate rental agreements more effectively. In similar way, Kim and Huh (2020) introduced the Autochain platform which was an expert automatic algorithm blockchain technology tailored for house rental applications and this demonstrated the innovative solutions blockchain can offer in property management. These studies highlighted the potential of blockchain to create more transparent and decentralized rental systems which eliminated the need for third-party intermediaries and empowering landlords and tenants to engage directly.

The potential of blockchain in optimizing the security and trust in lease and rental management was widely recognized. Jain et al. (2024) had highlighted the capacity of blockchain to enhance the efficiency and trust in these processes. Shanker (2019) examined the use of blockchain-enabled smart contracts in lease agreements, addressing issues such as eliminating third parties, enhancing trust between landlords and tenants, and facilitating secure transactions. The researcher highlighted how blockchain-based smart contracts could automate and streamline the lease management process by eliminating the need for intermediaries, such as property managers or rental agencies. This direct connection between landlords and tenants, facilitated by the smart contract, helped to build trust and transparency, as both parties could have a clear, immutable record of the rental agreement terms and conditions.

Ensuring the security and transparency of rental transactions was also a crucial concern, and several studies had addressed this. Yu et al. (2021) established a blockchain-based platform that enhanced transaction safety through the implementation of zero-knowledge proof for identity validation and homomorphic encryption for data protection. This could effectively reduce the risks posed by intermediaries and fraudulent practices in the rental market. Madhura and Mahalakshmi (2022) discussed the utilization of blockchain to create a decentralized, immutable ledger for property transaction. Thus, it was able to revolutionize lease and rental management with secure, tamper-proof solutions. These studies illustrated the potential of blockchain to

improve the security and transparency of rental transactions, thereby addressing the industry's apprehensions regarding data protection and information sharing. Nevertheless, there were gaps in these studies as there was no comprehensive solution or framework that encompasses the complete spectrum of challenges, such as tenant screening, lease management, rent collection, and dispute resolution.

2.5.4 Property Administration

The ways of managing and administering properties had long been troubled by inefficiencies. However, the presence of blockchain technology was able to address these longstanding inefficiencies.

2.5.4.1 Secure User Authentication and Authorization

In a blockchain-based property administration system, users were granted specific permissions and access rights based on their roles, such as property owner, property manager, or government official. This was achieved by using smart contracts to define and enforce the rules regarding who could perform various factions within the system (Konashevych, 2020a). For example, a smart contract specified that only the registered owner of a property had the authority to initiate a transfer of ownership or access the property's historical records.

Additionally, user identities were verified through cryptographic signatures and a blockchain-based registry. This approach ensured that only authorized individuals could access or modify property-related information. (Konashevych, 2020a). Hence, it significantly reduced the risk of data tampering and enhanced trust among users by eliminating need for a centralized authority to oversee these processes.

2.5.4.2 Tamper-Resistant Data Storage

Besides, blockchain provided a secure and transparent way to store property-related information, such as property ownership, transaction records, and asset details (Konashevych, 2020a). By recording property-related data on the blockchain's distributed ledger, the information became immutable and tamper-resistant. Each property was represented as a unique digital asset with

its ownership, transaction history, and other relevant details stored in a secure and verifiable manner (Konashevych, 2020a; Saari, Junnila and Vimpari, 2022). This eliminated the risk of data manipulation or loss that could occur in centralized databases thereby enhancing the overall trust and reliability of the property administration system (Akoguhi and Bhavsingh, 2023).

The decentralized nature of the blockchain also ensured that property records were accessible to authorized stakeholders such as property owners, managers, and government agencies in a transparent and real-time manner. This improved data accessibility facilitated better decision-making. It also enhanced property valuations and market analysis. Ultimately, these advancements led to more efficient property management (Akoguhi and Bhavsingh, 2023).

2.5.4.3 Decentralized Governance and Record-Keeping

Furthermore, blockchain-based smart contracts were designed to facilitate secure and transparent voting processes, allowing property owners to participate in decisions related to the management of their properties or shared common areas. The votes were recorded on the blockchain, ensuring a verifiable and tamper-resistant record of the decision-making process (Saari, Junnila and Vimpari, 2022). In contrast to the old centralized decision-making paradigm, this decentralized approach to governance emphasized transparency, accountability, and more inclusive decision-making.

Moreover, the blockchain served as a comprehensive and tamper-resistant record-keeping system for all property-related transactions, including ownership transfers, maintenance activities, and management decisions. The immutable nature of the blockchain ensured that this information could not be easily altered or manipulated, providing a reliable audit trail for stakeholders (Konashevych, 2020a). This helped to resolve disputes, improve compliance, and enhance the overall trust and transparency of the property administration system.

2.5.4.4 Automate Payments in Property Management

Automating payments in property management through blockchain technology demonstrated significant potential to enhance the efficiency and reliability of

financial transactions. Throughout the research, it became evident that blockchain served as a secure data-sharing program that improved the safety and reliability of payment processes (Nijland and Veuger, 2019). By employing blockchain, property managers were able to automate various tasks, such as the collection of management fees and payment of bills, which streamlined administrative operations and reduced the workload on staff. This automation was particularly crucial in handling strata fee payments, ensuring that they were collected consistently and on schedule.

Smart contracts emerged as a core component of this automation. As highlighted by Sigalov et al. (2021), smart contracts facilitated the automated execution of payment transactions upon the fulfilment of predefined conditions, such as adherence to payment schedules. This capability significantly reduced the risk of late or missed payments, and issues that frequently occurred in property management systems. By guaranteeing timely payments, property managers could maintain better cash flow and enhance relationships with service providers, thereby fostering a more efficient management environment.

Furthermore, the implementation of blockchain-based payment systems led to notable cost reductions. Nijland and Veuger (2019) indicated that the automation of payments minimized transaction costs associated with manual invoicing and processing. Celik, Abraham and Attaran (2024) supporting this, noting that blockchain-enabled systems could operate independently of human intervention, thus streamlining financial operations. The transparency and security features inherent in blockchain technology further enhanced trust among stakeholders, as all transactions were stored in a tamper-proof manner, allowing property owners and managers to track payments in real time (Celik, Abraham and Attaran, 2024). Overall, the automation of payments in property management through blockchain technology offered transformative benefits, leading to improved efficiency, reduced costs, and heightened transparency.

2.5.5 Property Financialisaton

The increasing financialization of the property sector had been a topic of growing concern and scholarly interest (Smith *et al.*, 2019). Researchers

explored various aspects of this phenomenon, including the role of blockchain technology in enabling new forms of property investment and management.

2.5.5.1 Tokenization and Fractional Ownership

One key aspect was the tokenization of assets. Blockchain-enabled tokenization could "break the investment further into fractional investment 'slices' (Smith *et al.*, 2019; Joshi and Choudhury, 2022). According to Joshi and Choudhury (2022), These tokens contained both non-fungible tokens (representing the property rights) and fungible tokens (representing the fractional ownership of the property). The fungible tokens represent the fractional ownership of the asset, and these fractional tokens can be minted and transferred to different investors, lowering the entry barrier and allowing for smaller investments in property. This fractional ownership model is particularly suitable for property structures like condominiums, timeshares, and co-ops, where individual investors can own a portion of a larger property (Smith *et al.*, 2019),

2.5.5.2 Improved Liquidity and Market Efficiency

Blockchain-based tokenization had also been explored for its potential to address the issue of illiquidity which was a major drawback of property investments. Researchers discovered that the tokenization of assets increased their liquidity by enabling the easy trading of fractional tokens on secondary markets. This expansion of the pool of potential investors and the unlocking of a more global investor base were facilitated by the low entry fee as mentioned earlier (Smith *et al.*, 2019). Additionally, it was observed that tokenized assets could be traded 24/7 on blockchain networks, rather than being limited to market hours and hence further enhancing liquidity. For instance, a $30 million tokenized luxury Manhattan condo development in the United States was reported to have seen increased market access and liquidity due to the tokenization process (Huang, Li and Yang, 2024).

The improved transparency from tokenizing the underlying physical property assets was also found to have the potential to accelerate due diligence processes and prevent price dislocations from lack of information, thereby improving overall market efficiency (Smith *et al.*, 2019). However, while the

authors argued that it enhanced liquidity, opponents had cautioned that the theoretical nature of such investments could lead to volatility and market distortions. Thus, it highlighted the need for a thorough understanding of the trade-offs between enhanced liquidity and the risks of speculative bubbles in increasingly financialized property markets (Chen, Ye and Lin, 2019; Saari, Junnila and Vimpari, 2022)

2.5.5.3 Innovative Property Investment Instruments

According to Pirgmann (2023) and Naz et al.(2024), the financialization of property also led to the development of novel investment instruments, such as blockchain-managed real estate investment trusts (REITs) and other property-backed financial products. Blockchain technology could be leveraged to automate the management and transactions associated with these investment vehicles, potentially improving efficiency and transparency. By using blockchain, the number of intermediaries involved in transactions had reduced thus decreasing the amount of management fees for governing (Smith *et al.*, 2019). However, the specific details and implications of these innovative financial instruments remain underexplored in the current body of research.

2.5.5.4 Property Valuation and Market Analysis

Blockchain-based platforms had the potential to revolutionize property valuation and market analysis by facilitating the collection, aggregation, and transparent sharing of property-related data such as ownership history, transaction details, and asset characteristics (Joshi and Choudhury, 2022; Pirgmann, 2023; Sanjeeva *et al.*, 2023). By utilizing decentralized ledgers, these platforms enhanced the accuracy and reliability of property data, reducing the risks associated with fraudulent activities and information asymmetry.

The incorporation of smart contracts further automated the valuation process and provided real-time insights into market dynamics, allowing stakeholders to make more informed decisions based on the most current information available (Pirgmann, 2023; Sanjeeva *et al.*, 2023). This capability to access timely and precise data not only improved property assessments but also fostered greater trust and confidence among investors and market

participants. The resulting enhanced transparency and data-driven decision-making could lead to a more efficient and equitable property market, significantly impacting the financialization of the property sector by attracting a broader range of investors and facilitating more informed transactions.

2.5.5.5 Stakeholder Collaboration and Coordination

Joshi and Choudhury (2022) as well as Sanjeeva et al. (2023) discussed how blockchain technology could enhance collaboration and coordination among various property industry stakeholders, such as property owners, investors, and service providers. Blockchain-based systems could enable decentralized decision-making and governance structures for property management. Hence, the stakeholders are allowed to participate in the decision-making process (Sanjeeva *et al.*, 2023). This peer-to-peer system, in which participants openly validated transactions using a consensus mechanism, had the potential to foster greater transparency and user confidence within the financialized property landscape (Joshi and Choudhury, 2022).

2.5.5.6 Societal Implications and Housing Affordability

The financialization of the property sector raised significant concerns about housing affordability, as the concentration of wealth among institutional investors often exacerbated affordability crises in urban areas (Smith *et al.*, 2019). Blockchain technology offered a potential solution by enhancing transparency in real estate transactions, thereby reducing fraud and corruption risks (Hoxha and Sadiku, 2019; Saari, Junnila and Vimpari, 2022). This transparency could increase trust among buyers, sellers, and investors, potentially attracting more foreign direct investment into real estate markets.

Additionally, blockchain facilitated innovative financing solutions, such as fractional ownership models. These models allowed multiple investors to collectively own shares of a property, thereby lowering entry barriers for potential homeowners (Wouda and Opdenakker, 2019). Such democratization of access to real estate investment enabled communities to establish decentralized organizations for managing local housing projects, thus aligning developers' interests with community needs. Overall, by promoting alternative investment structures and enhancing market efficiency, blockchain technology

could contribute to more sustainable housing solutions, particularly in urban areas experiencing steep price increases (Nijland and Veuger, 2019; Shaikh *et al.*, 2024)

2.5.6 Property Maintenance

According to Sia et al. (2018), the management and maintenance of high-rise residential buildings faced significant inefficiencies. These inefficiencies included inadequate maintenance by responsible bodies, deterioration of buildings over time, and a lack of awareness among residents. In addition, professionalism and transparency issues in property management are common. Addressing these inefficiencies was crucial for ensuring the longevity and efficient operation of these buildings. The existing literature suggested that blockchain technology could transform property maintenance (Saari, Junnila and Vimpari, 2022)

2.5.6.1 Data Management and Transparency

One of the primary potential of blockchain was its ability to maintain a secure, transparent, and immutable record of data (Jaskula and Papadonikolaki, 2021; Collins and Lindkvist, 2022; Rahman *et al.*, 2023). Jaskula and Papadonikolaki (2021) had explored the integration of blockchain technology with the concept of a Digital Twin. Digital twin was a digital representation of a physical asset, such as a property. It contained comprehensive information about the property's design, construction, operations, and maintenance (Jaskula and Papadonikolaki, 2021). The resulting blockchain-enabled Digital Twin became a single, authoritative source of information for all stakeholders, including maintenance records, operational data, and asset details, providing transparency and verifying the reliability of building-related data (Collins and Lindkvist, 2022).

By ensuring the integrity and traceability of these information, blockchain could address the lack of transparency and accountability often associated with property management practices (Sia *et al.*, 2018). n addition, the distributed nature of blockchain allowed for decentralized governance, enabling all stakeholders such as owners, tenants, and service providers to participate in shared decision-making processes (Rahman *et al.*, 2023). This

collaborative structure is particularly valuable in high-rise residential buildings, where transitioning maintenance responsibilities among stakeholders can be complex (Sia *et al.*, 2018).

2.5.6.2 Automated Maintenance and Smart Contracts

Blockchain-enabled smart contracts were also explored for their significant potential to automate various building management functions with improved efficiency and reduced human error. The use of smart contracts to streamline maintenance workflows in properties For example, scheduling regular inspections, triggering work orders, and managing vendor payments in a self-executing manner (Rahman *et al.*, 2023).

Besides automating maintenance tasks and payments, smart contracts on the blockchain were found to have the capacity to automate the administration of service provider contracts, thereby guaranteeing that the terms were adhered to through automated enforcement (Collins and Lindkvist, 2022). Furthermore, these smart contracts could enforce collectively agreed-upon rules without the need for centralized oversight, reinforcing decentralized decision-making and accountability among stakeholders (Collins and Lindkvist, 2022). These findings indicated that implementing blockchain-enabled smart contracts in building management could lead to improved maintenance schedules, more streamlined operations, and greater transparency in contract administration.

2.5.6.3 Asset Tracking and Supply Chain Management

Blockchain technology offered significant potential for improving property maintenance within property management, especially in the areas of asset tracking and supply chain management. According to Aliti et al. (2023), the decentralized nature of blockchain provided a clear and secure system for tracking property ownership and transaction history, which was important for managing assets effectively. This transparency not only reduced the risk of fraud but also ensured that all stakeholders, including property managers and tenants, had access to accurate and up-to-date information about assets and maintenance activities. The use of smart contracts helped automate maintenance processes, allowing quick responses to problems as they arose

and enhancing overall efficiency (Sharma, Isah and Rana, 2024). Additionally, Osho and Olaniyi (2024) pointed out the importance of tracking materials, stating that blockchain could monitor the origin and movement of building materials throughout the supply chain. This ability was essential for confirming compliance with safety standards and ensuring that only quality materials were used in property maintenance.

In terms of supply chain management, blockchain technology streamlined processes by providing a single source of truth for all transactions, which improved coordination among suppliers, contractors, and property managers (Sharma, Isah and Rana, 2024). This more organized approach not only reduced errors but also encouraged collaboration among different parties, leading to better procurement and maintenance operations. Osho and Olaniyi (2024) noted that the shared ledger offered by blockchain allowed all authorized participants to oversee the entire supply chain process, helping to reduce the risks related to the quality of materials and unauthorized changes. Aliti et al. (2023) added that removing intermediaries through blockchain could lower costs and make property transactions simpler, which increased trust and security throughout the supply chain. Overall, these insights highlighted the potential of blockchain technology to transform property maintenance practices, making them more efficient and reliable.

2.5.6.4 Predictive Maintenance and Optimization

Additionally, the application of blockchain in property management for predictive maintenance and optimization was emphasized (Jaskula and Papadonikolaki, 2021; Rahman *et al.*, 2023). It was crucial for appropriate maintenance strategies to ensure utility significant items and health, safety and environmentally significant items were working in optimal conditions. (Sia et al., 2018). By analysing the data stored on the blockchain, such as sensor readings and equipment performance metrics, blockchain-based systems could predict when maintenance was required. The system could employ predictive maintenance algorithms to forecast equipment failures and schedule proactive maintenance. This could lead to improved asset longevity, reduced downtime, and more efficient use of maintenance resources (Jaskula and Papadonikolaki, 2021; Rahman *et al.*, 2023).

Blockchain technology had significant potential to transform property maintenance and facilities management by offering secure data management, automated processes, decentralized governance, and predictive maintenance capabilities. However, existing literature had not fully explored this potential. As the adoption of blockchain in the property sector continued to grow, further research and implementation of these solutions could lead to more efficient, transparent, and sustainable property management practices.

2.6 Challenges of Implementing Blockchain Technology

The adoption of blockchain technology in property management faced challenges that must be addressed for successful implementation. The literature review had identified several key categories of challenges, including legal and regulatory, cost and liquidity, security and privacy, technical limitations, and institutional challenges. The literature map of challenges of implementing blockchain in property management was outlined in Table 2.3.

Table 2.3: Challenges of Adopting Blockchain Technology in Property Management

No.	Challenges	Previous Studies															
		Kalyuzhnova, 2018	Nijland and Veuger, 2019	Garcia-Teruel, 2020	Konashevych, 2020a	Konashevych, 2020b	Papadonikolaki, 2021 Jaskula and	Azari and Malek, 2022	Mahmudnia, Arashpour and Yang, 2022	Saari, Junnila, and Vimpari, 2022	Akoguhi and Bhavsingh, 2023	Avci and Erzurumlu, 2023	Cunha and Silva, 2023	Hutson, 2023	Pirgmann, 2023	Sanjeeva et al., 2023
	Legal and Regulatory															
1	Legal Consolidation			✓	✓			✓		✓						
2	Lack of Clear Regulations	✓	✓	✓				✓				✓	✓		✓	
3	Legal Recognition of Tokenization													✓	✓	
4	Lack of Standardized Practices and Outdated Legislation		✓							✓			✓			
	Cost and Liquidity															
5	Cost Challenges	✓							✓		✓		✓			
6	Liquidity Challenges									✓			✓			
7	Price Volatility				✓	✓		✓								
	Security and Privacy															
8	Cyber Threats and Security					✓		✓		✓	✓					
9	Trust and Uncertainty	✓	✓										✓			

Table 2.3 (Continued)

	Security and Privacy (Cont'd)													
10	Anonymity and Privacy	✓			✓			✓			✓			
11	Implementation of Know Your Customer (KYC) Procedures	✓									✓	✓		
12	Digital Identity and Signature Verification		✓		✓					✓	✓			
	Technical Limitations													
13	Compatibility and Interoperability		✓								✓			
14	Complexity	✓			✓					✓				
15	Scalability				✓	✓	✓				✓			✓
16	Smart Contract Challenges	✓						✓			✓			
17	Immutability and Error Correction	✓	✓					✓						
	Institutional Challenges													
18	Economic Implications and Stakeholder Collaboration	✓				✓			✓	✓				
19	Political and Regulatory Challenges				✓				✓			✓		
20	Society Consideration	✓				✓								
21	Governance Challenges	✓			✓									

2.6.1 Legal and Regulatory Challenges

A significant challenge to adopting blockchain in property management was the need for legal consolidation. This involved integrating blockchain technology with property registration systems which was challenging (Konashevych, 2020a; Saari, Junnila and Vimpari, 2022). A crucial requirement was the need to incorporate blockchain protocols with government-recognized digital ID systems to ensure the authentic identity of parties involved, as blockchain alone lacked the verification and replication capabilities offered by intermediaries like lawyers (Garcia-Teruel, 2020). Additionally, transitioning from paper-based to digital land registries was necessary for effective blockchain integration, but this process faced technical and regulatory challenges that varied across jurisdictions and led to uneven progress (Azari and Malek, 2022). For example, digitizing substantial amounts of legacy property records. Furthermore, the lack of this legal consolidation, which refers to the inability to seamlessly integrate blockchain with existing property registration and digital ID frameworks, presented a major challenge to the broader adoption of blockchain in property management (Garcia-Teruel, 2020). Resolving these integration challenges was essential to provide the required legal enforceability and authenticity for blockchain-based property transactions.

Furthermore, the lack of clear regulations surrounding blockchain in property transactions added another layer of complexity. The uncertainty regarding the legal status of tokenized property assets and their registration process was significant (Kalyuzhnova, 2018; Nijland and Veuger, 2019). Blockchain technology frequently struggled to comply with legal requirements, including those related to data protection (Cunha and Silva, 2023). Additionally, the ongoing debate about the classification of blockchain-based assets, combined with the increasing financialization of the property sector, emphasized the need for regulatory bodies to strike a balance between fostering innovation and ensuring investor protection (Avci and Erzurumlu, 2023; Pirgmann, 2023). This regulatory uncertainty weakened investor confidence and inhibited the broader adoption of blockchain in property management (Kalyuzhnova, 2018). Garcia-Teruel (2020) further highlighted the challenges in translating complex property rights such as co-ownership,

usufruct and servitudes into blockchain code. This highlighted the tension between the immutable nature of blockchain and the need for legal changes or corrections.

The legal recognition of tokenization in the metaverse further complicated the landscape. The legal relationship between tokenized assets, such as NFTs, and real-world property remained uncertain (Hutson *et al.*, 2023). Terms of service from platforms facilitating NFT transactions often resembled licensing agreements rather than conveyances of property rights. This means that when people purchased NFTs, they were not actually buying outright ownership of the underlying asset. The lack of clarity in this situation has the potential to cause misunderstandings and emphasizes the importance of being thorough and careful while handling tokenized assets. Additionally, the prevalence of mandatory arbitration clauses in these contracts might have prevented disputes from being resolved through current court systems, potentially leaving parties without adequate recourse (Pirgmann, 2023).

Additionally, the lack of standardized practices and outdated legislation presented a significant challenge. The existing legal framework required revision to accommodate blockchain-based land registries and ensure the effective enforcement of transactions (Saari, Junnila and Vimpari, 2022). Standardized data formats were crucial for facilitating blockchain integration, yet many existing regulations and standards were not aligned with blockchain technology (Cunha and Silva, 2023). Government regulations needed adjustments to align data protection laws and other relevant requirements with blockchain technology to support its adoption (Nijland and Veuger, 2019). Addressing these challenges through legislative updates and the establishment of standardized practices was essential for laying a solid legal foundation for blockchain in property management.

2.6.2 Cost and Liquidity Challenges

One of the primary challenges to blockchain adoption in property management was the high cost associated with using blockchain technology. Research indicated that substantial fees were involved in converting fiat money to digital currencies, which ranged from 0.5% to 5% (Kalyuzhnova, 2018). These conversion fees discouraged many potential users. Beyond conversion costs,

setting up and integrating blockchain infrastructure involved considerable upfront expenses. Besides, ongoing costs for network maintenance and smart contract deployment also had to be considered (Akoguhi and Bhavsingh, 2023). Cunha and Silva (2023) elaborated further by including additional factors such as information retrieval, negotiation, and property rights protection in the overall cost equation. These cumulative costs had challenged the financial feasibility of implementing blockchain solutions in property. Moreover, the computational costs associated with executing smart contracts could escalate if they were not properly optimized (Mahmudnia, Arashpour and Yang, 2022). While blockchain had the potential to reduce intermediary costs, it had introduced new cost structures that required careful management for successful implementation. The balance between promised cost savings and these new cost challenges was crucial for evaluating blockchain's viability in the property sector. The high costs associated with blockchain implementation, including conversion fees, infrastructure setup, and ongoing maintenance, posed a significant barrier to its widespread adoption in the property industry.

Moreover, the potential for blockchain to enhance liquidity in property markets presented a complex scenario. On one hand, tokenization had improved liquidity by allowing for fractional ownership of property assets, making investments more accessible and tradable (Saari, Junnila and Vimpari, 2022). On the other hand, increased liquidity might have reduced the illiquidity premium associated with property investments. The illiquidity premium was the extra return investors demanded for holding less liquid assets, such as property, and its reduction could have altered the risk-return profile of property as an asset. Additionally, the benefits of enhanced liquidity might not have been uniformly distributed across geographic regions. Blockchain-based property systems could have favoured areas with better technological infrastructure, potentially causing existing inequalities (Cunha and Silva, 2023). While some regions might have experienced improved tradability and fractional ownership, those with limited technological resources might have continued to face liquidity challenges. The impact of blockchain on property market liquidity was complex, with the potential to both enhance and disrupt liquidity dynamics. The uneven distribution of these benefits across regions

posed challenges for the equitable implementation of blockchain-based solutions in the property sector.

Price volatility was another critical challenge impacting blockchain's adoption in property transactions. The use of cryptocurrencies in property transactions had introduced the risk of value fluctuations, which could have disrupted blockchain systems managing property rights (Konashevych, 2020a). This volatility had added an additional layer of risk for both buyers and sellers, potentially reducing confidence in the viability of blockchain-based property transactions. The inherent price volatility of cryptocurrencies and digital assets used in blockchain-based property transactions had presented significant risks and uncertainties for stakeholders. According to Konashevych (2020b), fluctuations in the value of the digital tokens or coins used to facilitate property deals had led to unpredictable transaction costs and potential losses for property owners, buyers, and investors. This instability had eroded trust in blockchain-based property systems. The stakeholders might refuse to engage in transactions where asset values could change dramatically in a short period of time. Moreover, the price of cryptocurrencies and digital assets used in blockchain-based property transactions may have significant fluctuations as a result of speculation. This could have resulted in a negative user experience for those who rely on these assets to pay fees for publishing and managing data, performing smart contracts, and other related activities (Azari and Malek, 2022). Hence, the inherent price volatility of cryptocurrencies and digital assets used in blockchain-based property transactions posed a significant challenge. The unpredictable fluctuations in asset values and associated risks eroded trust in the viability of these systems, requiring robust solutions to address this critical issue.

2.6.3 Security and Privacy Challenges

The adoption of blockchain technology in property management presented significant challenges, particularly regarding cyber threats and security. While blockchain was mentioned for its potential to enhance trust through transparency and security, it was not immune to cyber-attacks. Saari, Junnila and Vimpari (2022) had highlighted that despite blockchain's robust security features, it remained vulnerable to attacks that could compromise sensitive

data and erode trust in property transactions. Akoguhi and Bhavsingh (2023) had agreed that enhanced security offered by blockchain came with its own set of challenges which complicated decision-making for stakeholders. The immutable nature of blockchain was beneficial for ensuring transaction integrity but it also exposed sensitive information. This highlighted the need for comprehensive cybersecurity strategies. Konashevych (2020b) had discussed this tension by emphasizing the necessity of balancing blockchain's transparency with adequate privacy measures to prevent the exposure of sensitive data. Additionally, the decentralized nature of blockchain had raised concerns about the potential monopolization of property transaction data, which could have enabled market manipulation (Azari and Malek, 2022). Overall, the integration of blockchain in property management required careful consideration of cybersecurity risks and the development of robust mitigation strategies to ensure the protection of sensitive data and maintain trust in the system.

Trust and uncertainty were also significant challenges to blockchain adoption in property management. The property market was widely distrusted due to its reliance on intermediaries which caused inefficiencies and information asymmetries (Kalyuzhnova, 2018). Besides, the inherent complexities of blockchain systems further exacerbated this reluctance to adopt this whole new technology (Nijland and Veuger, 2019). Property management involved high-value assets and sensitive information, so there was often resistance to adopting new, unfamiliar technologies like blockchain (Cunha and Silva, 2023). Stakeholders might be hesitant to trust a decentralized, blockchain-based system with full uncertainties as the technology was not yet mature.

Anonymity and privacy challenges were central to the adoption of blockchain technology. While blockchain could enhance privacy through pseudonymous (false name) transactions, its transparency had raised concerns about the potential exposure of sensitive information. Kalyuzhnova (2018) had highlighted this tension between transparency and privacy. While blockchain aimed to protect privacy, its transparency could conflict with the need for confidentiality in personal and financial matters. Compliance with regulations like the General Data Protection Regulation (GDPR) had added another layer

of complexity, as blockchain's immutability challenged the 'right to be forgotten' (Konashevych, 2020a). The conflict between maintaining user privacy and adhering to transparency and immutability requirements in blockchain systems was further highlighted by Akoguhi and Bhavsingh (2023) . Additionally, property transactions and agreements might contain sensitive data that governments do not want to be shared with a platform. This was a valid concern, as property was a strategic industry for every nation, and the property market is essentially the market for the land of that country (Azari and Malek, 2022). Addressing the balance between transparency, privacy, and regulatory compliance was crucial for the successful implementation of blockchain in property management, ensuring the protection of sensitive information while maintaining the benefits of the technology.

The integration of Know Your Customer (KYC) procedures into blockchain-based property management systems posed critical challenges facing to Russian bank and many foreign banks (Kalyuzhnova, 2018). KYC procedures were essential for verifying participant identities to prevent fraud and money laundering. Kalyuzhnova (2018) had emphasized the necessity for standard KYC checks to verify the sources of funds. However, many financial institutions remained unprepared to handle cryptocurrency transactions. Not only that, but the decentralized nature of blockchain had complicated KYC measures, which typically relied on centralized authorities for identity verification (Cunha and Silva, 2023). It was also important to integrate KYC procedures while maintaining blockchain's privacy-preserving features (Akoguhi and Bhavsingh, 2023). This balance was critical to ensuring the legitimacy of participants without compromising security and privacy. Developing effective KYC processes that aligned with the decentralized and privacy-focused nature of blockchain was a critical step in ensuring the integrity and trust of property transactions facilitated through blockchain-based systems.

Furthermore, establishing and verifying digital identities and signatures was a significant challenge in blockchain adoption. Nijland and Veuger (2019) had suggested that civil-law lawyers could have served as gatekeepers for identification and authorization, but the need for a comprehensive Public Key Infrastructure (PKI) remained a critical issue.

Konashevych (2020a) had highlighted that managing public and private keys could be cumbersome and error-prone, with the loss of private keys potentially leading to financial losses and challenging trust. Legal uncertainty had further complicated the adoption of digital signatures, as varying laws could create barriers (Saari, Junnila and Vimpari, 2022; Akoguhi and Bhavsingh, 2023). Establishing reliable digital identity and signature verification processes was essential for successful blockchain integration in property management. Resolving the challenges around digital identities and signatures was a crucial prerequisite for the widespread adoption of blockchain in property management, as it ensured the secure and legally binding nature of property transactions.

2.6.4 Technical Limitations

The integration of blockchain technology into the property industry has faced several significant technical challenges that needed to be addressed for widespread adoption.

One of the significant challenges will be compatibility and interoperability. For blockchain to be effective in property, it needed to be connected to other technological advancements and various databases used by institutions (Nijland and Veuger, 2019). The authors described this situation as a "low-level development," meaning that more significant improvements were needed to fully benefit from blockchain. Hence, attempts were made to integrate blockchain with systems like Multiple Listing Service (MLS) databases to create a distributable ledger structure that could be easily shared (Akoguhi and Bhavsingh, 2023). However, the lack of standardized protocols and interoperability between different blockchain platforms remained a significant challenge to seamless integration within the property ecosystem (Konashevych, 2020b).

The complexity of blockchain technology itself was another major challenge. Researchers described the evolution of blockchain from Blockchain 1.0 to 4.0, which illustrated the increasing difficulty of its applications as each presenting their own technical challenges (Kalyuzhnova, 2018). The complexity extended to implementing and maintaining blockchain solutions. Issues like the proof-of-work consensus mechanism and ongoing software

maintenance were significant challenges (Saari, Junnila and Vimpari, 2022), The high energy demands and specialized computing hardware required made it difficult to integrate blockchain into existing property systems. Hard forks, or splits in blockchain networks, could also lead to token duplication and create legal ambiguities regarding property rights management. This complicated the maintenance of data integrity and consistency, as the blockchain's immutable nature meant that errors or disputes could be difficult to resolve (Konashevych, 2020a).

Scalability was another crucial challenge for blockchain systems in the property management sector. Concerns were raised regarding blockchain's potential to scale effectively without disrupting established workflows, as the technology struggled with managing large transaction volumes and maintaining optimal speed and performance (Akoguhi and Bhavsingh, 2023; Sanjeeva *et al.*, 2023). Blockchain's limitations in transaction speed and throughput hindered real-time applications, such as those in construction (Jaskula and Papadonikolaki, 2021). The limitations of transaction volume and speed had caused a significant challenge to its adoption in property industry which required real-time updates and rapid processing of data. The public nature of blockchain also resulted in bandwidth limitations and high transaction fees, making it impractical for large-scale government applications (Konashevych, 2020a). Additionally, the energy-intensive nature of certain blockchain consensus mechanisms raised concerns about the environmental impact of widespread adoption (Konashevych, 2020b). This sustainability challenge had to be addressed for blockchain to gain broader acceptance.

The complexity of smart contracts also posed a significant challenge to the adoption of blockchain in property management. The legal frameworks required to support smart contracts revealed both technical and legal complexities, as current laws often struggled to accommodate their self-executing and coded nature (Kalyuzhnova, 2018). The enforceability of smart contracts remained a major concern, with a 2021 Deloitte survey finding that over 40% of respondents identified this as crucial for blockchain adoption (Azari and Malek, 2022). Blockchain technology also needed to navigate the strict legal requirements in some jurisdictions, such as those necessitating notaries or formal documentation, to gain acceptance (Azari and Malek, 2022).

Additionally, the rigidity of smart contracts in handling relational or open-ended terms common in property transactions raised concerns about their flexibility (Akoguhi and Bhavsingh, 2023).

Finally, the immutability of blockchain records, while enhancing security and trust, also presented challenges related to error correction. The difficulty of amending errors once data was recorded on the blockchain was noted (Kalyuzhnova, 2018). The "garbage in, garbage out" concept emphasized that flawed input data could lead to constant inaccuracies and hence further highlighted the need for robust data validation protocols (Nijland and Veuger, 2019). The immutable nature of blockchain also made it difficult to correct errors or reverse transactions, which was an important requirement in the property sector (Azari and Malek, 2022).

In conclusion, the integration of blockchain technology into the property sector faced a multitude of technical challenges, including compatibility with existing systems, the complexity of blockchain itself, scalability issues, smart contract complexities, and the challenges posed by blockchain's immutability. Addressing these challenges was crucial for the widespread adoption and successful implementation of blockchain-based solutions in the property industry.

2.6.5 Institutional Challenges

Despite the significant economic opportunities that blockchain technology offered in property, the integration of blockchain also came with considerable economic challenges that needed careful consideration (Saari, Junnila and Vimpari, 2022). The ability to streamline administrative processes, reduce transaction costs, and enhance transparency in property dealings was another major advantage (Mahmudnia, Arashpour and Yang, 2022). However, these benefits came with challenges that needed careful consideration. The integration of blockchain had the potential to disrupt existing business models, potentially leading to the redistribution of value among industry stakeholders and posing risks of economic imbalances if not managed equitably (Konashevych, 2020b). Players involved, such as property agents, may have needed to adapt to new roles or risk being marginalized, as the transition towards more decentralized and transparent property management systems

reduced the need for certain intermediary services (Saari, Junnila and Vimpari, 2022). Implementing blockchain technology required significant investments in infrastructure, such as developing new software and training the workforce (Kalyuzhnova, 2018). Organizations had to carefully manage these investments, often by forming alliances or consortiums to pool resources, share risks, and advocate for favourable regulations (Kalyuzhnova, 2018).

The political and regulatory environment played a critical role in the successful adoption of blockchain in property. Establishing clear guidelines around data privacy, smart contracts, and property rights within the blockchain ecosystem was vital for its success (Konashevych, 2020a). Supportive policymakers helped create an environment that encouraged innovation while protecting stakeholders. Engaging with government officials, lawmakers, and industry associations was crucial for garnering the necessary political buy-in (Cunha and Silva, 2023). Effective coordination among various government agencies was essential to ensure that blockchain adoption was smooth and consistent across different regions and sectors. Pilot projects had sometimes faced opposition due to concerns about job displacement (Mahmudnia, Arashpour and Yang, 2022). This situation highlighted the importance of transparent communication and addressing stakeholders' concerns early in the process. Furthermore, blockchain's inherent features of reliability and transparency could have been particularly beneficial in regions struggling with corruption, as it could have reduced opportunities for fraud and contributed to a more trustworthy property market (Konashevych, 2020a).

Moreover, the adoption of blockchain technology in property management raised significant social considerations, as the potential to increase transparency and reduce challenges in property transactions could improve access to housing, but also risked digital exclusion if marginalized communities were unable to participate due to a lack of technological literacy or access (Kalyuzhnova, 2018). This could lead to these communities being further excluded from the benefits of the new technology. Policymakers and industry stakeholders needed to engage in thoughtful discussions to ensure that blockchain adoption aligned with broader social and ethical goals (Konashevych, 2020b). This was necessary to protect vulnerable communities while still promoting innovation and technological progress.

The decentralized nature of blockchain technology had also introduced unique governance challenges that had to be addressed to ensure the technology's flexibility security, and reliability. One of the key features of blockchain was its potential to decentralize control. However, if governance became concentrated within a single entity or a narrow group of actors, this could have undermined the system's flexibility and created single points of failure. Effective governance structures that encouraged diverse participation from various stakeholders were essential to maintain the integrity of the blockchain ecosystem (Konashevych, 2020a). Transparent and accountable governance models were critical for ensuring that blockchain systems in property operated fairly and securely. These frameworks had to prioritize data integrity, security, and the alignment of incentives among all participants in order to build trust in the blockchain system and mitigate risks associated with its adoption. Furthermore, implementing blockchain in property required the development of adequate infrastructure to support decentralized networks. Infrastructure development had to be aligned with governance models to prevent centralization and ensure that blockchain systems were resilient and effective (Kalyuzhnova, 2018).

2.7 The Influence of Socio-Demographic Factors on Technology Adoption

Socio-demographic factors had a significant influence on the adoption of technology, shaping attitudes, access, and proficiency levels. These factors included age, gender, education, income, experience, job position, and company size. Each factor contributed to unique patterns of blockchain technology use and adoption across different populations and contexts.

Age had been consistently identified as a significant factor influencing technology adoption. Younger individuals generally exhibited higher adoption rates due to their familiarity with digital technologies and openness to new innovations. For example, in the context of smallholder farmers in South Africa, younger farmers were more adept at adopting ICT for weather forecasting, while older farmers faced challenges due to lower literacy levels and resistance to change (Alant and Bakare, 2021). Similarly, younger employees in the maritime industry were more interested in adopting

blockchain technology, reflecting generational differences in adaptability (Zhou *et al.*, 2020). In contrast, older farmers in Tunisia displayed reluctance towards adopting innovative technologies and preferred traditional practices (Dhraief *et al.*, 2019).

The role of gender in technology adoption showed varied results across studies. In Malaysia, women were found to be more enthusiastic early adopters of technology, showing a greater willingness to experiment with new innovations compared to men (Zulkifli and Abidin, 2024). In contrast, studies in Tunisia and Italy reported no significant gender differences in the adoption of agricultural or smartphone technologies (Dhraief *et al.*, 2019; Filippini *et al.*, 2020). Thus, the role of gender in technology adoption may have diminished in contexts where equal access was available. This variability emphasized the need to consider cultural and societal factors when evaluating the gender's role in technology use.

Education was consistently linked to higher technology adoption rates, as it equipped individuals with the skills and understanding necessary to use technological tools effectively. Studies showed that individuals with higher educational attainment demonstrated greater ICT proficiency, such as in South African farming communities, where educated farmers were better equipped to use digital weather forecasting tools (Alant and Bakare, 2021). Similarly, higher education levels in Tunisia and Malaysia positively influenced the adoption of agricultural and digital technologies, as education enhanced individuals' ability to navigate and integrate new systems into their practices (Dhraief *et al.*, 2019; Zulkifli and Abidin, 2024).

Income level was another vital socio-demographic factor influencing technology adoption. Higher-income individuals and households were more likely to adopt new technologies due to greater financial flexibility and access to resources. For instance, in Vietnam, higher-income respondents were more likely to use e-government services, as they had better access to internet connectivity and technological devices (Borazon and Nguyen, 2022). Similarly, affluent households in Tunisia were more willing to invest in advanced agricultural tools, showcasing income's direct role in facilitating technology access and adoption (Dhraief *et al.*, 2019). Conversely, lower-income groups

often faced challenges due to affordability issues, which restricted their ability to explore or integrate new technologies into their practices.

Experience played a dual role, sometimes hindering adoption due to reliance on traditional methods, and at other times fostering it through enhanced understanding of industry needs. In Tunisia, more experienced farmers showed resistance to innovative technologies and preferred conventional practices (Dhraief *et al.*, 2019). Similarly, in the maritime industry, professionals with extensive experience exhibited hesitancy towards blockchain adoption, reflecting the challenges of unlearning established workflows (Zhou *et al.*, 2020).

Job positions strongly influenced technology adoption, with managerial and executive roles often being more open to innovation due to their strategic focus and decision-making responsibilities. For instance, managers in Malaysia were found to adopt technologies more readily than business owners or retirees, as their roles aligned closely with organizational goals (Guo *et al.*, 2023; Zulkifli and Abidin, 2024). Similarly, executives in the maritime sector demonstrated greater familiarity with blockchain technology, enabling them to drive adoption within their organizations (Zhou *et al.*, 2020). In contrast, operational staff might have focused on immediate tasks, potentially limiting their engagement with new technologies. Therefore, targeted training may have been needed to bridge the adoption gap between different job levels.

Organizational characteristics, particularly company size, also influenced technology adoption. Larger organizations, particularly those with robust resources and structured management, were more likely to adopt advanced technologies such as blockchain. Clohessy and Acton (2019) noted that larger companies in Ireland were better positioned to implement blockchain technology due to their capacity to support employee training and technological infrastructure. Smaller organizations may have faced financial and resource challenges, limiting their adoption capabilities (Higgins, Tang and Stubbs, 2020).

In conclusion, socio-demographic factors such as age, gender, education, income, experience, job position, and company size significantly influenced technology adoption across various contexts. Younger, educated,

and higher-income individuals, as well as those in managerial roles or large organizations, were more inclined towards adopting new technologies. Recognizing these patterns allowed policymakers and practitioners to design targeted strategies that addressed challenges to adoption, ensuring that technological advancements benefited diverse demographic groups effectively.

2.8 Summary of Findings from Literature Review

In short, there were long-standing inefficiencies in property management across 6 sectors which were land administration, property transaction, leasing and renting, property administration, property financialization, and property maintenance. Blockchain technology presented significant potential for addressing these long-standing challenges in property management across the 6 sectors. However, the adoption of blockchain in property management varied among developers, influenced by challenges. These challenges were categorized into five main aspects which were legal and regulatory challenges, cost and liquidity challenges, security and privacy challenges, technical limitations, and institutional challenges. Each of these areas presented challenges that needed to be addressed to fully leverage blockchain's potential in property management.

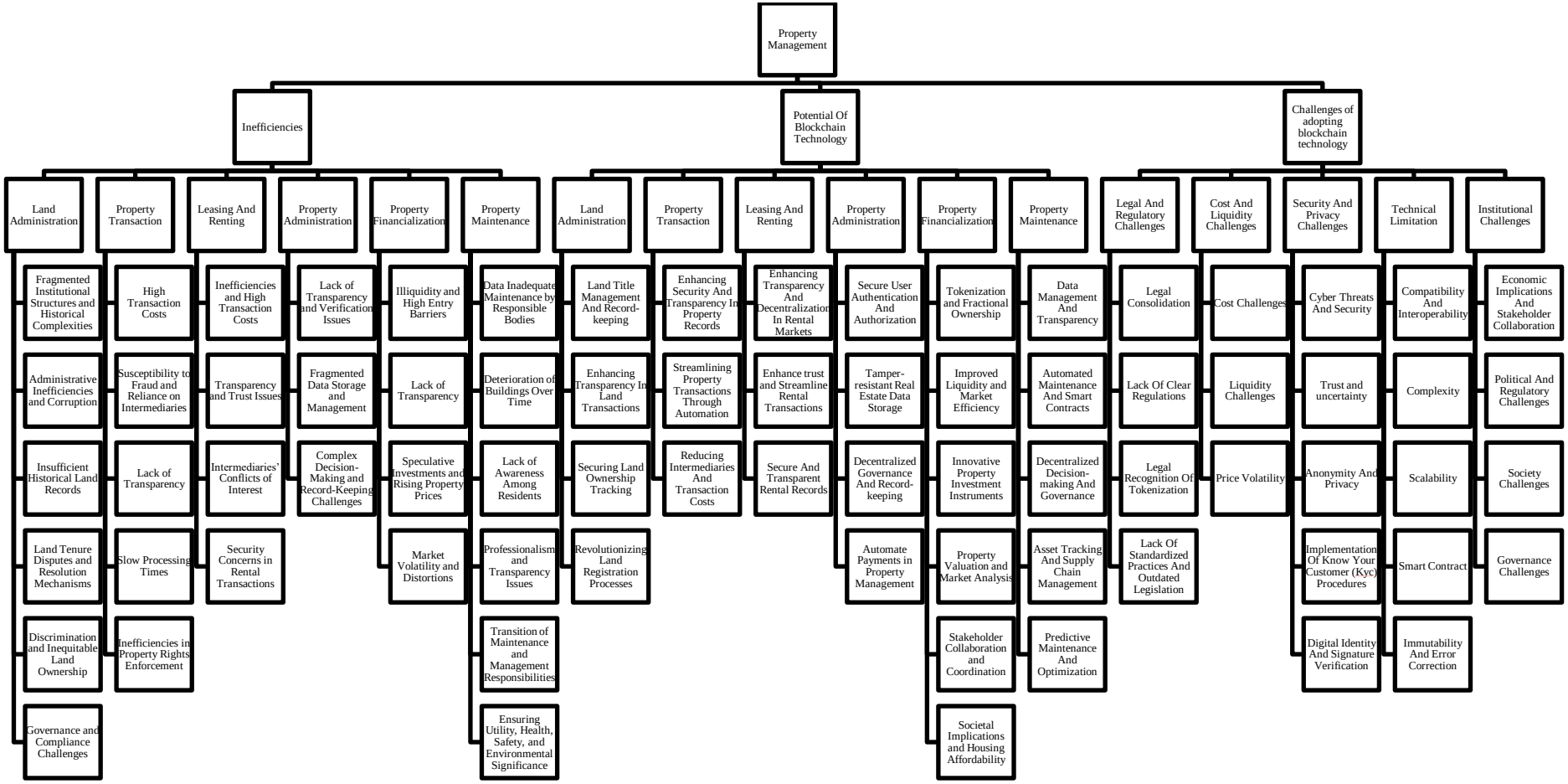

Figure 2.1: Inefficiencies and the Potential and Challenges of Blockchain Applications in Property Management

CHAPTER 3

INTRODUCTION

3.1 General Introduction

This chapter provides a detailed discussion of the steps and processes involved in data collection and analysis.

3.2 Research Method

According to Creswell and Creswell (2018), the research method outlined the philosophical assumptions, strategies, and methodologies that guided the study, aligning the researcher's worldview with data collection and analysis. There were three different kinds of research methods which are mixed, quantitative, and qualitative. Every study methodology consisted of unique benefits, constraints, and appropriate uses.

3.2.1.1 Quantitative Research Approach

Quantitative research focused on measuring and analyzing data using structured tools such as surveys, tests, and experiments. According to Sekaran and Bougie (2020), this method aimed to identify relationships between variables and used statistical techniques to analyze data. It followed a deductive approach, starting with theories or hypotheses that were tested to confirm or reject initial assumptions (Creswell and Creswell, 2018). The structured nature of the process allowed researchers to ensure objectivity and minimize bias, making the results reliable and replicable. Quantitative research also worked well for studying large populations, as findings were often generalizable.

The process typically began with defining a problem, reviewing existing research, and forming hypotheses. Data was then collected systematically and analyzed statistically to draw conclusions. However, quantitative research had some limitations. While it provided measurable and comparable results, it often lacked the depth needed to understand the context behind the data (Cooper and Schindler, 2014). Sekaran and Bougie (2020) also highlighted that its rigid structure limited flexibility and might have missed

unexpected insights. Furthermore, the quality of findings depended heavily on the design of the measurement tools. Despite these challenges, quantitative research offered a practical and efficient approach for addressing clearly defined research questions.

3.2.1.2 Qualitative Research Approach

Qualitative research, which often focuses on smaller, purposive sample groups to explore people's behaviours, experiences, and perspectives in-depth (Saunders, Lewis and Thornhill, 2023). Cooper and Schindler (2014) explained that this method emphasized understanding meaning and context rather than measuring numerical data. Researchers used methods such as interviews, focus groups, and observations to collect detailed, descriptive information. Creswell and Creswell (2018) noted that qualitative research followed an inductive approach, where insights emerged during the study rather than being predetermined. This flexibility allowed researchers to adapt their methods as new themes or patterns became evident.

The research process involved defining a broad problem, gathering data through open-ended techniques, and analysing the data for themes or patterns. However, qualitative research had its challenges. Cooper and Schindler (2014) pointed out that findings were often subjective, as they relied on the researcher's interpretations, which might have introduced bias. Sekaran and Bougie (2020) added that smaller sample sizes limited the generalizability of results, making them less applicable to larger populations. Additionally, qualitative research required significant time and effort, as the data collection and analysis process were often labour-intensive. Despite these limitations, qualitative research provided valuable insights into complex phenomena that could not be captured through numerical analysis.

3.3 Justification of selection

The quantitative research approach was selected for this study because it aligned with the research aim and objectives, which focused on investigating the potential of integrating blockchain technology into property management in Malaysia. Firstly, the quantitative approach through surveys helped gather numerical data and statistical evidence to identify inefficiencies faced in

property management practices. This provided measurable insights into the existing challenges in property management and addressed the first research objective. Additionally, questionnaires filled out by property developers were utilized to assess the potential of adopting blockchain technology in property management in Malaysia. The collected data offered a clear, quantifiable understanding of the perceived benefits and feasibility of blockchain adoption, fulfilling the second research objective. While the quantitative approach focused on efficiencies and potentials, it also implicitly includes understanding the challenges associated with implementing blockchain technology. By analyzing the data collected, this study can highlight perceived challenges faced by property developers, contributing to the overall comprehension of the third research objective.

On the other hand, qualitative research is not suitable for this study because it requires a large number of participants. Conducting interviews with many property developers would take a lot of time and be difficult to manage. Also, qualitative research relies on personal opinions, which can lead to inconsistencies and biases in the results. Since this study needs clear, measurable data that can be generalized, a quantitative approach was more suitable to achieve the research objectives. Therefore, the quantitative method was chosen as it allows the results to represent all property developers in Klang Valley as a whole.

3.4 Literature Review

According to Creswell and Creswell (2018), the literature review placed the proposed study within the broader research context by identifying gaps and providing a rationale for the research. It also justified the study's approach and its contribution to existing knowledge.

First, key terms such as "potential applications," "blockchain technology," "property management," and "real estate management " were used to guide the search for relevant literature. After that, journal articles, books, and conference papers related to the topic of research were searched using these keywords in academic databases such as Google Scholar, ScienceDirect, and ResearchGate. Approximately 50 relevant sources within

the last 5 to 10 years were located to ensure the most up-to-date information on the topic.

Next, abstracts, introductions, and conclusions of these articles were skimmed to determine the most relevant studies. This helped identify key themes and concepts. A literature map was then created to visually organize the relationships between different aspects of blockchain technology in property management, highlighting gaps in existing research. Relevant articles were analysed in depth, summarizing their findings, methodologies, and contributions. Finally, the literature review was compiled, organized thematically, and concluded with a summary of key themes, demonstrating how the proposed study could contribute to the field.

3.5 Quantitative Data Collection

In this research, a quantitative data collection approach was selected as it could produce reliable results through the use of large sample sizes. Questionnaires were used to collect primary data, which would be evaluated to produce conclusions that were consistent with the goals of the study.

3.5.1.1 Questionnaire Design

This study’s questionnaire, which focused on the potential of blockchain technology in property management began with a cover page. This cover page served as an introduction to the study, providing the researcher's details and a brief overview of the purpose of the questionnaire as well as definitions of key terms, such as blockchain technology, to ensure a common understanding among the respondents. It also provided clear instructions on how the respondent should complete the questionnaire.

The questionnaire was divided into five main sections. There were two types of questions, which were multiple choice questions or questions with a scale. The first section which was Section A, focused on obtaining the demographic information of the respondents, including their age, sector of employment, years of experience, job position, as well as the number of employees in the organization to determine the company size. This information can be used to analyse the responses and identify any potential

differences based on the respondent's background. The closed-ended questions were a better choice for this section.

Sections B, C, and D utilized a 5-point Likert scale with values from 1 to 5 to allow respondents to rate their experiences and perspectives on key aspects of blockchain technology in property management. Section B was designed to identify the inefficiencies in property management practices and aimed to gather data addressing the first research objective. Section C explored the potential of adopting blockchain technology in property management and was aligned with the second research objective.

Finally, section D explored the challenges associated with implementing blockchain technology in property management and achieving third objectives. Table 3.1 summarizes the questionnaire's sections. Additionally, a copy of the questionnaire used in this study is included in Appendix A.

Table 3.1: Summary of Questionnaire's Sections

Section	**A**	**B**	**C**	**D**
Types of question	Closed-ended	5-points Likert scale	5-points Likert scale	5-points Likert scale
No. of aspects	-	6	6	5
No. of questions	5	28	24	21
Scale	Nominal scale	Ordinal scale	Ordinal scale	Ordinal scale
Purpose of Questions	To obtain the respondents' demographic information	To achieve the objective 1	To achieve the objective 2	To achieve the objective 3
Section Focus	Demographic Background	Inefficiencies Faced in Property Management Practice.	Potential of Adopting Blockchain Technology in Property Management	Challenges of Implementing Blockchain Technology in Property Management.

3.5.1.2 Sampling Determination

It was difficult to obtain responses from the entire population. Therefore, it was recommended to decide on a sampling frame, which meant a list of the population from which the sample can be drawn (Saunders, Lewis and Thornhill, 2023). The target population for this research was developers which represent key stakeholders involved in property management within the Klang Valley region. Moreover, this study utilized a non-probability sampling approach to ensure that the sample was representative of the population. Snowball sample was used, where initial participants were asked to refer to other potential respondents to reach the desired sample size.

The sample size was determined using Slovin's formula, which allows for a precise calculation based on the desired confidence levels and margin of error. According to Field (2018), the Slovin's formula was:

$$n = \frac{N}{1+Ne^2}$$

where

n = sample size

N = population size

e = margin of error

A 95% confidence level and a 5% margin of error were decided as it is considered sufficiently accurate. With a population of 508 property developer companies in Klang Valley Real Estate and Housing Developers' Association (2019), an sample size was calculated as:

$$n = \frac{508}{1 + 508(0.05^2)} = \frac{508}{2.27} \approx 224$$

Thus, a sample size of 224 property developer companies was required for the study. To ensure practicality, it was assumed that one respondent from each company would serve as a representative, making the sample size both statistically valid and feasible.

3.5.1.3 Questionnaire Distribution

The questionnaire was generated via Google Forms and shared online through email and various social media platforms, including LinkedIn, WhatsApp and Email. The respondents targeted for this survey were property developers working in the Klang Valley region of Malaysia. Potential respondents include developers, property managers, and other professionals directly involved in property management.

The email addresses and contact details of the respondents were found from relevant organizations, such as the Real Estate and Housing Developers' Association (REHDA), the Malaysian Institute of Property and Facility Managers (MIPFM), and other industry associations focused on property development in the Klang Valley. Following the completion of the questionnaire design, the emails were sent to these companies within six weeks to encourage participation and collect responses effectively.

3.6 Data Analysis

In this study, data analysis was performed using the Statistical Package for the Social Sciences (SPSS) after the data had been collected. Four statistical tests were utilized for the analysis, namely Cronbach's Alpha Reliability Test, Arithmetic Mean, Mann-Whitney U Test, Kruskal-Wallis Test and Spearman Correlation Test.

3.6.1 Cronbach's Alpha Reliability Test

The Cronbach's Alpha Reliability Test was used to assess the internal consistency and reliability of the measurement scales used. Reliability referred to the extent to which data collection techniques and analytical procedures produced consistent findings (Field, 2018).

The Cronbach's Alpha values were interpreted, with values closer to 1 indicating higher reliability, and the commonly accepted threshold being 0.7 (Field, 2018). This approach ensured the consistency and trustworthiness of the survey instruments, which was crucial for the validity and reliability of the data collected in the questionnaire survey.

3.6.2 Arithmetic Mean

According to Field (2018), the arithmetic mean was a measure of central tendency used to calculate the average value of a dataset. It is calculated by summing up all the values in the dataset and dividing by the total number of observations.

In this study, the arithmetic mean was utilized to establish the central tendency of responses regarding inefficiencies in property management (Section B), the potential of blockchain adoption (Section C), and the challenges of implementing blockchain (Section D). The calculated mean values allowed for ranking the variables in order of significance.

3.6.3 Mann-Whitney U Test

According to Field (2018), the Mann-Whitney U Test was a non-parametric statistical test used to compare the differences between two independent groups when the dependent variable was either ordinal or continuous, but not normally distributed.

In this study, data were collected using a survey with a 5-point Likert scale, which is considered ordinal data. The independent variable is the sector of employment, which includes private and public, as recorded in Section A, while the dependent variables are the responses from Sections B (inefficiencies in property management), C (potential of blockchain), and D (challenges in implementing blockchain technology). To examine whether the sector of employment influences these responses, the following hypotheses are formulated:

Null Hypothesis (H_0): There is no significant difference between respondents from the private and public sectors in their views on inefficiencies in property management (Section B), the potential of blockchain (Section C), and challenges faced in implementing blockchain technology (Section D).

Alternative Hypothesis (H_1): There is a significant difference between respondents from the private and public sectors in their views on inefficiencies in property management (Section B), the potential of blockchain (Section C), and challenges faced in implementing blockchain technology (Section D).

3.6.4 Kruskal-Wallis Test

According to Field (2018), the Kruskal-Wallis Test was a non-parametric statistical test used to compare the differences among three or more independent groups when the dependent variable was either ordinal or continuous, but not normally distributed. The null hypothesis (H_0) assumes that the medians of all groups are equal, while the alternative hypothesis (H_1) suggests that at least one group's median is different.

In this study, the Kruskal-Wallis Test was used to analyse differences in responses across Sections B, C, and D based on respondents' age groups, job positions, years of experience, and company size. The following hypotheses are formulated:

Null Hypothesis (H_0): There is no significant difference between respondents from different age groups, job positions, years of experience and company size in their views on inefficiencies in property management (Section B), the potential of blockchain (Section C), and challenges faced in implementing blockchain technology (Section D).

Alternative Hypothesis (H_1): There is a significant difference between respondents from different age groups, job positions, years of experience and company size in their views on inefficiencies in property management (Section B), the potential of blockchain (Section C), and challenges faced in implementing blockchain technology (Section D).

3.6.5 Spearman Correlation Test

According to Field (2018), the Spearman correlation was a non-parametric method used to evaluate the strength and direction of the association between two ranked variables. The correlation coefficient ranges from -1 to 1, where -1 indicates a perfect negative correlation, 0 indicates no correlation, and 1 indicates a perfect positive correlation. A positive correlation means that both variables tend to change in the same direction, while a negative correlation means they change in opposite directions. Table 3.2 summarizes the interpretation of the Spearman correlation coefficient.

Table 3.2: Grading Standards Table of Spearman's Correlation Coefficient (ρ) (Yan *et al.*, 2019)

Spearman ρ	Correlation
0	No correlation
0 – 0.19	Very weak correlation
0.20 – 0.39	Weak correlation
0.40 – 0.59	Moderate correlation
0.60 – 0.79	Strong correlation
0.80 – 1.00	Very strong correlation
1.00	Monotonic correlation

In this study, the Spearman correlation test was used to analyze relationships between variables in Sections B, C and D. Specifically, it examined whether recognizing inefficiencies in property management (Section B) correlates with potential of blockchain (Section C), and whether developers who perceive greater blockchain potential (Section C) also perceive challenges while implementing blockchain (Section D). This analysis helped identify patterns between inefficiencies, blockchain potential, and implementation challenges. Hence, the following hypotheses are formulated:

Null Hypothesis (H_0): There is no significant relationship between inefficiencies in property management and the potential of blockchain; blockchain potential and challenges while implementing blockchain technology.

Alternative hypothesis (H_1): There is a significant relationship between the inefficiencies in property management and the potential of blockchain; blockchain potential and challenges while implementing blockchain technology.

3.7 Summary of Chapter

In summary, a quantitative research methodology was adopted. Besides, a questionnaire survey was designed and shared with the respondents targeted through email and social media platforms to gather primary data. Additionally, the literature review served as the source of secondary data. The Cochran

formula was applied to determine the appropriate number of respondents, specifically the property developers within Klang Valley. Snowball sampling was employed to select the participants. Finally, SPSS software was utilized for data analysis. Various tests were employed, including the Cronbach's Alpha Reliability Coefficient, Arithmetic Mean, Mann Whitney U, Kruskal-Wallis tests, and Spearman Correlation.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter displays the survey findings, beginning with respondent demographics and data reliability via Cronbach's Alpha. It then examines inefficiencies, blockchain potential, and implementation challenges using mean analysis. Mann-Whitney and Kruskal-Wallis tests identify significant differences across demographic groups, while relationships between variables are explored using Spearman's Correlation.

4.2 Demographic Background of Respondents

In total, 123 responses were obtained for this study. However, only 119 responses were included in the final analysis, as 4 of the respondents were interns who lacked sufficient experience and professional insight. The demographic information is summarized in Table 4.1.

Table 4.1: Summary of the Demographic of Respondent

Demographic Information	Categories	Frequency (n)	Percentage (%)
Age	Less than 21 years old	0	0.0
	21-25	32	26.9
	26-30	29	24.4
	31-35	21	17.6
	36-40	17	14.3
	41 and above	20	16.8
Sector of Employment	Public Sector	26	21.8
	Private Sector	93	78.2
Number of employees/ Company Size	Less than 5 employees (Micro)	10	8.4
	5 - 29 employees (Small)	31	26.1
	30 - 75 employees (Medium)	24	20.2
	More than 75 employees (Large)	54	45.4

Table 4.1 (Continued)

Demographic Information	Categories	Frequency (n)	Percentage (%)
Job Position	Junior Executive	42	35.3
	Senior Executive	28	23.5
	Manager/ Team Leader / Supervisor	34	28.6
	Assistant / Technical Director	6	5.0
	Director	6	5.0
	Other	3	2.5
Years of Experience in the current organization	Less than 6 years	70	58.8
	6-10 years	21	17.6
	11-15 years	19	16.0
	16-20 years	5	4.2
	21 years and above	4	3.4

Based on the demographic information shown in Table 4.1, the age distribution of the respondents is fairly varied. The majority fall within the age group of 21 to 25 years old, accounting for 26.9% of the total respondents, followed by 24.4% who are between 26 and 30 years old. Meanwhile, 17.6% of the respondents are aged 31 to 35, and 14.3% are within the 36 to 40 age group. Only 16.8% of the respondents are aged 41 years and above, while none are under the age of 21.

In terms of sector, a significant number of respondents are employed in the private sector, comprising 78.2%, while the remaining 21.8% work in the public sector. This indicates that the findings of this study are primarily reflective of private sector perspectives. Regarding company size, nearly half of the respondents (45.4%) are from large companies with more than 75 employees. Additionally, 26.1% work in small organizations with 5 to 29 employees, 20.2% are from medium-sized companies with 30 to 75 employees, and only 8.4% are employed in micro firms with fewer than 5 employees.

Looking at job positions, 35.3% of the respondents are junior executives, followed by 28.6% who serve as managers, team leaders, or supervisors. Another 23.5% hold senior executive roles. A small percentage are directors or assistant/technical directors, making up 5.0% each, while 2.5% of the respondents selected "Other" for their job roles. which include positions such as JMC (Joint Management Committee) member, business development

officer, and property officer. As for experience within their current organization, the majority of respondents (58.8%) have worked there for less than six years. Respondents with 6 to 10 years of experience make up 17.6%, followed by 16.0% with 11 to 15 years. Only a small portion have worked in the same organization for more than 15 years, with 4.2% having 16 to 20 years of experience, and 3.4% having served for 21 years or more.

4.3 Cronbach's Alpha Reliability Test

Table 4.2 presents the calculated Cronbach's Alpha coefficients for three variable sets. All variables exceeded the widely accepted internal consistency threshold of 0.70 (Sekaran and Bougie, 2020). Section B had a coefficient of 0.907, indicating excellent reliability, while Sections C and D showed very strong internal consistency, scoring 0.959 and 0.950, respectively. Therefore, all variables are considered reliable and will be used for further analysis.

Table 4.2: Reliability Statistics

Section	Number of Items	Cronbach's Alpha Values
Section B: Inefficiencies Faced in Property Management Practice	28	0.907
Section C: Potential of Blockchain in Property Management	24	0.959
Section D: Challenges of Adopting Blockchain in Property Management	21	0.950

4.4 Arithmetic Mean Test

This analysis examines the mean rankings of the three sub-sections, which are inefficiencies in property management, the potential of blockchain, and the challenges of implementing blockchain in property management, based on the data collected from respondents.

4.4.1 Mean Ranking of Inefficiencies in Property Management

Table 4.3 presented the overall ranking of six inefficiency aspects in Malaysian property management, with mean scores indicating construction professionals' level of agreement on their severity.

The overall rankings in Table 4.3 showed that property maintenance (mean = 4.18) was the top concern. This prioritization was consistent with the study by Musa et al. (2020) which highlighted its direct impact on building safety, client satisfaction, and asset performance. Proactive resident involvement was essential to ease maintenance burdens, though professionals often face limited influence over these complex, systemic issues during project delivery. Property Financialization (mean = 4.09) ranked second, aligning with findings from Banerjee *et al.* (2022) and Kaldor (2022) that illiquidity, high entry barriers, and market opacity restricted participation mainly to wealthier investors.

At the lower end, land administration (mean = 3.83) was seen as less immediate but still challenging due to governance complexity, This view was supported by Akotia, Opoku and Hafiz (2017) who found that practitioners in the UK who experienced varying levels of involvement in project phases were often hindered by the complexity of land governance. Furthermore, institutional frameworks that emphasized compliance and procedural adherence over participatory engagement, as noted by Oyedeji (2021) further restricted professionals' capacity and willingness to meaningfully contribute to land administration matters.

Table 4.3: Overall Mean Ranking of Inefficiencies in Property Management

Code	Aspect of Inefficiencies in Property Management	Mean	Ranking
TF	Property Maintenance	4.18	1
TE	Property Financialization	4.09	2
TB	Property Transaction	3.99	3
TD	Property Administration	3.99	3
TC	Leasing and Renting	3.88	4
TA	Land Administration	3.83	5

Following that, Table 4.4 presented a more detailed breakdown of the specific inefficiencies under each aspect. The inefficiencies with a higher mean value were seen as more serious inefficiencies from the perspective of developers in Klang Valley.

Table 4.4: Mean Ranking of Inefficiencies in Property Management

Code	Inefficiencies in Property Management	Mean	Ranking
TF3	Awareness gaps among residents.	4.37	1
TF2	Building deterioration over time.	4.30	2
TE3	Speculative investments often rise property prices in cities, making properties too expensive for low-income people.	4.24	3
TE4	Market volatility and distortions deter investment.	4.17	4
TF6	Lack of maintenance practices that align with green principles and consideration of health and safety.	4.16	5
TF5	Lack of communication with stakeholders.	4.15	6
TA2	Outdated paper-based processes.	4.13	7
TB1	High costs of property transactions.	4.13	7
TD2	Decentralized and unstructured data storage.	4.13	7
TF1	Inadequate maintenance by responsible bodies.	4.12	10
TB4	Slow bureaucratic processes in property transactions.	4.08	11
TB5	Ineffective enforcement of property rights.	4.01	12
TE1	Illiquid and high entry barriers make it difficult for investors to participate in property markets.	4.00	13
TF4	Lack of professionalism and transparency in management.	3.98	14
TB2	Vulnerable to fraud due to reliance on middlemen.	3.97	15
TD1	Lack of transparency and reliability in verification processes.	3.97	15
TE2	Lack of transparency in property markets creates uncertainty about ownership and investment security.	3.97	15
TC3	Reliance on agents increases conflicts of interest.	3.92	18
TC4	Failure to handle sensitive information in rental transactions.	3.89	19
TC1	Inefficient and outdated process cause high costs.	3.87	20
TD3	Inefficient process for paying management fee	3.87	20
TA3	Lack of reliable historical records on land ownership.	3.84	22
TA4	Unresolved disputes over land ownership and weak dispute resolution systems.	3.84	22
TC2	Lack of transparency and trust issues between landlords with tenants.	3.82	24

Table 4.4 (Continued)

Code	Inefficiencies in Property Management	Mean	Ranking
TA1	Different government agencies handle land administration system which creating inconsistency and ease for corruption.	3.79	25
TB3	Lack of transparency in property transactions.	3.78	26
TA6	Weak governance and limited capacity of institution.	3.73	27
TA5	Discrimination and unfair access to land ownership.	3.62	28

The analysis of Table 4.4 revealed that the highest-ranked inefficiency in property management was “awareness gaps among residents” (TF3), with a mean score of 4.37. This indicated that most respondents strongly agreed that resident awareness played a critical role in maintaining building conditions. This finding is supported by Kadhim and Altaie (2023), who noted that poor maintenance often results from user negligence or misunderstanding of basic upkeep responsibilities. They explained that when residents lack knowledge, minor issues tend to be ignored until they escalated into structural concerns. Similarly, McAleavey, O’Gorman and Clair (2025) observed in on-site experiences that avoidable deterioration frequently arises from user inaction. These observations align with practitioner perspectives, with professionals prioritizing this inefficiency not only due to its frequency but because they view it as a preventable problem solvable through better communication and resident education.

The second-ranked inefficiency was “building deterioration over time” (TF2), with a mean rank of 4.30. This concern is consistent with findings by Rajedran and Haja Maideen (2023), who emphasized the importance of consistent maintenance to protect buildings from environmental wear and structural fatigue. Janhunen, Leskinen, and Junnilab (2020) further highlighted that deferred maintenance increases repair costs and risks non-compliance with safety standards. Construction professionals’ agreement with this issue reflects their practical concern for ensuring long-term building functionality and safety.

The third-highest inefficiency, “speculative investments raise property prices” (TE3), scored 4.24. Banerjee *et al.* (2022) described how

speculative demand inflates property values beyond local affordability, complicating development planning. Huang, Li and Yang (2024) noted that speculation disrupts housing supply and creates financing risks, which aligns with professionals' views on market volatility and investment challenges. Kaldor (2022) highlighted that when these price bubbles collapse abruptly, financing for property maintenance and development can dry up, causing delays or neglect in upkeep. This instability makes it difficult for property managers to plan and maintain buildings effectively, reflecting professionals' concerns over the disruptive effects of speculative market behaviour.

Conversely, the lowest-ranked inefficiency, "discrimination and unfair access to land ownership" (TA5), received a mean score of 3.62, indicating moderate agreement. Sakib, Islam and Shishir (2022) suggested that while these issues are problematic, construction professionals may view them as outside their immediate influence due to their complex legal and political nature. Antonio *et al.* (2021) argued that such institutionalized challenges require systemic reform through public policy rather than project-level intervention, which is consistent with the lower urgency expressed by respondents.

Lastly, "weak governance and limited institutional capacity" (TA6) ranked second lowest, with a mean of 3.73. Ugonabo, Egolum and Sado (2023) proposed that governance issues are broader regulatory challenges, not directly related to daily operations in construction projects. Effossou, Cho and Ramoelo (2022) similarly noted that construction practitioners often consider such problems the responsibility of authorities rather than contractors, further explaining the limited concern for this factor among professionals.

In summary, the ranking patterns reflected a pragmatic prioritization by construction professionals. They tended to agree most with inefficiencies that were immediate, observable, and solvable through project-level action. Conversely, they showed less urgency toward systemic or policy-based issues that, while important, were perceived as requiring top-down reforms.

4.4.2 Mean Ranking of Potential of Blockchain in Property Management

Table 4.5 displayed the overall mean rankings of blockchain's potential across six domains of property management. Property Maintenance ranked highest (mean = 4.16), reflecting professionals' strong belief that blockchain could effectively address common challenges in this area. This was largely because blockchain enabled predictive maintenance through real-time tracking and immutable records, leading to cost savings and improved asset management, as supported by Rahman *et al.* (2023). The frequent and tangible nature of maintenance issues made blockchain solutions highly relevant and immediately actionable in this domain. Property Administration followed closely behind (mean = 4.12), indicating confidence in blockchain's potential to improve the efficiency, transparency, and security of property records and transactions. Researchers such as Konashevych (2020) as well as Akoguhi and Bhavsingh (2023) noted that blockchain's tamper-resistant, decentralized ledger enhanced trust among stakeholders and streamlined administrative processes, which reinforced its perceived value.

On the other hand, Land Administration ranked lowest (mean = 3.98). Professionals showed lower confidence here due to significant regulatory, legal, and institutional challenges that hindered blockchain implementation, as outlined by Aborujilah, Yatim and Al-Othmani (2021). Despite blockchain's theoretical benefits in enhancing transparency and traceability in land governance, these systemic complexities reduced its perceived feasibility in the short to medium term. This contrast highlighted that while operational blockchain applications had received stronger support, adoption in governance-heavy areas such as land administration faced deeper challenges at the time.

Table 4.5: Overall Mean Ranking of Potential of Blockchain in Property Management.

Code	Aspects of the Potential of Blockchain in Property Management	Mean	Ranking
PF	Property Maintenance	4.16	1
PD	Property Administration	4.08	2

Table 4.5 (Continued)

Code	Aspects of the Potential of Blockchain in Property Management	Mean	Ranking
PC	Leasing and Renting	4.05	3
PB	Property Transaction	4.04	4
PE	Property Financialization	4.02	5
PA	Land Administration	3.98	6

Following that, Table 4.6 presented a more detailed breakdown of the specific potential under each aspect.

Table 4.6: Mean Ranking of Potential of Blockchain in Property Management

Code	Potential of Blockchain in Property Management	Mean	Ranking
PF4	Blockchain enables predictive maintenance, optimizing resource use.	4.23	1
PF3	Blockchain provides a transparent and verifiable record of asset lifecycles and supply chain management.	4.19	2
PD2	Blockchain securely stores records with real-time access.	4.18	3
PC3	Blockchain secures rental payments with encryption and ID validation.	4.15	4
PD3	Blockchain enables transparent decision-making and record-keeping.	4.14	5
PF1	Blockchain ensures data reliability with consolidated maintenance records.	4.13	6
PB1	Blockchain enhances ownership visibility and prevent unauthorized changes hence reduces fraud.	4.08	7
PE4	Blockchain enhances transparency and accuracy in property valuation.	4.08	7
PF2	Blockchain automates maintenance schedules and contract management.	4.08	7
PE2	Blockchain improves liquidity by enabling 24/7 trading of property tokens.	4.06	10
PB2	Blockchain automates verification processes.	4.04	11
PD4	Blockchain streamlines payments for property management services.	4.04	11
PA2	Blockchain can decentralize and improve data storage and retrieval.	4.03	13
PE1	Blockchain enables fractional ownership and allows more people to invest in property.	4.03	13

Table 4.6 (Continued)

Code	Potential of Blockchain in Property Management	Mean	Ranking
PE5	Decentralized governance through blockchain facilitate greater stakeholder participation and trust.	4.03	13
PC2	Blockchain smart contracts automate and streamline lease 4ments.	4.01	16
PE3	Blockchain reduces property investment costs.	4.01	16
PB3	Blockchain allows direct transactions which reduces the need for brokers.	4.00	18
PC1	Blockchain supports transparent and peer-to-peer rental transactions.	4.00	18
PA4	Blockchain reduces the need for intermediaries in land registration.	3.99	20
PA3	Blockchain improves transparency in land lease and mortgage transactions.	3.98	21
PD1	Blockchain grants specific access rights.	3.95	22
PA1	Blockchain enhances the traceability of land ownership.	3.90	23
PE6	Blockchain financialization improves housing affordability.	3.88	24

Table 4.6 presented the mean rankings of 24 specific blockchain potential across different aspects of property management. The highest-ranked potential was “blockchain enabled predictive maintenance, optimizing resource use” (PF4) with a mean score of 4.23. Professionals strongly agreed that blockchain’s integration with sensor data and predictive algorithms could enhance maintenance scheduling by forecasting issues early, leading to improved asset longevity and reduced downtime. This aligned with Jaskula and Papadonikolaki (2021) as well as Rahman *et al.* (2023), who emphasized blockchain’s role in enabling secure and reliable data sharing for predictive maintenance, allowing more effective and cost-efficient property management. Sia *et al.* (2018) further highlighted that maintaining health and safety compliance was critical and that blockchain systems could support optimal operation of significant equipment. These findings underscored blockchain’s potential to transform maintenance practices by making them more proactive and data-driven, directly addressing pressing operational challenges.

Furthermore, “blockchain provided a transparent and verifiable record of asset lifecycles and supply chain management” (PF3) scored a mean of 4.19. This reinforced the importance of transparency and traceability in property maintenance. The decentralized ledger allowed all stakeholders to access immutable records of asset history and material provenance, which reduced fraud risks and verified compliance with safety standards (Aliti *et al.*, 2023; Osho and Olaniyi, 2024). Sharma, Isah and Rana (2024) stressed that smart contracts automated maintenance workflows, ensuring quick responses to issues, while also making supply chains more efficient by providing a single source of truth accessible to suppliers, contractors, and property managers. Such applications demonstrated blockchain’s potential to enhance collaboration and trust among parties, which was crucial for improving maintenance efficiency and reliability.

The third-highest ranked potential, “blockchain securely stored records with real-time access” (PD2) with a mean of 4.18 demonstrated strong support for blockchain’s potential to enhance property administrative functions. By providing tamper-resistant, easily accessible records, blockchain improved transparency and sped up decision-making processes. This was consistent with the findings of Konashevych (2020b) as well as Akoguhi and Bhavsingh (2023), who mentioned that blockchain’s immutable and decentralized data storage strengthened trust among stakeholders and reduced the risk of data loss or manipulation. In addition, Saari, Junnila and Vimpari (2022) also highlighted that blockchain simplified stakeholder communication and streamlined property administration. These benefits illustrated how blockchain could effectively address inefficiencies in property administration, reinforcing its practical value in everyday management tasks.

Potential such as “blockchain enhanced the traceability of land ownership” (PA1) which received a mean score of 3.90, ranked lower due to complex legal and institutional challenges involved. These concerns were supported by Aborujilah, Yatim and Al-Othmani (2021) and Christine *et al.* (2022), who stressed that while blockchain could improve transparency and security, challenges such as regulatory compliance, privacy, and governance frameworks had to be addressed for successful adoption. The comprehensive

frameworks proposed by these authors indicated that blockchain's potential in land administration remained promising but was not yet fully realized in practical terms. This cautious stance reflected the difficulties facing blockchain's integration into areas shaped by regulatory and policy environments.

Similarly, "blockchain financialization improved housing affordability" (PE6), the lowest-ranked item at 3.88, reflected the limited expectations professionals had regarding blockchain's potential on systemic social challenges like affordability. Smith *et al.* (2019) as well as Wouda and Opdenakker (2019) argued that while blockchain could enhance transactional efficiency, its capacity to directly influence housing prices and financing accessibility was constrained by broader economic and policy factors. This highlighted that although blockchain could contribute to greater efficiency, its role in addressing deep-rooted affordability issues was currently viewed as limited within the property sector.

In summary, the rankings in Table 4.6 revealed that construction professionals prioritized blockchain potential, with clear operational advantages, especially in predictive maintenance and supply chain transparency. Conversely, applications involving complex institutional systems such as land administration and financialization were viewed with cautious optimism due to ongoing regulatory and governance challenges. These findings emphasized that blockchain adoption was expected to advance first where practical, immediate benefits were evident, while systemic reforms remained necessary to unlock its full potential across all property management domains.

4.4.3 Mean Ranking of Challenges of Implementing Blockchain in Property Management

Table 4.7 presented the overall mean rankings of challenges affecting blockchain implementation in property management. Technical limitations ranked highest with a mean score of 4.04. This result aligned with findings by Zein and Twinomurinzi (2023), who emphasized that scalability issues, lack of interoperability, and inefficient consensus mechanisms were key technical

challenges to blockchain adoption. Professionals likely recognized these challenges due to practical constraints faced in real estate systems, particularly where integration with existing infrastructure proved difficult (Cunha and Silva, 2023). These findings suggest that professionals are aware of the technical complexity of integrating blockchain into existing property management systems, particularly when current infrastructure is not compatible.

Security and privacy challenges were ranked second, with a mean score of 4.01. This result was consistent with Morena *et al.* (2020), who argued that while blockchain improved trust and data integrity, concerns remained around unauthorized access and privacy risks. These risks were especially relevant in property management, where sensitive ownership and financial data were at stake. Garcia-Teruel (2020) further pointed out that misalignment between blockchain systems and legal frameworks could create gaps in data protection, making security and privacy an ongoing concern during implementation.

By contrast, cost and liquidity challenges were ranked lowest, with a mean score of 3.91. This result aligned with insights from Cunha and Silva (2023), who argued that financial concerns were often overestimated and failed to consider long-term savings. Professionals appeared to share this sentiment, recognizing that while initial costs were high, blockchain could enhance efficiency and reduce intermediary fees. Naz *et al.* (2024) supported this by highlighting blockchain's potential to improve liquidity and streamline transactions. Similarly, Mahmudnia, Arashpour and Yang (2022) emphasized the operational benefits of blockchain in simplifying processes and reducing delays, which further explained why cost and liquidity were not seen as the most pressing issues.

Table 4.7: Overall Mean Ranking of Challenges of Implementing Blockchain in Property Management

Code	Aspects of the Challenges of Implementing Blockchain in Property Management	Mean	Ranking
CD	Technical Limitations Challenges	4.04	1
CC	Security and Privacy Challenges	4.01	2

Table 4.7 (Continued)

CE	Institutional Challenges	3.96	3
CA	Legal and Regulatory Challenges	3.92	4
CB	Cost and Liquidity Challenges	3.91	5

Furthermore, Table 4.8 presented 24 specific challenges to blockchain adoption in property management, with mean scores ranging from 3.79 to 4.17.

Table 4.8: Mean Ranking of Challenges of Implementing Blockchain in Property Management

Code	**Challenges of Implementing Blockchain in Property Management**	**Mean**	**Ranking**
CD1	Lack of standardized protocols and interoperability between blockchain platforms.	4.17	1
CC3	Difficult to balance transparency, privacy, and regulatory compliance.	4.05	2
CC5	Difficult to establish reliable digital identity and signature verification.	4.05	2
CD3	Scalability issues limit real-time applications.	4.05	2
CC4	Difficult to identify and verify the client's identity while preserving privacy.	4.03	5
CD4	Smart contract rigidity affects enforceability and flexibility.	4.02	6
CB1	High expenses for currency conversion, setup, and maintenance.	4.01	7
CA2	Unclear legal status for tokenized property and data protection requirements.	4.00	8
CD2	The blockchain technology is too complex which requires high maintenance demand.	4.00	8
CE1	Difficult on managing economic impacts and value distribution.	4.00	8
CA4	Outdated regulations with a lack of standardization.	3.97	11
CC1	Lack of robust cybersecurity strategies to protect data.	3.97	11
CC2	Lack of trust and data privacy.	3.97	11
CD5	Difficult to amend errors once data was recorded	3.97	11
CE4	Difficult to achieve decentralized, inclusive, and secure governance.	3.97	11
CE2	Lack of strong political and regulatory support.	3.96	16
CB3	Cryptocurrency price fluctuations make transaction costs unpredictable.	3.93	17
CE3	Difficult to align with social and ethical aims.	3.91	18

Table 4.8 (Continued)

Code	Challenges of Implementing Blockchain in Property Management	Mean	Ranking
CA3	Uncertain legal guideline on tokenized assets like Non-fungible Tokens (NFTs).	3.89	19
CA1	Difficult to integrate with existing legal system.	3.81	20
CB2	Reduced illiquidity of property makes property a less profitable investment for investors	3.79	21

The highest-rated individual challenge was the "lack of standardized protocols and interoperability between blockchain platforms" (CD1), which scored 4.17. This underscored the importance of having a unified technical foundation across blockchain systems. Hoxha and Sadiku (2019)emphasized that the absence of standardized protocols hindered data exchange and integration between platforms. Similarly, Daniel and Speranza (2020) highlighted that without achieving interoperability, blockchain's potential could not be fully utilized across sectors. This challenge, therefore, represented a core technical issue that professionals believed had to be addressed before other aspects of blockchain implementation could be effectively pursued.

Tied in second place were several interconnected challenges that reflected the complex balance between transparency, security, and operational efficiency. The "difficulty balancing transparency, privacy, and regulatory compliance" (CC3) scored 4.05 and highlighted the inherent tension between blockchain's transparent nature and privacy protection requirements. While blockchain was inherently transparent, Zhou *et al.* (2020) emphasized that such openness could conflict with the need to protect user privacy. Thakur *et al.* (2020) added that aligning blockchain systems with existing regulatory frameworks was a significant challenge, as legal requirements often imposed restrictions that complicated the use of open data technologies. This challenge was especially relevant in property management, where sensitive personal and financial data had to be both accessible and secure, making compliance with data protection regulations a core concern for professionals.

Similarly, the "difficulty establishing reliable digital identity and signature verification" (CC5), also scoring 4.05, reflected the need for secure

and trustworthy identification mechanisms within blockchain systems. Daniel and Speranza (2020) pointed out that without robust digital identity systems, the risk of fraudulent transactions increased, which could undermine trust in the entire blockchain process. Thakur *et al.* (2020) supported this view, noting that digital identity was a foundational element of blockchain implementation. Without effective verification tools, stakeholders might hesitate to adopt blockchain solutions, particularly in high-value transactions like those in property management.

Moreover, the "scalability issues limit real-time applications" (CD3) challenge, also scoring 4.05, illustrated blockchain's limited capacity to process large volumes of transactions efficiently in real time. Guerriero (2023) observed that the decentralized nature of blockchain often resulted in slower transaction speeds compared to centralized systems, which was a critical limitation in property management operations that required high responsiveness. Daniel and Speranza (2020) further noted that existing blockchain architectures lacked the infrastructure necessary to support real-time performance at scale, making scalability a pressing technical challenge for widespread adoption in the sector.

At the bottom of the ranking were the challenges "difficult to integrate with existing legal system" (CA1) and "reduced illiquidity of property makes it a less profitable investment for investors" (CB2), with mean scores of 3.81 and 3.79 respectively. These results indicated that professionals believe legal frameworks could eventually adapt to technological advancements and that liquidity concerns were not perceived as an immediate challenge. Garcia-Teruel (2020) observed that legal systems tend to evolve in response to new technologies, while Naz *et al.* (2024) suggested that blockchain's long-term financial advantages may outweigh short-term liquidity concerns. Therefore, these challenges may be considered as longer-term considerations rather than urgent implementation problems.

Overall, the analysis revealed that professionals prioritized foundational technical and security challenges over adaptable regulatory and financial concerns when implementing blockchain in property management. Technical limitations, particularly interoperability and standardization issues,

dominated the rankings as prerequisite conditions for successful implementation, while security and privacy challenges were viewed as critical for establishing user trust and regulatory compliance. The relatively lower ranking of legal integration and cost-liquidity challenges indicated that these challenges were perceived as longer-term considerations that would adapt once robust technical infrastructure was established, suggesting that blockchain's feasibility in property management depended primarily on resolving core technical and security foundations before addressing regulatory and financial optimization.

4.5 Mann-Whitney U Test

Mann Whitney U test is used to identify the significant difference across sector of employment on the inefficiencies of property management, potential of blockchain in property management and challenges while implement blockchain. A p-value of 0.05 is adopted in this test.

4.5.1 Mann-Whitney U Test on Inefficiencies

In this test, the following hypotheses are formulated:

Null Hypothesis (H_0): There is no significant difference between respondents from the public and private sectors in their views on inefficiencies in property management.

Alternative Hypothesis (H_1): There is a significant difference between respondents from the public and private sectors in their views on inefficiencies in property management.

Table 4.9: Mann-Whitney U Test of Inefficiencies in Property Management Across Sectors of Employment

Code	Inefficiencies in Property Management	Mann-Whitney U	Wilcoxon W	Asymp. Sig. (2-tailed)
TE2	Lack of transparency in property markets creates uncertainty about ownership and investment security.	898.500	5269.500	0.027

Table 4.9 (Continued)

Code	Inefficiencies in Property Management	Mann-Whitney U	Wilcoxon W	Asymp. Sig. (2-tailed)
TE3	Speculative investments often rise property prices in cities, making properties too expensive for low-income people.	881.000	5252.000	0.020
TE4	Market volatility and distortions deter investment.	864.000	5235.000	0.014
TF1	Inadequate maintenance by responsible bodies.	921.000	5292.000	0.041
TF2	Building deterioration over time.	895.000	5266.000	0.026
TF5	Lack of communication with stakeholders.	829.500	5200.500	0.007
TF6	Lack of maintenance practices that align with green principles and consideration of health and safety.	900.000	5271.000	0.029

Table 4.9 present the results of the Mann-Whitney U test, which compared perceptions of inefficiencies in property management between public and private sector respondents. The test identified seven factors (T20, T21, T22, T23, T24, T27, and T28) that exhibited statistically significant differences ($p < 0.05$) between the two sectors. Therefore, the null hypothesis was rejected for these items.

Table 4.10: Mean Rank of Inefficiencies in Property Management Across Sectors of Employment

Code	Inefficiencies in Property Management	Sector	N	Mean Rank
TE2	Lack of transparency in property markets creates uncertainty about ownership and investment security.	**Public**	**26**	**71.94**
		Private	93	56.66
TE3	Speculative investments often rise property prices in cities, making properties too expensive for low-income people.	**Public**	**26**	**72.62**
		Private	93	56.47
TE4	Market volatility and distortions deter investment.	**Public**	**26**	**73.27**
		Private	93	56.29
TF1	Inadequate maintenance by responsible bodies.	**Public**	**26**	**71.08**
		Private	93	56.90

Table 4.10 (Continued)

Code	Inefficiencies in Property Management	Sector	N	Mean Rank
TF2	Building deterioration over time.	**Public**	**26**	**72.08**
		Private	93	56.62
TF5	Lack of communication with stakeholders.	**Public**	**26**	**74.60**
		Private	93	55.92
TF6	Lack of maintenance practices that align with green principles and consideration of health and safety.	**Public**	**26**	**71.88**
		Private	93	56.68

Note: **Bold** indicates the highest mean rank

As shown in Table 4.10, further analysis of the mean rank values revealed that the public sector expressed significantly greater concern about financial market risks, such as speculative investments and market volatility, than the private sector. The public sector scored very high on lack of transparency (TE2) with a mean rank of 71.94, on speculative investments (TE3) with a mean rank of 72.62, and on market volatility (TE4) with a mean rank of 73.27. These results aligned with the findings of Huang, Li and Yang (2024) which suggested that speculative investments disproportionately limit housing access for low-income populations. Public sector respondents assigned higher mean ranks, reflecting their institutional role in safeguarding social equity and preventing market-driven displacement, consistent with Christophers (2019) argument that public bodies prioritize social welfare over profit maximization. Further, the public sector's heightened sensitivity reflected its generally risk-averse nature and regulatory responsibilities, as described by Júnior *et al.* (2019) which likely motivated a stronger emphasis on ensuring market stability and protecting public interests.

Similarly, in relation to property maintenance and operational sustainability, public sector respondents rated inefficiencies such as inadequate maintenance (TF1), building deterioration (TF2), lack of communication with stakeholders (TF5) and lack of green and safety-compliant practices (TF6), were rated more severely by the public sector, with mean ranks of 71.08, 72.08, 74.60 and 71.88 respectively. This emphasis suggested a broader mandate within the public sector to ensure long-term asset durability, public health, and compliance with evolving sustainability regulations, consistent with insights

from Kadhim and Altaie (2023). he strong concern reflected in the highest mean score for TF5 highlighted the public sector's commitment to inclusive governance and transparency.This difference corresponded with observations by Musa *et al.* (2020) that public organizations typically engage more systematically with residents and other stakeholders to foster trust and support effective program implementation.

The consistent trend of higher mean ranks among public sector respondents suggested that their perspectives incorporated a more comprehensive understanding of property management inefficiencies that extended beyond financial metrics. As noted by Fateye *et al.* (2023), public sector approaches tended to integrate sustainability objectives, social equity concerns, and long-term community welfare into decision-making processes. In contrast, private sector actors, primarily driven by profit motives and market competition, might been less inclined to prioritize these broader socio-environmental considerations, explaining their relatively lower agreement with the presented inefficiencies.

Overall, these results reflected fundamental institutional differences between sectors. The public sector acted as a custodian of public welfare and implemented policies, which led it to perceive inefficiencies as more problematic due to their impact on social equity, sustainability, and community well-being. In contrast, the private sector's more transactional focus resulted in a comparatively lower perception of such risks.

4.5.2 Mann-Whitney U Test on Potential of Blockchain

In this test, the following hypotheses are formulated:

Null Hypothesis (H_0): There is no significant difference between respondents from the public and private sectors in their views on the potential of blockchain in property management.

Alternative Hypothesis (H_1): There is a significant difference between respondents from the public and private sectors in their views on the potential of blockchain in property management.

Table 4.11: Mann-Whitney U Test of Potential of Blockchain in Property Management Across Sectors of Employment.

Code	Potential of Blockchain in Property Management	Mann-Whitney U	Wilcoxon W	Asymp. Sig. (2-tailed)
PB1	Blockchain enhances ownership visibility and prevent unauthorized changes hence reduces fraud.	900.000	5271.000	0.028
PB2	Blockchain automates verification processes.	797.500	5168.500	0.004
PC3	Blockchain secures rental payments with encryption and ID validation.	915.500	5286.500	0.035
PD1	Blockchain grants specific access rights.	936.500	5307.500	0.050
PD2	Blockchain securely stores records with real-time access.	890.500	5261.500	0.026
PD3	Blockchain enables transparent decision-making and record-keeping.	819.000	5190.000	0.005
PD4	Blockchain streamlines payments for property management services.	874.000	5245.000	0.020
PE1	Blockchain enables fractional ownership and allows more people to invest in property.	803.000	5174.000	0.005
PE5	Decentralized governance through blockchain facilitate greater stakeholder participation and trust.	756.000	5127.000	0.001
PE6	Blockchain financialization improves housing affordability.	869.000	5240.000	0.017
PF3	Blockchain provides a transparent and verifiable record of asset lifecycles and supply chain management.	796.500	5167.500	0.004
PF4	Blockchain enables predictive maintenance, optimizing resource use.	613.500	4984.500	0.000

The results of the Mann-Whitney U test, as presented in Table 4.11, indicated statistically significant differences ($p < 0.05$) between the public and private sector respondents' perceptions of blockchain's potential across all aspects of property management. Consequently, the null hypothesis was rejected for each item.

Table 4.12: Mean Rank of Potential of Blockchain in Property Management Across Sectors of Employment

Code	Potential of Blockchain in Property Management	Sector	N	Mean Rank
PB1	Blockchain enhances ownership visibility and prevent unauthorized changes hence reduces fraud.	**Public**	**26**	**71.88**
		Private	93	56.68
PB2	Blockchain automates verification processes.	**Public**	**26**	**75.83**
		Private	93	55.58
PC3	Blockchain secures rental payments with encryption and ID validation.	**Public**	**26**	**71.29**
		Private	93	56.84
PD1	Blockchain grants specific access rights.	**Public**	**26**	**70.48**
		Private	93	57.07
PD2	Blockchain securely stores records with real-time access.	**Public**	**26**	**72.25**
		Private	93	56.58
PD3	Blockchain enables transparent decision-making and record-keeping.	**Public**	**26**	**75.00**
		Private	93	55.81
PD4	Blockchain streamlines payments for property management services.	**Public**	**26**	**72.88**
		Private	93	56.40
PE1	Blockchain enables fractional ownership and allows more people to invest in property.	**Public**	**26**	**75.62**
		Private	93	55.63
PE5	Decentralized governance through blockchain facilitate greater stakeholder participation and trust.	**Public**	**26**	**77.42**
		Private	93	55.13
PE6	Blockchain financialization improves housing affordability.	**Public**	**26**	**73.08**
		Private	93	56.34
PF3	Blockchain provides a transparent and verifiable record of asset lifecycles and supply chain management.	**Public**	**26**	**75.87**
		Private	93	55.56
PF4	Blockchain enables predictive maintenance, optimizing resource use.	**Public**	**26**	**82.90**
		Private	93	53.60

Note: **Bold** indicates the highest mean rank

As shown in Table 4.12, further analysis of the mean rank values revealed that public sector respondents consistently assigned higher importance to blockchain's potential across all property management categories compared to private sector respondents. This indicated that the public sector perceived blockchain technology as having more substantial potential to address inefficiencies and enhance operations within property management systems.

Under the category of Property Transaction (PB), public sector respondents recognized blockchain's potential to enhance ownership visibility and prevent fraud (PB1), scoring it highly with a mean rank of 71.88, as well as to automate verification processes (PB2), which received the highest mean rank of 75.83. This reflected the public sector's institutional responsibility to maintain transparent and accountable property records. The immutable nature of blockchain led to greater trust in ownership information, aligning with findings by Akoguhi and Bhavsingh (2023) that blockchain transparency significantly reduces fraud and mismanagement risks. Additionally, Thakur *et al.* (2020) supported the public sector's emphasis on blockchain securing land titles to promote authenticity and public confidence. The public sector's interest in automation as a tool to improve efficiency and reduce bureaucratic delays further explained the higher mean ranks in this area, consistent with the discussion of Daniel and Speranza (2020) on smart contracts improving public service delivery.

Regarding Leasing and Renting (PC), the stronger public sector rating of blockchain securing rental payments (PC3), which received a mean rank of 71.29, suggested greater concern for protecting vulnerable tenant groups within publicly subsidized housing programs. Saari, Junnila and Vimpari (2022) noted blockchain's impact on secure payment processing reduces disputes and promotes compliance, which is particularly valued by public entities overseeing social housing.

In the Property Administration (PD) aspect, the public sector perceived blockchain's potentials to grant specific access rights (PD1), ensure secure real-time record storage (PD2), facilitate transparent decision-making (PD3), and streamline payments (PD4), with mean ranks of 70.48, 72.25, 75.00, and 72.88 respectively. This pattern reflected the public sector's need to uphold governance standards, safeguard data integrity, and improve administrative efficiency. The public sector's focus on inclusive stakeholder engagement was consistent with the potential of blockchain in protecting sensitive information while enabling accountability (Hoxha and Sadiku, 2019; Thakur *et al.*, 2020). Moreover, the automation of financial processes echoed

findings from Cunha and Silva (2023) highlighting improvements in fiscal management that public agency found highly beneficial.

Within Property Financialization (PE), public sector respondents exhibited higher ratings for blockchain's potential to enable fractional ownership (PE1), foster decentralized governance and participation (PE5), and improve housing affordability (PE6) with mean ranks of 75.62, 77.42, and 73.08 respectively. These priorities aligned with the public mandate to promote equitable property access and community engagement. Hoxha and Sadiku (2019) emphasized blockchain's democratizing effect through fractional ownership, while Morena et al. (2020) supported the public sector's promotion of decentralized governance to increase stakeholder trust. The desire to improve housing affordability through cost reduction and process simplification was supported by Garcia-Teruel (2020) as well as Węgrzyn and Najbar (2020), aligning with the public sector's focus on social welfare. This focus is contrasted by the private sector's relative reticence, driven primarily by profit motives, as highlighted by Guan and Jang (2023).

Finally, in Property Maintenance (PF), the public sector highly rated the blockchain's potential to provide a transparent and verifiable record of asset lifecycles (PF3) and the optimization of resources via predictive maintenance (PF4) with mean ranks of 75.87 and an outstanding 82.90, respectively. This supported longstanding public sector objectives relating to accountability in asset management and efficient service delivery (Akoguhi and Bhavsingh, 2023). The public sector's greater emphasis on long-term stewardship contrasted with the private sector's concentration on short-term financial returns.

In conclusion, the results signified fundamental institutional differences in how blockchain's potential was perceived between the sectors. The public sector's higher mean ranks, and statistically significant differences reflected its broader institutional role as a custodian of public welfare, governance, and social equity. Conversely, the private sector's focus on immediate profitability and market competition appeared to moderate its enthusiasm for blockchain's far-reaching systemic benefits.

4.5.3 Mann-Whitney U Test on Challenges of Implementing Blockchain

In this test, the following hypotheses are formulated:

Null Hypothesis (H_0): There is no significant difference between respondents from the public and private sectors in their views on challenges of implementing blockchain in property management.

Alternative Hypothesis (H_1): There is a significant between respondents from the public and private sectors in their views on challenges of implementing blockchain in property management.

Table 4.13: Mann-Whitney U of Challenges of Implementing Blockchain in Property Management Across Sectors of Employment

Code	Challenges of Implementing Blockchain in Property Management	Mann-Whitney U	Wilcoxon W	Asymp. Sig. (2-tailed)
CB3	Cryptocurrency price fluctuations make transaction costs unpredictable.	928.500	5299.500	0.045
CC1	Lack of robust cybersecurity strategies to protect data.	819.000	5190.000	0.005
CC2	Lack of trust and data privacy.	835.000	5206.000	0.008
CC3	Difficult to balance transparency, privacy, and regulatory compliance.	756.000	5127.000	0.001
CD4	Smart contract rigidity affects enforceability and flexibility.	757.000	5128.000	0.001
CD5	Difficult to amend errors once data was recorded	664.000	5035.000	0.000

According to Table 4.13, the challenges featured a p-value less than 0.05, indicating statistically significant differences between public and private sector respondents. Therefore, the null hypothesis (H_0) was rejected for every listed challenge. This finding suggested that sector of employment played a meaningful role in shaping perceptions toward blockchain adoption challenges in property management.

Table 4.14: Mean Rank of Challenges of Implementing Blockchain in Property Management Across Sectors of Employment

Code	Challenges of Implementing Blockchain in Property Management	Sector	N	Mean Rank
CB3	Cryptocurrency price fluctuations make transaction costs unpredictable.	**Public**	**26**	**70.79**
		Private	93	56.98
CC1	Lack of robust cybersecurity strategies to protect data.	**Public**	**26**	**75.00**
		Private	93	55.81
CC2	Lack of trust and data privacy.	**Public**	**26**	**74.38**
		Private	93	55.98
CC3	Difficult to balance transparency, privacy, and regulatory compliance.	**Public**	**26**	**77.42**
		Private	93	55.13
CD4	Smart contract rigidity affects enforceability and flexibility.	**Public**	**26**	**77.38**
		Private	93	55.14
CD5	Difficult to amend errors once data was recorded	**Public**	**26**	**80.96**
		Private	93	54.14

Note: **Bold** indicates the highest mean rank

Table 4.14 showed that public sector respondents consistently assigned higher mean ranks than private counterparts, indicating greater concern over these challenges.

The public sector's concern about cost and liquidity challenges (CB) was particularly clear with cryptocurrency price fluctuations (CB3) scoring a mean rank of 70.79, reflecting the unpredictable transaction costs that complicate budgeting efforts. Given their limited budgets and accountability to taxpayers, this volatility made it difficult to forecast transaction costs related to property and service dealings, thus complicating budget management. Shaikh *et al.* (2024) emphasized the importance of effective regulatory frameworks to reduce these risks. Such frameworks were especially crucial for the public sector to stabilize expenses and enable careful budget planning.

Security and privacy challenges (CC) were also prominent. Public sector respondents expressed significantly greater concern regarding the lack of robust cybersecurity strategies (CC1), trust and data privacy issues (CC2), and the challenge of balancing transparency with privacy and regulatory compliance (CC3) with mean ranks of 75.00, 74.38, and 77.42nrespectively.

These concerns reflected the sector's responsibility to protect sensitive citizen information and comply with strict regulations. While blockchain offers strong cryptographic security features, complying with stringent data protection regulations and privacy frameworks remains challenging due to unresolved issues related to data quality, regulatory clarity, and privacy practices (Saari, Junnila and Vimpari, 2022). For the public sector, balancing transparency with privacy was essential to maintaining public trust.

Technical limitations within blockchain, particularly regarding smart contracts, drew significant concern (CD). The rigidity of smart contracts (CD4), which affected enforceability and flexibility, scored 77.38, while the difficulty of amending errors once data was recorded (CD5) scored even higher at 80.96. Hughes *et al.* (2019) supported the view that blockchain's immutability, while beneficial in maintaining accurate records, simultaneously increased the workload by necessitating rigorous data verification. This inflexibility was further reflected in challenges adapting smart contracts to evolving public regulations, such as legislative updates in land management and housing, as noted by Garcia-Teruel (2020). Thus, although blockchain technology enhanced transparency and reduced fraud, these technical constraints complicated its implementation in the public sector, which required a high degree of adaptability.

In conclusion, the public sector's stronger perception of blockchain implementation challenges reflected its institutional mission to ensure fiscal responsibility, robust security, regulatory compliance, and service adaptability. These factors distinguished its stance from that of the private sector, highlighting the complex environment in which blockchain must operate to succeed in public property management settings.

4.6 Kruskal-Wallis Test

This study's Kruskal-Wallis tests address three objectives which are identifying inefficiencies in property management, exploring blockchain's potential, and discovering challenges of its implementation in property management. Analyses used 119 responses for consistency, except for job position comparisons, which included 116 responses after excluding three

"Other" to meet the Central Limit Theorem's requirement of at least 30 samples per group for valid testing.

4.6.1 Inefficiencies in Property Management

This section uses the Kruskal-Wallis test to examine differences in perceptions of inefficiencies in property management across demographic groups such as age, company size, job position and years of experience.

4.6.1.1 Kruskal-Wallis Test on Inefficiencies in Property Management Across Age

In this test, the following hypotheses are formulated:

Null hypothesis (H_0): There is no significant difference among age groups in their perceptions of inefficiencies in property management.

Alternative hypothesis (H_1): There is a significant difference among age groups in their perceptions of inefficiencies in property management.

Table 4.15: Kruskal-Wallis Test on Inefficiencies in Property Management Across Age

Code	Inefficiencies in Property Management	Kruskal-Wallis H	Mean Rank
TA2	Outdated paper-based processes.	16.729	0.002
TB2	Vulnerable to fraud due to reliance on middlemen.	12.520	0.014
TD2	Decentralized and unstructured data storage.	11.634	0.020
TE2	Lack of transparency in property markets creates uncertainty about ownership and investment security.	11.348	0.023
TF1	Inadequate maintenance by responsible bodies.	22.095	0.000
TF3	Awareness gaps among residents.	12.147	0.016
TF4	Lack of professionalism and transparency in management.	11.816	0.019
TF5	Lack of communication with stakeholders.	15.643	0.004
TF6	Lack of maintenance practices that align with green principles and consideration of health and safety.	14.655	0.005

According to Table 4.15, 9 inefficiencies in property management were found to have significant differences in perception across age groups, all with p-values less than 0.05. These inefficiencies include outdated paper-based processes (TA2), vulnerability to fraud due to reliance on middlemen (TB2), decentralized and unstructured data storage (TD2), lack of transparency in property financial markets causing uncertainty over ownership and investment security (TE2), inadequate maintenance by responsible bodies (TF1), awareness gaps among residents (TF3), lack of professionalism and transparency in management (TF4), lack of communication with stakeholders (TF5), and maintenance practices that do not align with green principles and health and safety considerations (TF6). The significant findings indicate different age groups show distinct views on these inefficiencies. Hence, the null hypothesis of no difference among age groups is rejected for these inefficiencies.

Table 4.16: Mean Rank of Inefficiencies in Property Management Across Age

Code	Inefficiencies in Property Management	Age	N	Mean Rank
TA2	Outdated paper-based processes.	21-25	32	59.28
		26-30	29	70.84
		31-35	21	46.33
		36-40	17	42.41
		41 and above	**20**	**74.73**
TB2	Vulnerable to fraud due to reliance on middlemen.	21-25	32	64.33
		26-30	**29**	**69.52**
		31-35	21	62.86
		36-40	17	37.74
		41 and above	20	55.20
TD2	Decentralized and unstructured data storage.	21-25	32	53.77
		26-30	29	64.78
		31-35	21	45.69
		36-40	**17**	**77.00**
		41 and above	20	63.63
TE2	Lack of transparency in property markets creates uncertainty about ownership and investment security.	21-25	32	61.31
		26-30	29	59.84
		31-35	21	51.12
		36-40	**17**	**80.62**
		41 and above	20	49.93

Table 4.16 (Continued)

Code	Inefficiencies in Property Management	Age	N	Mean Rank
TF1	Inadequate maintenance by responsible bodies.	21-25	32	45.05
		26-30	29	51.17
		31-35	21	63.88
		36-40	**17**	**80.47**
		41 and above	20	75.25
TF3	Awareness gaps among residents.	21-25	32	45.98
		26-30	29	66.60
		31-35	21	56.50
		36-40	**17**	**72.38**
		41 and above	20	66.00
TF4	Lack of professionalism and transparency in management.	21-25	32	47.86
		26-30	29	58.86
		31-35	21	57.55
		36-40	**17**	**78.38**
		41 and above	20	68.03
TF5	Lack of communication with stakeholders.	21-25	32	42.91
		26-30	29	61.59
		31-35	21	67.31
		36-40	**17**	**76.68**
		41 and above	20	63.20
TF6	Lack of maintenance practices that align with green principles and consideration of health and safety.	21-25	32	45.25
		26-30	29	56.48
		31-35	21	65.93
		36-40	**17**	**77.50**
		41 and above	20	67.60

Note: **Bold** indicates the highest mean rank

By referring to Table 4.16, it was evident that individuals aged 41 and above placed the greatest emphasis on the inefficiency associated with outdated paper-based processes (TA2), demonstrating the highest mean rank of 74.73. This finding aligned with the expectation that older generations, having experienced such legacy systems extensively, were acutely aware of their limitations and challenges. As supported by Thakur *et al.* (2020), older adults tended to recognize the operational setbacks and risks embedded in manual, paper-reliant procedures, which could hinder accurate land ownership documentation and transaction efficiency. Their heightened concern likely

stemmed from direct exposure to bureaucratic delays and the increased potential for errors and fraud in such systems. This resonates with observation by Dhraief et al. (2019) that older farmers often exhibit risk aversion and a strong attachment to traditional methods, which could parallel similar dynamics in property management.

Meanwhile, those within the 36 to 40 years age group consistently ranked highest across many inefficiencies, including decentralized and unstructured data storage (TD2) with mean rank of 77.00, and lack of transparency in property markets (TE2) with mean rank of 80.62. Regarding property maintenance inefficiencies, the mean ranks among respondents aged 36 to 40 years were notably high. For example, they rated 80.47 for inadequate maintenance by responsible bodies (TF1), 72.38 for awareness gaps among residents (TF3), 78.38 for lack of professionalism and transparency in management (TF4), 76.68 for lack of communication with stakeholders (TF5), and 77.50 for insufficient maintenance practices aligned with green principles and health and safety considerations (TF6). This pattern suggested that this group, often at a life stage marked by active property ownership or management responsibilities, was deeply aware of the real impact these inefficiencies have on property value and community well-being. Their rankings were consistent with observations by Akoguhi and Bhavsingh (2023) that middle-aged property stakeholders, equipped with greater financial responsibilities and growing technological familiarity, tended to critically evaluate systemic inefficiencies while simultaneously acknowledging the potential of digital innovations such as blockchain. Interestingly, this finding contrasted with Dhraief *et al.* (2019) who reported a generally negative link between age and willingness to adopt innovations. Our results suggested a more complex relationship where middle age acted as a balance between experience with current methods and openness to change, which was not fully explored in Dhraief et al.'s focus on younger versus older groups.

In contrast, the 26 to 30 years age group showed particular concern over fraud vulnerabilities associated with middlemen in property transactions (TB2) with mean rank of 69.52. This trend similar with Banerjee *et al.* (2022) who argued that younger adults, often less experienced in property dealings

but more digitally literate, were particularly sensitive to risks posed by opaque intermediaries. Their preference for streamlined and transparent transaction processes could also be linked to a generational shift toward technology-enabled solutions, including blockchain platforms that reduce reliance on intermediaries (Junaid *et al.*, 2024). This aligned with Zhou et al. (2020) that younger generations were typically more open to trying new technologies, akin to how younger farmers readily adopted innovative practices.

Interestingly, the youngest group (21-25 years) generally reported lower concern across most inefficiency categories, which may reflect their limited exposure to property management problems or a greater optimism towards emerging technologies to resolve these issues (Thakur *et al.*, 2020). Younger people, being more familiar with digital technology, tend to be excited about new tech but might not fully realize how big these problems can be. For example, Dhraief et al. (2019) found that younger farmers exhibit less risk aversion.

In conclusion, the Table 4.16 highlighted a clear generational divergence in the perception of property management inefficiencies. The older generation aged 41 and over primarily concentrated on fundamental administrative shortcomings, while the middle-aged group aged 36 to 40 critically evaluated operational and maintenance challenges. The younger adults aged 26 to 30 emphasized transactional risks related to intermediary fraud. These patterns affirmed prior research suggesting that age-related differences in experience, financial involvement, and technological familiarity shaped attitudes toward property management practices. This segmentation underscores the necessity for strategies tailored specifically to address inefficiencies in ways that resonate with each age group's unique concerns and perspectives. However, the middle-aged group showed more active involvement and critical thinking compared to what Dhraief *et al.* (2019) suggested about age and adopting new ideas. This finding added more detail to our understanding of how different ages accept new technologies such as blockchain.

4.6.1.2 Kruskal-Wallis Test on Inefficiencies in Property Management Across Company Size

In this test, the following hypotheses are formulated:

Null hypothesis (H_0): There is no significant difference among company sizes in their perceptions of inefficiencies in property management.

Alternative hypothesis (H_1): There is a significant difference among company sizes in their perceptions of inefficiencies in property management.

Table 4.17: Kruskal-Wallis Test on Inefficiencies in Property Management Across Company Size

Code	Inefficiencies in Property Management	Kruskal-Wallis H	Mean Rank
TC2	Lack of transparency and trust issues between landlords with tenants.	7.953	0.047
TD1	Lack of transparency and reliability in verification processes.	8.734	0.033
TD3	Inefficient process for paying management fee	24.308	0.000
TE1	Illiquid and high entry barriers make it difficult for investors to participate in property markets.	19.011	0.000
TE2	Lack of transparency in property markets creates uncertainty about ownership and investment security.	9.511	0.023
TE4	Market volatility and distortions deter investment	12.382	0.006

According to Table 4.17, the Kruskal-Wallis test revealed six inefficiencies in property management with significant differences in perception among age groups, as all p-values were less than 0.05. These inefficiencies include the lack of transparency and trust issues between landlords and tenants (TC2), unreliability in verification processes (TD1), inefficient payment procedures for management fees (TD3), illiquidity and high barriers to entry hindering investor participation (TE1), lack of transparency in property markets causing uncertainty in ownership and investment security (TE2), and market volatility and distortions deterring investment (TE4). The findings suggested that age groups differ significantly in how they view these challenges, thereby rejecting the null hypothesis of uniform perception across ages. This indicated the importance of tailoring

property management strategies to address the concerns of diverse demographic segments.

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Table 4.18: Mean Rank of Inefficiencies in Property Management Across Company Size

Code	Inefficiencies in Property Management	Company Size	N	Mean Rank
TC2	Lack of transparency and trust issues between landlords with tenants.	**Micro**	**10**	**74.65**
		Small	31	65.27
		Medium	24	65.75
		Large	54	51.70
TD1	Lack of transparency and reliability in verification processes.	Micro	10	58.40
		Small	**31**	**70.66**
		Medium	24	66.29
		Large	54	51.38
TD3	Inefficient process for paying management fee	Micro	10	73.30
		Small	31	63.90
		Medium	**24**	**81.29**
		Large	54	45.83
TE1	Illiquid and high entry barriers make it difficult for investors to participate in property markets.	Micro	10	63.05
		Small	31	69.71
		Medium	**24**	**75.44**
		Large	54	47.00
TE2	Lack of transparency in property markets creates uncertainty about ownership and investment security.	Micro	10	54.70
		Small	31	65.02
		Medium	**24**	**73.88**
		Large	54	51.94
TE4	Market volatility and distortions deter investment.	Micro	10	61.40
		Small	31	59.47
		Medium	**24**	**78.54**
		Large	54	51.81

Note: **Bold** indicates the highest mean rank

As Table 4.18 illustrated, micro companies assigned the highest mean rank to lack of transparency and trust issues between landlords and tenants (TC2) with a mean rank of 74.65, indicating this inefficiency as their most significant concern. This pronounced perception stems from their limited managerial and legal capacities, which constrain their ability to formalize landlord-tenant agreements and effectively manage disputes. Such firms often depend on informal, personal agreements, exacerbating distrust and

vulnerability to non-compliance (Higgins, Tang and Stubbs, 2020). Supporting this, Nijland and Veuger (2019) highlighted that smaller firms faced greater risks due to insufficient administrative resources, while Aihie (2020) similarly found amplified inefficiencies related to trust and transparency among small firms in Nigeria.

Furthermore, small companies assigned the highest mean rank of 70..66 to lack of transparency and reliability in verification processes (TD1) under property administration, reflecting their challenges with informal contracts and frequent disputes, as noted by Júnior *et al.* (2019). Rao *et al.* (2024) observed that the high cost and procedural complexity of legal recourse discourage micro and small firms from efficiently addressing landlord-tenant conflicts. Blockchain technology has been proposed as an intervention to enhance transparency and trust through immutable contractual records (Borgentorp, Kaartinen and Junnila, 2023). However, its adoption remains largely feasible only for medium and large enterprises with sufficient financial and technical resources (Thakur et al., 2020).

In comparison, medium-sized companies rated inefficient management fee payment processes (TD3) and financialization-related inefficiencies, including investment barriers (TE1), ownership uncertainty (TE2), and market volatility (TE4), as their greatest concerns with mean ranks of 81.29, 75.44, 73.88, and 78.54, respectively. This suggests that as firms grow, their sensitivity shifted toward operational inefficiencies and financial market factors affecting scalability and investment. Medium firms also expressed significant concern about verification process inefficiencies, a finding echoed by Zhou et al. (2020) and Júnior et al. (2019), who linked reliance on informal contracts to frequent disputes. Although blockchain had been recommended to address these challenges, many medium firms faced resource constraints limiting effective implementation (Cunha and Silva, 2023).

Across all inefficiencies measured, larger companies consistently yielded the lowest mean ranks, indicating comparatively lower sensitivity to these inefficiencies. This contrast with findings by Clohessy and Acton (2019) as well as Zhou *et al.* (2020) who suggested that due to greater operational

complexity and scale, larger companies might experience more pronounced inefficiencies. The lower sensitivity observed among large firms in the Klang Valley sample might reflect stronger organizational formalization, effective delegation of operational issues, or better integration of innovative management solutions (Guan and Jang, 2023). This also partially contrast with Dhraief et al. (2019) and Zhou et al. (2020), who argued that although larger firms possessed greater resources and incentives for innovation, they also faced significant operational challenges. The unique Malaysian property management environment might help to mitigate such difficulties, leading to less perceived inefficiency among large firms in this context.

In conclusion, the Kruskal-Wallis test shows significant differences in perceptions of inefficiencies across company sizes. Micro and small companies are most affected by trust, transparency, and verification issues, reflecting their limited resources and informal operational approaches. Medium companies face greater concern with operational and financial inefficiencies, while larger companies report the least sensitivity to these challenges, likely due to formal processes and resource advantages. These findings emphasize the need for tailored strategies and supportive technologies that address the specific inefficiencies faced by different sized firms to enhance overall property management efficiency.

4.6.1.3 Kruskal-Wallis Test on Inefficiencies in Property Management Across Job Positions

In this test, the following hypotheses are formulated:

Null hypothesis (H_0): There is no significant difference among job positions in their perceptions of inefficiencies in property management.

Alternative hypothesis (H_1): There is a significant difference among job positions in their perceptions of inefficiencies in property management.

Table 4.19: Kruskal-Wallis Test on Inefficiencies in Property Management Across Job Positions

Code	Inefficiencies in Property Management	Kruskal-Wallis H	Mean Rank
TC1	Inefficient and outdated process cause high costs.	13.134	0.022
TC2	Lack of transparency and trust issues between landlords with tenants.	14.793	0.011
TC3	Reliance on agents increases conflicts of interest.	14.572	0.012
TC4	Failure to handle sensitive information in rental transactions.	14.110	0.015
TF1	Inadequate maintenance by responsible bodies.	15.538	0.008
TF5	Lack of communication with stakeholders.	10.600	0.031
TF6	Lack of maintenance practices that align with green principles and consideration of health and safety.	14.710	0.012

According to Table 4.19, several inefficiencies in property management exhibit statistically significant differences across job positions, with all p-values below 0.05. These inefficiencies include inefficient and outdated processes causing high costs (TC1), lack of transparency and trust issues between landlords and tenants (TC2), reliance on agents leading to conflicts of interest (TC3), failure to handle sensitive information properly during rental transactions (TC4), inadequate maintenance by responsible bodies (TF1), lack of communication with stakeholders (TF5), and insufficient maintenance practices aligned with green principles and health and safety considerations (TF6). These findings highlighted that perceptions of these inefficiencies vary notably by job role, suggesting the need for role-specific strategies to improve property management practices.

Table 4.20: Mean Rank of Inefficiencies in Property Management Across Job Positions

Code	Inefficiencies in Property Management	Job Position	N	Mean Rank
TC1	Inefficient and outdated process cause high costs.	Junior Executive	42	58.43
		Senior Executive	**28**	**73.70**

Table 4.20 (Continued)

Code	Inefficiencies in Property Management	Job Position	N	Mean Rank
		Manager/ Team Leader / Supervisor	34	52.28
		Assistant/ Technical Director	6	34.83
		Director	6	47.00
TC2	Lack of transparency and trust issues between landlords with tenants.	Junior Executive	42	62.13
		Senior Executive	**28**	**71.66**
		Manager/ Team Leader / Supervisor	34	50.35
		Assistant/ Technical Director	6	44.33
		Director	6	32.00
TC3	Reliance on agents increases conflicts of interest.	Junior Executive	42	58.58
		Senior Executive	**28**	**68.13**
		Manager/ Team Leader / Supervisor	34	60.78
		Assistant/ Technical Director	6	32.58
		Director	6	26.00
TC4	Failure to handle sensitive information in rental transactions.	Junior Executive	42	62.27
		Senior Executive	**28**	**68.29**
		Manager/ Team Leader / Supervisor	34	55.40
		Assistant/ Technical Director	6	34.00
		Director	6	28.50
TF1	Inadequate maintenance by responsible bodies.	Junior Executive	42	44.10
		Senior Executive	**28**	**68.98**
		Manager/ Team Leader / Supervisor	34	66.71
		Assistant/ Technical Director	6	57.42
		Director	6	65.00
TF5	Lack of communication with stakeholders.	Junior Executive	42	48.75
		Senior Executive	**28**	**73.00**
		Manager/ Team Leader / Supervisor	34	59.09
		Assistant/ Technical Director	6	58.08
		Director	6	56.17
TF6	Lack of maintenance practices that align with green principles and consideration of health and safety.	Junior Executive	42	46.02
		Senior Executive	28	69.98
		Manager/ Team Leader / Supervisor	34	62.13
		Assistant/ Technical Director	**6**	**79.33**
		Director	6	50.83

Note: **Bold** indicates the highest mean rank

Table 4.20 showed that perceptions of inefficiencies in property management differed across job positions. Senior executives consistently exhibited higher agreement on inefficiencies such as inefficient and outdated processes (TC1), lack of transparency and trust between landlords and tenants (TC2), reliance on agents (TC3), failure to handle sensitive information (TC4), inadequate maintenance (TF1), and lack of communication with stakeholders (TF5), with mean ranks of 73.70, 71.66, 68.13, 68.29, 68.98, and 73.00, respectively. These patterns aligned with their strategic oversight roles, where they connected operational shortcomings to financial outcomes and stakeholder satisfaction, consistent with Gao *et al.* (2023). This was further supported by Kadhim and Altaie (2023), who argued that their responsibility for overall costs and portfolio viability made them more sensitive to legacy inefficiencies that undermined competitiveness.

Furthermore, Zulkifli and Abidin (2024) characterized senior executives as moderately engaged with technology adoption, yet primarily responsible for broader organizational strategy and decision-making, influencing their tempered but critical attitudes. Similarly, Zhou et al. (2020) found that senior and assistant directors tend to focus more on organizational readiness, investment decisions, and legislative environments, emphasizing their strategic and leadership roles in enterprise transformation. Guo et al. (2023) also suggested that senior executives emphasized leadership's strategic impact on motivation and organizational performance, likely explaining their heightened awareness of systemic inefficiencies.

Assistant and Technical Directors, in contrast, showed the strongest agreement regarding the lack of maintenance practices aligned with green principles and health and safety considerations (TF6), scoring a mean rank of 79.33. Their frontline responsibility for day-to-day maintenance operations heightened their sensitivity to sustainability and occupant safety concerns. This reflected their technical expertise and focus on practical challenges, consistent with Fateye *et al.* (2023). According to Zulkifli and Abidin (2024) and supported by Zhou et al. (2020), this group occupies strategic yet operational roles, often focusing on compliance and technical execution, which explains their emphasis on maintenance deficiencies.

Managers, Team Leaders, and Supervisors reported moderate agreement, which can be understood via description by Zulkifli and Abidin (2024) that early adopters of emerging technologies who balance operational duties with privacy concerns. Zhou et al. (2020) also noted that middle management holds broader insight into operational inefficiencies and the organizational impact of blockchain, bridging operational and strategic concerns. Guo et al. (2023) further suggested that managers act as conduits of collaboration and motivation between senior executives and frontline employees, shaping their intermediate stance on inefficiencies.

Directors expressed lower agreement on various inefficiencies, which might reflect their strategic, high-level focus with less engagement in daily operational details. This aligned with views of Zulkifli and Abidin (2024) directors focusing more on policy-making, governance, and controlled information sharing, rather than direct interaction with operational challenges.

In short, these patterns demonstrated how job position influenced perceptions of inefficiencies, emphasizing the importance of addressing both strategic oversight and frontline realities for effective reform.

4.6.1.4 Kruskal-Wallis Test on Inefficiencies in Property Management Across Years of Experience

In this test, the following hypotheses are formulated:

Null hypothesis (H_0): There is no significant difference among years of experience in perceptions of inefficiencies in property management.

Alternative hypothesis (H_1): There is a significant difference among years of experience in perceptions of inefficiencies in property management.

Table 4.21: Kruskal-Wallis Test on Inefficiencies in Property Management Across Years of Experience

Code	Inefficiencies in Property Management	Kruskal-Wallis H	Mean Rank
TA4	Unresolved disputes over land ownership and weak dispute resolution systems.	11.624	0.040
TC1	Inefficient and outdated process cause high costs.	13.134	0.022

Table 4.21 (Continued)

Code	Inefficiencies in Property Management	Kruskal-Wallis H	Mean Rank
TC2	Lack of transparency and trust issues between landlords with tenants.	14.793	0.011
TC3	Reliance on agents increases conflicts of interest.	14.572	0.012
TC4	Failure to handle sensitive information in rental transactions.	14.110	0.015
TF1	Inadequate maintenance by responsible bodies.	15.538	0.008
TF6	Lack of maintenance practices that align with green principles and consideration of health and safety.	14.710	0.012

According to Table 4.21, the Kruskal-Wallis test revealed significant differences in perceptions of several inefficiencies in property management across different years of experience. These include unresolved disputes over land ownership and weak dispute resolution systems (TA4), inefficient and outdated processes leading to high costs (TC1), lack of transparency and trust issues between landlords and tenants (TC2), reliance on agents increasing conflicts of interest (TC3), failure to handle sensitive information during rental transactions (TC4), inadequate maintenance by responsible bodies (TF1), and insufficient maintenance practices aligned with green principles and health and safety considerations (TF6). These findings suggested that perceptions of these inefficiencies vary significantly depending on professionals' years of experience, highlighting the importance of considering experience levels when addressing the challenges in property management.

Table 4.22: Mean Rank of Inefficiencies in Property Management Across Years of Experience

Code	Inefficiencies in Property Management	Years of Experience	N	Mean Rank
TA4	Unresolved disputes over land ownership and weak dispute resolution systems.	Less than 6 years	70	62.34
		6-10 years	21	63.74
		11-15 years	19	40.71
		16-20 years	5	56.20
		21 years and above	**4**	**95.75**

Table 4.22 (Continued)

Code	Inefficiencies in Property Management	Years of Experience	N	Mean Rank
TC1	Inefficient and outdated process cause high costs.	Less than 6 years	70	56.56
		6-10 years	21	60.00
		11-15 years	19	59.53
		16-20 years	**5**	**89.80**
		21 years and above	4	85.25
TC2	Lack of transparency and trust issues between landlords with tenants.	Less than 6 years	70	58.02
		6-10 years	21	57.64
		11-15 years	19	55.55
		16-20 years	**5**	**101.20**
		21 years and above	4	76.63
TC3	Reliance on agents increases conflicts of interest.	Less than 6 years	70	59.55
		6-10 years	21	58.48
		11-15 years	19	49.82
		16-20 years	**5**	**104.50**
		21 years and above	4	68.63
TC4	Failure to handle sensitive information in rental transactions.	Less than 6 years	70	60.46
		6-10 years	21	55.02
		11-15 years	19	58.71
		16-20 years	5	68.90
		21 years and above	**4**	**73.13**
TF1	Inadequate maintenance by responsible bodies.	Less than 6 years	70	48.78
		6-10 years	21	72.26
		11-15 years	19	79.24
		16-20 years	5	70.20
		21 years and above	**4**	**87.88**
TF6	Lack of maintenance practices that align with green principles and consideration of health and safety.	Less than 6 years	70	52.08
		6-10 years	21	64.21
		11-15 years	19	77.03
		16-20 years	5	67.90
		21 years and above	**4**	**85.75**

Note: **Bold** indicates the highest mean rank

Table 4.22 showed that respondents with extensive experience in property management, especially those with 21 years and above, gave the highest mean ranks to several inefficiencies, indicating a strong agreement that these issues are critical. For unresolved disputes over land ownership and weak dispute resolution systems (TA4), this group rated the problem most severely with a mean rank of 95.75. This finding aligned with Thakur *et al.* (2020) and Antonio *et al.* (2021) who emphasized that long-standing ambiguities and ineffective dispute resolution remain key efficiency in property management. Professionals with decades of experience have

witnessed how these problems consistently delay transactions and reduce market confidence.

Regarding leasing and renting (TC), respondents with 16 to 20 years of experience also expressed strong concern regarding inefficient and outdated processes causing high costs (TC1) with a mean rank of 89.80. This indicated that experienced professionals are more aware of the enduring costs and operational delays perpetuated by legacy, manual procedures. This finding consistent with the observations by Nijland and Veuger (2019) who identified these inefficiencies as systemic challenges to efficient property management.

Moreover, transparency and trust problems between landlords and tenants (TC2) were perceived as particularly severe by respondents with 16 to 20 years of experience, who gave the highest mean rank of 101.20. This suggested that mid- to long-term professionals recognized the negative impact of opaque information flows on the landlord-tenant relationship. The result was consistent with the work of Cunha and Silva (2023) who highlighted how clarity and trust are essential for improving rental market operations. Moreover, the reliance on agents and intermediaries (TC3), was another inefficiency more critically viewed by those with 16 to 20 years of experience, scoring 104.50. This group's strong agreement supported the findings of Guan and Jang (2023) that commission-based agent structures could undermine transparency and fairness in leasing negotiations. In contrast, less experienced respondents showed less concern, indicating they might not have encountered these negative dynamics in depth.

Handling sensitive information during rental transactions (TC4) ranked moderately high among the most experienced practitioners, with a mean rank of 73.13 for those with over 21 years of experience, reflecting their awareness of the risks that mismanaging information posed for legal and financial problems. Garcia-Teruel (2020) also noted that secure management of sensitive data remained a persistent challenge in property administration, which supported this finding.

Regarding property maintenance (TF), respondents with over 21 years assigned high agreement to inadequate maintenance (TF1) and lack of maintenance aligned with green principles and health and safety

considerations (TF6) with mean ranks of 87.88 and 77.03 respectively. These results align with Musa *et al* (2020) and Kadhim and Altaie (2023), who emphasized that poor maintenance practices contribute to declining property value and occupant well-being over time.

In summary, more experienced professionals disproportionately perceived inefficiencies in property management to be more severe and persistent compared to less experienced respondents. This likely stemmed from their extended exposure to systemic challenges, including unresolved disputes, costly outdated procedures, trust deficits, conflicts of interest via agents, and poor maintenance regimes. Less experienced practitioners, while recognizing these issues, tended to be more optimistic, possibly influenced by newer technological solutions or less exposure to entrenched problems. \

4.6.2 Potential of Blockchain in Property Management

The Kruskal-Wallis test is applied here to explore variations in views on blockchain's potential benefits among different respondent groups.

4.6.2.1 Kruskal-Wallis Test on Potential of Blockchain in Property Management Across Age

In this test, the following hypotheses are formulated:

Null hypothesis (H_0): There is no significant difference among age groups in their perceptions of blockchain's potential in property management.

Alternative hypothesis (H_1): There is a significant difference among age groups in their perceptions of blockchain's potential in property management.

Table 4.23: Kruskal-Wallis Test on Potential of Blockchain in Property Management Across Age

Code	Potential of Blockchain in Property Management	Kruskal-Wallis H	Mean Rank
PC2	Blockchain smart contracts automate and streamline lease agreements.	20.444	0.000
PE4	Blockchain enhances transparency and accuracy in property valuation.	10.817	0.029
PF2	Blockchain automates maintenance schedules and contract management.	13.053	0.011

According to Table 4.23, the Kruskal-Wallis test revealed three aspects of blockchain potential in property management that showed significant differences in perception across age groups, with all p-values less than 0.05. These include the use of blockchain smart contracts to automate and streamline lease agreements (PC2), enhancement of transparency and accuracy in property valuation (PE4), and automation of maintenance schedules and contract management (PF2). The findings indicate that respondents from different age cohorts hold varying views on the potential benefits of blockchain, thereby leading to the rejection of the null hypothesis for these factors.

Table 4.24: Mean Rank of Potential of Blockchain in Property Management Across Age

Code	Potential of Blockchain in Property Management	Age	N	Mean Rank
PC2	Blockchain smart contracts automate and streamline lease agreements.	21-25	32	57.41
		26-30	29	68.43
		31-35	**21**	**72.21**
		36-40	17	31.29
		41 and above	20	63.50
PE4	Blockchain enhances transparency and accuracy in property valuation.	21-25	32	50.94
		26-30	29	68.66
		31-35	21	60.05
		36-40	17	47.35
		41 and above	**20**	**72.65**
PF2	Blockchain automates maintenance schedules and contract management.	21-25	32	49.20
		26-30	**29**	**71.24**
		31-35	21	65.71
		36-40	17	46.09
		41 and above	20	66.80

Note: **Bold** indicates the highest mean rank

According to Table 4.24, the age group 31 to 35 years demonstrated the strongest agreement that blockchain smart contracts can automate and streamline lease agreements (PC2), with the highest mean rank of 72.21. This finding was consistent with Aborujilah, Yatim and Al-Othmani (2021), who emphasized that individuals in this demographic tend to balance professional

maturity, financial stability, and openness to technological innovation. Their life and work experiences likely made them more aware of the inefficiencies of leasing processes and appreciative of blockchain's benefits in transparency, security, and operational efficiency. Similarly, Wouda and Opdenakker (2019) noted that this group's critical awareness of digital risks and trust mechanisms aligns well with the immutability and automation features of smart contracts. However, this contrasted somewhat with Zhou et al. (2020), who suggested middle-aged professionals may approach such innovations with cautious pragmatism, especially regarding legal and implementation concerns.

For "blockchain enhances transparency and accuracy in property valuation" (PE4), the 41 and above group reported the highest mean rank (72.65), reflecting their greater concern with transparency and accuracy in financial management. This result supported by Sharma, Isah and Rana (2024), who highlighted the sensitivity of experienced investors to immutable, auditable records that blockchain promises to deliver. Avci and Erzurumlu (2023) also supported this finding by showing how blockchain's immutable ledger and smart contract features improve valuation accuracy and reduce inconsistencies through real-time, transparent, and legally secure recording of property data. This advantage particularly appealed to older investors managing significant property portfolios. This attention to transparency and risk reduction aligned with Guerriero (2023) who emphasized the value of blockchain's tamper-proof ledger in securing property valuation histories. However, these findings partly conflicted with Collins and Lindkvist (2022), who argued that older individuals may be slower to adopt new technologies despite recognizing their theoretical benefits, echoing observations by Dhraief et al. (2019) on older farmers' risk aversion.

The 26 to 30 years age group showed the highest interest in using automation for property maintenance scheduling and contract management (PF2) with a mean rank of 71.24. This is likely because they are comfortable with digital tools and prefer clear, simple processes. Collins and Lindkvist (2022) found that professionals in this age group focus on using automation to reduce mistakes and delays. Sigalov *et al.* (2021) also showed that combining blockchain smart contracts with building models helps speed up contract work

and makes the process more transparent, which younger professionals appreciate.

In summary, this analysis revealed that perceptions of blockchain's potential in property management varied significantly by age, reflecting differences in professional maturity, technology adoption, and risk sensitivity. Younger and early-mid professionals aged from 26 to 35 showed the highest acceptance of blockchain's operational benefits, such as automating leases and maintenance, while older professionals aged 41 and above prioritized transparency in property financialization. These results agree with the findings of Aborujilah, Yatim and Al-Othmani (2021), Collins and Lindkvist (2022) as well as Sharma, Isah and Rana (2024), who highlighted the importance of tailoring blockchain implementations to meet the specific preferences and concerns of different age groups.

4.6.2.2 Kruskal-Wallis Test on Potential of Blockchain in Property Management Across Company Size

In this test, the following hypotheses are formulated:

Null hypothesis (H_0): There is no significant difference among company sizes in their perceptions of blockchain's potential in property management.

Alternative hypothesis (H_1): There is a significant difference among company sizes in their perceptions of tr blockchain's potential in property management.

Table 4.25: Kruskal-Wallis Test on Potential of Blockchain in Property Management Across Company Size

Code	Potential of Blockchain in Property Management	Kruskal-Wallis H	Mean Rank
PB3	Blockchain allows direct transactions which reduces the need for brokers.	11.754	0.008
PE5	Decentralized governance through blockchain facilitate greater stakeholder participation and trust.	10.817	0.013
PE6	Blockchain financialization improves housing affordability.	13.881	0.003
PF4	Blockchain enables predictive maintenance, optimizing resource use.	13.063	0.005

According to Table 4.25, the Kruskal-Wallis test revealed four aspects of blockchain's potential in property management exhibiting significant differences in perception across company sizes, all with p-values below 0.05. These included blockchain's potential to facilitate direct transactions reducing the need for brokers (PB3), decentralized governance promoting greater stakeholder participation and trust (PE5), blockchain-enabled financialization improving housing affordability (PE6), and predictive maintenance optimizing resource use (PF4). These findings indicated that companies of different sizes perceive these blockchain potentials differently, leading to the rejection of the null hypothesis of no difference among company size groups for these factors.

Table 4.26: Mean Rank of Potential of Blockchain in Property Management Across Company Size

Code	Potential of Blockchain in Property Management	Company Size	N	Mean Rank
PB3	Blockchain allows direct transactions which reduces the need for brokers.	Micro	10	57.10
		Small	31	63.74
		Medium	**24**	**76.13**
		Large	54	51.22
PE5	Decentralized governance through blockchain facilitate greater stakeholder participation and trust.	Micro	10	70.45
		Small	31	50.21
		Medium	**24**	**75.88**
		Large	54	56.63
PE6	Blockchain financialization improves housing affordability.	Micro	10	71.75
		Small	31	50.44
		Medium	**24**	**78.71**
		Large	54	55.00
PF4	Blockchain enables predictive maintenance, optimizing resource use.	Micro	10	47.45
		Small	31	59.97
		Medium	**24**	**79.67**
		Large	54	53.60

Note: **Bold** indicates the highest mean rank

As shown in Table 4.26, medium-sized companies consistently demonstrated the highest mean ranks for blockchain's potential in property management, indicating stronger recognition compared to micro, small, and large companies.

Specifically, “blockchain allows direct transactions which reduce the need for brokers” (PB3) was rated highest by medium firms with a mean rank of 76.13. This finding aligned with Cunha and Silva (2023) who argued that blockchain’s potential to eliminate intermediaries reduced transaction costs and accelerated processes. However, it contrasted with Clohessy and Acton (2019) who found that large companies were more likely to adopt blockchain due to superior resources, and Zhou *et al.* (2020) who suggested large firms’ broker networks reduced blockchain’s disintermediation impact. Our results differed by showing medium-sized companies in Malaysia possessed the readiness and flexibility to leverage blockchain benefits more strongly than both larger and smaller firms.

Regarding “decentralized governance through blockchain enhanced stakeholder participation and trust” (PE5), medium firms again placed the greatest emphasis with a mean rank of 75.88. This finding supported by Hoxha and Sadiku (2019), who highlighted that decentralized governance fostered inclusive stakeholder engagement. It also aligned with Guo *et al.* (2023), who noted that medium-sized organizations, with their more flexible yet formalized structures, benefited from broad input that reduced conflicts and improved decision-making. This finding contrasted with broader literature that viewed large firms as leaders in governance innovation, indicating medium firms in Malaysia were at the forefront of blockchain-enabled stakeholder engagement in property management.

For blockchain financialization improved housing affordability (PE6), medium enterprises perceived significant advantages (mean rank = 78.71). This aligned with Naz *et al.* (2024)) who described blockchain-enabled financial tools such as tokenization as useful in lowering market entry barriers. However, Clohessy and Acton (2019) as well as Aihie (2020) noted slower blockchain adoption in large firms due to regulatory complexity. Our findings suggested that medium firms in Klang Valley were better positioned to adopt these innovations.

Lastly, “blockchain enabled predictive maintenance, optimizing resource use” (PF4) attracted the strongest interest from medium-sized companies with a mean rank of 79.67. As Palm and Bohman (2023) observed,

integrating smart contracts with real-time analytics enabled proactive maintenance approaches, which medium firms needed to manage property assets efficiently. Smaller firms often lacked such infrastructure and larger firms delegated these functions, consistent with findings of Clohessy and Acton (2019). Yet, medium companies in Malaysia appeared more actively engaged with these technologies.

While these results highlighted prominent blockchain awareness among medium firms, Gururaja *et al.* (2024) cautioned that organizational priorities might vary with changing external factors. Nonetheless, the clear preference for blockchain's transformational features among medium-sized companies in Malaysia contrasted with much of the global literature, which often showed large firms as blockchain pioneers.

In conclusion, Table 4.26 shown significant differences in perceptions of blockchain's potential across company sizes. Medium firms rated blockchain potential including direct transactions, decentralized governance, housing affordability, and predictive maintenance higher than micro, small, and large companies. This divergence from international findings underscored the importance of tailoring blockchain adoption strategies to the scale, capabilities, and market dynamics unique to medium-sized enterprises in Malaysia's property management industry.

4.6.2.3 Kruskal-Wallis Test on Potential of Blockchain in Property Management Across Job Positions

In this test, the following hypotheses are formulated:

Null hypothesis (H_0): There is no significant difference among job positions in their perceptions of blockchain's potential in property management.

Alternative hypothesis (H_1): There is a significant difference among job positions in their perceptions of blockchain's potential in property management.

Table 4.27: Kruskal-Wallis Test on Potential of Blockchain in Property Management Across Job Position

Code	Potential of Blockchain in Property Management	Kruskal-Wallis H	Mean Rank
PE1	Blockchain enables fractional ownership and allows more people to invest in property.	16.645	0.002
PE2	Blockchain improves liquidity by enabling 24/7 trading of property tokens.	9.887	0.042
PE3	Blockchain reduces property investment costs.	11.899	0.018
PE4	Blockchain enhances transparency and accuracy in property valuation.	17.052	0.002
PE5	Decentralized governance through blockchain facilitate greater stakeholder participation and trust.	9.496	0.050
PF4	Blockchain enables predictive maintenance, optimizing resource use.	15.300	0.004

According to Table 4.27, the Kruskal-Wallis test showed significant differences in perceptions of blockchain's potential in property management across different job positions, with all p-values at or below 0.05. Key potentials showing differences included enabling fractional ownership to broaden investment accessibility (PE1), improving liquidity by allowing 24/7 trading of property tokens (PE2), reducing property investment costs (PE3), enhancing transparency and accuracy in property valuation (PE4), facilitating decentralized governance to increase stakeholder participation and trust (PE5) and enabling predictive maintenance for optimizing resource use (PF4). These results suggested that job roles influenced how blockchain's potential were perceived, emphasizing the importance of addressing role-specific needs when promoting blockchain adoption in property management.

Table 4.28: Mean Rank of Potential of Blockchain in Property Management Across Job Position

Code	Potential of Blockchain in Property Management	Job Position	N	Mean Rank
PE1	Blockchain enables fractional ownership and allows more people to invest in property.	Junior Executive	42	54.77
		Senior Executive	**28**	**68.73**
		Manager/ Team Leader / Supervisor	34	65.18
		Assistant/ Technical Director	6	22.50
		Director	6	35.00
PE2	Blockchain improves liquidity by enabling 24/7 trading of property tokens.	Junior Executive	42	56.93
		Senior Executive	**28**	**70.05**
		Manager/ Team Leader / Supervisor	34	58.59
		Assistant/ Technical Director	6	39.58
		Director	6	34.00
PE3	Blockchain reduces property investment costs.	Junior Executive	42	55.67
		Senior Executive	**28**	**73.80**
		Manager/ Team Leader / Supervisor	34	50.22
		Assistant/ Technical Director	6	69.25
		Director	6	43.08
PE4	Blockchain enhances transparency and accuracy in property valuation.	Junior Executive	42	55.31
		Senior Executive	**28**	**76.39**
		Manager/ Team Leader / Supervisor	34	50.66
		Assistant/ Technical Director	6	67.50
		Director	6	32.75
PE5	Decentralized governance through blockchain facilitate greater stakeholder participation and trust.	Junior Executive	42	53.55
		Senior Executive	**28**	**71.07**
		Manager/ Team Leader / Supervisor	34	59.25
		Assistant/ Technical Director	6	53.50
		Director	6	35.25
PF4	Blockchain enables predictive maintenance, optimizing resource use.	Junior Executive	42	51.05
		Senior Executive	**28**	**75.07**
		Manager/ Team Leader / Supervisor	34	55.50
		Assistant/ Technical Director	6	72.67
		Director	6	36.17

Note: **Bold** indicates the highest mean rank

Table 4.28 highlighted notable differences in perceptions of blockchain's potential across job positions. Senior executives consistently reported the highest mean ranks on most indicators related to blockchain-enabled financialization and predictive maintenance. For example, they rated blockchain's potential to enable fractional ownership (PE1) with a mean rank of 68.73, improve liquidity via 24/7 trading of property tokens (PE2) at 70.05, reduce investment costs (PE3) at 73.80, enhance transparency and accuracy in property valuation (PE4) at 76.39, and facilitate decentralized governance (PE5) at 71.07 more positively than other groups

This strong endorsement reflected their strategic roles, where long-term asset optimization, cost control, and enhanced transparency were paramount. Their leadership responsibilities compelled them to oversee transformation initiatives aimed at improving financial performance and stakeholder confidence (Zhou *et al.*, 2020). For example, senior executives recognized blockchain's potential to democratize property investment by lowering entry barriers through fractional ownership (PE1) and increasing liquidity via continuous trading (PE2), consistent with Clohessy and Acton (2019) as well as Kaldor (2022). Their experience of current market inefficiencies such as dependence on intermediaries and opaque valuation methods, informed their view that blockchain technologies could substantially boost market efficiency and competitiveness.

Moreover, senior executives appreciated blockchain's role in decentralized governance (PE5), which promoted greater stakeholder participation and trust, crucial for sustained investor confidence according to Konashevych (2020a). They understood that enhanced transparency and reduced reliance on intermediaries constituted both operational improvements and strategic advantages, drawing more investors and improving market functioning.

Senior executives also awarded high importance to blockchain's potential to enable predictive maintenance (PF4), with a mean rank of 75.07, emphasizing its function in resource optimization and asset longevity. This aligned with Hughes *et al.* (2019), who noted that immutable blockchain records combined with smart contracts could streamline maintenance

workflows and yield cost savings. Their oversight of operational and financial data provided them with a nuanced appreciation of both immediate and long-term benefits.

Conversely, Assistant and Technical Directors showed lower agreement on certain financialization aspects such as fractional ownership (PE1), with a mean rank of 22.50, and liquidity (PE2) at 39.58, but moderately agreed on blockchain's potential to reduce investment costs (PE3) and enhance valuation transparency (PE4). This response likely reflected their concentration on technical and operational concerns rather than broader strategic investment frameworks.

In conclusion, senior executives' expanded responsibilities for financial sustainability and strategic leadership positioned them to better appreciate blockchain's transformative capabilities in property financialization and maintenance optimization. Their strong support for features such as fractional ownership (PE1), liquidity enhancement (PE2), cost reduction (PE3), decentralized governance (PE5), and predictive maintenance (PF4) underscored the need to align digital innovation with organizational strategy and investor value creation.

4.6.2.4 Kruskal-Wallis Test on Potential of Blockchain in Property Management Across Years of Experience

In this test, the following hypotheses are formulated:

Null hypothesis (H_0): There is no significant difference among years of experience in their perceptions of blockchain's potential in property management.

Alternative hypothesis (H_1): There is a significant difference among years of experience in their perceptions of blockchain's potential in property management.

Table 4.29: Kruskal-Wallis Test on Potential of Blockchain in Property Management Across Years of Experience

Code	Potential of Blockchain in Property Management	Kruskal-Wallis H	Mean Rank
PA3	Blockchain improves transparency in land lease and mortgage transactions.	11.797	0.038
PB3	Blockchain allows direct transactions which reduces the need for brokers.	14.330	0.014
PC2	Blockchain smart contracts automate and streamline lease 4ments.	18.642	0.002
PE1	Blockchain enables fractional ownership and allows more people to invest in property.	18.465	0.002
PE3	Blockchain reduces property investment costs.	12.253	0.031
PE4	Blockchain enhances transparency and accuracy in property valuation.	22.075	0.001
PE5	Decentralized governance through blockchain facilitate greater stakeholder participation and trust.	15.119	0.010
PF4	Blockchain enables predictive maintenance, optimizing resource use.	19.398	0.002

Table 4.29 showed significant differences in perceptions of blockchain's potential in property management across different years of experience. These included blockchain's potential to improve transparency in land lease and mortgage transactions (PA3), enable direct transactions that reduced the need for brokers (PB3), automate and streamline lease agreements through smart contracts (PC2), facilitate fractional ownership allowing more people to invest in property (PE1), reduce property investment costs (PE3), enhance transparency and accuracy in property valuation (PE4), support decentralized governance that promoted greater stakeholder participation and trust (PE5), and enable predictive maintenance to optimize resource use (PF4). These findings suggested that professionals' views on the benefits of blockchain technology varied significantly depending on their years of experience, emphasizing the need to consider experience levels when promoting blockchain adoption in property management.

Table 4.30: Mean Rank of Potential of Blockchain in Property Management Across Years of Experience

Code	Potential of Blockchain in Property Management	Years of Experience	N	Mean Rank
PA3	Blockchain improves transparency in land lease and mortgage transactions.	Less than 6 years	70	60.89
		6-10 years	21	63.45
		11-15 years	19	50.74
		16-20 years	**5**	**68.50**
		21 years and above	4	59.63
PB3	Blockchain allows direct transactions which reduces the need for brokers.	Less than 6 years	70	60.09
		6-10 years	21	65.64
		11-15 years	19	50.42
		16-20 years	5	65.20
		21 years and above	**4**	**67.88**
PC2	Blockchain smart contracts automate and streamline lease agreements.	Less than 6 years	70	63.49
		6-10 years	21	61.21
		11-15 years	19	43.95
		16-20 years	**5**	**67.90**
		21 years and above	4	59.00
PE1	Blockchain enables fractional ownership and allows more people to invest in property.	Less than 6 years	70	56.41
		6-10 years	21	66.00
		11-15 years	19	64.00
		16-20 years	5	55.90
		21 years and above	**4**	**77.50**
PE3	Blockchain reduces property investment costs.	Less than 6 years	70	56.91
		6-10 years	21	66.86
		11-15 years	19	55.92
		16-20 years	**5**	**93.20**
		21 years and above	4	56.00
PE4	Blockchain enhances transparency and accuracy in property valuation.	Less than 6 years	70	59.26
		6-10 years	21	62.86
		11-15 years	19	50.45
		16-20 years	**5**	**91.20**
		21 years and above	4	64.25
PE5	Decentralized governance through blockchain facilitate greater stakeholder participation and trust.	Less than 6 years	70	58.34
		6-10 years	**21**	**69.74**
		11-15 years	19	56.74
		16-20 years	5	48.80
		21 years and above	4	67.38
PF4	Blockchain enables predictive maintenance, optimizing resource use.	Less than 6 years	70	52.38
		6-10 years	21	71.43
		11-15 years	19	63.47
		16-20 years	**5**	**86.40**
		21 years and above	4	83.88

Note: **Bold** indicates the highest mean rank

Table 4.30 revealed that respondents with 16 to 20 years of experience rated transparency in land lease and mortgage transactions (PA3) the highest, with a mean score of 68.50. These professionals' extensive experience gave them firsthand insight into issues such as mistrust and unclear records that often complicated property transactions. This background enabled them to appreciate blockchain's potential in offering immutable and transparent transaction histories. This perspective was consistent with findings by Hoxha and Sadiku (2019) as well as Daniel and Speranza (2020), who similarly acknowledged blockchain's value in securing land rights and minimizing disputes.

Smart contract automation and the streamlining of lease agreements (PC2) also received the highest mean score of 67.90 from the same 16 to 20 years experience group. These professionals, being deeply involved in managing contracts, were particularly aware of the delays and inefficiencies caused by manual processes. Junaid *et al.* (2024) emphasized that smart contracts could reduce the need for intermediaries and lower transaction costs, aligning with the operational priorities of mid-career managers in both local and international contexts.

Furthermore, the potential to reduce investment costs (PE3) and improve transparency and valuation accuracy (PE4) was strongly emphasized by this group, with respective high mean scores of 93.20 and 91.20. Their active roles in cost and asset management likely increased their sensitivity to blockchain's potential to provide secure, accurate records and reduce transactional expenses. These findings reflected the practical expectations documented by Amadi-Echendu (2021).

Additionally, optimization of resource use via predictive maintenance (PF4) was most supported by the 16 to 20 years group, receiving a mean score of 86.40. These professionals, responsible for overseeing property upkeep and operational efficiency, recognized blockchain's potential to automate maintenance scheduling and integrate real-time data. This viewpoint aligned with the work of Thakur *et al.* (2020) and Shuaib *et al.* (2022), who also highlighted blockchain's contribution to smarter facility management worldwide.

Supporting these insights, Dhraief *et al.* (2019) observed that individuals with 15 to 20 years of experience generally appreciated blockchain's potential, as they balanced professional experience with openness to technological innovations.

Interestingly, professionals in Klang Valley with over 21 years of experience gave the highest rating to blockchain's potential in reducing reliance on intermediaries through direct transactions (PB3), with a mean score of 67.88. Supported by Cunha and Silva (2023), these experienced experts possessed a strategic outlook shaped by years of dealing with the inefficiencies of property management systems, which frequently caused delays and added costs.

The same senior group also showed the strongest agreement regarding the benefits of fractional ownership (PE1), with a mean score of 77.50. Their long-term perspective enabled them to view blockchain-enabled tokenization as a valuable opportunity to expand investment accessibility. Smith *et al.* (2019) explained how blockchain tokenization divides asset ownership into smaller units, allowing more investors to participate and lowering the investment barrier. Therefore, senior professionals in the Klang Valley appeared ready to use blockchain for strategic purposes.

Their recognition of blockchain's peer-to-peer framework as a disruptive innovation corresponded with Dhraief *et al.* (2019) who noted that although highly experienced individuals might be cautious about adopting new technologies, they were open to innovations that addressed longstanding inefficiencies. Zhou *et al.* (2020) also emphasized that senior professionals often take a conservative stance toward complex technologies, which helped explain their selective endorsement of blockchain's strategic advantages. In line with global trends, Klang Valley professionals reflected a similarly cautious yet appreciative view, shaped by organizational culture and experience-driven perspectives.

Notably, professionals with 6 to 10 years of experience gave the highest rating to decentralized governance for improving stakeholder engagement and trust (PE5), with a mean score of 69.74. This group, often positioned between coordination and execution roles, valued transparency and

accountable governance. Morena *et al.* (2020) as well as Saari, Junnila and Vimpari (2022) supported blockchain's effectiveness in decentralized decision-making, a feature that resonated with this cohort's higher digital literacy and greater openness to innovation. This was also consistent with Alant and Bakare (2021) findings on younger professionals' receptiveness to ICT advancements.

In summary, the results from Table 4.30 indicated that professional experience significantly influenced perceptions of blockchain's potential. Mid-career professionals (16 to 20 years) were focused on operational improvements such as transaction transparency, contract automation, cost reduction, accurate valuation, and maintenance optimization. Senior professionals (21 years and above) emphasized strategic applications like disintermediation and fractional ownership. Meanwhile, less experienced professionals (6 to 10 years) emphasized governance benefits and stakeholder trust. Given the variation in ICT literacy and technological exposure across experience levels, tailored training and support programs are essential to encourage broader blockchain adoption in property management.

4.6.3 Challenges of Adopting Blockchain in Property Management

This section employs the Kruskal-Wallis test to investigate differences in challenges of blockchain adoption across demographic groups.

4.6.3.1 Kruskal-Wallis Test on Challenges of Implementing Blockchain Across Age

In this test, the following hypotheses are formulated:

Null hypothesis (H_0): There is no significant difference among age groups in their perceptions of the challenges in implementing blockchain in property management.

Alternative hypothesis (H_1): There is a significant difference among age groups in their perceptions of the challenges in implementing blockchain in property management.

Table 4.31: Kruskal-Wallis Test on Challenges of Implementing Blockchain in Property Management Across Age

Code	Challenges of Adopting Blockchain in Property Management	Kruskal-Wallis H	Mean Rank
CC1	Lack of robust cybersecurity strategies to protect data.	15.474	0.004
CD4	Smart contract rigidity affects enforceability and flexibility.	10.176	0.038
CD5	Difficult to amend errors once data was recorded	14.542	0.006
CE3	Difficult to align with social and ethical aims.	12.286	0.015
CE4	Difficult to achieve decentralized, inclusive, and secure governance.	10.577	0.032

According to Table 4.31, the Kruskal-Wallis test identified five challenges in adopting blockchain technology in property management that showed significant differences across age groups, with all p-values below 0.05. These challenges included the lack of robust cybersecurity strategies to protect data (CC1), the rigidity of smart contracts impacting enforceability and flexibility (CD4), difficulties in amending errors once data was recorded (CD5), challenges in aligning blockchain adoption with social and ethical goals (CE3), and the complexity of achieving decentralized, inclusive, and secure governance (CE4). These results suggested that perceptions regarding these challenges varied significantly among different age groups, leading to the rejection of the null hypothesis for these factors.

Table 4.32: Mean Rank of Challenges of Implementing Blockchain in Property Management Across Age

Code	Challenges of Implementing Blockchain in Property Management	Age	N	Mean Rank
CC1	Lack of robust cybersecurity strategies to protect data.	21-25	32	48.02
		26-30	29	55.40
		31-35	21	67.83
		36-40	**17**	**81.56**
		41 and above	20	59.30
CD4	Smart contract rigidity affects enforceability and flexibility.	21-25	32	51.92
		26-30	29	62.21
		31-35	21	67.79

Table 4.32 (Continued)

Code	Challenges of Implementing Blockchain in Property Management	Age	N	Mean Rank
		36-40	**17**	**74.21**
		41 and above	20	49.48
CD5	Difficult to amend errors once data was recorded	21-25	32	52.05
		26-30	29	56.81
		31-35	21	68.79
		36-40	**17**	**82.06**
		41 and above	20	49.38
CE3	Difficult to align with social and ethical aims.	21-25	32	56.52
		26-30	29	67.64
		31-35	**21**	**73.98**
		36-40	17	53.09
		41 and above	20	45.70
CE4	Difficult to achieve decentralized, inclusive, and secure governance.	21-25	32	56.47
		26-30	29	66.17
		31-35	**21**	**69.10**
		36-40	17	64.88
		41 and above	20	43.00

According to Table 4.32, the 36–40 age group consistently reported the highest concerns about technical challenges, including lack of strong cybersecurity measures to protect data (CC1) with a mean rank of 81.56, smart contract rigidity affecting flexibility and enforceability (CD4) with a mean rank of 74.21, and difficulty fixing errors after data was recorded (CD5) with a mean rank of 82.06. This group's higher concern likely came from their experience in mid- to senior-level roles, where they managed complex property assets and led digital changes. Their awareness was shaped by firsthand experience with cybersecurity risks and limits in current systems (Cunha and Silva, 2023). This matched the findings of Dhraief *et al.* (2019) that older people tend to be more cautious and less interested in technologies that add complexity without clear short-term benefits.

In contrast, the 31–35 age group showed the greatest concern about institutional challenges, such as difficulty balancing blockchain with social and ethical goals (CE3) with a mean rank of 73.98, and challenges in achieving decentralized, inclusive, and secure governance (CE4) with a mean

rank of 69.10. This group was often at a key point in their careers, involved in decisions that required balancing new technology with regulations and social responsibilities (Sari, 2023). Their concerns reflected both practical experience with existing governance systems and an understanding that blockchain could change social and technical norms. They seemed aware that without improvements in governance, blockchain might not fully meet its ethical and social goals (Antonio *et al.*, 2021). Their concerns were similar to those of younger farmers in study by Dhraief *et al.* (2019) that shown a shared sense that strong support systems are needed when adopting new technologies.

Younger groups who aged from 21 to 30 showed lower concern ratings across all challenges, suggesting they were more optimistic or less aware of the challenges in adopting blockchain. Being more familiar with digital technology such as blockchain, they might have underestimated the cybersecurity risks or governance issues that became clearer with experience Hughes *et al.* (2019). This agreed with finding of Dhraief *et al.* (2019) that younger people tend to adopt new technologies more quickly because they were more open and adaptable. Similarly, the 41 and above group showed moderate concern but generally had lower ratings than the mid-career groups. This might have reflected their cautious attitude, focusing more on stability, rules, and proven systems instead of quickly adopting new and possibly disruptive technologies (Hoxha & Sadiku, 2019).

Overall, these findings showed that views on blockchain adoption challenges in property management were strongly influenced by age factors such as digital skills, risk awareness, and knowledge of governance. Professionals aged from 31 to 40 years were the most critical, demanding solutions that balanced technical reliability with flexible governance. Younger people were optimistic but might need more exposure to real-world difficulties, while older professionals preferred stability over rapid change.

This variation by age showed the importance of creating blockchain solutions that address both technical and governance challenges while considering the different needs and concerns of all professional groups. Doing this would improve the chances of blockchain being widely and successfully

adopted in property management, as supported by previous studies (Hughes *et al.*, 2019; Antonio *et al.*, 2021; Cunha and Silva, 2023).

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4.6.3.2 Kruskal-Wallis Test on Challenges of Implementing Blockchain Across Company Size

In this test, the following hypotheses are formulated:

Null hypothesis (H_0): There is no significant difference among company sizes in their perceptions of challenges in implementing blockchain in property management.

Alternative hypothesis (H_1): There is a significant difference among company sizes in their perceptions of challenges in adopt implementing blockchain in property management.

Table 4.33: Kruskal-Wallis Test on Challenges of Implementing Blockchain in Property Management Across Company Size

Code	Challenges of Implementing Blockchain in Property Management	Kruskal-Wallis H	Mean Rank
CE4	Difficult to achieve decentralized, inclusive, and secure governance.	9.098	0.028

According to Table 4.33, the Kruskal-Wallis test identified a significant challenge in adopting blockchain technology related to governance (CE4) across different company sizes, with a p-value of 0.028. This indicated that perceptions of governance challenges varied by company size, leading to the rejection of the null hypothesis.

Table 4.34: Mean Rank of Challenges of Implementing Blockchain in Property Management Across Company Size

Code	Challenges of Implementing Blockchain in Property Management	Company Size	N	Mean Rank
CE4	Difficult to achieve decentralized, inclusive, and secure governance.	Micro	10	59.75
		Small	**31**	**73.40**
		Medium	24	51.52
		Large	54	56.12

Note: **Bold** indicates the highest mean rank

According to Table 4.34, small companies recorded the highest mean rank (73.40) for the challenge of "difficult to achieve decentralized, inclusive, and secure governance" (CE4), indicating they perceived this as a greater challenge compared to micro, medium, and large firms. This finding aligned with Hoxha and Sadiku (2019) Daniel and Speranza (2020) who emphasized that small firms often lacked the personnel, expertise, and formal structures required to implement complex decentralized governance systems. Small companies generally relied on a limited number of individuals managing multiple roles, making it difficult to achieve broad inclusivity in decision-making. Thakur *et al.* (2020) also noted that centralized leadership in small enterprises limited participatory governance models, conflicting with blockchain's decentralization principles.

Furthermore, Clohessy and Acton (2019) revealed that small firms frequently struggled to build robust cybersecurity infrastructure, an essential component enabling secure blockchain governance. These factors collectively explained why small companies faced greater difficulties adopting blockchain governance systems compared to larger organizations, which typically possessed the resources and formalized processes to manage such transitions smoothly. Additionally, Zhou *et al.* (2020) highlighted that smaller firms often experienced resource and expertise constraints compounded by regulatory ambiguities and financial limitations, constraining their blockchain uptake and organizational readiness. In summary, small companies encountered considerable institutional and governance challenges in adopting blockchain technologies, further underlining the importance of targeted support measures such as government initiatives, professional consultation, and ecosystem development to enhance adoption among resource-constrained firms (Clohessy and Acton, 2019; Hoxha and Sadiku, 2019; Thakur *et al.*, 2020).

4.6.3.3 Kruskal-Wallis Test on Challenges of Implementing Blockchain Across Job Positions

In this test, the following hypotheses are formulated:

Null hypothesis (H_0): There is no significant difference among job positions in their perceptions of the challenges in implementing blockchain in property management.

Alternative hypothesis (H_1): There is a significant difference among job positions in their perceptions of the challenges in implementing blockchain in property management.

Table 4.35: Kruskal-Wallis Test on Challenges of Implementing Blockchain in Property Management Across Job Positions

Code	Challenges of Implementing Blockchain in Property Management	Kruskal-Wallis H	Mean Rank
CB1	High expenses for currency conversion, setup, and maintenance.	22.562	0.000
CB2	Reduced illiquidity of property makes property a less profitable investment for investors	11.681	0.020
CB3	Cryptocurrency price fluctuations make transaction costs unpredictable.	10.600	0.031
CC1	Lack of robust cybersecurity strategies to protect data.	16.799	0.002
CC3	Difficult to balance transparency, privacy, and regulatory compliance.	14.082	0.007
CC4	Difficult to identify and verify the client's identity while preserving privacy.	11.371	0.023
CC5	Difficult to establish a reliable digital identity and signature verification.	14.767	0.005
CD2	The blockchain technology is too complex, which requires high maintenance.	9.716	0.045
CD5	Difficult to amend errors once data was recorded.	12.454	0.014
CE4	Difficult to achieve decentralized, inclusive, and secure governance.	12.102	0.017

According to Table 4.35, the Kruskal-Wallis test revealed significant differences in perceptions of challenges associated with implementing blockchain technology in property management across different job positions. The most prominent challenge, with the highest level of significance ($p = 0.000$), was the “high expenses related to currency conversion, setup, and

maintenance" (CB1). Other challenges showing significant differences included "reduced illiquidity making property investments less profitable" (CB2), "cryptocurrency price fluctuations" (CB3), "lack of robust cybersecurity strategies" (CC1), "difficulties balancing transparency, privacy, and regulatory compliance" (CC3), challenges in "client identity verification" (CC4) and "digital signature reliability" (CC5), "complexity and maintenance demands of blockchain technology" (CD2), "inability to amend errors once data is recorded" (CD5), and "challenges in achieving decentralized, inclusive, and secure governance" (CE4). These findings indicated that employees in different job positions perceived and prioritized these challenges differently, likely reflecting their diverse roles, responsibilities, and expertise.

Table 4.36: Mean Rank of Challenges of Implementing Blockchain in Property Management Across Job Positions

Code	Challenges of Implementing Blockchain in Property Management	Job Position	N	Mean Rank
CB1	High expenses for currency conversion, setup, and maintenance.	Junior Executive	42	47.63
		Senior Executive	**28**	**74.27**
		Manager/ Team Leader / Supervisor	34	66.16
		Assistant / Technical Director	6	49.58
		Director	6	26.50
CB2	Reduced illiquidity of property makes property a less profitable investment for investors	Junior Executive	42	54.70
		Senior Executive	**28**	**70.16**
		Manager/ Team Leader / Supervisor	34	58.76
		Assistant / Technical Director	6	61.92
		Director	6	25.75
CB3	Cryptocurrency price fluctuations make transaction costs unpredictable.	Junior Executive	42	53.93
		Senior Executive	**28**	**68.09**
		Manager/ Team Leader / Supervisor	34	62.82
		Assistant / Technical Director	6	50.83
		Director	6	28.92
CC1	Lack of robust cybersecurity strategies to protect data.	Junior Executive	42	48.82
		Senior Executive	28	66.41
		Manager/ Team Leader/ Supervisor	**34**	**69.15**

Table 4.36 (Continued)

Code	Challenges of Implementing Blockchain in Property Management	Job Position	N	Mean Rank
		Assistant / Technical Director	6	58.50
		Director	6	29.00
CC3	Difficult to balance transparency, privacy, and regulatory compliance.	Junior Executive	42	50.18
		Senior Executive	**28**	**69.21**
		Manager/ Team Leader / Supervisor	34	64.72
		Assistant / Technical Director	6	62.67
		Director	6	27.33
CC4	Difficult to identify and verify the client's identity while preserving privacy.	Junior Executive	42	54.56
		Senior Executive	**28**	**66.11**
		Manager/ Team Leader / Supervisor	34	64.63
		Assistant / Technical Director	6	47.67
		Director	6	26.67
CC5	Difficult to establish reliable digital identity and signature verification.	Junior Executive	42	51.49
		Senior Executive	**28**	**71.95**
		Manager/ Team Leader / Supervisor	34	63.66
		Assistant / Technical Director	6	39.50
		Director	6	34.58
CD2	The blockchain technology is too complex which requires high maintenance demand.]	Junior Executive	42	53.30
		Senior Executive	**28**	**68.84**
		Manager/ Team Leader / Supervisor	34	60.96
		Assistant / Technical Director	6	57.50
		Director	6	33.75
CD5	Difficult to amend errors once data was recorded	Junior Executive	42	51.85
		Senior Executive	**28**	**66.84**
		Manager/ Team Leader / Supervisor	34	66.63
		Assistant Director / Technical Director	6	49.75
		Director	6	28.83
CE4	Difficult to achieve decentralized, inclusive, and secure governance.	Junior Executive	42	58.54
		Senior Executive	**28**	**67.89**
		Manager/ Team Leader / Supervisor	34	59.22
		Assistant / Technical Director	6	42.67
		Director	6	26.17

Note: **Bold** indicates the highest mean rank

As presented in Table 4.36, significant differences were observed across job positions regarding perceptions of blockchain implementation challenges in property management. The results indicated that senior executives consistently recorded higher mean ranks across various challenges, including high expenses for currency conversion, setup and maintenance (CB1), reduced illiquidity making property less profitable (CB2), balancing transparency and privacy (CC3), transaction cost unpredictability due to cryptocurrency price fluctuations (CB3) digital identity verification (CC4, CC5), technical complexity (CD2), data immutability issues (CD5), and decentralized governance (CE4), with mean ranks of 74.27, 70.16, 68.09, 69.21, 66.11, 71.95, 68.84, 66.84, and 67.89 respectively. This finding suggested that senior executives had heightened awareness of the strategic risks, operational challenges, and governance complexities involved in blockchain implementation.

This result was consistent with the findings of Clohessy and Acton (2019) as well as Akoguhi and Bhavsingh (2023), who emphasized that top management typically assumed responsibility for evaluating blockchain's potential risks, including cost, cybersecurity, and compliance issues. Furthermore, the concern among senior executives about security and privacy challenges aligned with the observations of Clohessy and Acton (2019) as well as Hughes *et al.* (2019), who noted that blockchain's transparency features often conflicted with privacy regulations, thus requiring careful balancing by senior leadership.

Similarly, senior executives' concerns regarding technical rigidity, such as the difficulty in amending errors once recorded immutably (CD5), echoed Clohessy and Acton (2019) view that blockchain's irreversible nature posed technological risks that demanded cautious investment strategies. The governance challenges identified, such as difficulty in achieving decentralized and inclusive management (CE4), also aligned with Akoguhi and Bhavsingh (2023) who stressed that existing centralized corporate structures could conflict with blockchain's decentralized ideals.

However, a contrast was noted when compared to Zhou *et al.* (2020) who observed variability in top management's support for blockchain

initiatives, with some executives reportedly lacking commitment or clear policy direction for adoption. In contrast, the findings of this study suggested that senior executives demonstrated strong awareness and concern, implying more proactive strategic involvement compared to the context of Zhou *et al.* (2020).

Meanwhile, managers/team leaders and assistant/technical directors recorded the highest mean ranks for 'Lack of robust cybersecurity strategies to protect data' (CC1), suggesting that middle management was aware of blockchain's operational challenges but focused more on practicalities rather than strategic risks. This was supported by Clohessy and Acton (2019), who reported that middle management often played a bridging role, facilitating communication between top leadership and operational teams during technological adoption processes.

Interestingly, junior executives showed comparatively lower concern, indicating greater optimism or less perceived risk regarding blockchain adoption challenges. This differed from Zhou *et al.* (2020), who reported that junior-level staff were often more fearful about the complexity and potential disruptions caused by blockchain technology. The divergence could be due to differences in organizational culture, awareness levels, or maturity stages of blockchain adoption across industries.

In summary, the findings reinforced that senior executives' stronger concern toward blockchain implementation challenges was consistent with their strategic roles and responsibilities, as highlighted by previous research (Clohessy and Acton, 2019; Akoguhi and Bhavsingh, 2023). However, the variation in findings compared to Zhou *et al.* (2020) who emphasized that top management support for blockchain adoption could not be assumed universally, and tailored strategies were necessary to engage each organizational level effectively.

4.6.3.4 Kruskal-Wallis Test on Challenges of Implementing Blockchain Across Years of Experience

In this test, the following hypotheses are formulated:

Null hypothesis (H_0): There is no significant difference among years of experiences in their perceptions of the challenges in implementing blockchain in property management.

Alternative hypothesis (H_1): There is a significant difference among years of experiences in their perceptions of the challenges in implementing blockchain in property management.

Table 4.37: Kruskal-Wallis Test on Challenges of Adopting Blockchain in Property Management Across Years of Experience

Code	Challenges of Implementing Blockchain in Property Management	Kruskal-Wallis H	Mean Rank
CA2	Unclear legal status for tokenized property and data protection requirements.	13.901	0.016
CB1	High expenses for currency conversion, setup, and maintenance.	22.331	0.000
CB2	Reduced illiquidity of property makes property a less profitable investment for investors	11.690	0.039
CB3	Cryptocurrency price fluctuations make transaction costs unpredictable.	13.525	0.019
CC1	Lack of robust cybersecurity strategies to protect data.	19.638	0.001
CC3	Difficult to balance transparency, privacy, and regulatory compliance.	14.606	0.012
CC4	Difficult to identify and verify the client's identity while preserving privacy.	11.884	0.036
CC5	Difficult to establish reliable digital identity and signature verification.	15.214	0.009
CD3	Scalability issues limit real-time applications.	12.686	0.027
CD5	Difficult to amend errors once data was recorded	13.812	0.017
CE2	Lack of strong political and regulatory support.	11.723	0.039
CE4	Difficult to achieve decentralized, inclusive, and secure governance.	13.073	0.023

According to Table 4.37, significant differences exist in perceptions of the challenges of implementing blockchain in property management across different years of experience. These challenges include unclear legal status for tokenized property and data protection requirements (CA2), high expenses for

currency conversion, setup, and maintenance (CB1), reduced illiquidity making investment less profitable (CB2), and unpredictable transaction costs due to cryptocurrency price fluctuations (CB3). Other significant concerns are the lack of robust cybersecurity strategies (CC1), difficulties balancing transparency, privacy, and regulatory compliance (CC3), challenges in client identity verification (CC4), challenges in establishing reliable digital signatures (CC5), scalability issues limiting real-time applications (CD3), difficulties amending recorded data errors (CD5), lack of strong political and regulatory support (CE2), and challenges in achieving decentralized, inclusive, and secure governance (CE4). These findings suggested that perceptions of blockchain adoption challenges vary significantly depending on professionals' years of experience, highlighting the importance of tailoring solutions to address concerns relevant to different experience groups.

Table 4.38: Mean Rank of Challenges of Implementing Blockchain in Property Management Across Years of Experience

Code	Challenges of Implementing Blockchain in Property Management	Years of Experience	N	Mean Rank
CA2	Unclear legal status for tokenized property and data protection requirements.	Less than 6 years	70	55.51
		6-10 years	**21**	**80.90**
		11-15 years	19	54.08
		16-20 years	5	67.00
		21 years and above	4	48.25
CB1	High expenses for currency conversion, setup, and maintenance.	Less than 6 years	70	53.89
		6-10 years	21	75.79
		11-15 years	19	53.55
		16-20 years	**5**	**95.50**
		21 years and above	4	70.38
CB2	Reduced illiquidity of property makes property a less profitable investment for investors	Less than 6 years	70	54.70
		6-10 years	21	61.26
		11-15 years	19	66.18
		16-20 years	**5**	**100.50**
		21 years and above	4	66.13
CB3	Cryptocurrency price fluctuations make transaction costs unpredictable.	Less than 6 years	70	56.74
		6-10 years	**21**	**73.93**
		11-15 years	19	60.82
		16-20 years	5	52.10
		21 years and above	4	50.00
CC1	Lack of robust cybersecurity strategies to protect data.	Less than 6 years	70	52.48
		6-10 years	21	72.60

Table 4.38 (Continued)

Code	Challenges of Implementing Blockchain in Property Management	Years of Experience	N	Mean Rank
		11-15 years	**19**	**76.61**
		16-20 years	5	68.10
		21 years and above	4	36.50
CC3	Difficult to balance transparency, privacy, and regulatory compliance.	Less than 6 years	70	54.43
		6-10 years	21	71.76
		11-15 years	19	64.21
		16-20 years	**5**	**74.00**
		21 years and above	4	58.25
CC4	Difficult to identify and verify the client's identity while preserving privacy.	Less than 6 years	70	55.94
		6-10 years	21	68.29
		11-15 years	19	64.53
		16-20 years	**5**	**75.20**
		21 years and above	4	47.00
CC5	Difficult to establish reliable digital identity and signature verification.	Less than 6 years	70	54.95
		6-10 years	21	71.14
		11-15 years	19	57.92
		16-20 years	**5**	**93.20**
		21 years and above	4	58.25
CD3	Scalability issues limit real-time applications.	Less than 6 years	70	54.87
		6-10 years	21	68.19
		11-15 years	**19**	**74.32**
		16-20 years	5	55.50
		21 years and above	4	44.38
CD5	Difficult to amend errors once data was recorded	Less than 6 years	70	51.49
		6-10 years	**21**	**77.95**
		11-15 years	19	72.42
		16-20 years	5	57.50
		21 years and above	4	58.88
CE2	Lack of strong political and regulatory support.	Less than 6 years	70	59.01
		6-10 years	**21**	**71.90**
		11-15 years	19	50.16
		16-20 years	5	79.50
		21 years and above	4	37.25
CE4	Difficult to achieve decentralized, inclusive, and secure governance.	Less than 6 years	70	56.79
		6-10 years	**21**	**76.02**
		11-15 years	19	56.79
		16-20 years	5	59.50
		21 years and above	4	48.00

Note: **Bold** indicates the highest mean rank

Table 4.38 reported practitioners' perceptions of the challenges to implementing blockchain in property management, analysed across different

experience groups, technical constraints, and institutional challenges compared to other groups.

Respondents with 6 to 10 years of experience consistently assigned the highest concern to issues such as the unclear legal status of tokenized property and stringent data protection requirements (CA2), with a mean rank of 80.90. This heightened awareness arguably stemmed from their unique position bridging current property systems and emergent blockchain technologies, which made them acutely sensitive to regulatory uncertainties. This aligned with Garcia-Teruel (2020) who highlighted the pivotal role of clear legal frameworks for enabling blockchain implementation in real estate. Additionally, these mid-career professionals appeared to possess sufficient technological literacy and willingness to engage with innovations, as noted in studies like Zhou *et al.* (2020) which identified younger or mid-level experienced workers as more open to complex technologies but still aware of emerging risks.

Price volatility (CB3), which was another significant challenge flagged by the 6–10 years cohort with a mean rank of 73.93, underscored their recognition of financial unpredictability introduced by cryptocurrencies. This finding cohered with Konashevych (2020b) and Azari and Malek (2022) who observed that such fluctuations generated variable transaction costs and diminished stakeholder trust. Their concern suggested a pragmatic understanding of blockchain's economic risk layer at the operational level.

Technical limitations, particularly the challenge of amending errors on immutable ledgers (CD5), also figured prominently, with this group assigning a mean rank of 77.95. Hughes *et al.* (2019) similarly indicated that such technical rigidity could constrain operational flexibility, a reality that practitioners with enough blockchain interaction to experience these limitations naturally emphasized.

Institutional challenges were also highlighted, as the 6–10 years group demonstrated considerable apprehension about inadequate political and regulatory support (CE2), rating it with a mean rank of 71.90. They also assigned a mean rank of 76.02 regarding the challenge of achieving genuinely decentralized, inclusive governance (CE4). Their dual system exposure likely

sharpened their critique of existing governance structures, consistent with findings of Garcia-Teruel (2020) that institutional reform was a prerequisite for blockchain success.

In contrast, practitioners with 16 to 20 years of experience prioritized economic concerns, with mean ranks of 95.50 and 100.50 recorded for costs associated with currency conversion and system setup (CB1) and reduced liquidity impacting investor returns (CB2), respectively. These findings resonated with Clohessy and Acton (2019) as well as Akoguhi and Bhavsingh, (2023), emphasizing seasoned professionals' conservative, investment-centric perspectives. Alongside economic concerns, this group also expressed technical concerns regarding the balance between transparency and privacy (CC3), client identity verification (CC4), and digital signature reliability (CC5), with mean ranks of 74.00, 75.20, and 93.20. These concerns indicated an awareness of complex cybersecurity and compliance challenges, aligning with the discussion of Hughes *et al.* (2019) on the tension between blockchain's open nature and privacy requirements. This overall cautious stance was consistent with Dhraief *et al.* (2019) who explained that longer-tenured individuals tended to resist new technology adoption and preferred stable, familiar processes.

Moreover, the respondents with 16 to 20 years of experience also voiced pronounced apprehension about balancing transparency with privacy and regulatory compliance (CC3) as well as difficulties in identity verification (CC4) and digital signature reliability with mean ranks of 74.00, 75.20, and 93.20, respectively. These concerns indicated an awareness of complex cybersecurity and compliance challenges, aligning with discussion of Hughes *et al.* (2019) about the tension between blockchain's open nature and privacy requirements.

Conversely, the 11 to 15 years of experience group focused primarily on security and technical limitations. They attributed high importance to shortcomings in cybersecurity strategies (CC1) and scalability constraints affecting real-time blockchain applications (CD3), with mean ranks of 76.61 and 74.32, respectively. This reflected their active involvement in digital transformation efforts, aligning with Jaskula and Papadonikolaki (2021) who

emphasized middle management's role in addressing operational issues amid technological change.

Interestingly, the group with less than 6 years of experience showed relatively low attention in most challenges. Their lower mean ranks could be due to limited exposure to legacy system failures or an optimistic view stemming from greater familiarity and comfort with emerging technologies such as blockchain. Meanwhile, those with over 21 years of experience often reported the lowest mean ranks on many challenges, which may reflect either a more cautious, traditional outlook or greater reliance on established systems rather than emerging blockchain solutions.

In conclusion, practitioners with 6 to 20 years of experience demonstrated the most critical evaluation of blockchain implementation challenges in property management. Their combination of exposure to both inefficiencies and emerging technological realities gave them a comprehensive understanding of the legal, economic, technical, and institutional challenges that had to be overcome. These findings aligned with Garcia-Teruel (2020), Hughes *et al.* (2019), and Akoguhi and Bhavsingh (2023). Meanwhile, the varying levels of concern among less and more experienced cohorts underscored the role of professional experience in shaping perceptions towards blockchain technologies in the property sector. This was supported by Zhou *et al.* (2020), who emphasize the need for training and managerial support to bridge experience-related gaps in blockchain adoption, which also supported the findings of Alant and Bakare's (2021) observation that greater experience often correlated with lower technological readiness.

4.7 Spearman's Correlation Test

This section consists of the findings of the Spearman's correlation analysis, which was conducted to investigate the relationships between inefficiencies in property management and blockchain-enabled potentials, as well as the correlations between blockchain potentials and adoption challenges.

4.7.1 Inefficiencies and Potential of Blockchain in Property Management

According to Table 4.39, the analysis showed significant positive correlations between inefficiencies in property and blockchain-enabled potentials. These results explain how blockchain technology directly addresses longstanding challenges in the property sector by targeting the root causes of these inefficiencies.

Additionally, the lack of transparency in property transactions (TB1) correlated moderately at 0.449 with blockchain-enabled ownership visibility (PB1). This connection existed because property transactions often involved opaque ownership chains and unverifiable records, increasing fraud risk and reducing trust. Blockchain's immutable distributed ledger increases ownership visibility for all parties, preventing unauthorized changes, as emphasized by Hoxha and Sadiku (2019). Furthermore, blockchain's smart contracts automate verification processes, reducing human error and speeding transactions, which was demonstrated by Joshi and Choudhury (2022). The disintermediation effect also enhances transparency and reduces transaction costs by facilitating direct owner-to-buyer interactions, an advantage supported by Hoxha and Sadiku (2019). Nonetheless, moderate correlations suggest that further factors, such as regulatory challenges and legacy systems, affect the full deployment of these potential (Guerriero, 2023).

Unresolved land ownership disputes (TA4) showed a moderate positive correlation of 0.436 with blockchain-enabled decentralized governance (PE5). This correlation existed because land administration suffered from siloed data and opaque processes, which led to corruption and errors. Blockchain's decentralized and immutable ledger created a shared, tamper-proof database accessible to all stakeholders, increasing transparency and reducing opportunities for fraud and manipulation. This interpretation was supported by Ameyaw and Vries (2020) who highlighted corruption risks due to poor record-keeping, and was consistent with Banerjee *et al.* (2022) who stated blockchain enhanced trust through public verifiability. Furthermore, these findings aligned with Shuaib et al. (2022), who confirmed blockchain's suitability for improving land governance. Moreover, blockchain-enabled

smart contracts automated administrative processes, helping overcome the inefficiencies of manual paperwork, as noted by Thakur *et al.* (2020). Additionally, blockchain reliably preserved comprehensive ownership histories, reducing disputes caused by incomplete records, as supported by (Christine *et al.*, 2022).

Market volatility in property financialization (TE4) correlated moderately at 0.442 and 0.406 with the potential of blockchain, such as fractional ownership (PE2) and reduced investment costs (PE3). This relationship exists because property investment markets have high entry barriers and lack transparency, excluding many potential investors. Blockchain tokenization divides large property assets into smaller, tradable shares, democratizing access and improving liquidity, a concept supported by Hughes *et al* (2019). Blockchain's transparent ledger provides accurate valuations and reduces information asymmetry, increasing investor confidence as stated by Christophersb (2019). Decentralized governance limits market manipulation by distributing control, stabilizing prices, and enhancing affordability, also according to Hughes *et al* (2019). These blockchain features effectively address core financialization inefficiencies in property markets.

Finally, blockchain potentials related to property maintenance aligned with green principles (TF6) correlated moderately at 0.418 with blockchain-enabled predictive maintenance (PF4). This correlation arose because maintenance suffered from fragmented record keeping, inefficient scheduling, and poor lifecycle oversight that hindered sustainability efforts. Blockchain's immutable ledger consolidated maintenance records, improving transparency and compliance with environmental standards, as noted by Aliti *et al.* (2023). Automated smart contracts schedule and trigger maintenance tasks efficiently, reducing environmental impact Collins and Lindkvist (2022). Asset lifecycle tracking verifies adherence to green standards over time, consistent with findings by Jaskula and Papadonikolaki (2021). Predictive maintenance, informed by historical blockchain data, enables proactive issue resolution, minimizing waste and resource consumption, in line with Rahman *et al.* (2023). These features align with research by Fateye *et al.* (2023) demonstrating blockchain's potential in sustainable property management.

In summary, lack of transparency in property transactions (TB3) emerged as the most pervasive inefficiency, with 22 significant correlations. This finding was consistent with Thakur *et al.* (2020), who described transparency issues as central challenges across land administration, leasing, financialization, and broader property management. Blockchain's decentralized and immutable ledger provided real-time, verifiable access to ownership and transaction data. This reduced fraud risks and over-reliance on intermediaries, as supported by Bhanushali *et al.* (2020). The foundational role of blockchain in enhancing data traceability, automating verification, decentralizing governance, and securing recordkeeping explained its broadest correlations with blockchain potentials (Junaid *et al.*, 2024).

Among blockchain potentials, blockchain-enabled predictive maintenance (PF4) and decentralized governance (PE5) showed the strongest correlations with property management inefficiencies, with 23 and 21 significant correlations, respectively. Predictive maintenance improved resource use and maintenance management by leveraging real-time data and smart contracts to anticipate and automate upkeep, reducing costs, downtime, and information fragmentation, as supported by Junaid *et al.* (2024). Meanwhile, decentralized governance enhanced transparency and trust through secure, participatory decision-making among stakeholders, reducing inefficiencies tied to centralized intermediaries in leasing, land management, and transactions, as agreed by Garcia-Teruel (2020). This approach fostered collaboration and accountability, streamlining dispute resolution and administrative processes. Together, these potentials addressed fundamental inefficiencies across land administration, leasing, property transactions, financialization, and maintenance, highlighting blockchain's potential on creating more efficient and trustworthy property management systems.

Table 4.39: Correlation between Inefficiencies and Potential of Blockchain in Property Management

Inefficiencies \ Potential	PA1	PA2	PA3	PA4	PB1	PB2	PB3	PC1	PC2	PC3	PD1	PD2	PD3	PD4	PE1	PE2	PE3	PE4	PE5	PE6	PF1	PF2	PF3	PF4	TOTAL COLLERATIONS
TA1	-	-	-	.270**	.203*	-	-	-	-	-	.221*	.345**	.283**	.187*	.320**	.368**	.303**	.326**	.213*	.360**	-	.255**	.318**	.267**	15
TA2	-	-	.217*	.242**	-	.229*	-	.186*	.240**	.298**	.299**	.320**	.267**	-	-	.249**	-	.277**	.268**	-	.336**	.317**	.295**	.246**	16
TA3	.189*	.225*	.267**	.208*	-	.200*	.233*	.230*	.185*	-	.206*	-	.225*	.211*	.206*	-	-	-	.298**	-	.208*	.226*	.190*	.251**	17
TA4	.190*	.274**	.299**	.189*	-	-	.246**	.183*	.239**	.225*	.294**	-	-	-	-	-	-	.200*	.269**	-	**.436****	.303**	-	.278**	14
TA5	-	-	-	-	-	.226*	-	-	-	-	-	-	-	-	.259**	-	-	-	.251**	.321**	-	-	.204*	-	5
TA6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.219*	.237**	-	-	-	.214*	.310**	.279**	-	.227*	6
TB1	.338**	-	.293**	-	.272**	**.449****	-	.309**	-	-	.208*	-	.228*	.258**	.244**	.270**	-	.225*	.362**	.264**	.222*	.219*	.376**	.261**	17
TB2	-	.183*	.221*	.281**	.195*	.189*	**.412****	.327**	.288**	-	.219*	-	-	-	-	.203*	-	-	-	.241**	.377**	.282**	-	-	13
TB3	.256**	.251**	-	.298**	.266**	.228*	.302**	.351**	.291**	.250**	-	.237**	.335**	.320**	.312**	.334**	.334**	.250**	.315**	.303**	.348**	.355**	.283**	.316**	**22**
TB4	-	-	-	-	-	-	-	-	.195*	.213*	.189*	.241**	.266**	.181*	.219*	.293**	-	.253**	.229*	-	.253**	-	.184*	.185*	13
TB5	-	-	-	-	-	-	-	-	-	.182*	.251**	-	.195*	.194*	-	.227*	.251**	.259**	.195*	-	-	.193*	-	.283**	10
TC1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.203*	-	-	-	-	-	-	-	1
TC2	-	-	-	-	-	-	-	-	-	-	-	-	.199*	.276**	.293**	.211*	-	-	-	-	-	-	.225*	-	5
TC3	-	-	-	.186*	-	-	.217*	-	-	-	-	-	-	-	-	-	.218*	-	-	.182*	-	-	-	-	4
TC4	-	.220*	-	.198*	-	-	.200*	.197*	-	-	.217*	-	-	-	.228*	.221*	.204*	.186*	.261**	.275**	.189*	-	-	.190*	13

Table 4.39 (Continued)

Inefficiencies / Potential	PA1	PA2	PA3	PA4	PB1	PB2	PB3	PC1	PC2	PC3	PD1	PD2	PD3	PD4	PE1	PE2	PE3	PE4	PE5	PE6	PF1	PF2	PF3	PF4	TOTAL COLLERATIONS
TD1	-	.238**	-	.205*	.220*	-	.245**	.222*	-	-	.218*	-	-	-	.275**	.260**	.302**	-	.194*	.215*	.221*	.233*	-	.254**	14
TD2	.202*	-	-	.225*	.303**	.208*	-	.190*	-	-	-	.297**	.242**	.190*	.218*	.260**	.193*	-	.274**	-	-	.222*	.232*	.262**	15
TD3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.195*	-	-	-	.253**	-	-	-	.186*	3
TE1	-	-	.239**	.282**	.249**	-	.372**	.227*	-	-	.224*	-	-	-	.231*	.266**	.344**	-	-	-	.346**	.302**	-	.286**	12
TE2	-	-	-	-	.300**	-	-	-	-	-	.217*	.306**	.282**	.262**	.244**	.189*	.269**	.221*	.313**	.321**	-	-	.300**	.313**	13
TE3	.243**	.228*	-	-	.307**	-	-	-	-	-	.181*	.289**	.358**	.273**	-	-	-	-	.189*	.206*	.258**	.188*	.344**	.301**	13
TE4	.206*	.224*	.201*	-	-	.288**	.230*	.234*	-	-	.284**	**.442****	.406**	.346**	.189*	-	.280**	.269**	**.412****	.310**	.320**	.263**	.304**	.399**	19
TF1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.190*	-	-	.188*	.208*	.291**	4
TF2	-	-	.282**	-	-	.237**	-	-	-	-	-	.257**	.314**	-	-	-	-	-	.202*	-	.233*	-	.312**	.259**	8
TF3	-	-	-	-	.291**	.233*	.220*	.256**	-	-	.184*	.262**	.282**	.261**	-	-	-	-	.279**	-	.221*	.235*	.278**	.305**	13
TF4	-	-	-	-	-	-	.241**	.249**	-	-	-	-	-	-	-	-	-	-	.183*	-	-	-	-	.244**	4
TF5	-	-	-	-	.218*	.199*	.235*	.258**	-	-	-	-	.210*	-	.181*	.182*	.201*	.271**	.347**	.246**	-	-	.212*	.328**	13
TF6	.323**	.320**	.209*	-	-	.256**	.222*	.299**	-	.228*	-	-	.263**	-	-	-	.190*	.221*	.397**	-	.184*	.212*	.273**	**.418****	15
Total Correlations	8	9	9	11	11	12	13	15	6	6	15	10	16	12	15	16	13	12	21	14	16	17	17	**23**	

Note: ** denote significance of correlation at the 0.01 level (two-tailed).

*. denote significance of correlation at the 0.05 level (2-tailed).

4.7.2 Potential of Blockchain in Property Management and Challenges While Implementing

According to Table 4.40, the analysis revealed significant negative correlations between blockchain-enabled potentials and security challenges in property management. These findings highlighted how blockchain's innovative features encountered fundamental limitations in digital identity verification and data management, revealing critical trade-offs in technological implementation.

The blockchain potential granting specific access rights (PD2) demonstrated the strongest negative correlation with the challenge of establishing reliable digital identity and signature verification (CC5). with a correlation value of –0.323. This relationship emerged because blockchain's access control mechanisms fundamentally relied on digital identity verification, which proved inherently problematic. While blockchain could precisely define access rights, the underlying identity verification mechanisms remained vulnerable. As Sharma, Isah and Rana (2024) noted, the decentralized nature of blockchain meant that centralized authentication methods became ineffective, creating a fundamental tension between granular access control and reliable digital identity establishment across a distributed network.

Furthermore, decentralizing and improving data storage and retrieval (PA2) also showed a notable negative correlation of –0.305 with the challenge of digital identity and signature verification challenge (CC5). The correlation arose from the fundamental conflict between decentralization and identity verification. Dispersing data storage across multiple nodes created significant challenges in maintaining consistent and reliable user authentication (Gao *et al.*, 2023). While decentralization enhanced data transparency and reduced single points of failure, it simultaneously complicated the process of verifying user identities. Daniel and Speranza (2020) explained that cryptographic mechanisms, though designed for security, became potential weak points when key management proved inconsistent or vulnerable to compromise, ultimately undermining the system's reliability.

Similarly, secure record storage with real-time access (PD1) correlated negatively with this challenge (CC5) at –0.311, revealing critical

vulnerabilities in blockchain's record management systems. The effectiveness of secure record storage depended entirely on the reliability of digital identity verification. Akoguhi and Bhavsingh (2023) highlighted a fundamental paradox: while blockchain could provide immutable and instantly accessible records, the authentication mechanisms determining access and modification remained fundamentally unreliable. This weakness potentially undermined the entire security infrastructure of blockchain-based property management systems, exposing a critical gap between technological potential and practical implementation.

The challenge such as difficulties in establishing reliable digital identity and signature verification (CC5) emerged as particularly significant, featuring 24 distinct negative correlations. Hughes *et al.* (2019) and Zulkifli and Abidin (2024) argued that this challenge stemmed from blockchain's decentralized architecture, which lacked a centralized authority for comprehensive identity verification. The distributed nature of blockchain meant that no single entity could definitively validate user identities, creating systemic vulnerabilities in authentication processes that challenged the technology's core promise of security and transparency.

Simultaneously, technical limitations in amending recorded data (CD5) showed 24 significant negative correlations, highlighting another fundamental challenge. Hutson *et al.* (2023) explained that blockchain's immutability, while beneficial for maintaining data integrity, created significant operational challenges. The inability to easily correct errors or adapt to changing regulatory requirements meant that even legitimate modifications became extremely difficult, potentially creating long-term complications in property management systems.

Together, these findings demonstrate a fundamental trade-off in blockchain technology. As Konashevych (2020b) argued, the features that made blockchain attractive such as decentralization, immutability, and distributed control simultaneously created significant challenges in maintaining robust security and flexibility. This observation underscored the complex nature of blockchain adoption in property management.

In conclusion, the analysis suggested that blockchain's transformative potential in property management remained constrained by critical challenges in digital identity verification and data management. The negative correlations did not invalidate blockchain's promise but instead highlighted the urgent need for more sophisticated identity verification protocols, flexible yet secure data modification mechanisms, and advanced cryptographic techniques that could address these fundamental limitations. Continued research and development were crucial to bridging the gap between blockchain's theoretical benefits and its practical implementation in property management.

Table 4.40: Correlation between Potential and Challenges of Implementing Blockchain in Property Management

Potential \ Challenges	CA1	CA2	CA3	CA4	CB1	CB2	CB3	CC1	CC2	CC3	CC4	CC5	CD1	CD2	CD3	CD4	CD5	CE1	CE2	CE3	CE4	TOTAL COLLERATIONS
PA1	-	-.226*	-	-	-	-	-	-.239**	-	-.186*	-.201*	-.280**	-.279**	-.190*	-.210*	-.241**	-.232*	-.239**	-.208*	-.234*	-.245**	14
PA2	-	-.238**	-	-	-	-	-	-.255**	-	-.182*	-.234*	-.305**	-.257**	-.189*	-.236**	-.233*	-.263**	-.251**	-.200*	-.240**	-.253**	14
PA3	-	-.187*	-	-	-	-	-	-.202*	-	-	-.189*	-.262**	-.292**	-	-.223*	-.203*	-.231*	-.207*	-.188*	-.208*	-.236**	12
PA4	-	-	-	-	-	-	-	-.208*	-	-	-.186*	-.259**	-.273**	-	-.213*	-.200*	-.229*	-	-	-.182*	-.208*	9
PB1	-	-.187*	-	-	-	-	-	-.186*	-	-	-	-.256**	-.257**	-	-.194*	-.184*	-.216*	-.189*	-	-.200*	-.229*	10
PB2	-	-	-	-	-	-	-	-.184*	-	-	-	-.245**	-.204*	-	-	-.189*	-.228*	-	-	-.187*	-	6
PB3	-	-	-	-	-	-	-	-	-	-	-	-.200*	-.210*	-	-	-	-.192*	-	-	-.192*	-	4
PC1	-	-.191*	-	-	-	-	-	-.185*	-	-	-	-.226*	-.230*	-.182*	-.228*	-.207*	-.239**	-	-	-.190*	-.252**	10
PC2	-	-.182*	-	-	-	-	-	-.181*	-	-	-	-.219*	-.230*	-.189*	-.227*	-.207*	-.244**	-	-	-.192*	-.248**	10
PC3	-	-	-	-	-	-	-	-.181*	-	-	-	-.245**	-.200*	-.189*	-.224*	-.231*	-.272**	-	-	-	-.191*	8
PD1	-	-.261**	-	-	-	-	-	-.269**	-	-.203*	-.240**	-.311**	-.213*	-	-.236**	-.277**	-.275**	-.245**	-	-.232*	-.244**	12
PD2	-	-.278**	-.181*	-	-	-	-	-.288**	-	-.214*	-.258**	-.323**	-.222*	-	-.256**	-.279**	-.283**	-.269**	-	-.259**	-.264**	13
PD3	-	-.238**	-	-	-	-	-	-.255**	-	-.206*	-.211*	-.282**	-.219*	-	-.215*	-.253**	-.251**	-.237**	-	-.249**	-.236**	12
PD4	-	-.251**	-.191*	-	-	-	-	-.257**	-	-.195*	-.229*	-.294**	-.208*	-	-.229*	-.275**	-.288**	-.238**	-	-.231*	-.235*	13
PE1	-	-.204*	-	-	-	-	-	-.216*	-	-	-	-.264**	-.203*	-	-.200*	-.248**	-.262**	-	-	-	-.196*	8

Table 4.40 (Continued)

Potential \ Challenge	CA1	CA2	CA3	CA4	CB1	CB2	CB3	CC1	CC2	CC3	CC4	CC5	CD1	CD2	CD3	CD4	CD5	CE1	CE2	CE3	CE4	TOTAL COLLERATIOS
PE2	-	-.187*	-	-.183*	-	-	-	-.184*	-	-.186*	-	-.230*	-.238**	-	-.202*	-.234*	-.227*	-.183*	-	-.210*	-.243**	12
PE3	-	-.185*	-	-	-	-	-	-.187*	-	-	-	-.234*	-.198*	-	-	-.234*	-.246**	-	-	-.186*	-.201*	8
PE4	-	-.206*	-	-	-	-	-	-.211*	-	-	-.186*	-.258**	-.196*	-	-.187*	-.255**	-.261**	-.203*	-	-.202*	-.206*	11
PE5	-	-.189*	-	-	-	-	-	-.180*	-	-	-	-.250**	-	-	-	-.225*	-.268**	-	-	-	-	5
PE6	-	-.194*	-	-	-	-	-	-.190*	-	-	-.187*	-.257**	-	-	-.184*	-.253**	-.268**	-.183*	-	-	-	8
PF1	-	-.201*	-	-	-	-	-	-.206*	-	-	-.188*	-.234*	-.216*	-	-.217*	-.225*	-.221*	-.188*	-	-.224*	-.265**	11
PF2	-	-.210*	-	-	-	-	-	-.221*	-	-	-.200*	-.253**	-.188*	-	-.201*	-.267**	-.280**	-.200*	-	-.198*	-.209*	11
PF3	-	-.207*	-	-	-	-	-	-.234*	-	-.182*	-.199*	-.246**	-.191*	-	-.201*	-.237**	-.239**	-.213*	-	-.235**	-.217*	12
PF4	-	-.232*	-	-	-	-	-	-.250**	-	-.205*	-.246**	-.284**	-.208*	-	-.239**	-.262**	-.258**	-.228*	-	-.225*	-.239**	12
Total Correlations	0	20	2	1	0	0	0	23	0	9	14	24	22	5	20	23	24	15	3	20	20	-

Note: ** denote significance of correlation at the 0.01 level (two-tailed).

*. denote significance of correlation at the 0.05 level (2-tailed).

4.8 Summary of Chapter

This chapter provides a comprehensive discussion of the inefficiencies in property management, the potential of blockchain in property management, and the challenges associated with implementing blockchain. A total of 123 questionnaires were returned, but 4 sets were excluded due to insufficient experience, as these respondents were interns. The data were analyzed using Cronbach's Alpha Reliability Test, Arithmetic Mean, Mann-Whitney U Test, Kruskal-Wallis Test, and Spearman's Correlation Test. The results from the Arithmetic Mean revealed that, among inefficiencies and blockchain potentials, "property maintenance (PF)" was highly agreed upon, whereas "land administration (PA)" received less agreement. Regarding blockchain implementation challenges, "Legal and Regulatory Challenges (CA)" was highly agreed upon, while "Institutional Challenges (CE)" was less agreed. Moreover, the study found that the public sector placed greater emphasis on transparency, governance, and regulatory challenges compared to the private sector. Significant differences in inefficiencies, blockchain potentials, and implementation challenges were observed across demographic variables such as age, years of experience, job position, and company size. Spearman's Correlation test showed that transparency in property transactions was the most significant inefficiency, predictive maintenance the most promising blockchain potential, and cybersecurity weaknesses alongside smart contract inflexibility were the most critical challenges affecting adoption

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter serves as the conclusion of the research. It outlines the accomplishment of the three stated objectives. Furthermore, the contributions, limitations, and recommendations of this study are examined and discussed. Finally, a summary of the chapter is provided.

5.2 The Accomplishment of Research Objectives

The property management sector in Malaysia is facing significant challenges due to current practices, especially in the context of modern advancements in construction. As the industry navigates issues such as lengthy verification processes, lack of transparency in property ownership, and security concerns, the adoption of blockchain technology presents a promising solution. However, despite its potential to improve efficiency and build trust within property management, the use of blockchain in Malaysia is still limited.

Prior research has mainly focused on specific uses of blockchain, such as property transactions and land registration. This narrow focus has created a gap in understanding how blockchain can be integrated into the entire property management process. Additionally, much of the existing research has been conducted in other countries, leading to a lack of clarity on how blockchain can be applied effectively in Malaysia's unique property environment. As a result, this study aims to explore the potential for adopting blockchain technology in the property management sector in Malaysia. To achieve this goal, three specific objectives have been outlined.

5.2.1 Objective 1: To Identify Inefficiencies Faced in Property Management Practice

For objective 1, the findings revealed that property maintenance (TF) is perceived as the most severe inefficiency. This is particularly evident in issues such as awareness gaps among residents (TF3) and the deterioration of

buildings over time (TF2). In contrast, land administration (TA) was regarded as the least critical area of concern, with respondents expressing relatively low levels of apprehension regarding weak governance (TA6) and discriminatory access to land ownership (TA5).

Additionally, substantial differences emerged between the public and private sectors. Public sector respondents consistently rated inefficiencies such as such as market transparency issues (TE2), speculative price inflation (TE3), market volatility (TE4), inadequate maintenance (TF1), building deterioration over time (TF2), poor stakeholder communication (TF5), and lack of green maintenance practices (TF6) higher than their private sector counterparts. This discrepancy suggests that the public sector is more acutely aware of the systemic challenges facing property management.

Demographic analysis revealed significant variations in perceptions of inefficiencies. Older respondents, aged 41 and above, tended to focus on administrative inefficiencies, particularly issues stemming from outdated paper-based processes. Mid-career respondents, particularly those in the 36-40 age bracket, prioritized challenges around market transparency and maintenance issues. Meanwhile, younger cohorts, specifically those aged 26-30, exhibited heightened concern regarding the risks associated with fraud in property transactions.

Further differentiation in perceptions was noted based on company size. Micro firms demonstrated the greatest sensitivity to trust and transparency issues, while medium-sized firms were more concerned with operational and financial inefficiencies. In contrast, larger firms exhibited less sensitivity to these problems, likely due to the presence of more formalized systems and processes that mitigate these inefficiencies.

Job positions also played a significant role in shaping perceptions of inefficiencies. Senior executives placed greater emphasis on strategic inefficiencies tied to costs and trust issues, while assistant and technical directors highlighted maintenance and sustainability challenges. Managers and supervisors articulated balanced concerns that reflected their intermediary roles within organizational hierarchies. Additionally, professionals with over 16 years of experience were able to discern persistent systemic problems,

including unresolved disputes and costly, outdated processes, more acutely than their less experienced peers.

The Spearman's correlation analysis further highlighted the interconnectivity of property transaction-related inefficiencies, specifically the lack of transparency in property transactions (TB3), which exhibited 22 significant correlations with various potential blockchain benefits. This finding suggests that improving transparency in property transactions is a pivotal factor that could address multiple inefficiencies and should be a primary focus for any reform or technological adoption strategy.

5.2.2 Objective 2: To Identify the Potential of Adopting Blockchain Technology in Property Management in Malaysia

For Objective 2, blockchain-enabled transparent asset lifecycle tracking (PF3) and secure real-time record storage (PD2) were perceived as the most promising potentials. Conversely, blockchain financialization improving housing affordability (PE6) and enhanced traceability of land ownership (PA1) received the lowest mean rankings. These results indicate that while blockchain is recognized for its potential to improve transparency and data security, its impact on affordability and ownership traceability is perceived as less significant within the sector.

Public sector respondents rated blockchain potentials such as ownership visibility (PB1), verification automation (PB2), secure rental payments (PC3), access rights (PD1), real-time record storage (PD2), transparent decision-making (PD3), payment streamlining (PD4), fractional ownership (PE1), decentralized governance (PE5), financialization for affordability (PE6), transparent asset tracking (PF3), and predictive maintenance (PF4) significantly higher than private sector respondents. This suggests greater public sector recognition of blockchain's transformative potential in property management. This suggests that public sector practitioners may be more inclined to recognize the transformative potential of blockchain technology in enhancing transparency, security, and accessibility in property management.

Demographic influences also shaped views on blockchain potential. Younger to early-mid career respondents, aged 26-35, exhibited the most enthusiasm for operational improvements, particularly regarding smart contracts that automate lease agreements (PC2) and maintenance processes (PF2). Conversely, older respondents (41 and over) placed greater importance on transparency and accuracy in property valuation (PE4), reflecting their concerns about established processes and regulations.

The size of the company further affected perceptions of blockchain advantages. Medium-sized firms demonstrated the strongest recognition of blockchain's benefits, particularly in relation to enhancing ownership visibility (PB3), enabling decentralized governance (PE5), improving housing affordability through financialization (PE6), and optimizing resource use through predictive maintenance (PF4). This may reflect a balance of operational flexibility and resource availability that allows these firms to leverage new technologies effectively.

Job position also influenced how blockchain's potential was viewed within organizations. Senior executives exhibited the highest appreciation for blockchain's strategic applications, especially concerning fractional ownership (PE1), liquidity enhancement (PE2), cost reduction (PE3), and governance improvements (PE5). On the other hand, assistant and technical directors responded with moderate levels of agreement, especially on issues related to cost-effectiveness and valuation accuracy.

The Spearman's correlation analysis reinforced these insights, identifying PF4 (predictive maintenance) as the most strongly linked potential, with 23 significant positive correlations to various inefficiencies. This underscores its critical role in addressing core operational challenges, particularly in the realm of property maintenance, and reflects the increasing interest among practitioners in utilizing blockchain for proactive asset management. Conversely, two critical potentials associated with land administration, which were blockchain enhances the traceability of land ownership (PA1) and blockchain can decentralize and improve data storage and retrieval (PA2), showed significant negative correlations with 14 implementation challenges each. These negative correlations indicate that

despite their importance for improving transparency and security in land records, these potentials confront substantial challenges to implementation. Challenges such as unclear legal frameworks, cybersecurity vulnerabilities, and difficulties in governance need to be addressed to fully realize the benefits of these blockchain applications.

5.2.3 Objective 3: To Discover the Challenges of Implementing Blockchain Technology in Property Management

The findings for objective 3 revealed that technical limitations topped the list of concerns, with lack of standardized protocols and interoperability between blockchain platforms (CD1) ranking highest. Security and privacy challenges, including difficulties in balancing transparency with regulatory compliance (CC3) and establishing reliable digital identity verification (CC5), tied for second place. While legal and regulatory issues were significant, they ranked lower in priority, with challenges such as difficulties in integrating blockchain with existing legal systems (CA1) ranking 20th out of 21 individual challenges. Similarly, institutional challenges like achieving decentralized governance (CE4) and aligning with social and ethical aims (CE3) ranked in the middle to lower tiers. This underscores that professionals prioritized resolving foundational technical infrastructure and security concerns before addressing regulatory harmonization and institutional transformation

Differences in sector employment were notable in perceptions of implementation challenges. Public sector respondents viewed challenges such as cryptocurrency price fluctuations causing unpredictable transaction costs (CB3), lack of robust cybersecurity strategies (CC1), concerns over trust and data privacy (CC2), difficulties balancing transparency, privacy, and regulatory compliance (CC3), smart contract rigidity affecting enforceability (CD4), and inability to amend recorded errors (CD5) as more severe than their private sector counterparts. This suggests that public sector stakeholders may prioritize addressing these challenges to ensure safer and more compliant blockchain implementation.

Demographic analyses showed additional insights into how different groups perceive these challenges. For instance, mid-career professionals (ages

36–40) expressed the strongest concerns regarding cybersecurity (CC1), smart contract inflexibility (CD4), and the challenges of data immutability (CD5). Meanwhile, the 31–35 age group emphasized institutional and governance difficulties (CE3, CE4).

Company size played a decisive role as well, with small companies facing significant governance challenges (CE4), likely due to their limited resources and capacity. Job position affected awareness and concern levels, with senior executives reporting heightened awareness of strategic challenges, including high costs associated with blockchain setup and maintenance (CB1), identity verification issues (CC4, CC5), and governance complexities (CE4). Middle management exhibited moderate levels of concern, while junior staff tended to show less apprehension, indicating either a lack of awareness or optimism regarding blockchain adoption.

Among the various challenges identified, Spearman's correlation analysis found that difficulties in establishing a reliable digital identity and signature verification (CC5) and technical limitations in amending recorded data (CD5) had the most negative correlations, totalling 24 with blockchain adoption potentials. These challenges emerged as principal barriers to effective implementation and underscore the urgent need for focused improvements in security measures, privacy protocols, and more flexible technological solutions capable of adapting to the dynamic requirements of property management.

5.3 Research Contributions

This study contributes to the field of property management by examining how blockchain technology can be applied at different stages of the property management process in Malaysia. Unlike previous research that focuses on specific areas such as property transactions, land registration, or rental agreements, this study takes a broader approach by analyzing blockchain's role in the entire lifecycle, from property acquisition to maintenance and resale. By addressing this gap, the study highlights how blockchain can improve transparency, security, and efficiency in property management, making it a valuable resource for developers and industry stakeholders. Additionally, the comprehensive approach and robust statistical analysis provide a valuable

foundation for future academic research in blockchain adoption in property management.

By applying Kruskal-Wallis, Mann-Whitney U, and Spearman's correlation tests, this study reveals significant differences and relationships in blockchain acceptance across diverse demographic groups, including sector of employment, company size, job position, age, and years of professional experience. These findings offer nuanced insights into how different segments perceive blockchain technology within Malaysia's property management sector. For industry practitioners, the results inform the design and deployment of blockchain solutions aligned with varying stakeholder needs. Policymakers and organizations can leverage these insights to develop targeted educational campaigns, supportive policies, and incentives that foster wider adoption of blockchain technology, ultimately advancing efficiency and transparency in Malaysia's property management industry.

More specifically, this research examines inefficiencies, blockchain potentials, and implementation challenges in an integrated manner. It identifies key inefficiencies in property maintenance and transparency and highlights valuable blockchain capabilities like transparent asset lifecycle tracking and predictive maintenance. Additionally, the study provides clear direction for government regulatory reform and capacity-building initiatives to address significant legal, regulatory, institutional, cybersecurity, and technical challenges, especially affecting public sector professionals. Such reforms are essential for creating an enabling environment that supports blockchain adoption, ultimately enhancing efficiency and transparency in Malaysia's property management sector.

5.4 Research Limitations

While this study offers important insights, it has several limitations that should be acknowledged. One of the main limitations is its geographical focus on Klang Valley, Malaysia. Since property management practices and blockchain adoption may vary in different parts of the country, the findings may not fully represent the broader real estate sector. Developers in other states may have different challenges, or levels of adoption. Therefore, the results of this study

may not be applicable to the entire country. Future research should expand the study to include property developers from multiple regions to provide a more comprehensive understanding of blockchain adoption.

Another limitation of this study is its reliance on a purely quantitative research approach. Surveys are useful for collecting measurable data, but they do not capture detailed insights into the experiences and perspectives of developers. Factors such as personal opinions, and real-world challenges cannot always be fully understood through numerical data alone.

Additionally, the study depends on self-reported data from developers, which may introduce bias or inaccuracies. Respondents may unintentionally overestimate or underestimate their actual blockchain adoption levels due to misunderstandings, personal biases, or external pressures. This could lead to discrepancies between reported and actual blockchain adoption rates.

Another specific limitation is the lack of multi-stakeholder perspectives. The study emphasizes the developer viewpoint, which, although important, does not fully capture the views and attitudes of other key players such as tenants, government bodies, legal authorities, and technology providers. As blockchain implementation requires cross-sector collaboration, excluding these perspectives narrows the scope of analysis.

Moreover, although the study outlines key blockchain features, it does not delve into a comparative evaluation of blockchain platforms (e.g., Ethereum vs. Hyperledger), which limits understanding of which technologies are most suitable for various property management functions. Similarly, while property financialization is identified as a potential area, the treatment of topics like real estate crowdfunding, and blockchain-based REITs remains relatively brief.

Finally, the field of blockchain in property management is still evolving, particularly in Malaysia where real-world implementations remain limited. As such, the findings are more conceptual than evidence-based, which may affect their practical transferability. Additionally, the search terms used during the literature review were somewhat limited and may have excluded relevant studies. For example, keywords like “smart contract” were not included, which could have helped capture additional important papers.

5.5 Research Recommendations

To overcome the limitation of geographical focus, future research should expand the study to include property developers from various states across Malaysia. This would provide a clearer picture of how blockchain adoption differs based on location and market conditions. A comparative study between urban and rural areas could help identify specific challenges and opportunities unique to different regions. Additionally, conducting cross-country studies would allow researchers to compare Malaysia's blockchain adoption with other countries and learn from best practices implemented in more advanced markets.

To address the limitations of a purely quantitative approach, future research should adopt a mixed-method strategy. While surveys provide valuable statistical data, integrating qualitative methods such as interviews and case studies would allow researchers to explore developers' experiences, concerns, and motivations in greater depth. Interviews with property developers, policymakers, and blockchain experts could provide a deeper understanding of the real-world factors influencing blockchain adoption. A combination of quantitative and qualitative approaches would result in a more well-rounded and insightful study.

Besides, to minimize bias in self-reported data, future studies should incorporate triangulation methods by using multiple sources of information. For example, researchers could cross-check survey responses with company reports, blockchain implementation case studies, and government records. Direct observations of blockchain applications in real estate companies could also provide a more objective assessment of adoption levels. By using multiple data sources, researchers can reduce the risk of inaccurate reporting and gain a more reliable understanding of blockchain adoption in property management.

Furthermore, researchers should aim to include multiple stakeholder groups, such as tenants, regulators, legal professionals, and blockchain experts, to offer a more holistic view of the ecosystem. These perspectives are crucial for understanding how blockchain adoption can succeed across different layers of the property management value chain.

Additionally, future studies may explore comparative evaluations of blockchain platforms to identify the most appropriate technology stacks for different property functions. A more detailed investigation into property financialization through blockchain such as tokenization models, smart REITs, and decentralized investment platforms could also enrich the academic literature and offer forward-looking insights into real estate innovation.

Given that the field is still emerging, researchers should also consider longitudinal case studies as blockchain initiatives develop. Tracking these projects over time would allow for refinement and validation of initial findings, transforming conceptual insights into evidence-based conclusions. Future research should also expand the search terms used in literature reviews to include keywords such as “smart contract” to improve the coverage and depth of relevant studies. Moreover, as blockchain technology matures and more empirical evidence becomes available, another literature review should be conducted to update and strengthen the understanding of blockchain applications in property management in Malaysia and beyond.

5.6 Summary of Chapter

This chapter has provided an in-depth overview of the research background, identified gaps, and outlined the aim and objectives. It also summarized the key findings and discussed the study’s contributions to the field. Additionally, the chapter addressed the research limitations and offered recommendations to guide and enhance future studies.

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APPENDICES

Appendix A: Questionnaire

Dear Sir/Madam,

I am Lai Hong Jie, a final-year undergraduate student pursuing a Bachelor of Science (Honours) in Quantity Surveying at Universiti Tunku Abdul Rahman (UTAR). As part of my final year project, I am conducting a survey entitled "Exploring the Potential of Blockchain Technology in Property Management." This research aims to investigate the potential adoption of blockchain technology in property management practices in Malaysia.

The questionnaire comprises four sections and will take approximately 10 minutes to complete. I sincerely appreciate your participation in this survey, as your professional insights and experiences will significantly contribute to the success of this research. Please be assured that all responses will remain confidential and anonymous, used solely for academic purposes.

Should you have any questions regarding this survey or require further clarification, please do not hesitate to contact me.

Thank you for your valuable time and participation.

Student name: Lai Hong Jie
Contact number: 012-878 3511
E-mail: laihongjie@1utar.my

Blockchain is a digital ledger technology that securely records and verifies transactions across a decentralized network without the need for intermediaries.

Do you know what Blockchain technology is?

I. Yes.
II. No.

Are you working in business related to property management sector?

I. Yes.
II. No.

Section A: Demographic Information

a. Age
    I. Less than 21 years old
    II. 21-25
    III. 26-30
    IV. 31-35
    V. 36-40
    VI. 41 and above
b. Sector of Employment
    I. Public Sector
    II. Private Sector
c. How many employees in your organization?
    I. Less than 5 employees
    II. 5 - 29 employees
    III. 30 - 75 employees
    IV. More than 75 employees
d. Job Position
    I. Junior Executive
    II. Senior Executive
    III. Manager/ Team Leader / Supervisor
    IV. Assistant Director / Technical Director
    V. Director
    VI. Others (Please specify): _____
e. Years of Experience in current organization
    I. Less than 6 years
    II. 6-10 years
    III. 11-15 years
    IV. 16-20 years
    V. 21 years and above

Section B: Inefficiencies Faced In Property Management Practice

This section contains a list of inefficiencies faced in property management practice. Based on your experience, rate the inefficiencies for the following statements on a scale of 1 (Strongly Disagree) to 5 (Strongly Agree).

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

	Land Administration	**1 2 3 4 5**
1	Different government agencies handle land administration system which creating inconsistency and ease for corruption.	
2	Outdated paper-based processes.	
3	Lack of reliable historical records on land ownership.	
4	Unresolved disputes over land ownership and weak dispute resolution systems.	
5	Discrimination and unfair access to land ownership.	
6	Weak governance and limited capacity of institution.	
	Property Transaction	**1 2 3 4 5**
7	High costs of property transactions.	
8	Vulnerable to fraud due to reliance on middlemen.	
9	Lack of transparency in property transactions.	
10	Slow bureaucratic processes in property transactions.	
11	Ineffective enforcement of property rights.	
	Leasing and Renting	**1 2 3 4 5**
12	Inefficient and outdated process cause high costs.	
13	Lack of transparency and trust issues between landlords with tenants.	
14	Reliance on agents increases conflicts of interest.	
15	Failure to handle sensitive information in rental transactions.	

	Property Administration	**1 2 3 4 5**
16	Lack of transparency and reliability in verification processes.	
17	Decentralized and unstructured data storage.	
18	Inefficient process for paying management fee	
	Property Financialization	**1 2 3 4 5**
19	Illiquid and high entry barriers make it difficult for investors to participate in property markets.	
20	Lack of transparency in property markets creates uncertainty about ownership and investment security.	
21	Speculative investments often rise property prices in cities, making properties too expensive for low-income people.	
22	Market volatility and distortions deter investment.	
	Property Maintenance	**1 2 3 4 5**
23	Inadequate maintenance by responsible bodies.	
24	Building deterioration over time.	
25	Awareness gaps among residents.	
26	Lack of professionalism and transparency in management.	
27	Lack of communication with stakeholders.	
28	Lack of maintenance practices that align with green principles and consideration of health and safety.	

Section C: Potential of Blockchain in Property Management in Malaysia

This section contains a list of potential of adopting blockchain technology in property management. Rate the potential for the following statements on a scale of 1 (Strongly Disagree) to 5 (Strongly Agree).

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

	Land Administration	**1 2 3 4 5**
1	Blockchain enhances the traceability of land ownership.	
2	Blockchain can decentralize and improve data storage and retrieval.	
3	Blockchain improves transparency in land lease and mortgage transactions.	
4	Blockchain reduces the need for intermediaries in land registration.	
	Property Transaction	**1 2 3 4 5**
5	Blockchain enhances ownership visibility and prevent unauthorized changes hence reduces fraud.	
6	Blockchain automates verification processes.	
7	Blockchain allows direct transactions which reduces the need for brokers.	
	Leasing and Renting	**1 2 3 4 5**
8	Blockchain supports transparent and peer-to-peer rental transactions.	
9	Blockchain smart contracts automate and streamline lease agreements.	
10	Blockchain secures rental payments with encryption and ID validation.	
	Property Administration	**1 2 3 4 5**
11	Blockchain grants specific access rights.	
12	Blockchain securely stores records with real-time access.	

13	Blockchain enables transparent decision-making and record-keeping.	
14	Blockchain streamlines payments for property management services.	
	Property Financialization	**1 2 3 4 5**
15	Blockchain enables fractional ownership and allows more people to invest in property.	
16	Blockchain improves liquidity by enabling 24/7 trading of property tokens.	
17	Blockchain reduces property investment costs.	
18	Blockchain enhances transparency and accuracy in property valuation.	
19	Decentralized governance through blockchain facilitate greater stakeholder participation and trust.	
20	Blockchain financialization improves housing affordability.	
	Property Maintenance	**1 2 3 4 5**
21	Blockchain ensures data reliability with consolidated maintenance records.	
22	Blockchain automates maintenance schedules and contract management.	
23	Blockchain provides a transparent and verifiable record of asset lifecycles and supply chain management.	
24	Blockchain enables predictive maintenance, optimizing resource use.	

Section D: Challenges of Adopting Blockchain

This section contains a list of the challenges of implementing blockchain technology in property management. Rate the challenges for the following statements on a scale of 1 (Strongly Disagree) to 5 (Strongly Agree).

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

	Legal and Regulatory	**1 2 3 4 5**
1	Difficult to integrate with existing legal system.	
2	Unclear legal status for tokenized property and data protection requirements.	
3	Uncertain legal guideline on tokenized assets like Non-fungible Tokens (NFTs).	
4	Outdated regulations with a lack of standardization.	
	Cost and Liquidity	**1 2 3 4 5**
5	High expenses for currency conversion, setup, and maintenance.	
6	Reduced illiquidity of property makes property a less profitable investment for investors	
7	Cryptocurrency price fluctuations make transaction costs unpredictable.	
	Security and Privacy	**1 2 3 4 5**
8	Lack of robust cybersecurity strategies to protect data.	
9	Lack of trust and data privacy.	
10	Difficult to balance transparency, privacy, and regulatory compliance.	
11	Difficult to identify and verify the client's identity while preserving privacy.	
12	Difficult to establish reliable digital identity and signature verification.	
	Technical Limitation	**1 2 3 4 5**

13	Lack of standardized protocols and interoperability between blockchain platforms.	
14	The blockchain technology is too complex which requires high maintenance demand.	
15	Scalability issues limit real-time applications.	
16	Smart contract rigidity affects enforceability and flexibility.	
17	Difficult to amend errors once data was recorded	
	Institutional Challenges	**1 2 3 4 5**
18	Difficult on managing economic impacts and value distribution.	
19	Lack of strong political and regulatory support.	
20	Difficult to align with social and ethical aims.	
21	Difficult to achieve decentralized, inclusive, and secure governance.	