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Enhancing estate governance through blockchain: An analysis of transparency, efficiency and security in estate management

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ABSTRACT

This study investigates the impact of blockchain technology on estate governance focusing on enhancing transparency, efficiency and security within the sector. A structured questionnaire using a 5-point Likert scale was distributed to 317 estate management professionals to collect quantitative data which was subsequently analyzed using SmartPLS 4. The results underscore transformative potential of blockchain technology revealing strong correlations between its implementation and improved estate governance outcomes. This study demonstrates how blockchain can significantly enhance estate administration by addressing inefficiencies, bolstering security and fostering greater transparency. The proposed framework for integrating blockchain into estate governance offers a comprehensive strategy to manage frozen estates more effectively, reduce administrative delays and minimize disputes. The study's primary contribution lies in its innovative application of blockchain technology to solve prevalent issues in estate management providing a strategic blueprint for future implementations. This study offers actionable insights and practical recommendations for estate management stakeholders emphasizing the critical role of blockchain in ensuring more efficient, transparent and secured governance practices. This study highlights the profound impact blockchain can have on modernizing estate management practices and establishing robust governance frameworks by thoroughly examining the dimensions of transparency, efficiency, and security. This study concludes by advocating for the adoption of blockchain technology to enhance estate governance effectiveness and improve overall management outcomes.

Contribution/Originality: This study contributes to the substantial benefits of blockchain technology in estate management by enhancing security, efficiency and transparency for better estate planning and execution. The findings emphasize the positive relationship between blockchain governance and estate governance, affirming the potential of blockchain technology to revolutionize conventional estate governance processes.

1. INTRODUCTION

Recent years have seen a paradigm shift in governance and management across many different areas as a result of the fusion of new technology with conventional industries (Al-Zaqeba, Ineizeh, Jarah, Hamour, & Zeyad, 2022; Jarah, Jarrah, & Al-Zaqeba, 2022). The integration of blockchain technology into estate governance is an important

instance of this shift in the dynamics of estate administration. Blockchain originally designed as the underlying technology for cryptocurrencies has developed into a strong decentralized system that enables safe, open-book transactions. Managing frozen estates is a multidimensional and complex task within the estate management field. Frozen estates become evident during legal conflicts, doubts about how an estate will be administered or issues with the legality of a will. These situations frequently result in lengthy delays in asset distribution creating substantial obstacles for both beneficiaries and the whole estate management process (Almatarneh, Ineizeh, Jarah, & Al-Zaqeba, 2022; Zobi, Al-Zaqeba, & Jarah, 2023).

Malaysia, like many other countries, struggles to manage frozen estates despite urgent concerns about efficiency, security and transparency (Rahman, 2019; Wadee, 2023). The handling of frozen assets in Malaysia is further complicated by legal complexities including legislative uncertainties, jurisdictional conflicts and procedural roadblocks. Legal battles brought on by disputes within the family, disagreements over the distribution of assets or challenges to the legality of a will severely impede the resolution of disputes that take months or even years to conclude, impeding the efficient administration and asset distribution of the estate (Rahman, 2019). The lack of knowledge and resources is another common issue in Malaysia when managing frozen estates successfully. People or administrators in charge of frozen estates sometimes lack the necessary expertise which can lead to inefficiencies and possible mismanagement. In-depth knowledge of property rights, probate law and relevant rules is necessary for effectively managing frozen estates (Nasrul, Manaf, Syafril, & Fathurrohman, 2021). The problems in managing and allocating assets within these estates are further exacerbated by a lack of knowledge and resources, weak land administration institutions and complex legal issues. The complex problems affecting the management of frozen estates may be overcome with a convincing solution using blockchain technology which is recognized for its decentralized and transparent features.

Malaysia has the potential to successfully solve the challenges posed by frozen estate management by leveraging the core characteristics of blockchain including immutability, transparency and smart contracts. A paradigm shift in how estate-related activities and procedures are carried out within the Malaysian context will be presented through the use of blockchain in managing frozen estates. Nevertheless, integrating blockchain technology with frozen estate management has transparency as a key benefit. The intrinsic characteristics of blockchain enable transparent and unchangeable record-keeping expediting Malaysia's estate management procedures. All stakeholders have access to a single, reliable source of data since transactions and crucial estate-related data are securely stored on a blockchain. This openness considerably reduces disagreements, assures accurate record-keeping and creates a trustworthy audit trail for beneficiaries, executors and judicial authorities (Anuar, Azmi, & Sidek, 2023; Chavali, Reddy, Taran, & Chandana, 2024).

Another crucial aspect that blockchain adds to frozen estate administration is security. It is challenging to alter or gain unauthorized access to data since blockchain technology is decentralized and the data is distributed across several nodes. Additionally, the cryptographic methods used in blockchain technology guarantee strong data encryption, protecting private information about stakeholders and sensitive estate information (Chhabra, Saha, Kumar, & Kim, 2021). The use of self-executing contracts recorded on the blockchain or smart contracts eliminates the need for traders and automates a variety of procedures. This decrease in paperwork speeds up asset transfers lowers administrative costs and improves overall effectiveness.

Additionally, blockchain-based solutions make it possible to manage and monitor frozen estates in real-time, giving all relevant stakeholders accurate and updated information. This study explores how blockchain technology might transform estate governance with particular focus on three important elements: security, efficiency, and transparency. Estate governance includes a range of legal, financial and operational obligations for the complex administration, management and control of assets, estates and inheritances (Al-Zaqeba, Jarah, et al., 2022; Almatarneh et al., 2022; Jarah et al., 2022; Zobi et al., 2023).

Blockchain technology integration has the potential to modernize and streamline estate management procedures, alleviate current problems and usher in a new era of effective governance. Transparency is a key component of good governance but traditional estate administration may hinder it sometimes due to involvement and excessive paperwork. This problem is solved by the immutable and open ledger structure of the blockchain which enables a shared, decentralized record of all estate-related transactions and acts. Additionally, estate administration efficiency has increased significantly as a result of blockchain's automation features which reduce duplication and speed up transactions. Security is an essential concern in estate affairs and blockchain's cryptography capabilities and decentralized consensus process provide a secure environment for sensitive data and transactions. However, the purpose of this study is to evaluate the possible effects of incorporating blockchain technology into estate governance by analyzing how it can improve security, efficiency and transparency. We want to provide insights and suggestions that promote estate governance practices by exploring these important facets. This will enable stakeholders to make decisions about the future of estate management in a world that is becoming more digital and networked.

The possible revolution in estate administration that blockchain technology may bring about is clearly shown in this study. Transparency, security and efficiency are highlighted as key characteristics that are destined to have an influential impact on estate governance processes due to blockchain technology. The use of blockchain is presented as a way to improve and simplify current estate management procedures specifically addressing issues with efficiency, security and transparency. A detailed review of the literature is then conducted in the next section, exploring the body of information already available about blockchain technology, its uses in estate governance and the complex environment of maintaining frozen estates. This review tries to gather ideas and information, laying the groundwork for developing hypotheses later on and creating a research model. The next section moves on to the development of hypotheses that are supported by a thorough literature assessment and in line with the research questions of the study laying the groundwork for hypothesis testing and validation. The chosen research model and the methods for gathering and analyzing data are then thoroughly described providing readers with a comprehensive understanding of the study's approach. The following portion of the paper presents the study's findings, which include path coefficients, reliability metrics and the results of hypothesis testing. This section critically examines the collected data to show how blockchain integration affects the efficiency, security and transparency of estate management. We find that the study provides an in-depth review of the results concerning the research model and underlying hypotheses by examining the discussion section.

It examines the implications of the results emphasizing how crucial blockchain technology is to bringing estate governance updated and fixing the issues that were discovered. The study's major conclusions and their ramifications are finally and briefly summarized in the conclusion which also provides an outlook on the possible application of blockchain technology in estate management. It draws attention to the potential advantages of using blockchain technology for estate management practices.

2. LITERATURE REVIEW

2.1. Blockchain Mechanism and Characteristics

Blockchain technology has become a game-changing innovation that offers several advantages to several sectors, including supply chains, finance and healthcare. Understanding the fundamentals of blockchain technology is crucial to appreciating its vast range of potential uses and implications. The fundamental mechanism is a distributed ledger that processes through linked blocks a collection of transactions or data and is updated by several network members (nodes). The primary characteristic of blockchain technology is decentralization which eliminates the need for a central authority to verify and authorize transactions. Instead, a consensus process is used by network users to cooperatively maintain ledger integrity, creating a more democratic and robust system (Swan & Melanie, 2015). Blockchain essentially consists of a decentralized network of nodes which are computers, servers

and laptops that are connected to the blockchain and verify record and store data blocks that are linked together in chains. Multiple transaction records are contained in each block and each record is identifiable by a hash which is an alphanumeric string of defined length created by a mathematical function from a string of letters. This hash contains important transaction information encoded in the blockchain algorithm such as sender, recipient, date, time, and other pertinent data (Salmon & Myers, 2019). The blockchain is a continuously expanding chain of blocks each of which is connected to the one before it by a special hash. Transactions are added to the chain when network users confirm their legitimacy through a consensus method (Zīle & Strazdiņa, 2018). Asymmetric-key cryptography which is used in blockchain transactions uses public and private keys that are held by participating nodes. The counterparty uses the public key created by the counterparty to verify the transaction's integrity and origin while the private key encrypts data, thereby signing the transaction. Transactions inside the network are safe and verifiable due to encryption and decryption using keys. Nodes may conduct transactions without the need for middlemen in a low-cost, trustless peer-to-peer (P2P) network due to the decentralized and distributed structure of the blockchain (Christidis & Devetsikiotis, 2016). Its decentralized nature reduces the possibility of a single point of failure, increasing the system's overall resiliency (Alam, Gupta, & Zameni, 2019; Raval, 2016). Additionally, once data is recorded, it cannot be altered since blockchain technology is immutable. A cryptographic hash based on each block's contents is included and any changes would cause the hash to change making any tampering obvious (Hileman & Rauchs, 2017; Vora, 2015). The blockchain network's immutability characteristic maintains data integrity and raises user confidence. A new chain is created whenever data in a block is modified making fraudulent modifications traceable and potentially fraudulent operations lessened (Decker & Wattenhofer, 2013).

2.2. Blockchain Models

Numerous blockchain models have emerged as blockchain technology has advanced, each with unique features that meet the needs and use cases of a particular sector. It is essential to understand the traits and differences between these models in order to adapt blockchain to certain situations. Public, private, consortium and hybrid blockchain are the main types of blockchains covered by blockchain models. Public permission also permits writing by any network user with commitment being carried out by all or a fraction of authorized nodes as shown in well-known examples like Bitcoin and Ethereum. In contrast, the public permission approach limits writing to authorized nodes and ensures commitment from all of them or just a subset of them.

According to Biryukov, Khovratovich and Pustogarov (2014) and Meiklejohn et al. (2013) closed systems may further restrict some actions to specified parties creating problems with transparency and auditability. Academics advise using public blockchains with zero-knowledge proof to validate transactions without disclosing sensitive data to overcome confidentiality issues in closed blockchains (Kosba, Miller, Shi, Wen, & Papamanthou, 2016). On the other hand, private blockchains ensure permission access and transaction validation by restricting participation to a certain group frequently under the authority of a single corporation or consortium. This architecture puts scalability and efficiency first making it suited for businesses or sectors with particular needs in terms of data protection (Siegfried, Rosenthal, & Benlian, 2022).

Private blockchains where sensitive data is exchanged only with authorized users place a strongly emphasizes privacy and confidentiality. This enables enterprises to use blockchain technology while ensuring data security (Christidis & Devetsikiotis, 2016). In addition, private blockchains frequently outperform public blockchains in terms of scalability and speed allowing for high transaction volumes and low latency requirements (Lu, Huang, Azimi, & Guo, 2019). Consensus blockchains also achieve balance by enabling a small number of users to join validate transactions and manage the network. This paradigm encourages cooperation and shared governance between trustworthy institutions while enhancing privacy, scalability and control. Consortium blockchains which are limited to recognized and reputable participants guarantee the secure exchange of sensitive data which is essential in sectors that demand secrecy and regulatory compliance (Aslam, Saleem, Khan, & Kim, 2021).

Hybrid blockchains combine the strengths of both public and private blockchains with flexibility and control over their networks. Transparency, decentralization and data privacy are all concurrently provided by this model's integration of public and private components. Organizations may specify the amount of data visibility and control, balancing openness and privacy according to their needs. Hybrid blockchains enable smooth data interchange and collaboration across public and private networks using the advantages of both components (Agrawal, Kumar, Pal, Wang, & Chen, 2021). However, the range of possible uses for blockchain technology has been greatly increased by the diversity of blockchain models. Blockchain models that are public, private, consortium or hybrid, each have unique features that are tailored to certain use cases and market demands. It is critical to comprehend the subtleties and trade-offs of each blockchain model when choosing the best one for a certain application.

2.3. Frozen Estate Management in Malaysia

A will is a legally enforceable document that controls important issues including the efficient management and equal distribution of an individual's assets after their death. A person's wishes for how their assets should be divided and allocated among beneficiaries are stated in their will which provides clarity and direction for the distribution process. However, difficulties may arise that hinder a will from being implemented smoothly leading to frozen estates. In the context of wills, frozen estates happen when legal problems, objections to the will's validity, outstanding financial commitments or other difficulties impede or postpone the regular administration and distribution of assets from an estate.

These frozen estates can greatly prolong the time it takes to settle a deceased person's affairs which frequently upsets the beneficiaries and the executor of the will. It is essential to comprehend the idea of frozen estates within the framework of wills to successfully navigate the complicated legal environment that may emerge during the administration of an estate. Additionally, a full grasp of the legal structure and processes involved in estate administration is required for the handling of frozen estates including wills in Malaysia. The distribution of assets may be pushed off when a will is disputed or conflicts occur creating difficult situations for the beneficiaries and executor.

Conflicts over entitlement, asset valuation or the interpretation of the decedent's objectives as stated in the will are major causes of these disputes (Ayuni et al., 2022). Everyone engaged, including executors, administrators and beneficiaries must be aware of all applicable laws and regulations. Malaysia's regulation of frozen estates includes the legal framework and enforcement protocols established to control the management and preservation of assets that have been seized or frozen. Regulation of these assets is necessary to ensure accountability, transparency and ease of asset recovery procedures.

The High Court, Syariah Court, Amanah Raya Berhad and Land Office are just a few of the organizations working together to regulate frozen estates in Malaysia. Each institution has a specific duty to play in maintaining and administering frozen assets based on the legal and regulatory framework (Nasrul et al., 2021). In Malaysia, the high court also has significant influence in determining how assets are distributed after death. In Malaysia, the high court has jurisdiction over civil cases such as inheritance disputes and estate management. When a person passes away, their estate is divided by the high court's probate division in accordance with either Islamic inheritance rules (for Muslims) or the Distribution Act 1958 (for non-Muslims). After someone passes away, their estate must be handled and dispersed to the proper heirs and beneficiaries (Shafie, Yusoff, & Al-Edrus, 2014). In Malaysia, the high court has jurisdiction over cases involving the distribution and administration of estates. The procedure is supervised by the court which also makes sure that it is carried out legally. The executor designated in the will may request a Grant of Probate from the high court if the decedent left a valid will. The validity of the will and the executor's power to manage the estate are established by the Grant of Probate. If satisfied, the high court grants probate after reviewing the will and confirming its legitimacy (Shah, Nasrul, Halim, & Hak, 2022). A suitable individual often a close family member or next of kin may be granted letters of administration by the high court if

the decedent failed to leave a valid will or name an executor. This enables the designated individual to manage the estate and distribute the assets in accordance with the intestacy legislation. The high court manages the division of assets after obtaining the grant of probate or letters of administration.

The Syariah Court which runs concurrently with the civil court system has authority over issues relating to Islamic law including the management of frozen estates in cases involving Muslims. The Syariah Court also deals with issues about Islamic law such as Muslim heirs' inheritance issues (Islamic Law (Federal Territories); Act 1993). Islamic inheritance rules which are based on the Quran and Hadith control how Muslim heirs are distributed property. The Syariah Court has the authority to impose injunctions or freezing orders based on Islamic principles to ensure the preservation and management of assets in conformity with Islamic law. Islamic law only applies to Muslims. Hence, the Syariah Court examines whether a person was a Muslim when they passed away. The Syariah Court has authority over Muslims in inheritance disputes, hence this decision is significant. The Syariah Court has the power to divide the assets in accordance with Faraid if the decedent was a Muslim and had not created a valid will. According to Doğan and Ertemel (2023) unique is the Islamic rule of inheritance that controls how the deceased's property is divided up among his or her legal heirs. The Syariah Court evaluates the familial ties and determines the shares of each eligible successor in accordance with the established Faraid criteria. The Syariah Court is in charge of ensuring that the dead person's estate is handled and dispersed in line with Islamic law by supervising the estate administration. A family member or other competent person may be chosen by the court to serve as the administrator who will oversee the estate administration procedure. Malaysia's government has designated Amanah Raya Berhad as the trust company in charge of overseeing and maintaining frozen estates. Until they are released or destroyed in accordance with court decisions or legal requirements, Amanah Raya Berhad serves as the custodian of frozen assets, protecting and maintaining their value. The Amanah Raya Berhad Act of 1995 (Act 533) regulates its function.

The business also offers expert estate management services such as asset appraisal, money management and asset distribution to beneficiaries. Amanah Raya Berhad can carry out the duties of an executor or trustee for those who name them in their wills or through the creation of trusts. Upon appointment, Amanah Raya Berhad takes on the duty of managing and allocating the decedent's assets in line with the terms of their will or trust. If no executor has been designated, the decedent's beneficiaries or relatives may hire Amanah Raya Berhad to handle the estate's administration. The required legal procedures will be handled by Amanah Raya Berhad including obtaining the grant of probate or letters of administrator from the high court gathering and protecting assets, paying off debts and distributing the residual assets to the proper recipients. The land office is a key player in controlling frozen estates involving immovable properties such as land and real estate and falls under the purview of state governments.

The land office makes sure that frozen properties are properly registered, transferred and managed. They also impose limitations on their sale or transfer. For the purpose of facilitating the preservation and recovery of frozen assets, the office also works with other institutions. When a person passes away, it may be necessary to transfer their land or other assets to the correct beneficiaries or new owners. This transfer process must be facilitated by the land office. The beneficiaries or legal representatives of the decedent must file the required paperwork and follow all applicable rules to transfer ownership of the land. The governance of frozen estates in Malaysia poses a number of difficulties that obstruct efficient asset allocation and administration. Multiple laws, rules and court rulings make up Malaysia's regulatory framework for frozen estates which creates significant legal issues. Asset management and distribution may be unpredictable and delayed as a result of the interpretation and application of these rules (Nasrul et al., 2021).

The overlapping jurisdictions of multiple organizations such as the land office, Amanah Raya Berhad, high court and Syariah Court affect the regulation of frozen estates significantly. When dealing with the distribution of assets, each authority may have its own set of policies and processes which can lead to confusion and potential

disputes. The ineffective settlement of frozen estates may be hampered by a lack of coordination and harmonization across various authorities, extending the waiting period for beneficiaries (Nasrul et al., 2021). The absence of special legislation designed to treat frozen estates thoroughly creates another problem. Despite the existence of pertinent legislation like the Administration of Estates Act 1965, Probate and Administration Act 1959, Civil Law Act 1956, and Land Titles Act 1960, these laws generally address general estate administration as opposed to provide detailed instructions on how to handle frozen estates. The special difficulties and complexity connected with frozen estates may not be sufficiently addressed by the legal system resulting in further delays and legal battles.

Additionally, proper coordination between several organizations is essential for the administration of frozen estates. Law enforcement organizations, regulatory agencies and judicial institutions must work together to regulate frozen estates (Ayuni et al., 2022). When multiple agencies are involved in the investigation and management of frozen estates, it can be difficult to ensure effective collaboration and information sharing. This lack of coordination between these agencies frequently results in inefficiencies and delays in the resolution of disputes related to frozen estates (Abdullah, Nasir, Muhamad, Ab Aziz, & Awang, 2020). A lack of information exchange across authorities also makes it difficult to comprehend frozen estates which causes delays and ineffective decision-making (Ahmad & Laluddin, 2010; Aloqaily, 2023).

The administration of Malaysia's frozen estates has several issues that might be solved by blockchain technology. Stakeholders may resolve problems with information sharing, trust and accountability by using the inherent characteristics of blockchain such as decentralization, transparency and immutability. To provide transparency in the administration of estate-related transactions, ownership transfers and asset preservation, blockchain offers safe and tamper-proof record-keeping. On the blockchain, smart contracts may automate the enforcement of contracts enabling the transparent and effective implementation of estate management procedures. Additionally, blockchain-based identity verification systems can build confidence among several parties engaged in the management of frozen estates. Malaysia may improve efficiency, safeguard stakeholder interests and streamline the management of frozen estates by using blockchain technology.

2.4. The Role of Blockchain in Frozen Estate Management

The efficient management of frozen estates is fraught with difficulties stemming from complex legal issues, coordination problems and the need for openness and responsibility. Blockchain technology provides a disruptive solution that can alter the management of frozen estates with its distinctive characteristics such as decentralization, transparency, immutability and smart contract capabilities. Additionally, one of the key benefits of blockchain technology is its capacity to resolve a number of problems with the management of frozen estates by ensuring transparency and traceability. Blockchain's decentralized and unchangeable nature enables transparency and traceability throughout the management of frozen estates. All transactions and activities associated with the frozen estate are recorded on a shared ledger that is only accessible to authorized participants ensuring transparency and reducing the risk of fraud while fostering trust among all parties (Khairi & Azmin, 2022). The blockchain is accessible to all parties participating in the management process including administrators, beneficiaries and legal representatives allowing them to check and audit all transactions and decisions made. The creation of a thorough and auditable history of asset ownership, transfers and transactions is another benefit of blockchain. The blockchain creates an immutable audit trail by permanently and time-stamping each modification or transfer of ownership (Andoni et al., 2019). This traceability function ensures accountability and helps to avoid disagreements or inconsistencies in ownership claims by providing a comprehensive perspective of the estate's management history.

Frozen estate administration might be completely transformed by blockchain technology's automation capabilities and smart contract capabilities. Delays, inefficiencies and disagreements in the management of frozen estates may all be considerably reduced by the use of smart contracts which represent established rules and conditions inside the blockchain. Smart contracts may be used to automate estate-related procedures ensuring the

effective and precise application of preset regulations (Bailis, Narayanan, Miller, & Han, 2017). Automation reduces reliance on intermediaries and manual procedures which reduces human error and improves the overall efficiency and accuracy of estate administration. Smart contracts provide a clear and auditable record of all contract-related activity, fostering openness and confidence among parties. This openness promotes fairness and accountability in the management process by ensuring that all stakeholders have access to the same information and preventing disagreements (Casino, Dasaklis, & Patsakis, 2019). Blockchains' decentralized design and cryptographic algorithms assure the integrity and security of data enhancing confidence among stakeholders by lowering the possibility of fraud, data tampering and illegal access to estate-related information. Once a transaction or record is posted to the blockchain, it is guaranteed to stay unalterable and cannot be erased without consensus from the network members due to the immutability and tamper-resistant characteristics of the blockchain (Nakamoto, 2012). For estate-related transactions, this feature offers a high level of security by limiting unauthorized changes and lowering the possibility of fraud or manipulation. Cryptographic methods are also used by blockchain technology to safeguard data and confirm the legitimacy of transactions. The blockchain creates a chain of trust by encrypting all transactions and connecting them to earlier transactions using cryptographic hashes (Swan & Melanie, 2015). This cryptographic security makes sure that data is safe and cannot be altered, fostering trust in the reliability and honesty of estate management procedures. On the other hand, blockchain technology has enormous promise for resolving issues related to the management of frozen estates. Blockchain technology has the potential to improve accountability in the management of frozen estates by streamlining processes, reducing conflicts and enabling smart contracts.

3. MATERIAL AND METHODS

A quantitative survey is used as the research methodology. The data for this study is collected through questionnaires. The data for the study was gathered by distributing questionnaires on a 5-point Likert scale. The study's sample population comprises professionals specialized in estate management encompassing estate administrators, legal experts, financial advisors and technology professionals with a nuanced understanding of blockchain applications within the real estate sector. A total of 317 were collected from the respondents. The collected data underwent analysis using Partial Least Squares Structural Equation Modelling (SmartPLS4). This statistical analysis technique was chosen for its appropriateness in evaluating intricate relationships and structural models within the dataset. SmartPLS4 facilitates a comprehensive understanding of how the implementation of blockchain technology impacts transparency, efficiency and security in the management of frozen estates. In addition, Smart PLS4 version 4.0.9.6 was used to examine intricate connections between latent variables in structural equation models. Its relevance stems from its efficacious handling of complicated models, many variables, and small sample sizes. PLS-SEM is very useful for examining complex interactions within datasets since it is essential for comprehending linkages and causalities among variables (Basah et al., 2018; Khairi & Azmin, 2022; K. F. Khairi et al., 2023; Shubailat, Al-Zaqeba, Madi, & Khairi, 2024). However, this paper advances the usage of the last version of PLS-SEM and SmartPLS4 more than previous studies that may have relied on covariance-based SEM or standard statistical approaches. The uses of SmartPLS4 in this study provide a deeper understanding of the potential transformative impact of blockchain technology in this domain by enabling a more nuanced and detailed exploration of the relationships between blockchain governance, estate governance and estate management outcomes within the particular context of frozen estate management.

4. HYPOTHESIS DEVELOPMENT AND RESEARCH MODEL

Figure 1 shows the relationship between the variables based on the literature review in the previous section. However, this study proposes a set of hypotheses to investigate the relationships between blockchain governance, estate governance, efficiency, security, transparency and estate management within the context of estate operations.

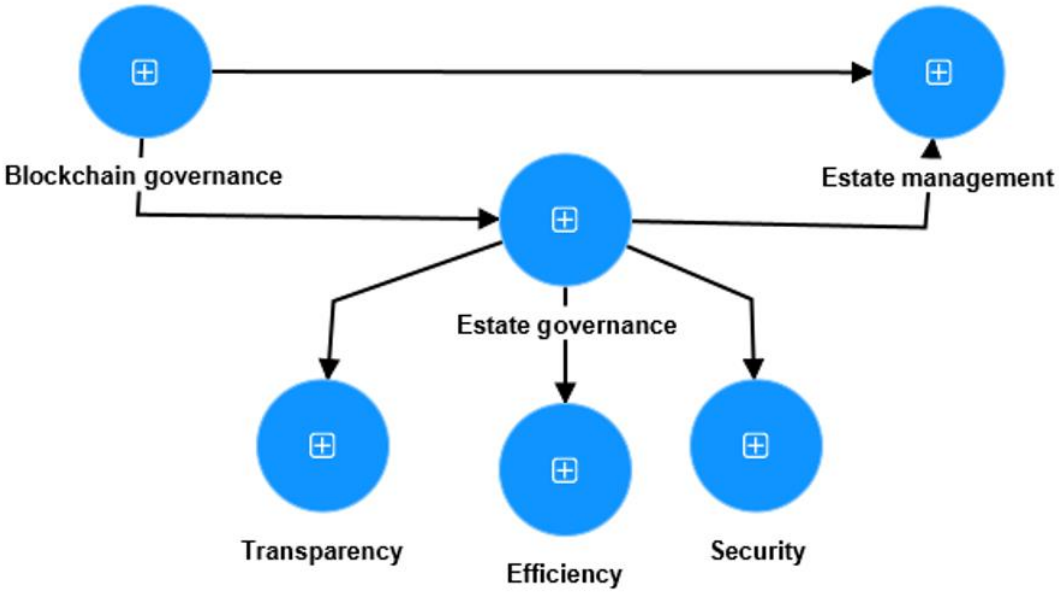

Figure 1. Research model.

4.1. Blockchain Governance and Estate Governance

Blockchain governance and estate governance are intricately linked working in tandem to revolutionize traditional estate management practices. Blockchain governance characterized by its decentralized, transparent and secure nature provides a foundation for reshaping how transactions, record-keeping and agreements are managed in the estate domain (Khairi & Azmin, 2022). On the other hand, estate governance involves the effective administration, regulation and management of assets, properties and inheritances encompassing a wide spectrum of legal, financial and operational responsibilities. The synergy between these two forms of governance is vital for optimizing estate management processes. Blockchain governance provides the technological infrastructure and tools necessary to enhance transparency, efficiency and security within the estate governance landscape (Andoni et al., 2019; Casino et al., 2019). Through smart contracts, cryptographic security and decentralized consensus mechanisms, blockchain governance ensures the integrity of estate-related data and transactions. It automates processes, minimizes redundancy and accelerates transactions ultimately streamlining estate management. In essence, blockchain governance complements estate governance by infusing it with the capabilities and efficiencies needed to navigate the modern complexities of estate management, ensuring a more transparent, efficient and secure approach to handling estates.

The foundational hypothesis (H1) posits that the governance mechanisms facilitated by blockchain technology exert a positive influence on the governance of estates within the frozen estate management domain. This aligns with the decentralized and transparent nature of blockchain which could enhance and reshape traditional estate governance systems (Casino et al., 2019; Khairi & Azmin, 2022). In addition, H1.1 hypothesize that an effective estate governance structure positively correlates with enhanced efficiency in frozen estate management processes. This hypothesis is informed by the potential for smart contract automation and streamlined processes facilitated by blockchain ultimately contributing to increased efficiency (Bailis et al., 2017). For H1.2, we posit that a robust estate governance framework is associated with heightened security in managing frozen estates. This is grounded in the secure and immutable nature of blockchain ensuring the integrity and safeguarding sensitive estate-related data (Andoni et al., 2019; Nakamoto, 2012). Moreover, hypothesis 1.3 suggests that a well-structured estate governance system leads to improved transparency in frozen estate management. The transparency inherent in blockchain allowing all authorized stakeholders to verify and audit transactions, likely augments transparency within the estate governance structure (Andoni et al., 2019; Khairi & Azmin, 2022). However, the hypotheses are as follows:

H_1: Blockchain governance positively affects estate governance.

$H_{1.1}$: Estate governance positively affects efficiency.

$H_{1.2}$: Estate governance positively affects security.

$H_{1.3}$: Estate governance positively affects transparency.

4.2. Blockchain Governance and Estate Management

Blockchain *governance* and estate management represent an innovative fusion of technology and traditional estate administration presenting a transformative approach to handling assets, properties and inheritances in the modern era. Blockchain *governance* embodies a decentralized, transparent and secure framework offering an effective mechanism to govern and streamline the management of estates (Khairi & Azmin, 2022). Blockchain governance ensures secure, immutable record-keeping and automated execution of agreements through cryptographic techniques, consensus algorithms and smart contracts. On the other hand, estate management involves the comprehensive administration and regulation of assets involving legal, financial and operational intricacies. Transparency, efficiency and security are significantly enhanced by integrating blockchain governance into estate management. Transactions and key estate-related information are securely recorded and accessible to authorized stakeholders, minimizing disputes and ensuring accurate record-keeping (Casino et al., 2019). Additionally, the cryptographic characteristics enhanced by the decentralized architecture of blockchain enhance data privacy and security in real estate transactions. The collaboration of blockchain governance and estate management stands to revolutionize the landscape of estate handling, enabling a more streamlined, secure and efficient approach to managing and distributing assets.

H2 posits that the implementation of robust blockchain governance mechanisms exerts a positive influence on the overall management of estates. Blockchain governance characterized by decentralized decision-making and consensus mechanisms enhances the efficiency, security and transparency of estate management processes (Andoni et al., 2019; Khairi & Azmin, 2022). The decentralized nature of blockchain minimizes the reliance on centralized authorities and intermediaries, streamlining and securing estate-related transactions, ownership transfers and asset preservation. This hypothesis reflects the potential of blockchain governance to revolutionize traditional estate management paradigms by infusing greater efficiency, security and transparency ultimately contributing to the improved management of estates. However, the hypothesis is as follows:

H_2: Blockchain governance positively affects estate management.

4.3. Estate Governance and Estate Management

Estate governance and estate management encompass critical dimensions in handling assets, properties and inheritances within a legal and administrative framework. Estate governance involves a broader regulatory and policy-oriented approach outlining the rules, guidelines and legal foundations that dictate how estates should be managed, administered and distributed. This governance framework sets the stage, providing the necessary legal and ethical guidelines that guide the entire process (Khairi & Azmin, 2022). On the other hand, estate management is the practical, day-to-day application of these rules and guidelines. It involves the execution of estate plans, asset valuation, allocation to beneficiaries and ensuring compliance with legal requirements. The relationship between estate governance and estate management is intricate and interdependent. Effective estate governance sets the rules and expectations for efficient estate management while efficient estate management ensures adherence to the established governance, creating a symbiotic relationship that ensures the proper and legal management of estates. Collaboratively, they establish a framework that balances legal compliance, efficiency and the best interests of beneficiaries and stakeholders within the realm of estate affairs. Moreover, based on the comprehensive analysis of the literature above, H3 indicates that effective estate governance, encompassing structured administration, regulation and strategic management of estates positively impacts the overall management of estates. Effective governance practices such as clear asset allocation strategies, timely legal compliance and transparent decision-

making processes contribute to streamlined estate management (Andoni et al., 2019; Khairi & Azmin, 2022). A well-governed estate ensures that assets are managed efficiently, disputes are minimized and resources are allocated judiciously, ultimately enhancing the management of the estate. This hypothesis underscores the critical role of governance in shaping how estates are managed highlighting the potential for structured governance practices to significantly influence and optimize estate management. However, the hypothesis is as follows:

H_3: Estate governance positively affects estate management.

4.4. Mediation effect of Estate Governance

The integration of blockchain governance has a transformative impact on estate-related processes, enhancing transparency, efficiency and security (Andoni et al., 2019; Casino et al., 2019). However, the effectiveness of this impact is contingent upon the robustness and appropriateness of the estate governance mechanisms in place. Estate governance acts as a bridge facilitating the efficient implementation of blockchain-based solutions within the estate management domain. It ensures that the principles and functionalities of blockchain governance are seamlessly embedded and operationalized within the estate management framework. Through well-defined protocols, regulations and processes, estate governance mediates the potential of blockchain governance optimizing its contribution to the overall efficiency and security of estate management practices. In essence, estate governance acts as an intermediary translating the promise of blockchain governance into tangible enhancements in the broader landscape of estate management. Empirical research and further analysis are essential to quantify and validate the extent of this mediation effect. Furthermore, estate governance serves as a critical mediator in the relationship between blockchain governance and estate management. Nevertheless, building on the insights from the literature, H4 hypothesizes that estate governance plays a mediating role in the relationship between blockchain governance and estate management. Estate governance acts as an intermediary mechanism through which the influence of blockchain governance is transmitted to impact the overall management of estates. Effective estate governance characterized by efficient processes, transparency and security in estate affairs (Casino et al., 2019; Khairi & Azmin, 2022) is expected to mediate and enhance the influence of blockchain governance on how estates are managed. This hypothesis suggests that to comprehensively understand the impact of blockchain governance on estate management, it is crucial to consider the role of estate governance as a mediating factor. However, the hypothesis is as follows:

H_4: Estate governance mediates the relationship between blockchain governance and estate management.

5. RESULTS

The path coefficient is evaluated to demonstrate the magnitude of the independent variable's impact on the dependent variable. To measure the degree of effect an exogenous variable has on an endogenous variable, the determination coefficient (R-Square) is also used. The endogenous latent variables in our structural model have an R2 value of 0.67 or higher indicating a significant positive relationship between the exogenous and endogenous variables. The accomplishment motivation research framework's route coefficients are shown in detail in Figure 2.

All indicators of the several research variables consistently have outer loading values greater than 0.70 demonstrating a significant correlation between the observable variables and the corresponding underlying constructs. A few indications are somewhat below the 0.70 level. According to Mulyono, Hadian, Purba, and Pramono (2020) an outer loading value in the range of 0.5 to 0.6 is thought to be sufficient to satisfy the requirements for convergent validity. No variable indicator in our analysis registers an outer loading below 0.50 despite these lower values. This confirms the reliability and validity of the chosen indicators in assessing their respective constructs reaffirming their acceptability for use in research and highlighting their usefulness for future in-depth exploration.

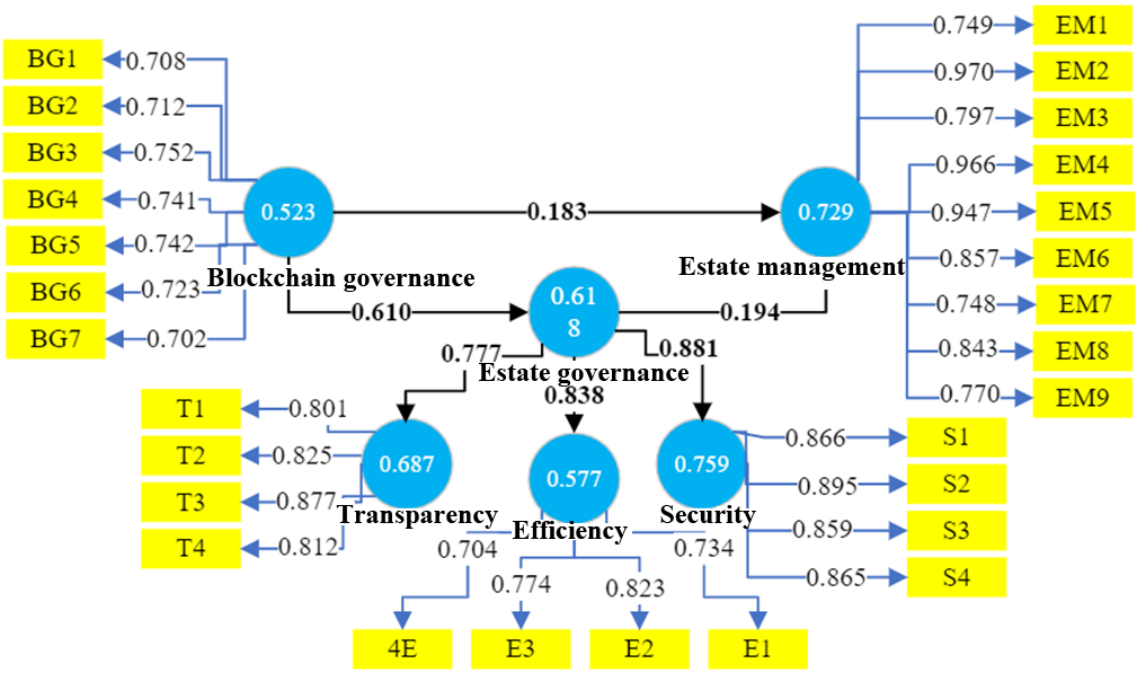

Figure 2. Measurement model.

The reliability of a variable was evaluated in the below table using three frequently used metrics: Cronbach's alpha, composite reliability and Average Variance Extracted (AVE). By employing the Partial Least Squares (PLS) method, structural equation modelling (SEM) assesses the internal consistency, overall dependability and convergent validity of constructs. Strong internal consistency and reliability of the constructs under analysis are indicated when the coefficients of Cronbach's alpha and composite reliability are above the 0.70 cutoff and the AVE is high generally surpassing 0.50. These evaluations support the dependability of the constructs listed in Table 1 by confirming the validity, internal coherence and accurate assessment of the study's intended notions.

Table 1. Reliability and average variance extracted (AVE) testing.

Variables	Cronbach's alpha	Composite reliability (rho_a)	(AVE)
Blockchain governance	0.896	0.901	0.523
Efficiency	0.762	0.768	0.577
Estate governance	0.842	0.854	0.618
Estate management	0.952	0.966	0.729
Security	0.895	0.897	0.759
Transparency	0.848	0.85	0.687

Table 1 shows the results of reliability testing for different research constructs using Cronbach's alpha, composite reliability (rho_a) and Average Variance Extracted (AVE) and three important reliability measures. With values ranging from 0.762 to 0.952, Cronbach's alpha, a measure of internal consistency showcases substantial correlations among the elements within each construct. Similar to Cronbach's alpha, composite reliability (rho_a) emphasizes the accuracy of observable variables in determining the underlying construct. All constructs show strong reliability with values ranging from 0.768 to 0.966. Additionally, all constructs have average variance extracted (AVE) which exceeds 0.5 and measures the amount of variation that the construct captures in comparison to measurement error. With respect to assessing the concepts of blockchain governance, efficiency, estate governance, estate management, security, and transparency, the constructs have high values across all reliability metrics which attests to their dependability, internal consistency and correctness. However, the determination coefficient (R2) and adjusted determination coefficient (R2 adjusted) values are shown in Table 2 for the several

constructs included in the study. These values show the percentage of variation in each construct that can be explained by the predictor variables.

Table 2. R^2 - adjusted results.

Variables	R-square	R-square adjusted
Efficiency	0.702	0.702
Estate governance	0.372	0.370
Estate management	0.114	0.109
Security	0.776	0.775
Transparency	0.603	0.602

Based on the above table, the percentage of variance in each construct that can be explained by the predictor variables is shown by the R2 values for each construct. For instance, R2 is 0.702 for efficiency indicating that the predictor variables in the model account for 70.2% of efficiency's variability. The R2 values for those constructions demonstrate the explained variance in other dimensions, including estate governance, estate management, security and transparency. R2 adjusted additionally takes the number of predictors in the model into account producing a more cautious estimate of explained variance. The revised R2 values fall between 0.109 and 0.775. These figures show the proportion of the construct variance when model complexity is taken into consideration can be accounted for by the predictor variables. Considering the number of predictors in the model, the adjusted R-squared (R2 adjusted) offers a more conservative estimate of the explained variance. The adjusted values which vary from 0.109 to 0.775 show how much of each construct's variance can be explained by the model's complexity. For instance, the efficiency R2 of 0.702 indicates that the chosen predictors account for 70.2% of the variation in efficiency.

In the instance of estate governance, the predictors account for around 37.2% of the construct's variability. Understanding how much the predictor variables contribute to explaining the variability seen in each construct depends on knowing the R-squared and modified R-squared values. Insights into the model's explanatory power and the links between the variables under consideration are shown by higher R-squared values which show a larger effect of the predictor variables in explaining the variance in the associated construct.

5.1. Hypotheses Testing

The assessment of hypotheses in statistical analysis entails a detailed investigation of a number of indicators, including original value sample estimates (O), t-statistics (T) and p-values (P). The direction and importance of correlations between variables can be better understood due to these indicators. The numerical estimate obtained from the sample data is represented by the original value sample estimate (O). An indicator of a positive association between the variables is a number close to +1 whereas a value close to -1 denotes a negative relationship. The importance of the link is greatly influenced by t-statistics (T). If the t-statistics result is more than 1.96, there is likely to be a significant link between the variables (given a 95% confidence level). Furthermore, key to assessing significance are p-values (P) where a p-value less than the selected significance threshold (usually 0.05) denotes the presence of a statistically significant association between the variables. By taking into account these variables, researchers may establish the direction of the association (positive or negative) based on the estimations of the original value sample (O) and establish the degree of significance using t-statistics (T) and p-values (P). The subsequent display of these indicators in Figure 3 and Table 3 provides an in-depth look at the outcomes of hypothesis testing assisting with the understanding of the correlations between variables and allowing researchers to reach meaningful conclusions that are backed by statistical evidence.

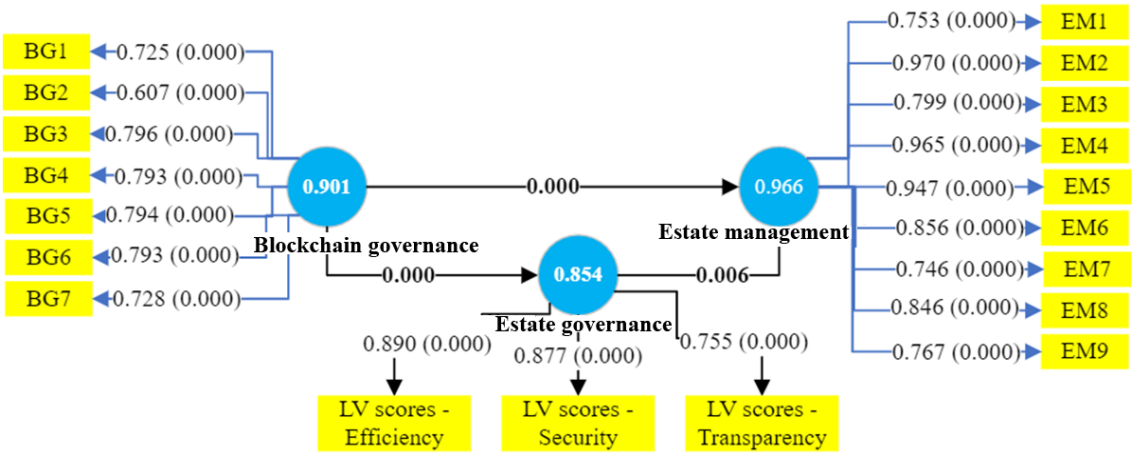

Figure 3. Structural model.

The hypothesis testing procedure which comprises evaluating the research hypotheses is shown in Figure 3. For this testing, the previously indicated route coefficients offer critical information. In order to support the hypotheses being investigated, Table 3 provides information on the strength and significance of the relationships between the various research variables. This table enables the examination of the hypotheses and offers a thorough description of the correlations between the variables. Researchers can decide if the study hypotheses have been supported or rejected based on the direct effects seen between variables as shown in Table 3.

Table 3. Results of hypothesis testing.

Path	B	STDEV	T-values	P-values
Direct effect				
Blockchain governance -> Estate governance	0.636	0.034	18.853	0.000
Blockchain governance -> Estate management	0.240	0.060	3.985	0.000
Estate governance -> Estate management	0.165	0.060	2.751	0.006
Dimensional effect – Med				
Estate governance -> Efficiency	0.848	0.014	58.847	0.000
Estate governance -> Security	0.891	0.011	79.536	0.000
Estate governance -> Transparency	0.780	0.026	29.579	0.000
Indirect effect				
Blockchain governance -> Estate management	0.105	0.039	2.692	0.007

For direct effects testing, the relationships between the IVs (e.g., blockchain governance, estate governance) and the DVs (e.g., estate governance, estate management) are examined with dimensional effect (estate governance on efficiency, security and transparency). In Table 3, the results of hypothesis testing are presented for the different paths examined in the study. In the "direct effect" section, we observe significant beta coefficients (β) for the relationships between blockchain governance and estate governance (β = 0.636), blockchain governance and estate management (β = 0.240), and estate governance and estate management (β = 0.165). These coefficients indicate strong positive relationships. The corresponding t-values are notably high indicating a high level of significance for these relationships (t-values of 18.853, 3.985, and 2.751, respectively) with very low p-values (all-Pv < 0.01) confirming the statistical significance of these relationships. Moving to the "Dimensional Effect - Med" section, we find substantial beta coefficients for the relationships between estate governance and efficiency (β = 0.848), estate governance and security (β = 0.891) and estate governance and transparency (β = 0.780). These coefficients demonstrate strong positive relationships. The t-values for these relationships are extremely high (t-values of 58.847, 79.536, and 29.579, respectively), and the p-values are close to zero (all < 0.001) underscoring the statistical significance of these relationships. In the "indirect effect" section, the beta coefficient for the relationship between

blockchain governance and estate management is smaller (β = 0.105) indicating a weaker indirect relationship. The associated t-value is 2.692 with a p-value of 0.007 indicating a statistically significant relationship although not as strong as those observed in the direct and dimensional effects. However, Table 4 shows the result of mediation effecting testing.

Table 4. Mediation testing results.

Path	β	STDEV	T-values	P values
Blockchain governance -> Estate governance -> Efficiency	0.536	0.031	17.150	0.000
Blockchain governance -> Estate governance -> Transparency	0.493	0.034	14.431	0.000
Blockchain governance -> Estate governance -> Security	0.563	0.031	18.018	0.000
Fully mediation effect				
Blockchain governance -> Estate governance -> Estate management	0.105	0.039	2.692	0.007

Based on the above, estate governance mediated the effect of blockchain governance on estate management because the indirect effect (Blockchain Governance -> Estate Governance -> Estate Management) is significant (B=0.105, T 2.692 which is more than 1.96 and p-value is 0.007 which is greater than 0.05). In addition, the dimensional mediation effect also accepted while this dimensional mediation effect is not included in this paper. Thus, H4 is accepted. H4 indicates that *"estate governance mediates the relationship between blockchain governance and estate management"*.

With delving into previous literature, H1 posits a positive relationship between blockchain governance and estate governance. The result aligns with prior research that emphasizes how blockchain technology can enhance governance structures. Blockchain's decentralized and transparent nature can streamline estate governance processes by reducing the need for intermediaries and enhancing transparency and trust (Laroiya, Saxena, & Komalavalli, 2020). In addition, this study found a positive association between estate governance and efficiency. This aligns with prior literature emphasizing how effective governance positively impacts the efficiency of estate management processes. Proper governance frameworks can lead to streamlined operations, reducing delays and improving overall efficiency in estate management (Allioui & Mourdi, 2023). In addition, the study establishes a positive link between estate governance and security. This finding is consistent with earlier research highlighting that robust governance practices contribute to increased security measures within estate management. Well-governed processes ensure that security protocols are in place to protect estate-related data and assets (Catalini & Gans, 2020). This paper indicates a positive relationship between estate governance and transparency. Previous studies support this relationship underscoring that effective governance mechanisms enhance transparency by providing stakeholders with clear and accessible information. Transparency in estate management is vital for trust and accountability (Al-Taani, Al-Zaqeba, Maabreh, & Jarah, 2024).

6. DISCUSSION

This paper investigates frozen estate management in Malaysia and the vital connections between blockchain governance, estate governance and estate management. Accordingly, this paper indicates that blockchain governance and estate governance have a beneficial link (Khairi & Azmin, 2022). The decentralized, open and safe nature of blockchain demonstrates its ability to optimize estate governance procedures and raise transparency and efficiency providing a solid platform for changing conventional estate governance methods. According to earlier literature (Swan & Melanie, 2015) this is consistent with the revolutionary potential of blockchain technology to revolutionize conventional estate management practices. Moreover, this study validates the relationship between estate governance and crucial outcomes in estate management efficiency, security and transparency. This aligns with prior research emphasizing the role of effective estate governance in enhancing operational processes and

ensuring compliance (Al-Taani et al., 2024). A well-structured estate governance system is positively correlate with efficiency and security, vital aspects of managing frozen estates efficiently. The study also affirms the hypothesis that blockchain governance positively influences estate management. The transformative potential of blockchain technology in optimizing estate management aligns with prior literature (Swan & Melanie, 2015). The findings support the mediating effect of estate governance signifying that the impact of blockchain governance on estate management is partially channeled through its influence on estate governance structures aligning with the notion that a well-regulated estate governance system plays a mediating role in optimizing estate management processes (Pan, Wu, & Choguill, 2023). The discussion extends to the practical implications of these findings exploring how leveraging blockchain technology can significantly improve the efficiency, transparency and security of frozen estate management in Malaysia. Furthermore, the study suggests that policymakers and stakeholders should consider the integration of blockchain in estate governance frameworks for optimal outcomes. Nevertheless, the suggested flowchart system architecture addresses issues with asset preservation, accountability, transparency and security while offering a thorough overview of a blockchain-based system designed for managing frozen estates. The design describes in detail how this system will be put into practice with a focus on how smart contracts, user interfaces, identity verification processes, blockchain networks, secure data management and agency coordination will all be integrated. Moreover, the architecture underscores the setup of a blockchain network customized for frozen estate management, ensuring privacy and controlled access for authorized participants. When it comes to automating and enforcing estate-related operations, smart contracts are essential since they minimize manual involvement and improve accuracy. User interfaces cater to various stakeholders allowing interaction with the blockchain network, access to estate-related information, transaction initiation and process monitoring. Identity verification mechanisms enhance security and cryptographic techniques ensure secure data management within the blockchain providing an auditable record of estate-related activities.

7. CONCLUSION

This paper has delved into the significant potential of integrating blockchain technology into the domain of frozen estate management. The identified positive relationships between blockchain governance, estate governance and key outcomes in estate management underline the substantial impact effective governance practices can have on enhancing the efficiency, security and transparency of estate management processes. The mediating role of estate governance further emphasizes the interconnectedness and interdependence of governance structures within the estate management framework. Nevertheless, this paper has shed light on the intricate relationship between blockchain governance, estate governance and estate management in the context of frozen estate management in Malaysia. The findings validate the positive association between blockchain governance and estate governance, affirming the potential of blockchain technology to revolutionize conventional estate governance processes. This aligns with the broader consensus in literature regarding blockchain's decentralized and transparent nature enhancing governance structures. Furthermore, the study establishes that estate governance plays a mediating role in the relationship between blockchain governance and estate management. This mediation effect underscores the importance of a well-structured estate governance system in optimizing estate management processes, emphasizing efficiency, security and transparency within the frozen estate management domain. Effective governance practices were found to positively correlate with enhanced efficiency, strengthened security measures and improved transparency, essential aspects for managing frozen estates effectively. This paper also supports the hypothesis that blockchain governance positively influences estate management highlighting the transformative potential of blockchain technology in optimizing estate management practices.

7.1. Implications

The results highlight how using blockchain technology in frozen estate management has the potential to be revolutionary. Positive correlations between estate governance, blockchain governance and estate management results emphasize how important good governance is to improving estate management's effectiveness, security and transparency. Furthermore, the confirmation of blockchain governance's beneficial impact on estate management raises the possibility that blockchain may completely transform current estate governance procedures. One practical consequence is that managing frozen estates in Malaysia might be made more efficient, transparent and secure by integrating blockchain technology into estate governance structures. This research highlights the potential of blockchain technology to improve security, collaboration and transparency in frozen estate administration and provides a thorough implementation guide.

7.2. Limitations

This study has some drawbacks despite its merits. The study's exclusive emphasis on Malaysia's frozen estate management environment may have limited the applicability of its conclusions to other estate types or geographical areas. Furthermore, the amount of insight that qualitative approaches might give about intricate intricacies within estate management may be limited by the dependence on a quantitative survey methodology. Furthermore, even though the study's sample was specifically focused on estate management, it may not have included all pertinent viewpoints from the industry which might effect on how thorough the results are.

7.3. Future Research Suggestions

Subsequent investigations may tackle the constraints by expanding the range to encompass a wider range of geographical settings and sorts of estates, therefore furnishing a more all-encompassing comprehension of blockchain's influence on estate governance worldwide. Combining qualitative research techniques with quantitative surveys may provide a deeper understanding of the complex dynamics of estate management as impacted by blockchain technology. Furthermore, the study's breadth and depth may be improved by broadening the sample diversity to include a greater spectrum of estate management experts and stakeholders. Furthermore, longitudinal research monitoring the use of blockchain-based solutions in frozen estate administration would shed light on the issues that emerge over time and their long-term efficacy.

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Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: Conceptualization, resources, writing—original draft preparation, writing—review and editing, K.K., N.H.L. and M.A.Z.; methodology, software, formal analysis, data curation, M.A.Z.; visualization, and validation, K.K. and N.H.L.; investigation, N.H.L.; supervision, project administration, and funding acquisition, K.K. All authors have read and agreed to the published version of the manuscript.

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