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Land Certificate Authenticity Using Blockchain Technology in Indonesia

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Abstract—Indonesia’s land registration system suffers from data integrity deficiencies and limited stakeholder interconnectedness, leading to duplicate certificates. This research addresses these challenges by proposing a digital land certificate system built on a decentralized, transparent, and hybrid blockchain technology. The system aims to streamline land transactions in Indonesia, facilitating the process from digital transfer to National Land Agency (BPN) registration. The methodology employs a qualitative analysis framework, drawing upon literature reviews of existing blockchain land management research and stakeholder interviews. Data analysis guides the design model recommendations and prototype application development. Findings suggest that digitizing land certificates through a transfer media system is a critical initial step for blockchain implementation. Furthermore, a hybrid blockchain model, coupled with Public Key Infrastructure (PKI), appears best suited for the Indonesian context. This approach leverages smart contract verification and peer-to-peer networks to ensure data authenticity. Building upon this research, future applications can explore integrating blockchain technology into land buying and selling systems alongside enhancements to relevant websites.

Keywords—land certificate authenticity, hybrid blockchain, smart contract, land ownership

I. INTRODUCTION

A land certificate is an evidence that provides an essential meaning for the legal certainty of land rights. Conventional land certificates in Indonesia possess inherent vulnerabilities, including susceptibility to damage from natural disasters and theft. In response, the Ministry of Agrarian and Spatial Planning/National Land Agency (ATR/BPN) has embarked on a digitalization initiative by introducing Electronic Land Certificates. However, the transition from physical to digital certificates may need to adequately address the core challenges plaguing land certificate systems, such as opacity, operational inefficiencies, potential forgery or duplication, and the inherent complexities associated with centralized record-keeping. Many countries have used electronic cadastral systems for years, but at the same time, they still heavily rely on paper transactions [1]. Even though title and property rights are recorded electronically, these records are secondary and after the transactions in paper form. Indonesia’s land registry system needs comprehensive digitization, resulting in significant inaccurate and outdated information. These errors and inconsistencies within the registry disrupt the National Land Agency’s (BPN) ability to furnish stakeholders, including citizens, with reliable data.

Using blockchain in land certificates involves leveraging decentralized, secure, and transparent technology to manage, record, and verify land ownership and property rights [2]. This technology functions as a secure database and ownership management mechanism, an inherent characteristic of this technology. Utilizing Distributed Ledger Technology (DLT), users can directly oversee their property through peer-to-peer (P2P) transactions [3]. Applying blockchain technology to land ownership can enhance transparency within stakeholder networks, thereby mitigating the risk of corruption and record manipulation. This increased transparency can foster trust among users and contribute to a reduction in land disputes. Furthermore, by establishing a transparent and immutable record of land ownership, blockchain technology can facilitate a streamlined process for transferring ownership or titles, potentially reducing associated time and cost burdens.

Despite its promise, blockchain technology presents certain limitations and challenges in the context of land registration. Firstly, a significant portion of the population may need more familiarity with blockchain’s underlying mechanisms, hindering user adoption due to low public literacy. Secondly, scalability concerns plague public blockchains, potentially limiting transaction speeds [4]. As blockchain usage grows, a surge in transactions can overburden the network due to data synchronization requirements. Transaction validation, a resource-intensive and time-consuming process, further exacerbates this issue. While increasing block size can address this to some extent, it creates challenges in network propagation. Thirdly, robust regulations and standardized protocols still need to be addressed for businesses considering blockchain implementation [5]. These limitations must be considered when establishing a legal, secure, reliable land registration system. Ensuring a clear consensus on legal ownership rights remains a fundamental requirement in such a system [6].

Blockchain technology for land management is starting to be widely discussed and researched for its adoption process in various countries. Republic of Georgia (the first mover in adopting blockchain technology for land registration), Ukraine, Brazil, Honduras, Ghana, Sweden, and the United Arab Emirates are actively exploring and implementing blockchain technology to enhance land registration and transfer processes [7]. Without a universally standard framework, potential solutions often incorporate hybrid blockchain architectures. Land information is recorded in a private blockchain before publishing on a public blockchain to ensure user data privacy and immutability. Sweden’s land registration system currently needs more transparency,

extended transaction processing times (often ranging from 3 to 6 months), and continued dependence on paper-based documentation [8]. These factors contribute to concerns about potential errors during the registration process. In response to these challenges, Sweden is exploring the potential of full document and identity signature digitization for real estate transactions. This initiative aims to reduce processing times to just a few days significantly.

Furthermore, numerous recent studies have explored the theoretical framework for integrating blockchain technology into land management systems. In India, adopting real estate tokenization could offer significant advantages, particularly in border regions, by enhancing border security to deter foreign intrusion due to the country's extensive territory and proximity to neighboring nations [9]. Likewise, in Bangladesh, Kazakhstan, Pakistan, and Thailand, the use of blockchain can overcome problems related to manual land registration processes, such as transparency, centralization, authenticity, and reliability [10], [11], [12], [13]. Previous research has identified challenges associated with integrating blockchain technology into land management. These challenges include limitations in the adaptability of government agencies or administering bodies to define land boundaries and plots precisely. The current computerized land registry system operates siloed, lacking integration between various land recording and registration departments. This necessitates a central server to store data collaboratively, which needs improvement.

This research proposes a model for land certificates that leverages blockchain technology to guarantee authenticity. Recognizing the need to balance confidentiality with transparency, the model employs a hybrid blockchain architecture. These architectures combine elements of both public and private blockchains, fostering an equilibrium between the two. This approach facilitates participation by the public (users) and authorized entities (BPN officers) in overseeing the blockchain system. Public blockchains offer unrestricted access for browsing and exploration, while private blockchains maintain internal records accessible only to designated owners and entities. Both components are essential for a functional land marketplace. Prior research suggests that a hybrid blockchain approach offers significant advantages over alternative blockchain models in Indonesia's land sector context. This is particularly relevant as it enables public access to reliable, cost-effective land records. Key information would be readily available on a public ledger, reducing the need for frequent land data verification submissions to the land office [14].

Considering the complexities of land management in Indonesia, our research involved collaboration with experts who deeply understand Indonesian land authorities, policies, and regions. While Indonesia has yet to adopt blockchain technology due to digitizing physical land certificates, the Ministry of Agrarian and Spatial Planning/National Land Agency (ATR/BPN) is demonstrably aware of its potential future application in resolving land-related issues. In this context, we propose a blockchain technology model suitable for adoption as a novel technological intervention in Indonesia. Our model focuses on transitioning physical land certificates to a digital format, followed by their secure recording on the blockchain through a centralized portal – specifically, the BPN website. This model leverages the combined strengths of blockchain technology, smart contract

verification, the Public Key Infrastructure (PKI) model, and a media transfer system to ensure the authenticity of digital land certificates. We organize this paper into a literature review in section II, research methodology in section III, results and discussion in section IV, and conclusions and future work in section V.

II. LITERATURE REVIEW

A. Existing Land Certification System in Indonesia

Indonesia's land certification system currently prioritizes the completion of outstanding land registrations. President Joko Widodo has set a goal of achieving complete registration and certification of all land plots in Indonesia by 2025. Recognizing the inherent complexities of the land management system, the Indonesian government has implemented various initiatives to address the challenge of land certification. One such initiative is the National Priority Program for Accelerated Complete Systematic Land Registration (PTSL), spearheaded by the Ministry of Agrarian and Spatial Planning/National Land Agency (ATR/BPN). This program is governed by the Regulation of the Minister of ATR/BPN of the Republic of Indonesia Number 6 of 2018, which has been in effect since April 11, 2018. PTSL program is shown in Fig. 1.

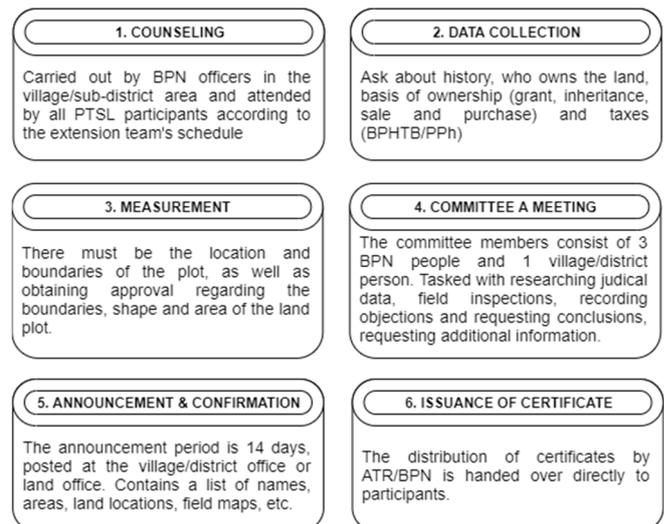


Fig. 1. PTSL program for land registration in Indonesia.

PTSL is the government's comprehensive effort to streamline land registration procedures and implement the government's obligations to guarantee certainty and legal protection for community land ownership at affordable or even accessible costs. PTSL is the first registration process for land that does not yet have ownership rights. The aim is to provide added economic value to Indonesian society. However, the current land certification system consists of a long series of procedures that require much time to complete. This process involves many departments for managing essential documents but often escapes the general public's attention, giving rise to the risk of node failure and a need for more transparency.

B. Blockchain Technology

Blockchain technology is a decentralized data infrastructure that allows users to securely share, synchronize, validate, and replicate digital data across a distributed network of multiple entities without a centralized

governance mechanism to establish trust among network participants [15]. Blockchain technology ensures data privacy and controlled access by preserving data confidentiality, integrity, and authentication [16]. Blockchain technology relies on two key drivers: Smart Contracts and Distributed Ledger Technology (DLT). Due to the unpredictable terms of Smart Contracts, a meticulous review by both parties is essential before signing [17]. Smart contracts facilitate the automated execution of transactions upon fulfilling predefined conditions. The agreement is automatically enforced once both parties agree to the terms and conditions that are embedded digitally and complete all requirements. Smart contracts are stored on the blockchain. The ledger functions as a database housing the complete record of transactions within the blockchain [18]. Due to the decentralized nature of the network without a central authority, the ledger is distributed across the network. Once a transaction is appended to the ledger, it becomes permanent and cannot be removed, ensuring the immutability of the ledger. Blockchain's decentralized ledger simplifies recording transactions and monitoring assets in a business network. Whether tangible, like real estate or cash, or intangible, like patents, virtually any valuable asset can be tracked and traded on a blockchain network, reducing risks and costs for all parties involved [19].

Utilizing blockchain technology makes it possible to record transactions without a central authority verifying their validity. No centralized entity is responsible for storing all records as a single source of truth, making the records immutable and resistant to data modification or tampering and ensuring consistency around the network [20], [21]. Hence, blockchain technology facilitates distributed databases without needing third-party intervention and authentication, enabling various industries' transparency, traceability, and efficiency [22]. The blockchain consensus protocol establishes rules for operations and interactions within a distributed system to achieve agreement on the future state of the blockchain, requiring majority participant consensus [23]. The primary obstacles to advancing blockchain technology are decentralization, scalability, and security. Striking a balance between these aspects poses a significant challenge, often called the blockchain trilemma. Prioritizing the attainment of equilibrium among these elements is crucial in developing dependable and effective blockchain systems [24].

C. Blockchain for Land Certificate

Land management in Indonesia faces numerous challenges, including corruption, manipulation, duplication of land records, the presence of land mafia, and lengthy land registration processes. Blockchain technology presents a potential solution to these issues. Land registration is one application of blockchain technology in public services, where details about land, including its physical condition and associated rights, can be registered and accessible on the blockchain [25]. This technology facilitates the transparent documentation and monitoring of any land modifications, such as ownership transfers or mortgage creation, potentially improving the effectiveness of public services. By ensuring the security of physical and legal data on registered land plots, blockchain technology can mitigate the problem of duplicate land certificates in Indonesia. This enhanced security makes it significantly more difficult for unauthorized parties to manipulate land data [26]. Furthermore, blockchain offers solutions to the challenges associated with public key

infrastructure and privacy regulations [27]. The proposed system leverages blockchain technology to create a solution that provides synchronized and transparent data, facilitates easy accessibility, ensures immutable record management, and promotes cost-effectiveness [28].

III. METHODOLOGY

This research workflow is divided into three stages, as shown in Fig. 2.: business process understanding and data collection, model construction, and prototyping application.

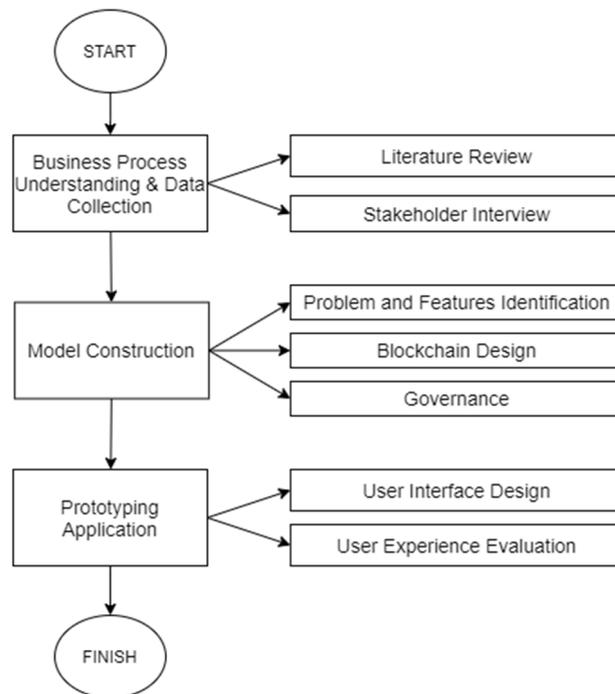


Fig. 2. Research model diagram.

The first stage is understanding the business process of implementing land certificates in Indonesia by studying literature from various research journal articles and conference proceedings regarding blockchain-based land management systems, encompassing established and developing implementations worldwide, including research from Indonesia. News sources and social media maintained by Indonesian land institutions provided complementary, up-to-date information. Additionally, semi-structured interviews were conducted with key stakeholders to ascertain their perspectives on integrating blockchain technology into existing land registration business processes. Following a detailed explanation of the proposed blockchain mechanism for transparent land registration, participants were invited to provide feedback on the design model. This included their views on the proposed workflow, its potential for implementation in the Indonesian context, and their aspirations for the future of land and property management in Indonesia. The participants in this study included 50 individuals from Indonesia, aged 30 to 60, and of both genders. These participants represented a range of stakeholders in the land management system, including landowners, property agencies, and government representatives from the National Land Agency (BPN).

The second stage is to design the adoption of blockchain infrastructure in a land certificate by identifying problems and features and looking at potential aspects from a governance perspective. Due to the complexity of land

administration in Indonesia, the second stage is divided into three substages:

1. Problem and Features Identification

This research investigates the potential of blockchain technology to enhance the authentication and security of land certificate management in Indonesia. Land management in Indonesia faces a well-documented challenge of corruption within the National Land Agency (BPN). Instances have been reported where BPN officials have exploited their positions for personal gain or engaged in mismanaging land acquisition processes. Furthermore, the current BPN processes need more transparency, hindering public and stakeholder comprehension of agency operations and decision-making procedures. This lack of transparency can erode trust and impede the BPN's ability to cultivate positive relationships with the public. Blockchain technology offers a potential solution by fostering transparency, decentralization, data security, and immutability in land certificate management. Additionally, blockchain enables smart contract-based ownership transfers, facilitates clear transaction history for dispute resolution, and promotes open information access.

2. Blockchain Design

Implementing land certificates in Indonesia using blockchain technology is necessary to create a use case diagram for each stakeholder, system, and the relationships between them. This design is foundational for developing a blockchain model for land certificate management. The model will meticulously detail the roles of each stakeholder, the nature of data exchange, and the interactions between them through workflow data records.

3. Governance

Effective governance is paramount to safeguarding the integrity of blockchain-based land records. This necessitates the development of a clear and comprehensive governance strategy. The strategy should establish precise access controls, define who can write and access data, and ensure that only authorized stakeholders possess system access [29]. The plan must balance transparency with controlled access in the context of land ownership certificates. Transparency in ownership history is crucial, enabling landowners and prospective buyers to conduct secure peer-to-peer transactions directly through their digital wallets, streamlining the process. However, to maintain the integrity of the land registry, only the National Land Agency (BPN) should possess the authority to add new records to the blockchain and update land ownership status. Therefore, a well-defined governance strategy is essential to facilitate the successful adoption of blockchain technology in land certificate management.

The final stage is the prototyping application for land certificate registration data input and ownership history tracing. The user interface design is a rough representation of the BPN website, where stakeholders can record data, add data related to land certificate ownership (if permitted), and view the entire land certificate record. Then, the user interface design will be tested to determine user understanding of the land certificate registration process and evaluate the model being built. Feedback from the user interface demo will be used as a model evaluation due to the development stage of this system.

IV. RESULT AND DISCUSSION

In contrast to the proposed blockchain system's reliance on digital land certificates, Indonesia's current land ownership records remain in physical paper certificates. Consequently, the initial step towards blockchain integration necessitates digitizing these existing certificates. A media transfer system is paramount to facilitate this process and enable the subsequent recording of land transactions on the blockchain. This research presents a novel system that seamlessly converts physical land certificates into digital records suitable for blockchain storage. Notably, the media transfer process within this system is restricted to authorized government agencies, specifically the National Land Agency (BPN). Fig. 3. visually depicts the integration of the media transfer system with the blockchain architecture.

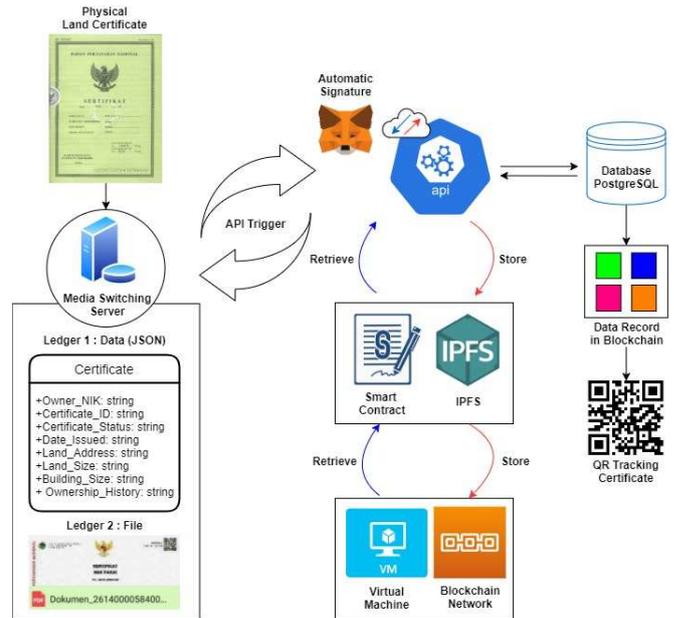


Fig. 3. Proposed system design.

Digital land certificate data will be recorded on two ledgers. Ledger 1 records certificate data, such as NIK, ID, status, etc. Ledger 2 records scans of physical certificate files (e-certificates) in PDF. Both data will be stored on the server, where ledger one is stored on the blockchain and ledger two is stored on the Interplanetary File System (IPFS). IPFS is an appropriate storage option for decentralized social applications, leveraging decentralized character and the capacity to link devices globally [30]. An API Trigger executes table update commands within the ledger to maintain data consistency during application and service interactions. The process commences with an API Post request, transmitting data in JSON format to the server. Subsequently, the server automates electronic signatures to facilitate the creation of smart contracts. The data is uploaded simultaneously to the blockchain and IPFS after successfully processing the land certificate registration request. Finally, the server transmits an API response. Data retrieval occurs through an API Get request, fetching certificate data from the server for subsequent storage in each ledger. Before storage in Ledgers 1 and 2, a validation step verifies the smart contract using the automated digital signature process. Following successful validation and storage on the blockchain and IPFS, the server receives confirmation via another API Response. This sequence of actions culminates in successfully recording the digital certificate on the blockchain. Once land ownership

data resides on the blockchain, a land certificate tracking QR code can be utilized to verify its authenticity.

The proposed design model recommendations analysis identifies three critical stakeholders within the system: landowners, the National Land Agency (BPN), and users. Landowners are individuals who possess land ownership but lack a formal certificate. BPN officers manage the entire land certificate lifecycle, including creating, finalizing, and storing records within the blockchain database. Users, categorized as regular or potential buyers (hereafter referred to as "buyers"), can leverage the dedicated website search feature to access traceability information on land ownership. Landowners and BPN officers possess read-write access privileges within the system, while user access is restricted to read-only functionality. It is crucial to emphasize that only BPN officers can record data onto the blockchain system. The use case diagram of the stakeholders, system, and relationship between them is shown in Fig. 4.

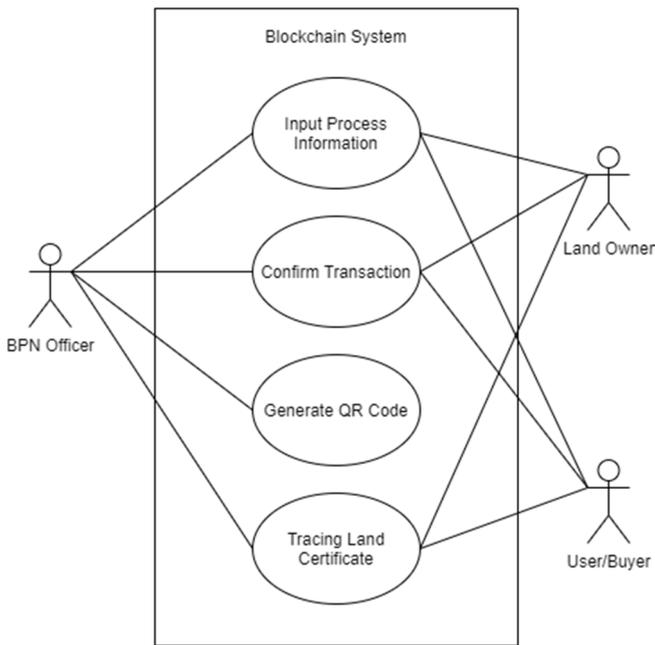


Fig. 4. Use case diagram.

Fig. 4. illustrates the processes involving actors and their roles in a blockchain system. Landowners initiate the data entry by submitting land ownership information into the BPN system, typically accessed through the BPN website. Subsequently, BPN officers facilitate the transfer of this recording, encompassing the certificate data, onto the blockchain system. To enhance accessibility and verification of land or building ownership certificates, BPN generates QR codes linked to the blockchain data. Users leverage these QR codes to verify the authenticity of land certificates by scanning them. A detailed illustration of the data record workflow for each stakeholder is presented in Fig. 5.

Blockchain technology empowers decentralized governance through two models: off-chain and on-chain. On-chain governance, gaining traction for its ability to bolster public trust via increased user voting rights, fosters an inclusive environment where all participants share benefits. Three entities in the proposed on-chain land certificate system handle data input and posting: users (land certificate stakeholders), the BPN website interface, and the blockchain itself. Fig. 6. illustrates this process with a sequence diagram.

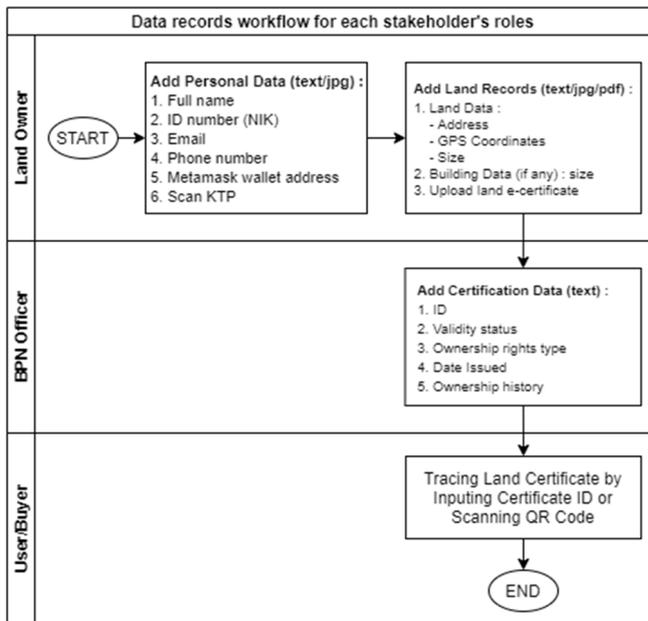


Fig. 5. Data records workflow for each stakeholder's roles.

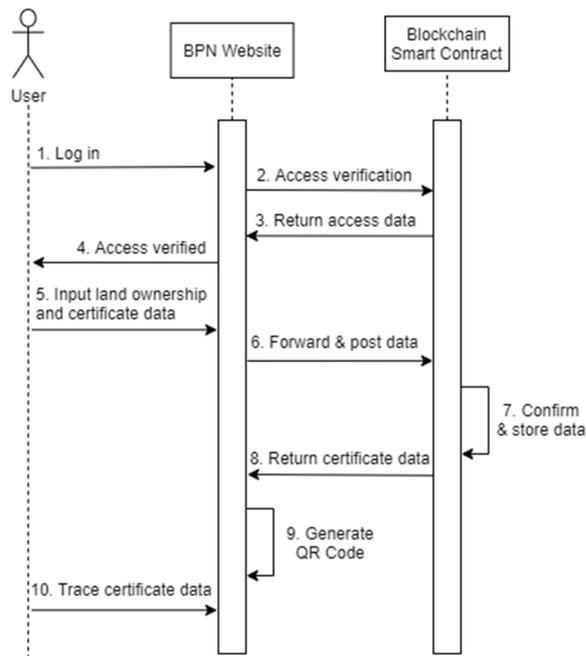


Fig. 6. sequence diagram of on-chain blockchain system.

We offer a land ownership certification system using hybrid blockchain technology to solve problems and maintain data authenticity. The system incorporates a tiered access structure, granting public visibility to designated sections while restricting access to sensitive information. Public Key Infrastructure (PKI) is the secure communication channel for landowners, users, and BPN officers acting as trusted third parties. PKI issues digital certificates to authenticate participants and safeguard data transmission. This system utilizes a public-private key pair for cryptographic security. While public keys facilitate secure communication, they are inherently susceptible to attacks, necessitating a robust infrastructure [31]. The proposed system empowers users to manage the blockchain system despite the data residing on a private chain, provided they possess the key issued by BPN [14]. The interconnection between two blockchains (public

and private) is by using a gateway that connects the two, the BPN website, which BPN provides as a PKI holder. Hybrid blockchain in various industries provides positive feedback even in permanent use [32]. It can also address the issues of data security breaches, unauthorized modifications or deletions, lack of transparency, high maintenance, subscription, licensing expenses, and vulnerability to hacking attacks.

The current prototype focuses on capturing land certificate and owner data, as illustrated in Fig. 7. Meanwhile, Fig. 8. showcases the utilization of QR codes for enhanced traceability. Following secure storage on the blockchain's immutable ledger, stakeholders can confidently contribute and store their data. Future iterations will expand data recording functionalities to encompass more comprehensive land information, such as photographs of the land or buildings.

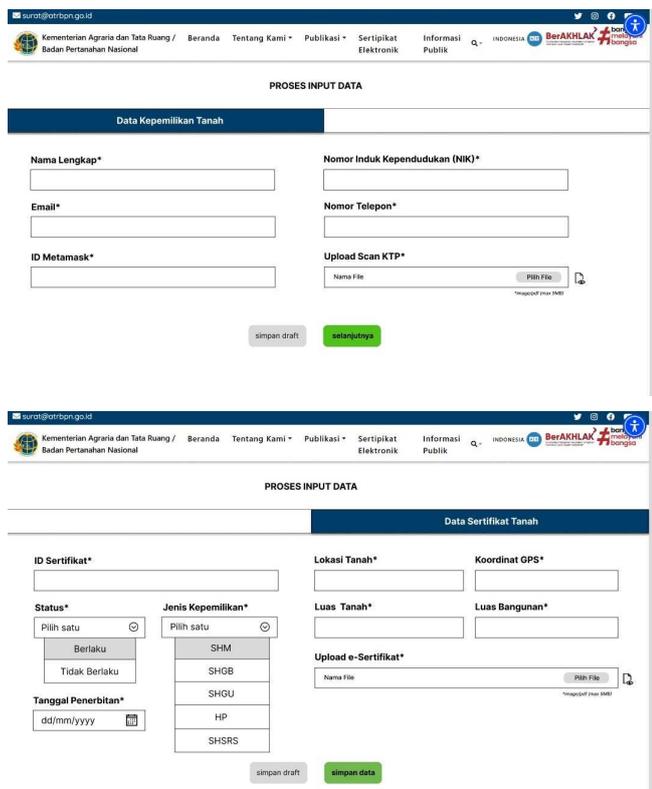


Fig. 7. User interface for land owner and land data record.

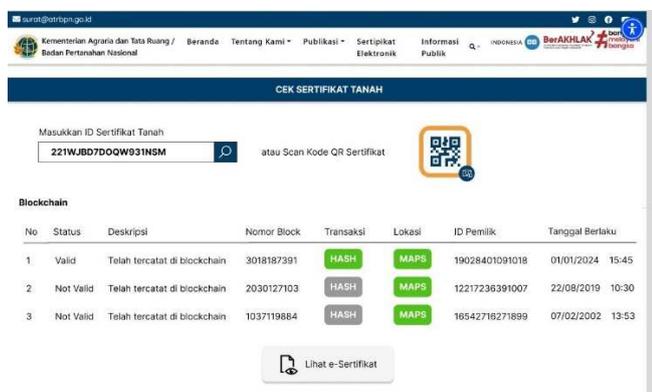


Fig. 8. Tracking authenticity of land certificate.

On the BPN website, there is a menu to check land certificates. Users can search for registered land certificates

by inputting the identity of the certificate. The aim is to track the authenticity of land certificates by displaying e-certificates and tracing land ownership history (if any). Because land owner data is confidential, it will use a private blockchain. Meanwhile, detailed land data uses public blockchain so all users can still access it. The owner ID displayed on the website is not the NIK but a new number configuration.

We evaluate the design model by conducting user testing through a brief presentation of the recommended system and demonstration of an application prototype (Fig. 7. and Fig. 8.). Whether they understand blockchain technology, land owners and property enthusiasts are the target sources. Besides that, we also involve people who need help understanding the land industry. All interviewees agree to adopt blockchain technology for Indonesia's future land certificate recording system. Regarding website design, it is also easy to use and understand all features (user-friendly). However, it is essential to consider integrating the laws in force in Indonesia and blockchain applications to optimally overcome land problems.

Over the past five years, more than 3,000 research studies have explored the adoption of blockchain technology across different sectors, with over 400 studies explicitly addressing the resolution of land governance issues through this innovative technology. The practical implementation of Blockchain in India's land records management requires finalizing the attributes to be included in transactions, developing smart contracts, and ensuring the preservation of records for archival purposes [27]. The proposed system in Pakistan and Thailand addresses issues in traditional land management systems. It provides a cost-effective solution for land record management utilizing private blockchain technology as the proposed Land Records Management system [12], [13]. In Kazakhstan, hybrid blockchain is preferred for land management even though the government still needs to adopt blockchain to improve public administration [11] Bangladesh provides a suitable environment for land registration by using a public and permissionless Blockchain like Ethereum, which offers unlimited processing facilities and transparency to accomplish Sustainable Development Goals (SDGs) and economic development [10].

Meanwhile, in this research, implementing a hybrid blockchain with a Public Key Infrastructure model in Indonesia guarantees data authenticity through smart contract verification and peer-to-peer networks. The system also includes a media transfer system, which ensures the accurate digitization of physical land certificates. The process can help maintain the authenticity of the digital certificates by securely transferring the data from the physical certificates to the blockchain. Recent research has increasingly conceptualized a framework for blockchain in management. Different types of blockchain are chosen, employing diverse technical tools, while various studies have integrated blockchain with other technologies like Artificial Intelligence and the Internet of Things.

V. CONCLUSION AND FUTURE WORKS

This study uses blockchain technology to present Indonesia's foundational land certificate authenticity verification model. The design incorporates an ID scanning feature to verify individual land ownership certificates.

Recognizing Indonesia's ongoing land certificate registration process, the proposed system includes a media transfer system to streamline the transition from physical certificates to blockchain records. The research aims to contribute to the theoretical understanding and practical implementation of blockchain technology within the land management domain.

However, limitations currently hinder real-world implementation. The system needs the integration of government or other authorized entities as validators within the land authenticity verification process. Additionally, challenges persist in the research itself, including the inherent complexity of the technology, the evolving legal landscape surrounding its implementation, and the public's limited understanding of blockchain. While blockchain technology offers promising advancements in technological solutions and business models, the absence of established best practices or standardized protocols creates a significant barrier.

Future research will focus on buying and selling systems of land and building that leverage tokenization. Furthermore, a prototype application has been developed and rigorously tested to record land registration and ownership data on the blockchain via the BPN website. Direct collaboration with BPN is envisaged, along with a demonstration of the model design to facilitate potential adoption.

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Land Certificate Authenticity Using Blockchain Technology in Indonesia

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Abstract—Indonesia's land registration system suffers from data integrity deficiencies and limited stakeholder interconnectedness, leading to duplicate certificates. This research addresses these challenges by proposing a digital land certificate system built on a decentralized, transparent, and hybrid blockchain technology. The system aims to streamline land transactions in Indonesia, facilitating the process from digital transfer to National Land Agency (BPN) registration. The methodology employs a qualitative analysis framework, drawing upon literature reviews of existing blockchain land management research and stakeholder interviews. Data analysis guides the design model recommendations and prototype application development. Findings suggest that digitizing land certificates through a transfer media system is a critical initial step for blockchain implementation. Furthermore, a hybrid blockchain model, coupled with Public Key Infrastructure (PKI), appears best suited for the Indonesian context. This approach leverages smart contract verification and peer-to-peer networks to ensure data authenticity. Building upon this research, future applications can explore integrating blockchain technology into land buying and selling systems alongside enhancements to relevant websites.

Keywords—land certificate authenticity, hybrid blockchain, smart contract, land ownership

I. INTRODUCTION

A land certificate is an evidence that provides an essential meaning for the legal certainty of land rights. Conventional land certificates in Indonesia possess inherent vulnerabilities, including susceptibility to damage from natural disasters and theft. In response, the Ministry of Agrarian and Spatial Planning/National Land Agency (ATR/BPN) has embarked on a digitalization initiative by introducing Electronic Land Certificates. However, the transition from physical to digital certificates may need to adequately address the core challenges plaguing land certificate systems, such as opacity, operational inefficiencies, potential forgery or duplication, and the inherent complexities associated with centralized record-keeping. Many countries have used electronic cadastral systems for years, but at the same time, they still heavily rely on paper transactions [1]. Even though title and property rights are recorded electronically, these records are secondary and after the transactions in paper form. Indonesia's land registry system needs comprehensive digitization, resulting in significant inaccurate and outdated information. These errors and inconsistencies within the registry disrupt the National Land Agency's (BPN) ability to furnish stakeholders, including citizens, with reliable data.

Using blockchain in land certificates involves leveraging decentralized, secure, and transparent technology to manage, record, and verify land ownership and property rights [2]. This technology functions as a secure database and ownership management mechanism, an inherent characteristic of this technology. Utilizing Distributed Ledger Technology (DLT), users can directly oversee their property through peer-to-peer (P2P) transactions [3]. Applying blockchain technology to land ownership can enhance transparency within stakeholder networks, thereby mitigating the risk of corruption and record manipulation. This increased transparency can foster trust among users and contribute to a reduction in land disputes. Furthermore, by establishing a transparent and immutable record of land ownership, blockchain technology can facilitate a streamlined process for transferring ownership or titles, potentially reducing associated time and cost burdens.

Despite its promise, blockchain technology presents certain limitations and challenges in the context of land registration. Firstly, a significant portion of the population may need more familiarity with blockchain's underlying mechanisms, hindering user adoption due to low public literacy. Secondly, scalability concerns plague public blockchains, potentially limiting transaction speeds [4]. As blockchain usage grows, a surge in transactions can overburden the network due to data synchronization requirements. Transaction validation, a resource-intensive and time-consuming process, further exacerbates this issue. While increasing block size can address this to some extent, it creates challenges in network propagation. Thirdly, robust regulations and standardized protocols still need to be addressed for businesses considering blockchain implementation [5]. These limitations must be considered when establishing a legal, secure, reliable land registration system. Ensuring a clear consensus on legal ownership rights remains a fundamental requirement in such a system [6].

Blockchain technology for land management is starting to be widely discussed and researched for its adoption process in various countries. Republic of Georgia (the first mover in adopting blockchain technology for land registration), Ukraine, Brazil, Honduras, Ghana, Sweden, and the United Arab Emirates are actively exploring and implementing blockchain technology to enhance land registration and transfer processes [7]. Without a universal standard framework, potential solutions often incorporate hybrid blockchain architectures. Land information is recorded in a private blockchain before publishing on a public blockchain to ensure user data privacy and immutability. Sweden's land registration system currently needs more transparency,

extended transaction processing times (often ranging from 3 to 6 months), and continued dependence on paper-based documentation [8]. These factors contribute to concerns about potential errors during the registration process. In response to these challenges, Sweden is exploring the potential of full document and identity signature digitization for real estate transactions. This initiative aims to reduce processing times to just a few days significantly.

Furthermore, numerous recent studies have explored the theoretical framework for integrating blockchain technology into land management systems. In India, adopting real estate tokenization could offer significant advantages, particularly in border regions, by enhancing border security to deter foreign intrusion due to the country's extensive territory and proximity to neighboring nations [9]. Likewise, in Bangladesh, Kazakhstan, Pakistan, [15] Thailand, the use of blockchain can overcome problems related to manual land registration processes, such as transparency, centralization, authenticity, and reliability [10], [11], [12], [13]. Previous research has identified challenges associated with integrating blockchain technology into land management. These challenges include limitations in the adaptability of government agencies or administering bodies to define land boundaries and plots precisely. The current computerized land registry system operates siloed, lacking integration between various land recording and registration departments. This necessitates a central server to store data collaboratively, which needs improvement.

This research proposes a model for land certificates that leverages blockchain technology to guarantee authenticity. Recognizing the need to balance confidentiality with transparency, the model employs a hybrid blockchain architecture. These architectures combine elements of both public and private blockchains, fostering an equilibrium between the two. This approach facilitates participation by the public (users) and authorized entities (BPN officers) in overseeing the blockchain system. Public blockchains offer unrestricted access for browsing and exploration, while private blockchains maintain internal records accessible only to designated owners and entities. Both components are essential for a functional land marketplace. Prior research suggests that a hybrid blockchain approach offers significant advantages over alternative blockchain models in Indonesia's land sector context. This is particularly relevant as it enables public access to reliable, cost-effective land records. Key information would be readily available on a public ledger, reducing the need for frequent land data verification submissions to the land office [14].

Considering the complexities of land management in Indonesia, our research involved collaboration with experts who deeply understand Indonesian land authorities, policies, and regions. While Indonesia has yet to adopt blockchain [13] technology due to digitizing physical land certificates, the Ministry of Agrarian and Spatial Planning/National Land Agency (ATR/BPN) is demonstrably aware of its potential future application in resolving land-related issues. In this context, we propose a blockchain technology model suitable for adoption as a novel technological intervention in Indonesia. Our model focuses on transitioning physical land certificates to a digital format, followed by their secure recording on the blockchain through a centralized portal – specifically, the BPN website. This model leverages the combined strengths of blockchain technology, smart contract

verification, the Public Key Infrastructure (PKI) model, and a media transfer system to ensure the authenticity of digital land certificates. We organize this paper into a literature review in section II, research methodology in section III, results and discussion in section IV, and conclusions and future work in section V.

II. LITERATURE REVIEW

A. Existing Land Certification System in Indonesia

Indonesia's land certification system currently prioritizes the completion of outstanding land registrations. President Joko Widodo has set a goal of achieving complete registration and certification of all land plots in Indonesia by 2025. Recognizing the inherent complexities of the land management system, the Indonesian government has implemented various initiatives to address the challenge of land certification. One such initiative is the National Priority Program for Accelerated Complete Systematic Land Registration (PTSL), spearheaded by the Ministry of Agrarian and Spatial Planning/National Land Agency (ATR/BPN). This program is governed by the Regulation of the Minister of ATR/BPN of the Republic of Indonesia Number 6 of 2018, which has been in effect since April 11, 2018. PTSL program is shown in Fig. 1.



Fig. 1. PTSL program for land registration in Indonesia.

PTSL is the government's comprehensive effort to streamline land registration procedures and implement the government's obligations to guarantee certainty and legal protection for community land ownership at affordable or even accessible costs. PTSL is the first registration process for land that does not yet have ownership rights. The aim is to provide added economic value to Indonesian society. However, the current land certification system consists of a long series of procedures that require much time to complete. This process involves many departments for managing essential documents but often escapes the general public's attention, giving rise to the risk of node failure and a need for more transparency.

B. Blockchain Technology

Blockchain technology is a decentralized data infrastructure that allows users to securely share, synchronize, validate, and replicate digital data across a distributed network of multiple entities without a centralized

governance mechanism to establish trust among network participants [15]. Blockchain technology ensures data privacy and controlled access by preserving data confidentiality [17], integrity, and authentication [16]. Blockchain technology relies on two key drivers: Smart Contracts and Distributed Ledger Technology (DLT). Due to the unpredictable terms of Smart Contracts, a meticulous review by both parties is essential before signing [17]. Smart contracts facilitate the automated execution of transactions upon fulfilling predefined conditions [28]. The agreement is automatically enforced once both parties agree to the terms and conditions [29] that are embedded digitally and complete all requirements. Smart contracts are stored on the blockchain. The ledger functions as a database housing the complete record of transactions within the blockchain [18]. Due to the decentralized nature of the network without a central authority, the ledger is distributed across the network. Once a transaction is appended to the ledger, it becomes permanent and cannot be removed, ensuring the immutability of the ledger. Blockchain's decentralized ledger simplifies ordering transactions and monitoring assets in a business network. Whether tangible, like real estate or cars, or intangible, like patents, virtually any valuable asset can be tracked and traded on a blockchain network, reducing risks and costs for all parties involved [19].

Utilizing blockchain technology makes it possible to record transactions without a central authority verifying their validity. No centralized entity is responsible for storing all records as a single source of truth, making the records immutable and resistant to data modification or tampering and ensuring consistency around the network [20], [21]. Hence, blockchain technology facilitates distributed databases without needing third-party intervention and authentication, enabling various industries' transparency, traceability, and efficiency [22]. The blockchain consensus protocol establishes rules for operations and interactions within a distributed system to achieve agreement on the future state of the blockchain, requiring majority participant consensus [23]. The primary obstacles to advancing blockchain technology are decentralization, scalability, and security. Striking a balance between these aspects poses a significant challenge, often called the blockchain trilemma. Prioritizing the attainment of equilibrium among these elements is crucial in developing dependable and effective blockchain systems [24].

C. Blockchain for Land Certificate

Land management in Indonesia faces numerous challenges, including corruption, manipulation, duplication of land records, the presence of land mafia, and lengthy land registration processes. Blockchain technology presents a potential solution to these issues. Land registration is one application of blockchain technology in public services, where details about land, including its physical condition and associated rights, can be registered and accessible on the blockchain [25]. This technology facilitates the transparent documentation and monitoring of any land modifications, such as ownership transfers or mortgage creation, potentially improving the effectiveness of public services. By ensuring the security of physical and legal data on registered land plots, blockchain technology can mitigate the problem of duplicate land certificates in Indonesia. This enhanced security makes it significantly more difficult for unauthorized parties to manipulate land data [26]. Furthermore, blockchain offers solutions to the challenges associated with public key

infrastructure and privacy regulations [27]. The proposed system leverages blockchain technology to create a solution that provides synchronized and transparent data, facilitates easy accessibility, ensures immutable record management, and promotes cost-effectiveness [28].

III. METHODOLOGY

This research workflow is divided into three stages, as shown in Fig. 2.: business process understanding and data collection, model construction, and prototyping application.

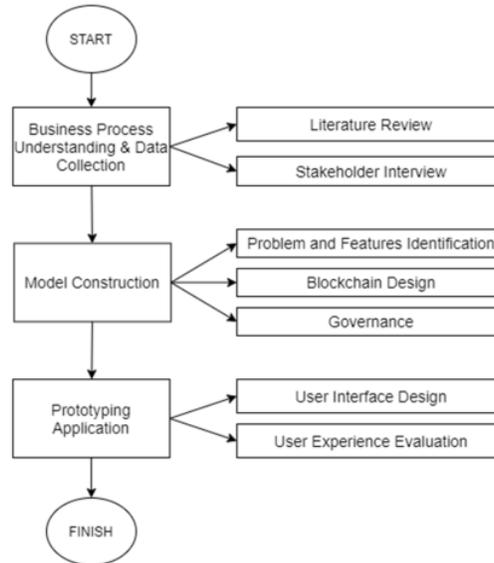


Fig. 2. Research model diagram.

The first stage is understanding the business process of implementing land certificates in Indonesia by studying literature from various research journal articles and conference proceedings regarding blockchain-based land management systems, encompassing established and developing implementations worldwide, including research from Indonesia. News sources and social media maintained by Indonesian land institutions provided complementary, up-to-date information. Additionally, semi-structured interviews were conducted with key stakeholders to ascertain their perspectives on integrating blockchain technology into existing land registration business processes. Following a detailed explanation of the proposed blockchain mechanism for transparent land registration, participants were invited to provide feedback on the design model. This included their views on the proposed workflow, its potential for implementation in the Indonesian context, and their aspirations for the future of land and property management in Indonesia. The participants in this study included 50 individuals from Indonesia, aged 30 to 60, and of both genders. These participants represented a range of stakeholders in the land management system, including landowners, property agencies, and government representatives from the National Land Agency (BPN).

The second stage is to design the adoption of blockchain infrastructure in a land certificate by identifying problems and features and looking at potential aspects from a governance perspective. Due to the complexity of land

administration in Indonesia, the second stage is divided into three substages:

1. Problem and Features Identification

This research investigates the potential of blockchain technology to enhance the authentication and security of land certificate management in Indonesia. Land management in Indonesia faces a well-documented challenge of corruption within the National Land Agency (BPN). Instances have been reported where BPN officials have exploited their positions for personal gain or engaged in mismanaging land acquisition processes. Furthermore, the current BPN processes need more transparency, hindering public and stakeholder comprehension of agency operations and decision-making procedures. This lack of transparency can erode trust and impede the BPN's ability to cultivate positive relationships with the public. Blockchain technology offers a potential solution by fostering transparency, decentralization, data security, and immutability in land certificate management. Additionally, blockchain enables smart contract-based ownership transfers, facilitates clear transaction history for dispute resolution, and promotes open information access.

2. Blockchain Design

Implementing land certificates in Indonesia using blockchain technology is necessary to create a use case diagram for each stakeholder, system, and the relationships between them. This design is foundational for developing a blockchain model for land certificate management. The model will meticulously detail the roles of each stakeholder, the nature of data exchange, and the interactions between them through workflow data records.

3. Governance

Effective governance is paramount to safeguarding the integrity of blockchain-based land records. This necessitates the development of a clear and comprehensive governance strategy. The strategy should establish precise access controls, define who can write and access data, and ensure that only authorized stakeholders possess system access [29]. The plan must balance transparency with controlled access in the context of land ownership certificates. Transparency in ownership history is crucial, enabling landowners and prospective buyers to conduct secure peer-to-peer transactions directly through their digital wallets, streamlining the process. However, to maintain the integrity of the land registry, only the National Land Agency (BPN) should possess the authority to add new records to the blockchain and update land ownership status. Therefore, a well-defined governance strategy is essential to facilitate the successful adoption of blockchain technology in land certificate management.

The final stage is the prototyping application for land certificate registration data input and ownership history tracing. The user interface design is a rough representation of the BPN website, where stakeholders can record data, add data related to land certificate ownership (if permitted), and view the entire land certificate record. Then, the user interface design will be tested to determine user understanding of the land certificate registration process and evaluate the model being built. Feedback from the user interface demo will be used as a model evaluation due to the development stage of this system.

IV. RESULT AND DISCUSSION

In contrast to the proposed blockchain system's reliance on digital land certificates, Indonesia's current land ownership records remain in physical paper certificates. Consequently, the initial step towards blockchain integration necessitates digitizing these existing certificates. A media transfer system is paramount to facilitate this process and enable the subsequent recording of land transactions on the blockchain. This research presents a novel system that seamlessly converts physical land certificates into digital records suitable for blockchain storage. Notably, the media transfer process within this system is restricted to authorized government agencies, specifically the National Land Agency (BPN). Fig. 3. visually depicts the integration of the media transfer system with the blockchain architecture.

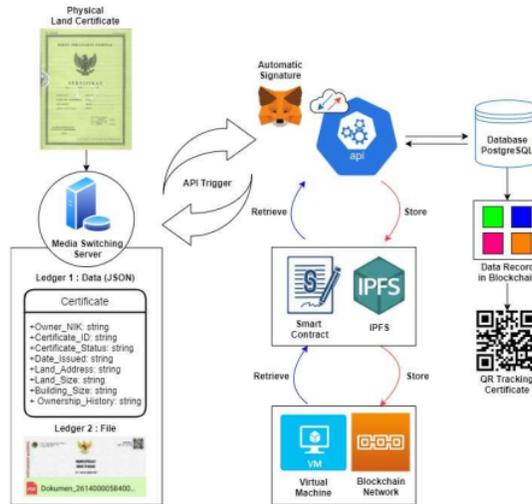


Fig. 3. Proposed system design.

Digital land certificate data will be recorded on two ledgers. Ledger 1 records certificate data, such as NIK, ID, status, etc. Ledger 2 records scans of physical certificate files (e-certificates) in PDF. Both data will be stored on the server, where ledger one is stored on the blockchain and ledger two is stored on the Interplanetary File System (IPFS). IPFS is an appropriate storage option for decentralized social applications, leveraging decentralized character and the capacity to link devices globally [30]. An API Trigger executes table update commands within the ledger to maintain data consistency during application and service interactions. The process commences with an API Post request, transmitting data in JSON format to the server. Subsequently, the server automates electronic signatures to facilitate the creation of smart contracts. The data is uploaded simultaneously to the blockchain and IPFS after successfully processing the land certificate registration request. Finally, the server transmits an API response. Data retrieval occurs through an API Get request, fetching certificate data from the server for subsequent storage in each ledger. Before storage in Ledgers 1 and 2, a validation step verifies the smart contract using the automated digital signature process. Following successful validation and storage on the blockchain and IPFS, the server receives confirmation via another API Response. This sequence of actions culminates in successfully recording the digital certificate on the blockchain. Once land ownership

data resides on the blockchain, a land certificate tracking QR code can be utilized to verify its authenticity.

The proposed design model recommendations analysis identifies three critical stakeholders within the system: landowners, the National Land Agency (BPN), and users. Landowners are individuals who possess land ownership but lack a formal certificate. BPN officers manage the entire land certificate lifecycle, including creating, finalizing, and storing records within the blockchain database. Users, categorized as regular or potential buyers (hereafter referred to as "buyers"), can leverage the dedicated website search feature to access traceability information on land ownership. Landowners and BPN officers possess read-write access privileges within the system, while user access is restricted to read-only functionality. It is crucial to emphasize that only BPN officers can record data onto the blockchain system. The use case diagram of the stakeholders, system, and relationship between them is shown in Fig. 4.

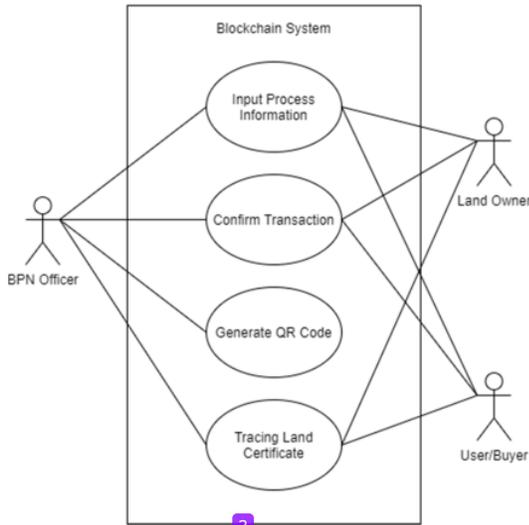


Fig. 4. Use case diagram.

Fig. 4. illustrates the processes involving actors and their roles in a blockchain system. Landowners initiate the data entry by submitting land ownership information into the BPN system, typically accessed through the BPN website. Subsequently, BPN officers facilitate the transfer of this recording, encompassing the certificate data, onto the blockchain system. To enhance accessibility and verification of land or building ownership certificates, BPN generates QR codes linked to the blockchain data. Users leverage these QR codes to verify the authenticity of land certificates by scanning them. A detailed illustration of the data record workflow for each stakeholder is presented in Fig. 5.

Blockchain technology powers decentralized governance through two models: off-chain and on-chain. On-chain governance, gaining traction for its ability to bolster public trust via increased user voting rights, fosters an inclusive environment where all participants share benefits. Three entities in the proposed on-chain land certificate system handle data input and posting: (land certificate stakeholders), the BPN website interface, and the blockchain itself. Fig. 6. illustrates this process with a sequence diagram.

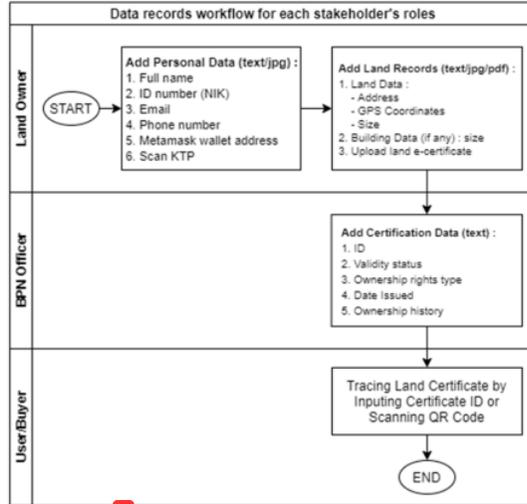


Fig. 5. Data records workflow for each stakeholder's roles.

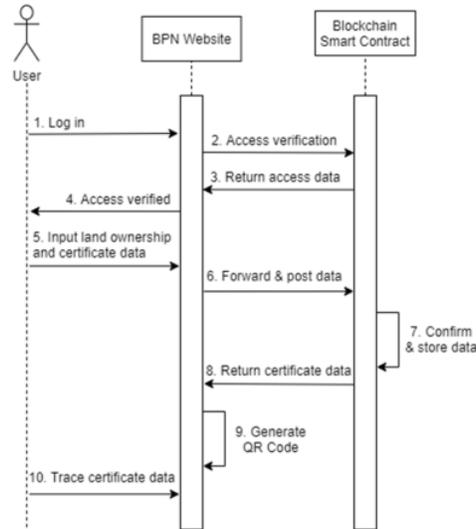


Fig. 6. sequence diagram of on-chain blockchain system.

We offer a land ownership certification system using hybrid blockchain technology to solve problems and maintain data authenticity. The system incorporates a tiered access structure, granting public visibility to designated sections while restricting access to sensitive information. Public Key Infrastructure (PKI) is the secure communication channel for landowners, users, and BPN officers acting as trusted third parties. PKI issues digital certificates to authenticate participants and safeguard data transmission. This system utilizes a public-private key pair for cryptographic security. While public keys facilitate secure communication, they are inherently susceptible to attacks, necessitating a robust infrastructure [31]. The proposed system empowers users to manage the blockchain system despite the data residing on a private chain, provided they possess the key issued by BPN [14]. The interconnection between two blockchains (public

and private) is by using a gateway that connects the two, the BPN website, which BPN provides as a PKI holder. Hybrid blockchain in various industries provides positive feedback even in permanent use [32]. It can also address the issues of data security breaches, unauthorized modifications or deletions, lack of transparency, high maintenance, subscription, licensing expenses, and vulnerability to hacking attacks.

The current prototype focuses on capturing land certificate and owner data, as illustrated in Fig. 7. Meanwhile, Fig. 8. showcases the utilization of QR codes for enhanced traceability. Following secure storage on the blockchain's immutable ledger, stakeholders can confidently contribute and store their data. Future iterations will expand data recording functionalities to encompass more comprehensive land information, such as photographs of the land or buildings.

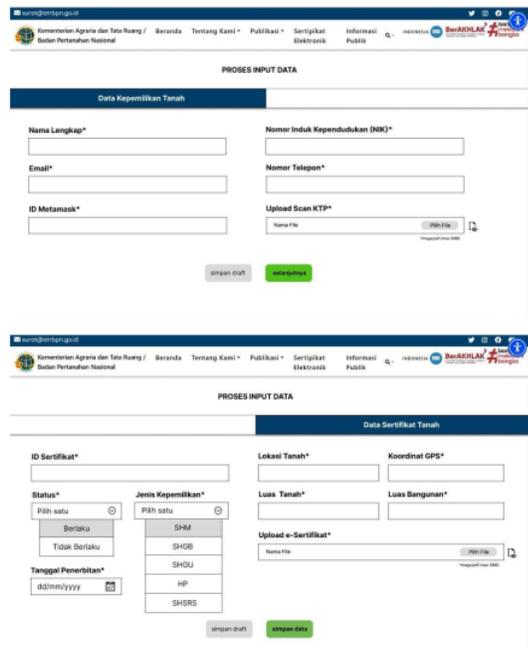


Fig. 7. User interface for land owner and land data record.



Fig. 8. Tracking authenticity of land certificate.

On the BPN website, there is a menu to check land certificates. Users can search for registered land certificates

by inputting the identity of the certificate. The aim is to track the authenticity of land certificates by displaying e-certificates and tracing land ownership history (if any). Because land owner data is confidential, it will use a private blockchain. Meanwhile, detailed land data uses public blockchain so all users can still access it. The owner ID displayed on the website is not the NIK but a new number configuration.

We evaluate the design model by conducting user testing through a brief presentation of the recommended system and demonstration of an application prototype (Fig. 7. and Fig. 8.). Whether they understand blockchain technology, land owners and property enthusiasts are the target sources. Besides that, we also involve people who need help understanding the land industry. All interviewees agree to adopt blockchain technology for Indonesia's future land certificate recording system. Regarding website design, it is also easy to use and understand all features (user-friendly). However, it is essential to consider integrating the laws in force in Indonesia and blockchain applications to optimally overcome land problems.

Over the past five years, more than 3,000 research studies have explored the application of blockchain technology across different sectors, with over 400 studies explicitly addressing the resolution of land governance issues through this innovative technology. The practical implementation of Blockchain in India's land records management requires finalizing the attributes to be included in transactions, developing smart contracts, and ensuring the preservation of records for archival purposes [27]. The proposed system in Pakistan and Thailand addresses issues in traditional land management systems. It provides a cost-effective solution for land record management utilizing private blockchain technology as the proposed Land Records Management system [12], [13]. In Kazakhstan, hybrid blockchain is preferred for land management even though the government still needs to adopt blockchain to improve public administration [11] Bangladesh provides a suitable environment for land registration by using a public and permissionless Blockchain like Ethereum, which offers unlimited processing facilities and transparency to accomplish Sustainable Development Goals (SDGs) and economic development [10].

Meanwhile, in this research, implementing a hybrid blockchain with a Public Key Infrastructure model in Indonesia guarantees data authenticity through smart contract verification and peer-to-peer networks. The system also includes a media transfer system, which ensures the accurate digitization of physical land certificates. The process can help maintain the authenticity of the digital certificates by securely transferring the data from the physical certificates to the blockchain. Recent research has increasingly conceptualized a framework for blockchain in management. Different types of blockchain are chosen, employing diverse technical tools, while various studies have integrated blockchain with other technologies like Artificial Intelligence and the Internet of Things.

V. CONCLUSION AND FUTURE WORKS

This study uses blockchain technology to present Indonesia's foundational land certificate authenticity verification model. The design incorporates an ID scanning feature to verify individual land ownership certificates.

Recognizing Indonesia's ongoing land certificate registration process, the proposed system includes a media transfer system to streamline the transition from physical certificates to blockchain records. The research aims to contribute to the theoretical understanding and practical implementation of blockchain technology within the land management domain.

However, limitations currently hinder real-world implementation. The system needs the integration of government or other authorized entities as validators within the land authenticity verification process. Additionally, challenges persist in the research itself, including the inherent complexity of the technology, the evolving legal landscape surrounding its implementation, and the public's limited understanding of blockchain. While blockchain technology offers promising advancements in technological solutions and business models, the absence of established best practices or standardized protocols creates a significant barrier.

Future research will focus on buying and selling systems of land and building that leverage tokenization. Furthermore, a prototype application has been developed and rigorously tested to record land registration and ownership data on the blockchain via the BPN website. Direct collaboration with BPN is envisaged, along with a demonstration of the model design to facilitate potential adoption.

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has been accepted to be part of the 2024 12th International Conference on Information and Communication Technology (ICoICT).

Information about payment and registration fee can be seen at the website <https://www.icoict.org/pendaftaran/>. We kindly request that you carefully consider the reviewers' comments to prepare your final version (detailed information has been sent to your email).

Looking forward to meeting you in Bandung in coming 7-8 August. If you have any questions or need more information, please contact the ICoICT 2024 secretaries.

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