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Blockchain Technology in Land Registration: A Systematic Literature Review

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Abstract: Blockchain technology (BT) is increasingly important in digital government as a means of efficient information management, decision making and an instrument for reform. This study presents a systematic review of BT's potential and application in land registration within low-income countries. The study uncovers diverse approaches to BT implementation that are influenced by local conditions and government structures. The study reveals that while there is a burgeoning interest in this field, actual implementations remain limited. The key barriers include resistance from government officials and a lack of local BT skills. Public blockchains have shown a high tendency for adoption, indicating a shift towards more transparent relationships between governments and citizens. The Hyperledger Fabric platform emerges as a popular choice due to its ability to provide secure, scalable, and robust solutions. However, there is a lack of clarity regarding the consensus mechanisms used, indicating a potential gap in current research practices. The study recommends an incremental approach to BT implementation, starting with non-threatening, transparent processes that could be expanded as part of broader government reform programs. Despite the potential of BT to revolutionize land registration systems and democratize tracking, it also poses a threat to existing power structures. Therefore, more robust empirical research is needed to evaluate the impacts and navigate the associated sociotechnical, legal, and institutional challenges. The study also proposes the establishment of a BT collaborative network among low-income countries to leverage shared experiences and develop a common framework for implementation. In the single instance where it was implemented in Georgia, public trust in government was restored. The study contributes to understanding how BT can be effectively harnessed to improve land registration systems in low-income countries.

Keywords: Blockchain technology; digital transformation; land registration; digital assets; consensus mechanism

1. Introduction

There are many different challenges and gaps in managing information around land registration that lead to corruption and contentions, such as data centralization, lack of open data, poor information sharing and intermediaries. These challenges result in disputes which divert limited government resources from the judiciary (Shuaib et al., 2020) and adversely impact the economy (Thamrin et al., 2021). For example, threatened land rights are the main reason for global poverty, injustice, political insecurity and social unrest and violence (Nguyen et al., 2020). The attempt to digitize land registration is usually done by implementing digital technologies on top of traditional land registration systems. However, the digitization has not stopped the tampering of records, generating multi-sale certificates and other human errors arising from data recording (Aquib et al., 2020). The opportunity for governments lies in implementing blockchain technology (BT) to create land registration systems that are trustworthy, efficient and free of corruption (Shang & Price, 2021). BT are a special type of database that stores information across a network of computers in a decentralized and distributed manner. This means that there is no single entity with ultimate control over the entire network but that every participating entity has a copy of the entire BT. BT transactions are grouped together in blocks and added to the chain in a linear, chronological order making BT a transparent and secure way of recording and verifying transactions. Furthermore, this means that every participant can see the entire history of transactions. Once a transaction is added to BT, it is nearly impossible to change or remove, also known as immutability and irreplaceability.

BT can therefore, offer important land registration features, such as deeds, proof of purchase and ownership transference and inheritance. BT would provide integrated mechanisms with a high level of data originality and safety (Thamrin et al., 2021). The immutability and irreplaceability feature would prevent data alteration and double spending challenges (Gupta et al., 2019) or the altering of land titles and ownership transfers (Lemieux, 2017b; Xu et al., 2017). For example, in BT a land title deed is linked to its historical ownership and the way it has changed through time is also recorded which is an appealing feature of land registration (Mintah et al., 2020). Smart contracts, another key integratable feature in BT, are self-executable code that integrates the terms of any contract, such that the contract automatically executes when its conditions have been fulfilled (Pervez et al., 2019; Porat et al., 2017). BT enhanced with smart contracts therefore, presents a modern approach to land registration in which legally-linked agreements are supported with real-world agreements (Shang & Price, 2021) with minimal to no need for a third-party (Anand et al., 2016; Lepore et al., 2020; Xu et al., 2016).

BT's immutable, auditable and traceable features and its transparent nature have recently been adopted by governments, such as the United Kingdom, United States of America, and Estonia to decentralize land registration (Gupta et al., 2019; Indhuja & Venkatesulu, 2021; Jalal et al., 2020; Xu et al., 2017; Zheng, Xie, Dai, Chen, et al., 2017). There are, however, limited studies on BT adoption for land registration in low-income countries, where land registration challenges are particularly exacerbated (Deininger & Feder, 2009). Therefore, this study seeks to understand how BT could contribute to land registration in low-income countries, considering the unique resource constraints of such countries. Specifically, the paper seeks to answer the research question, "How has blockchain technology (BT) been researched in the context of the land registration in low-income countries?"

The remainder of the paper is structured as follows; the next section presents the literature on the potential of BT in lands registration. The third section is the methodological approach. The fourth section is the classification framework followed for analysing the data. The fifth section presents the discussion and the final section presents the conclusion, areas for further research and limitations.

2. Background

2.1. Blockchain technology

Blockchain technology (BT) is a decentralized peer-to-peer (P2P) distributed ledger technology (Reyan M. Zein & Twinomurinzi, 2019) that targets transactional activities to ensure the safety of recording, data exchangeability and synchronization between distributed network parties (Sladić et al., 2021). Unlike traditional systems, blockchains do not have centralized supervision (Xu et al., 2016) and serve as an implementation layer in a distributed system, to assure the authenticity, integrity, and safety of data (Bragagnolo et al., 2018).

The structure of a blockchain is an immutable, time-stamped, append-only series of blocks. Each block stores information signed with a hash and each block is digitally connected to others (Akinyemi et al., 2022; Indhuja & Venkatesulu, 2021; Sladić et al., 2021). Designed as a public ledger, confirmed transactions are stored in a series of blocks that continually grow by appending more blocks (Al-Saqqa & Almajali, 2020; Zheng, Xie, Dai, & Wang, 2017). Each block consists of a header that always holds the previous digital signature, a body that holds the transactions and the block hash that contains the digital signature. This peer-to-peer distributed ledger is valuable for cloud-computing services, as it needs data source confirmation, auditing, digital assets tracking and distributed consensus administration (Xu et al., 2016).

The BT network employs a consensus protocol, to establish agreement on the sequence of transactions, ledger updates and the selection of the miner responsible for generating the next block (Ismail & Materwala, 2019). This consensus method fosters a tamper-resistant environment where transactions are validated by a trusted set of participants or miners (Tosh et al., 2017; Zheng, Xie, Dai, Chen, et al., 2017). The process is secured through the use of hashing techniques, digital signatures and wallets. A variety of cryptographic algorithms and consensus protocols are in place to protect the blocks from manipulation and to safeguard the blockchain from potential attacks (Xu et al., 2017).

Digital signatures serve as a key tool for recording data onto the block and assigning an identity to digital data. They play a crucial role in identifying forgery and tampering (Lepore et al., 2020; Xu et al., 2017), offering protection against fraudulent activities or repeated transactions and eliminating the necessity for third-party involvement (Indhuja & Venkatesulu, 2021).

Based on access control, BT can be broadly categorized into permissionless and permissioned blockchains (Ismail & Materwala, 2019). Permissionless blockchains, such as Bitcoin, allow open participation (Al-Saqqa & Almajali, 2020) in the consensus mechanism without the need for access authorization (Lemieux, 2017a), fostering a high degree of decentralization. Conversely, permissioned blockchains, like those used in private corporate networks or consortium blockchains, have stricter access controls (Rossi & Abbatemarco, 2019), with authorized users verifying every transaction (Al-Saqqa & Almajali, 2020; Lemieux, 2017a).

Hybrid blockchains represent a blend of the openness of public blockchains and the controlled transaction authorization typical of private blockchains (Sladić et al., 2021). In these systems, transactions remain private but are open to scrutiny by specific nodes within a public chain (Sankar et al., 2017). This arrangement is particularly advantageous in scenarios where transparency and privacy need to coexist (Indhuja & Venkatesulu, 2021), such as when decisions are recorded on a private chain while the hashes of key documents are registered on a public chain for auditability (Benbunan-fich & Castellanos, 2018).

2.1.1. BT challenges

BT is nonetheless still in its nascent stages and presents several challenges that need to be addressed before its full potential can be realized. From a technological perspective, blockchains face issues related to security, scalability, and flexibility (Batubara et al., 2018; Lin & Liao, 2017). Usability and interoperability are also significant challenges, as is computational efficiency. The storage size and cost-effectiveness of blockchain systems can pose additional hurdles (Zheng, Xie, Dai, Chen, et al., 2017). Some blockchain systems, particularly those using Proof-of-Work consensus algorithms, are known for their high energy consumption (Berryhill et al., 2018). Furthermore, the operation of public blockchains often requires actual money to maintain computations, adding to the cost of these systems (Xu et al., 2016). From an organizational standpoint, one of the major challenges is the lack of modern governance models that can accommodate the unique requirements of BT. Successful implementation of BT requires the cooperation of various stakeholders, which can be difficult to achieve (Rinearson, 2019). BT skills shortages are another significant issue, as this can directly impact the development and success of BT projects (Alketbi et al., 2018; Mendling et al., 2018). Complexity is a key challenge from a social perspective (R. M. Zein & Twinomurinzi, 2022). The intricate nature of BT systems can be daunting for users, especially in low-income countries, potentially affecting the adoption of this technology in public sector services (R. M. Zein & Twinomurinzi, 2022). However, it's important to note that many of these technological challenges are being addressed through the development of new consensus algorithms. Each new algorithm aims to solve some of the problems encountered in previous versions, gradually improving the efficiency and usability of blockchain systems. Therefore, further research is required to examine approaches of creating unique consensus mechanism, considering low-income countries challenges towards BT.

2.1.2. BT features appealing to digital government

Data is central to national infrastructure and has been defined as the key to efficiency in government (Van Loenen et al., 2021). While data is seen as an asset, which immediately makes governments wealthy, there are still difficulties to get value from government data, particularly in low-income countries (García, 2019). The main motivation to open up government data is to support the economy with smooth digital services innovation, increase employment opportunities (Hernandes

Oliveira de Oliveira et al., 2021) and maximize value creation (Natvig et al., 2021). The minimum requirements to open up government data are confidentiality, availability, integrity, and transparency (Natvig et al., 2021), which are the same requirements inherent in BT (Truong et al., 2019).

BT is therefore, an ideal approach to maximising government data (Xu et al., 2016) by securely recording transactions of any type of registry (Mintah et al., 2020) while embedding transparency, immutability and data protection. In addition, the open nature of most BT protocols allow for interoperability among the blockchains. This interoperability could drive BT utilization in governments of low-income countries as a leap-frogging technology that is sharable between the different departments of a complex governmental ecosystem (Rossi & Abbatemarco, 2019).

Another appealing feature of BT in government are the integration with smart contracts. Smart contracts are organized by formulating contractual configurations among parties into a form of computer code and keeping them into a blockchain that is tamper-proof and self-executing. By decreasing human intervention, the contractual operation could be turned into a less insecure and more cost-effective operation (Paper, 2016; Sladić et al., 2021).

3. Land registration and centralized systems

Land is of social, economic and political value in each society, and thus, forms a great part of national wealth (Katigbak, 2019; Sladić et al., 2021). Land utilization has always been viewed as the most comprehensive product of human practice and innovation, as well as, the most evident sort of material value. The Land Registration System (LRS) department is therefore, quite significant in any governance system that manages the land registry (Shuaib et al., 2020).

Ownership value is considered as a participation responsibility between different institutes who are involved in property transfers, as various role-players contribute different components towards the end-to-end property process (Amadi-Echendu, 2021). Therefore, LRS's are multi-stakeholder government systems that record the details of ownership entitlement (Thamrin et al., 2021) even though the processes vary according to the local operation of each country (Mendi et al., 2020). Land entitlement is an essential aspect of the social and economic resilience of citizens. Whereas, the world bank claims that about 70% of the world population do not own any land title (Shang & Price, 2021; Shuaib et al., 2020), the UN identifies weak governance and corruption in LRS's in more than 61 countries (Aquib et al., 2020). Land records that are secure and up-to-date help governments in tax collection, service delivery and other aspects of governance (Lemieux, 2017b; Sladić et al., 2021). LRS's are, as such, one of the major sources of income for many countries.

Nonetheless, LRS's have major weaknesses; 20% of citizens around the world have acknowledged paying bribes to record their ownership or access property ownership information. Moreover, corrupt officials can exploit their status to tamper land registry data without any concern for detection (Shang & Price, 2021).

Traditional LRS's using centralized systems lack the mechanisms to track the complete trail for the transfer of ownership of land and often lack verification or authentication mechanisms (Aquib et al., 2020; Shuaib et al., 2020; Thamrin et al., 2021). In terms of security, most LRS's are based on centralized databases that are subject to threats, such as data theft and loss, as well as, manipulation of records (Ali et al., 2020; Gupta et al., 2019). Land double spending, which means that the same person can sell the same piece of land to multiple parties (Alam et al., 2020; Shuaib et al., 2020), often arises when irresponsible parties use fake documents and bribe government officials when selling land to other parties (Thamrin et al., 2021). Such practices result in reduced accountability. The person-in-charge can also compromise transparency by falsifying documents (Alam et al., 2020; Ali et al., 2020) to take over land by force because records are prone to alteration by anyone who can access them (Shuaib et al., 2020). When this happens, it becomes hard to define the actual number of assets owned by an individual (Gupta et al., 2019). Centralized systems also create an enabling environment for bribery because of inherent inefficiencies, such as the costly judiciary processes (Alam et al., 2020; Thamrin et al., 2021) that require paper and other forms of verification, physical visits and the slow update of the massive size of records (Gupta et al., 2019). Centralized systems also mean that middlemen find an opportunity to charge a considerable amount of money to "smoothen" the process (Shuaib et al., 2020). Therefore, BT presents a viable decentralized and distributed approach to land registration.

3.1. Blockchain potential in land registration

The emergence of disruptive technologies presents a significant opportunity to enhance the efficiency, effectiveness, openness and transparency of governments—the four key factors crucial for modernizing the public sector (Wimmer et al., 2020). BT offers secure and transparent features that grant a transaction through a distributed setting, with the absence of a central authority that may own the transaction (Al-Saqqa & Almajali, 2020; Indhuja & Venkatesulu, 2021). In addition, BT offers a safe environment that allows an asset to be traced back to the original owner (Lepore et al., 2020; Mendi et al., 2020). As a consequence, the distributed and transparent features of BT facilitates the tracking of all transaction events (Aquib et al., 2020), and this increases the network security, efficiency and transparency (Ismail & Materwala, 2019).

By using BT, there is a high potential to increase affirmation and safety among all land transaction participants, before the transactions accomplished. Such an approach, could lead to a highly credible, reliable, tamper-proof and immutable land transaction platform (Mintah et al., 2020). In addition, the application of BT in LRS's improves the transparency of the processes and optimizes costs and time (Gupta et al., 2019; Mezquita et al., 2021; Shuaib et al., 2020). Table 1 lists the contributions of BT to LRS's:

Table 1: Blockchain types contribution in lands registration

Criteria	Description	Factors	Contribution
Increase efficiency	No centralized authority and third-party verification needed.	Time	Registration or consultation is immediate (Gupta et al., 2019; Mezquita et al., 2021; Thamrin et al., 2021).

		Cost	Cost is decreased dramatically as there are no third parties or middlemen involved (Mezquita et al., 2021; Thamrin et al., 2021).
Credibility	Termination of risks associated with originality and authenticity of the data.	Security	Data is stored using encryption methods that prevent alterations without proper authentication (Gupta et al., 2019; Mezquita et al., 2021).
		Privacy	No requirement to disclose user identity (Shuaib et al., 2020).
Asset's tracking	Once the registrar confirms the transfer of land title, smart contracts update the new buyer ownership and stores the transaction on the blockchain.	Smart contracts	Workflows managed and executed without the need for any external triggering (Mendi et al., 2020). Limits issuance of certificates to one at a time (Aquib et al., 2020; Thamrin et al., 2021)
		Availability	Data are available for checking by an authorized persons anytime from anywhere (Mezquita et al., 2021; Shuaib et al., 2020).
		Transparency	Every node holds a history of the transactions and any change is recorded, as a discordance is detected (Mezquita et al., 2021; Shuaib et al., 2020; Sladić et al., 2021).
Accountability	Immutable record of documents and transactions could prove the ownership and prevent forgery.	Integrity	Consensus mechanism ensure that only information changes when all relevant parties agree (Aquib et al., 2020; Thamrin et al., 2021).
		Reliability	An Immutable ledger holds data that cannot be tampered. Digital signatures and a time-stamped fingerprint of the data validate the information (Mezquita et al., 2021; Shang & Price, 2021).

Utilization of this technology in land registration, as one of the public sector could enforce some politics and strategic changes of the sector. Government could be in charge of offering the legality and trustiness for this technology, instead of being responsible for being a central authoritative role.

According to Google Trends the terms "blockchain" and "land registration" are being searched extensively worldwide (see Figure 1). In particular, since the beginning of 2017 (worldwide, 1/1/2013 – 1/1/2022, law & government, web search).

Figure 1: Blockchain and land registration trending

Over the past five years, academics and researchers have shown a strong interest in the terms "blockchain" and "land registration", as indicated by the high level of engagement observed through the lens of the scholarly search website, which is a service provided by Cambia—an independent non-profit social enterprise. Journal articles are the most prominent type of publications, with conference proceedings articles following closely behind, in terms of popularity (see Figure 2).

Figure 2: Blockchain and land registration publishing

The potential of using BT in land registration could work efficiently in the low-income country contexts. The study therefore, focuses on low-income countries usage of BT in land registration. Specifically, the study seeks to answer the question, "How has BT been researched in the context of the land registration in low-income countries?"

3.2. Successful experiences as a guide

The differences between low-income and high-income countries necessitate a cautious approach when applying the governance and practices of high-income countries to low-income environments. The distinct social, political, economic and technological factors in these environments make it impractical to directly adopt the methods used in high-income countries. Accordingly, it is important to develop new governance and strategies which take into account the situations in every country (Mulili & Wong, 2011). Therefore, the strategies adopted by high-income countries may not be fitted for developing economies, as each country has separate contextual challenges and various development phases in developing services (Wan Zahari Wan Yusoff and Maziah Ismail, 2008). In contrast, these experiences could be beneficial to low-income countries in their studies for utilizing new strategies to improve public services, provided that any generated models are designed particularly for their resources, challenges and opportunities (Hobday, 2005). There has, as such, been growing enthusiasm among LRS authorities worldwide for BT. The following two examples are noteworthy examples of BT LRS implemented in high-income countries.

3.2.1. United Arab Emirates

'Blockchainization' of land registry is one of the strategies that were targeted by Dubai to conduct all governmental transactions through BT. In 2016, a blockchain solution was developed to register all the historical stages of property from the conception to sale (Themistocleous, 2018). Dubai Land Department (DLD) designed the Emirates Real Estate solution (ERES), the big and complex system which presents services to all stakeholders involved in the process of property, including land registration. After that, DLD the title deed management platform based on BT (Berryhill et al., 2018; Breslow, 2021).

This was followed by converting the rental listing service to the Blockchain platform and connecting with all governmental actors, like utilities (DEWA-Dubai Electricity and Water Authority) and the real estate community. In addition, the buy and sell community and smart mortgages were combined into the Blockchain platform. Moreover, a new payment system Noqodi is presented to link the banks and the participated actors (Papadaki & Karamitsos, 2021).

3.2.2. Sweden

Sweden's land registry authority commenced a development of BT system to register and manage land ownership transactions. As the system proved its effectiveness, the authority was enthused to extend the functionality of this system (Themistocleous, 2018).

In 2016, a consortium of the Lantmäteriet strategy consultancy Kairos Future, with the telecom Telia Company and the BT startup ChromaWay, sought to search potential BT applications for real estate in Sweden. They designed a model which stores real estate transactions into a blockchain once a sale agreement is done, and stay immutable until the land ownership is transferred. The model aimed to eliminate information asymmetries by permitting all participants (banks, land registry, brokers, buyers, and sellers) to track the transaction proceeding, and probably cost reduction (Berryhill et al., 2018; Carin et al., 2018). The project is designed on two products owned by Chromaway.

The first; Esplix, the smart workflow middleware by which operations and workflows are conducted by the participants. The second; Postchain, is a consortium database which mixes traditional databases ability with private blockchains power (McMurren et al., 2018). To manage system access, Telia's secure ID is used to verify "rights to act in the system" (Carin et al., 2018).

3.3. Research objective

This study conducts a systematic review of literature of BT for LRS in low-income countries and proposes a conceptual framework for aiding lands registration transactions through this technology. This study therefore, seeks to answer the following primary research question: How has BT been researched in the context of the land registration in low-income countries? The primary question is linked to the following two secondary questions, namely: What is the potential of using BT for land registration in low-income countries? And what are the opportunities, challenges and risks identified in the research on BT for land registration in low-income countries?

4. Methodological approach

This study attempts to define ways in which BT has been researched in the context of the land registration. Okoli and Schabram's guide (Okoli & Schabram, 2012) was used to perform this systematic literature review (SLR), including organizing the structure of the study, selecting the targeted studies, defining the analysis criteria and discussing the results.

4.1. Data source and research strategy

While Google Scholar crawls many academic publishing databases, it sometimes does not have access to data hidden behind exclusive access, or that uses a different search mechanism. Hence a further search in the popular multidisciplinary databases is also necessary. An initial list of relevant journal articles for collating this systematic literature review was generated by performing keyword searches of the following electronic databases:

- IEEE Explore (https://ieeexplore.ieee.org/Xplore/home.jsp)
- Springer (https://www.springer.com/gp)
- Google Scholar (http://scholar.google.com/)
- Elsevier Science Direct (https://www.sciencedirect.com)

A combination of terms related to blockchains, land registrations and low-income countries were used to generate the initial journal article list. To this end, the Boolean operator "AND" was used to get the aggregations of the different probabilities of the three terms.

4.1.1. First Stage. Collecting the Related Papers

The final search string that was used for searching the, above-mentioned, academic databases was as follows: (Blockchain technology OR Block-chain technology OR Block chain technology OR Blockchain) AND (Land Administration OR Land Management OR Land Registration OR Land

Deed OR Land Title OR Land Ownership OR Land Property OR Lands) AND (low-income Countries OR Low-income Countries OR Growing Countries).

4.1.2. Second Stage. The Inclusion and Exclusion Criteria

An exclusion and exclusion criteria were used to select the papers that would be adopted and transferred to the next stage of the review.

The following inclusion criteria were used:

- The primary research question criteria.
- Language criteria (English-only papers).
- Date range criteria (since 2015).

In addition, all editorials, discussion comments, news, and summaries of tutorials, panels, and poster sessions were excluded. Further, a scanning process was conducted in all the titles, abstracts, and keywords of the studies resulting from the second stage.

4.1.3. Third Stage. Practical Screening

This stage excluded articles unrelated to the SLR domain. Regarding the included studies, both introduction and conclusion sections of each of the journal articles was reviewed to determine the relevance of the articles. The outcome of these procedures is described in Table 2.

Table 2: Returned Papers

Electronic database	Returned articles	After exclusion and quality checks
IEEE Explore (https://ieeexplore.ieee.org/Xplore/home.jsp)	19	10
Springer (https://www.springer.com/gp)	15	8
Google Scholar (https://scholar.google.ae/)	33	13
Elsevier Science Direct (https://www.sciencedirect.com)	14	7

This fetching method produced an overall of 81 hits, that contained 36 previously redundant papers.

4.1.4. Fourth Stage. Quality Checklist

The following inquiries were applied to define the quality of the resultant set of studies.

- Does the study handle any utilization of BT in land registration?
- Does the study investigate the real-life practice of utilizing BT in land registration?
- Is the objective of the study clearly illustrated?
- Does the study have enough research on the contextual factors of land registration?

This stage resulted in the final list of 13 accepted papers. The articles that were included in the study are listed in Table 3 and a summary of the articles is indicated in Table 4.

Table 3: Included Papers

	Paper	Title	Journal	Year	Cited	Country
1	(Aquib et al., 2020)	Blockchain-Based Land Record Management in Pakistan	IEEE	2020	0	Pakistan
2	(Thamrin et al., 2021)	Blockchain-Based Land Certificate Management in Indonesia	ADI Journal on Recent Innovation (AJRI)	2021	1	Indonesia
3	(Alam et al., 2020)	A Blockchain-Based Land Title Management System for Bangladesh	Journal of King Saud University - Computer and Information Sciences	2020	2	Bangladesh
4	(Sladić et al., 2021)	A Blockchain Solution for Securing Real Property Transactions: A Case Study for Serbia	International journal of Geo-Information	2021	1	Serbia
5	(Shang & Price, 2021)	A Blockchain-based Land Titling Project in the Republic of Georgia	Innovations	2021	38	Georgia
6	(Nguyen et al., 2020)	Towards Blockchainizing Land Valuation Certificate Management Procedures in Vietnam	IEEE Xplore	2020	1	Vietnam

7	(Mendi et al., 2020)	A Blockchain Based Land Registration System Proposal for Turkey	IEEE	2020	0	Turkey
8	(Shuaib et al., 2020)	Blockchain-Based Framework for Secure and Reliable Land Registry System	TELKOMNIKA Telecommunication, Computing, Electronics and Control	2020	16	Malaysia
9	(Gupta et al., 2019)	Landledger: Block-chain-Powered Land Property Administration System	IEEE Xplore	2019	0	India
10	(Ali et al., 2020)	A Transparent and Trusted Property Registration System on Per-missioned Blockchain	IEEE	2020	3	Saudi Arabia
11	(Mintah et al., 2020)	Skin Lands in Ghana and Application of Blockchain Technology for Acquisition and Title Registration	Journal of Property, Planning and Environmental Law	2020	23	Ghana
12	(Christen et al., 2023)	Towards the Development of A Block-chain System for Philippine Government Processes for Enhanced Transparency and Verifiability	Procedia Computer Science	2023	0	Philippine
13	(Adeolu Seun, 2020)	Blockchain Technology for Managing Land Titles in Nigeria	International Journal of Advanced Trends in	2020	3	Nigeria

			Computer Science and Engineering			

Table 4: A brief description of the objectives and results of the articles

#	Brief Summary and findings	Strengths	Weaknesses
1	The study suggests a blockchain-based solution to address a shortage of land record management cases in Pakistan. The solution was examined on pseudo data. The buyer and seller's bio-data sent by the Revenue and Registrar departments are confirmed by NADRA department then processed to be saved in the blockchain.	Main actors and workflow of the proposed system is well illustrated. The tools used are defined clearly.	The proposed system has been tested on dummy data not in real scenarios. More descriptions of the proposed system functionalities are needed.
2	The research involves a three-phase utilization of blockchain (i.e., public blockchain, the hybrid blockchain, and applying the full hybrid blockchain) to digitize land rights in Indonesia. This study proposed a smart contract design on a public blockchain and a model framework was developed using a trial network of Ethereum blockchain. The suggested solutions are inexpensive, speedy and more user friendly to the general public and land administration employees. Not everyone could use this Ethereum Blockchain system because it will grow quickly when used in real life.	The existing system is described clearly. The system is tested using the local test network and the live test network ropsten taken from Ethereum	The research is completely for academic purposes and not any government bodies. The system architecture details are not clear.
3	This study proposed a phase-by-phase blockchain adoption paradigm to facilitate unregistered land detection and decrease the land and TAX gaps. The BT begins with a public blockchain ledger and thereafter, gradually moves to the hybrid blockchain level. It offers	The structure, processes and functions of the existing system is described clearly in details.	More details about the platform and tools that were used is needed.

	smart contracts design of the public blockchain and implements a prototype system using Ethereum. Results show that the proposed model decreases the number of travels, cost of information processing and offers easy access to vital information. In addition, the Gas price differentiate with ETH value which will make it difficult to be used by people. Not everyone could use this Ethereum Blockchain system because it will grow quickly when used in real life.	The proposed system architecture is presented in a clear manner and supported by the proper diagrams. The study focused clearly in the development and utilization of smart contracts. The study is supported with a comparison of a proposed system with available benchmark data, and the costs of developed smart contract transactions.	The study is not related to the official governmental sector.
4	This study addresses how transactions are treated in the Serbian land administration and the way this operation could be backed by new ledger technologies, such as blockchain, for both cadastral processes and transactions, in addition to legislative and organizational aspects. The study offers a theoretical framework and general system design. All the specifics regarding transactions in the land information system is saved or restored via DApp.	The study presents a high illustration of smart contracts utilization, functionality, and development. Access options and identity management are reasonably presented.	The proposed system details part is too little when compared with the theoretical part. The overall architecture is yet to be proved in practice.
5	The land registration project in Georgia highlights government effectiveness in lands transactions management, which is achieved in two stages. The first stage is a blockchain-based time stamping layer over the occurring digital land registry system. The second stage involves a private blockchain	The proposed system based on blockchain workflow is well presented. Also, a comparison between the previous system and the	No details regarding the proposed system architecture, functionality, development tools and platform.

	framework, aimed at sending data to the Bitcoin Blockchain to save a hash of a system to a public source. The main goal is to eliminate the manager's unconditional trust of a public Blockchain and to save data privacy.	blockchain based system is provided. The study showed how educated users and high quality data could affect the success of the proposed system.	
6	The BT was developed to issue land appraisal certificates in Vietnam. The study suggests three layers to a decentralized implementation to offer the processes of land appraisal certificate management. The BT permits the certificates to be saved and can be tracked from the blockchain network to ensure transparency. There is a limitation of transaction numbers that can be packaged in a block. Processing time is less than 200 milliseconds when the number of transactions is small, but it is raised sharply when the number of transactions is more than 1000. Latency is raised and throughput is decreased when the returned data contains certificates' information.	Clear presentation of existing system. Rich description of the proposed system architecture layers including services, operations flow, platform and tools, and supported with diagrams. The study provides performance and throughput evaluation via conducting a stress test.	More details regarding the proposed system implementation is required.
7	The BT in Turkey implemented an eight-step procedure for land registration. Six stakeholders were identified, namely: the owner, the receiver, the municipality of the property, the bank of the buyer, the bank of the seller, and the land registry office. The BT decreases physical procedures and operations that could be accomplished safely in the digital framework. The decision is made to use a sequential approval mechanism,	Satisfied analysis of the previous studies literature. The proposed system design of stakeholders, workflow, and sequence of transactions are presented, in addition to iden-	No testing details provided.

	namely Proof of Authority (PoA), as no mining effort will be required.	tifying and justifying the selected infrastructure tools.	
8	A land registry system setting that utilizes BT was suggested for Malaysia, using smart contracts at different phases, with an algorithm that guarantees the pre-approval between buyer and seller, depending on their identifications, land identification and payment specifics. The suggested system is economical and needs fewer trustworthy individuals.	Previous studies from both high-income and low-income countries are provided. The flow of new transaction block, smart land contract and algorithm of pre-agreement- are well illustrated. The proposed framework model is clearly presented and supported with rich diagrams.	The proposed framework is at the conceptual stage.
9	The suggested design of LandLedger achieves property confirmation, recording and cancellation via specific transactions on a blockchain that has permission, which are controlled by different sections. LandLedger utilizes Merkle Patricia Tree to execute possession confirmation and ownership history using an efficient verification process. The LandLedger system is uncomplicated and can be smoothly linked to the traditional system to record land ownership and related processes.	The proposed system architecture is clearly illustrated, the main actors are defined with their roles, and transaction-flow is well described. All the protocols of the proposed system is illustrated and supported by an algorithm containing input, output, and function.	Implementation of the proposed system is very brief.
10	This study offers an environment for achieving transparency by offering a reliable property registration system, via	The proposed system architecture is described with	The proposed system functionality and services

	Blockchain, for Saudi Arabia, through activation of a smart contract. The solution provides a specified property history and highly reliable records of information. An additional link is provided through Restful to allow existing conventional property apps to access real-time land records, such as dimension, location and price.	the main parts: Membership services, Endorsement policy and the consensus mechanism. Smart contracts development are clearly illustrated and supported with sub-codes.	needs more illustration.
11	This paper attempts to solve some gaps in the current system by proposing a framework that merges public BT in skin land acquisition and title registration process in Ghana, as a method to bring reliability of the integrity, confidentiality and transparency in the land governance of skin lands in Ghana.	The study offered a description of the current acquisition and title registration workflow for skin lands. The blockchain-enabled skin land acquisition model and its significance are illustrated and supported with diagrams and a comparison with the old system.	Limited to no details of the proposed framework architecture and functionality.
12	The prototype presents a blockchain system that uses smart contracts deployed on the Ethereum Ropsten network. It can store confidential user data off-chain via IPFS and restrict access to data, such that only authorized users can manage them. This complex architecture has been made user-friendly through a client-facing frontend website made in React. The prototype offers a foundation upon which other decentralized applications can follow and build upon. This is to promote transparency and verifiability within and among government processes.	The proposed prototype is defined by describing components of blockchain network and the architecture. Blockchain Mechanisms for Verifiability and Transparency are illustrated. Stakeholder Insights on Prototype	There is a need for more details of the system workflow, interactions and functionality.

		Testing is presented. Measuring of the efficiency and scalability of the proposed prototype is provided.	
13	This paper attempts using blockchain smart contract for managing land titles in Nigeria, to control the transfers between owner, government and buyer. The application is designed using ethereum smart contract and the previous system for managing the land titles which are in the national archives. This study got feedback of the tested blockchain from stakeholders of ministry of land, Lagos Nigeria.	The proof-of-identity consensus algorithm is presented and supported by the identity verification process. Smart contract development is illustrated by solidity code, compiled, and evaluated.	There is a need for details of the existing system. The proposed system architecture design and functionality needs more details.

5. Analysis

5.1. Thematic Analysis

Thematic analysis was used to evaluate the selected papers, as it enables a classification into the most attractive BT features employed in research on land registration, thereby enabling the discovery of patterns and behaviours (Alhojailan & Ibrahim, 2012; Steyn et al., 2019; Vaismoradi et al., 2016). The coding process was carried out by reviewing the selected papers and identifying the predominant patterns. This step culminated in the generation of initial codes, which are instrumental in distinguishing the interconnected ideas within each paper (Alhojailan & Ibrahim, 2012). By merging related codes, a set of sub-codes was extracted which resulted in the main patterns (Alhojailan & Ibrahim, 2012; Steyn et al., 2019; Vaismoradi et al., 2016). Table 5 below, shows the themes and their related codes.

Table 5: Themes and codes

Themes	Codes	Frequency
DECENTRALIZATION		
Consensus Mechanism	Verification	18
	Approval	15

System Threats Prevention	Security attacks	9
	System failure	2
Total		44
AVAILABILITY		
Land Sector Services	Monitoring assets	14
	Search a land-for-sale	11
	Land History	16
Total		41
IMMUTABILITY		
Manipulation Resistance	Data loss	3
	Data Alteration	29
Forgery Prevention	Double Spending	8
Total		40
TRANSPARENCY		
Collaboration	Integration	6
	Information sharing	15
Anti-Corruption	Accountability	13
	Auditing	4
Total		38
SMART CONTRACTS		
Procedures Automation	Time reduction	11
	Workflow improvement	8
Intermediaries Elimination	Cost reduction	6
	Minimize human intervention	14
Total		39

Most of the proposed frameworks aimed to strengthen the current digitization reforms being recommended by their governments in the land sector. Each study sought to benefit certain blockchain features in order to overcome their existing systems drawbacks.

5.1.1. Decentralization

BT mitigates the need for a singular, controlling authority, by using the decentralized approach that involves multiple governing parties operating network blocks (Shuaib et al., 2020; Singh, 2020). These parties maintain the network through consensus mechanisms, which work to validate proper transactions and block those deemed improper. This mechanism significantly reinforces processes that involve multiple entities, particularly in government scenarios where the potential for distrust or malicious activities exists (Christen et al., 2023). Each governmental entity maintains a copy of the ledger, enabling independent transaction verification.

The potential and effectiveness of decentralization was observed in multiple countries. For example, in Serbia, decentralization was presented as an alternative to relying on trusted third parties for transaction verification, thus, negating the need for a central authority (Sladić et al., 2021). Meanwhile, in Malaysia, a decentralized standard system for land registration records proved beneficial. It not only minimized the role of intermediaries but also, reduced the time and cost associated with the process. Furthermore, the system enhanced the overall registration process and fostered trust between transacting parties (Shuaib et al., 2020). Similar sentiments were found in the Philippines, where respondents found their system to be more robust due to the data integrity preserved by blockchain's decentralized nature (Christen et al., 2023).

5.1.2. Availability

BT land systems provide immediate information for the users and could be accessed anytime from anywhere (Gupta et al., 2019). This accessibility greatly reduces time and effort costs. For instance, potential land buyers can easily verify the authenticity of ownership data using the information provided by the blockchain-based land register (Mintah et al., 2020). Similarly, a complete land history can be conveniently retrieved in the event of a dispute (Thamrin et al., 2021).

In countries, such as Bangladesh, Serbia, and Indonesia, availability is viewed as a critical component of land sector services. This is because every participating node in a BT land system maintains a comprehensive, tamper-proof and up-to-date copy of the entire land ledger (Alam et al., 2020; Sladić et al., 2021; Thamrin et al., 2021). A study from Saudi Arabia also underlined the importance of availability for owners to effectively track and monitor their assets (Ali et al., 2020).

In the context of Ghana, one of the significant drawbacks of the existing system is the dependency on the secretary, and the respective local chief, to provide reliable information regarding the ownership history of any land and to confirm its availability. This issue is particularly prominent for lands within skin land regions. Therefore, the availability feature offered by BT land systems is perceived as a valuable solution. (Mintah et al., 2020).

5.1.3. Immutability

Immutability, a core BT feature, ensured that once a transaction was securely stored, it could not be altered or rolled back, thus, preventing data corruption (Gupta et al., 2019; Singh, 2020). Modifying or deleting a stored transaction was also challenging because it necessitated changes to all subsequent transactions due to the use of cryptographic hashes, timestamps and digital signatures (Gupta et al., 2019). In the context of land registration, the immutability offered by blockchain technology has been embraced by several nations to safeguard land records. For instance, in Ghana, blockchain's immutability was used to protect land records from tampering, enhancing the credibility of the land system through encrypted ledger data (Mintah et al., 2020). Georgia's experience with blockchain-based land systems highlighted citizens' appreciation of the technology's ability to preserve the immutability of land data while simultaneously maintaining privacy (Shang & Price, 2021). Similarly, India sought to ensure the immutability of land data by employing the SHA256 cryptographic hash function and digital signatures to secure transactions between buyers and sellers (Gupta et al., 2019). Immutability also addressed problems like double-spending, as noted in Nigeria (Adeolu Seun, 2020). The immutability of blockchain records guarantees that a single land asset cannot be sold to multiple buyers, ensuring the integrity of land transactions. Additionally, the transparency provided by BTs immutability enhanced trust among stakeholders, a crucial factor in countries struggling with corruption in land management. This transparency mitigated the risk of fraudulent land transactions, offering a secure and reliable system for land registration.

Overall, the immutability provided by BT plays a pivotal role in LRS, offering numerous benefits, such as protection against tampering, enhanced transaction security, solution to double-spending problems and increased transparency and trust.

5.1.4. Transparency

Transparency makes all blockchain transactions visible and shared overtly for willing parties (Christen et al., 2023) because each participant node possesses a history of all transactions (Shuaib et al., 2020). This attribute emerged as a key finding in the papers analysed, with many highlighting its significance due to its ability to detect transaction manipulations and identify the involved parties (Sladić et al., 2021). For instance, in the context of Ghana, blockchain's transparency could provide a robust solution to issues of ownership violation. The transparent nature of blockchain allows officials to confirm the identity of landowners before proceeding with any transactions, enhancing the integrity of the process (Mintah et al., 2020). On the other hand, a study from Turkey predicted that blockchain's transparency and security features could effectively address challenges associated with land tax determination (Mendi et al., 2020). Similarly, Serbia viewed the potential of BT to revolutionise the relationship between the government and citizens, in terms of transparency and trust, a critical factor for countries in the transformation stage (Sladić et al., 2021).

The Indian study underscored the importance of transparency, a feature currently lacking in many LRS systems (Gupta et al., 2019). In contrast, several countries, including the Philippines (Christen et al., 2023), Indonesia (Thamrin et al., 2021) and Bangladesh (Alam et al., 2020) proposed BT land frameworks to leverage BT’s capacity to enhance transparency among stakeholders.

Accountability was found to be essential to some countries, such as Saudi Arabia (Ali et al., 2020) and Vietnam (Nguyen et al., 2020). For example, a study from Nigeria proposed a framework that sought to improve transaction transparency by assigning a block number and detailing the number of participating nodes that confirmed the transaction's validity, using their public keys to generate a digital signature (Adeolu Seun, 2020).

The analysed papers consistently highlighted the importance of transparency and accountability features offered by BT in LRS systems. These features not only enhance the integrity and credibility of transactions, but also, foster trust and innovation in the relationship between governments and citizens.

5.1.5. Smart contracts

Smart contracts, executable programs on the BT, ensured transaction reliability and authenticity by verifying the conditions of the embedded land contracts (Adeolu Seun, 2020; Mendi et al., 2020) before they were executed on the BT ledger (Thamrin et al., 2021). These land contracts contained the agreement rules that parties must accept to interact with others, without the need for third-party involvement to ensure that it is correct (Christen et al., 2023). The practical applications of this feature were seen in the issuance of ownership certifications in Pakistan (Aquib et al., 2020) and land allocation in Ghana (Mintah et al., 2020).

The Philippine study argued that, smart contracts should be accessible to all authorized participants, including government representatives. The study emphasized the contracts' capacity to meet the requirements for executing government operations on the BT, provided they are appropriately programmed with relevant regulations, laws, and conditions (Christen et al., 2023). Similarly, a study from Turkey valued smart contracts for their ability to automate workflows without the need for external intervention or a central authority (Mendi et al., 2020). The Saudi Arabia study presented an argument for the use of smart contracts, stating that they simplify the improvement of business logic (Ali et al., 2020). Smart contracts also provided the potential to reduce costs, in terms of both time and money, due to their automated execution. For instance, they could facilitate asset sales without an intermediary, as demonstrated in studies from Serbia and Malaysia (Shuaib et al., 2020; Sladić et al., 2021).

The papers underscored the significant role of smart contracts in enhancing the reliability, authenticity and efficiency of transactions in blockchain-based land registration systems. The benefits extend beyond cost and time savings, offering a framework for increased transparency, automation and improved business logic.

5.2. Classification Framework

To further analyse the studies, four essential classifiers were used. A brief description of each of these classifiers, which are also summarized in Table 6, is as follows:

1) Research Status: Status refers to the status of the research, that is, whether the research has already been applied in the real world, the results thereof, have been published and evaluated or simulated and compared with a known benchmark, or are still in the planning phase. There are basically three categories of research status, namely 1A (research implemented); 1B (research simulated) and 1C (research proposed).
2) Blockchain Taxonomy: BT systems can be classified into four types, namely: 2A (public blockchains); 2B (private blockchains); 2C (consortium blockchains) and 2D (hybrid blockchain).
3) Platform Architecture: Architecture refers to the structure of the layers that reflects the process of the prototype design, that is, 3A (Bitcoin); 3B (Ethereum); 3C (Fabric ledger); 3D (Multichain); and 3F (Other).
4) Consensus Mechanism: This classification considers the consensus mechanism adopted in the studies. This factor is classified as 4A (PoW); 4B (PoS); and 4C (Not mentioned).

Table 6: Classifiers and factors codes

Classification		Code
Research Status		
	Implemented	1A
	Simulated	1B
	Proposed	1C
Blockchain Taxonomy		
	Public	2A
	Private	2B
	Consortium	2C
	Hybrid	2D
Platform architecture		
	Bitcoin	3A
	Ethereum	3B
	Hyper Ledger Fabric	3C
	Other	3D
Consensus Mechanism		
	POW	4A
	POS	4B
	POA	4C
	POE	4D
	Not Mentioned	4F

6. Results

Table 7 describes the analysed journal articles in terms of the four essential classifiers.

Table 7: Results of the analysed papers

No.	Research status	Blockchain Taxonomy	Platform Architecture	Consensus Mechanism
1	1B – Simulated	2B - Private	3C - Hyper Ledger Fabric	4F - Not Mentioned
2	1B – Simulated	2D - Hybrid	3B - Ethereum	4F - Not Mentioned
3	1B – Simulated	2D - Hybrid	3B - Ethereum	4F - Not Mentioned
4	1C – Proposed	2A - Public	3B - Ethereum	4A - POW
5	1A – Implemented	2D - Hybrid	3A - Bitcoin	4F - Not Mentioned
6	1B – Simulated	2B - Private	3C - Hyper Ledger Fabric	4F - Not Mentioned
7	1B – Simulated	2B - Private	3C - Hyper Ledger Fabric	4C - POA
8	1C – Proposed	2A - Public	3C - Hyper Ledger Fabric	4D - POE
9	1B – Simulated	2B - Private	3C - Hyper Ledger Fabric	4C - POA
10	1C – Proposed	2C - Consortium	3C - Hyper Ledger Fabric	4D - POE
11	1C – Proposed	2A - Public	3D - Other	4F - Not Mentioned
12	1A – Implemented	2A - Public	3A - Ethereum	4A - POW
13	1A – Implemented	2A - Public	3A - Ethereum	4C - POW

The results displayed in Table 8 have been calculated, visualized, and discussed as follow:

6.1. Research status

Table 8: Research status

Description	Value	Frequency	Percentage
Implemented	1A	3	24%
Simulated	1B	6	46%
Proposed	1C	4	31%

Figure 3: Research status

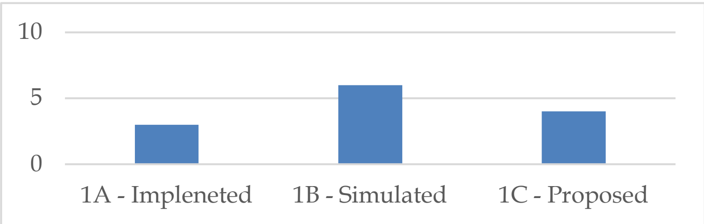


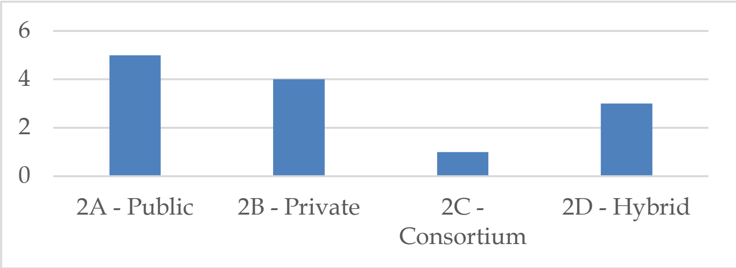
Table 8 and Figure 3 suggest that, only three LRS BT projects have been implemented (i.e., in Georgia, Philippine, and Nigeria). The other journal articles discussed proposed or simulated studies using experimental data. The greatest challenge to implementation was identified as resistance (Benbunan-fich & Castellanos, 2018) from government officials (Nickson & Lambert, 2002) and a lack of local BT skills in low-income countries. It is therefore, necessary to develop solutions for these important sociotechnical challenges when attempting BT implementation in low-income countries.

6.2. Blockchain taxonomy

Table 9: Blockchain Taxonomy

Description	Value	Frequency	Percentage
Public	2A	5	39%
Private	2B	4	31%
Consortium	2C	1	8%
Hybrid	2D	3	24%

Figure 4: Blockchain taxonomy



Although Table 9 and Figure 4 show five public blockchains have been used, it revealed that seven of the 13 studies adopted a private and hybrid BT taxonomy. This finding indicates some concerns about transparency and data openness which could result when adopting BT. The selection of a BT that has permission could be considered as an intermediate step between a centralized system and the full openness of the public BT. In contrast, there is a high tendency towards using public BT, seeking for an open institutional relationship between government and citizens. The main challenge here, is to explore and identify the Institutional factors that could support introducing public BT to guarantee the successful adoption in the land registration sector.

6.3. Platform architecture

Table 10: Platform architecture

Description	Value	Frequency	Percentage
Bitcoin	3A	1	8%
Ethereum	3B	5	39%
Hyper Ledger Fabric	3C	6	46%
Other	3D	1	8%

Figure 5: Platform architecture

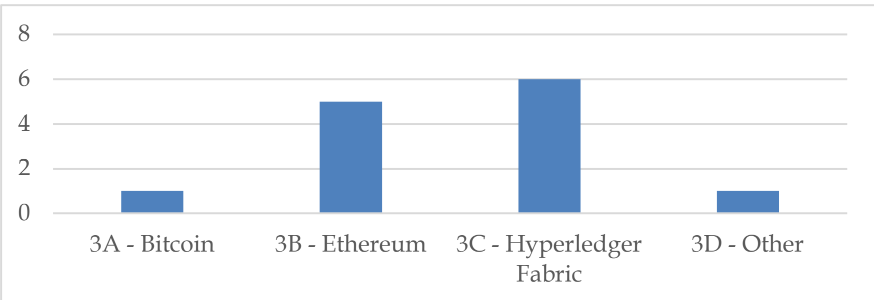


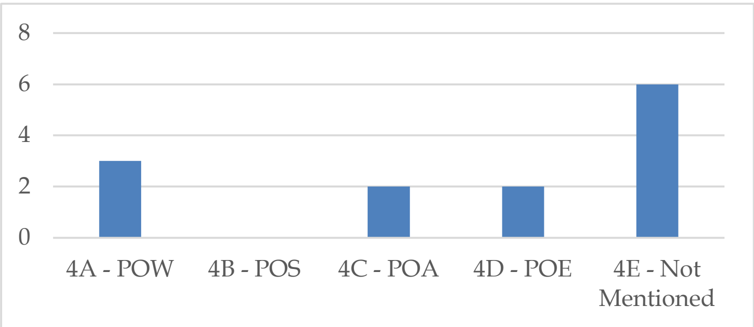
Figure 5 shows somewhat similar results between hyperledger fabric and ethereum, which prove the high tendency towards using smart contracts. The hyper-ledger fabric is considered as the most popular platform (Table 10 and Figure 5). It is regarded as a blockchain with permission in an open source platform that is useful for businesses (Cachin et al., 2017). Hyper-ledger Fabric has several characteristics that can address land record transactions and smart contracts in low-income countries because it executes a ledger that has permission and possesses a protection infrastructure that supports authentication and authorization. In addition to privacy, hyper-ledger fabric supports scalability, which makes it ideal to be linked with the conventional existing land application through application programming interface (API) (Mukne et al., 2019).

6.4. Consensus mechanism

Table 11: Consensus mechanism

Description	Value	Frequency	Percentage
POW	4A	3	23%
POS	4B	0	0%
POA	4C	2	15%
POE	4D	2	15%
Not mentioned	4E	6	46%

Figure 6: Consensus mechanisms



As shown in Table 11 and Figure 6, most studies failed to declare the consensus mechanism that was used. The other studies were almost similar, where PoW and PoA were used equally for three studies and only a two studies used PoE. None of the articles used PoS. These findings suggest that the final decision on consensus mechanism depends on the context. It could also mean that consensus mechanisms are treated as a secondary factor that follows the selection of the platform architecture.

7. Implications of research findings

This paper presented a comprehensive view of BT potential and applications, in the context of land registration of the low-income countries, from both theoretical and empirical perspectives about the BT benefits and challenges faced by previous research studies. This study conducted a systematic literature review of retrieved, previous studies, related to introducing BT in the land registration sector, and highlighted four essential classifiers of BT related to land registration: research status, BT taxonomy, platform architecture and consensus mechanism. Further, 13 low-income countries reported on BT in land management.

Out of the thirteen studies examined, only four reported actual, real-life implementations, with three using public blockchains and one employing a hybrid blockchain. Notably, none of the studies that had been put into practice used private or hybrid blockchains. This observation could suggest a gradual shift in attitudes toward the concept of decentralization, particularly if these implemented research initiatives demonstrate successful outcomes.

All, but one, of the included studies targeted the use of smart contracts, underscoring the necessity to align these with a country's legal laws and regulations governing workflow. It's likely that research into blockchain for land registration would necessitate collaboration with relevant government bodies to formalize the process of constructing smart contracts, ensuring they are subject to judicial oversight.

The application of blockchain technology in land registration provides an exceptionally secure environment that curbs corrupt practices through its inherent transparency and immutability. All data transactions are logged in a shared distributed ledger, enabling automatic auditing. A noteworthy trend revealed through the review in the majority of relevant publications, emerged in 2020, signalling a burgeoning interest in this technology within low-income countries.

One of the key findings emphasizes the importance of identifying the sociotechnical factors that influence the implementation of blockchain technology. This could pave the way for context-dependent solutions suited to low-income settings, particularly in relation to consensus mechanisms.

There is a discernible preference for private BT, as it allows for certain constraints, potentially offering a safer transition from a fully centralized authority, such as with the hyperledger fabric. However, this preference may be somewhat idealistic at present, given the limited knowledge of blockchain technology among citizens and their lack of confidence in managing their property registration procedures, without assistance from land registration authority personnel.

Despite blockchain technology being described in the literature as a disruptive force, especially in the land sector, the studies indicate a tendency to adopt any type of blockchain without preference. This may reflect a stage of exploration and confusion around the technology, as each type has its unique advantages and disadvantages, as outlined in Section 2.3.

The currently applied land blockchain systems are largely in their infancy, necessitating greater focus on scalability, diffusion and alignment of interests, and satisfaction with relevant stakeholders.

This implies a need for additional work on legislative and organizational aspects to navigate the potential legal and institutional changes following the adoption of blockchain technology.

Generally, there is a pressing need for further research to evaluate the impacts of implemented land blockchain systems and identify potential challenges. Such evaluations could benefit other countries in similar situations by considering these challenges during the planning stages and determining how they might be overcome.

This study recommends the establishment of a BT consortium among low-income countries. This collaborative effort could leverage shared experiences and skills, with the aim of developing a guiding framework and training program for implementing blockchain technology in land registration.

7.1. Limitations

The paper was limited in its focus only on low-income countries, which therefore, excludes some lessons from other countries. However, it has been observed that low-income countries present unique contexts that calls for such a study.

8. Conclusion

In this study, a systematic review of research relating to the implementation of BT in land registration was conducted. Ten journal articles were eventually selected from five multidisciplinary publication outlets. Despite the limited number of studies, the existing literature reveals the potential of BT to bring about transformative changes in LRS of low-income countries.

A salient finding is that there is no single "best practice" for implementing BT for land registration in low-income countries. Instead, the myriad features offered by BT, lead to implementation decisions being made, based on suitability and alignment with existing government structures. As such, the advantages brought by BT, such as centralized land registration, administration, and enhanced transparency, may not be fully realized. Moreover, the potential of BT to empower citizens by enabling them to monitor and trace their assets could pave the way for a new level of democratic participation and social engagement. However, this also presents challenges. BT poses a significant threat to established power structures within governments. As a result, governments committed to maintaining the status quo might be less likely to benefit from implementing BT.

It is, therefore, recommended to adopt an incremental approach in implementing BT in land registration in low-income countries. This process should start with non-threatening and transparent processes. Over time, these could be expanded and integrated into broader government reform programs, thus, maximizing the benefits of BT while mitigating the potential socio-political disruptions.

It is clear that while BT holds immense potential for improving land registration systems in low-income countries, a one-size-fits-all approach may not be feasible or desirable. Instead, the development of context-dependent solutions, collaboration among these countries and an incremental approach to implementation may hold the key to the successful and sustainable adoption of this technology.

However, there is still a need for more robust empirical research to evaluate the impacts and to navigate the sociotechnical, legal and institutional challenges associated with such disruptive technological changes. By so doing, low-income countries can leverage BT to enhance their land registration systems, encourage social engagement and ultimately, support their broader development goals.

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