Independent Verification: Where Blockchain Meets Land Rights

Kieran Mc Gowan
Dept. of Computer Science
Dublin City University
Dublin, Ireland
kieran.mcgowan9@mail.dcu.ie

ABSTRACT

This research paper discusses the digitisation of land registries and the problems encountered during the move to paperless registration. Blockchain has been touted as a strong enabler for land administration and there have been many attempts to integrate blockchain and land registries over the last ten years. By examining ten active pilots this paper shows that while blockchain may be suitable in certain cases the majority of the pilots were too ambitious, were not well supported or did not allow a sufficient amount of time and have subsequently failed. As this analysis will show, the best chance of success is an incremental approach, augmenting existing land registries with a layer of security and trust through independent verification.

Keywords: blockchain, land registry, pilot, failures

I. INTRODUCTION

There are 7.5 billion people on this planet, 2/3 of whom have no legally registered title to their land [1]. Many *untitled* have no legal identity, no address, no healthcare, have limited access to credit or public services and pay no tax. Land titling programmes and the creation of land registries are underway across the world in an attempt to address this imbalance.

A land title is a document that secures land tenure and property rights for the holder building trust between government and citizens and promoting investment. Land tenure security is the first step on the path to ending global poverty. The UN Sustainable Development Goals 2030 of 'No Poverty', 'Zero Hunger', 'Clean Water and Sanitation', 'Sustainable Cities and Communities', 'Life on Land', 'Peace Justice and Strong Institutions' all begin with and are supported by secure land tenure [2]. However, paper documents are subject to manipulation, capture and fraud. Digital titles can replace paper titles and together with blockchain technology titles can become verifiable digital assets for which changes can be tracked over time. A publicly available and verifiable registry of titles can provide a trusted and secure source of truth.

In this context this paper aims to answer the questions: Why do land registries fail? Why do projects to digitize them often fail? Why do blockchain pilots crash and burn? and is an independently verifiable land registry a solution?

In section II we provide background on land rights, tenure security and reasons for land registry and failures. In section III we delve into existing research surrounding blockchain uses for government services and land administration and review their successes and failures. Section IV builds on these lessons and introduces frameworks for assessing blockchain as a solution for the land administration problem. In section V we survey ten recent blockchain for land pilots around the world and document their progress and results. In section VI we analyze these results and identify reasons for high levels of blockchain pilot failure. In section VII we turn to a discussion about the findings before recommending a new approach to land administration that focuses on adding value to existing land registries through independent verification. The paper concludes with recommendations.

II. BACKGROUND

1) Land Rights and Land Tenure Security

Land and housing are the most important assets of the poor [3]. The right to property is enshrined as a human right in international law [4]. Property rights recognise the right of citizens to peacefully enjoy their property and the fruits of their own labor and are essential for the preservation of human life, human dignity and social wellbeing.

Land rights (also known as property rights) describe *what* can be done with land and the associated natural resources. They are the rights, restrictions and responsibilities afforded to a parcel such as the right to access, water, fishing, and firewood. Land tenure on the other hand governs *how* these rights are held and who owns what land. It describes the relationship between people and land or the terms and conditions on which land is held, used and transacted by individuals, groups or communities.

Land tenure security is certainty that ownership and land rights will be recorded and upheld over time. Land as a limited resource is constantly under threat from dispossession, inequality and exploitation. Improving tenure security for both women and men can have a greater impact on household income, food security, and equity [3]. Secure land tenure can help strengthen women's rights, reduce gender-based violence and child mortality, and enable families to pass on wealth to future generations. Land tenure security promotes food security and clean water supply. Farmers are more likely to invest in improving their land, entrepreneurs can create jobs by raising capital to start businesses using land titles as collateral. Secure land rights help environmental agencies hold polluters and corporations to account for the over extraction and exploitation of natural resources.

2) Land Registries

Land registries are the foundation of any modern economy building trust with citizens and enabling the collection of property taxes that fund public services. A secure land registry is vital for democracy to function and for keeping the peace. Land registries are often strategic targets during conflicts since an attack on the registry is an attack on democracy and can quickly destabilize a population. Across Europe we are witnessing the horror of war where millions of families have been displaced. With the help of secure land registries once the war is over homes can be returned or reconstructed back to their original owners. An efficient land registry means developing economies can compete in a global market. Governments can attract foreign direct investment, generate tax revenue, enforce poverty rights and support a functioning property market. Formalizing land tenure is a significant undertaking. The Land Tenure Regularization programme LTR in Rwanda involved the mapping and enumeration of 9 million land parcels, took 8 years to complete and cost tens of millions of dollars.

3) Land Registry Failures

It is important to distinguish between land registries and land administration systems. The creation of a land registry is the first step but keeping that land registry up to date and secure is an entirely different matter. When first registration is complete, and titles are issued an active secondary land market begins to emerge as requests for inheritance, transfers, splitting and merging become part of a formal active land market. It is at this point that land registries become land administration systems. Paper based land administration systems are highly inefficient and vulnerable to loss, fraud and mismanagement. They are there to serve the government's need for taxation and the needs of the citizens are rarely a priority.

The process of digitization of land registries introduces new risks and challenges that often force registries to be kept private and offline. These challenges include:

- Lack of skilled IT staff
- Limited IT infrastructure servers and backups
- Data sovereignty requirements
- Document scanning and storage requirements
- Data inaccuracy, fraud, corruption and loss
- Low data verification requirements
- The growing risk of cyber attack

Land registries fail because they are not fit for the purpose of land administration and the needs of the secondary land market. When long lines form at the land office, when multiple trips are required, when a lot of documentation is required and when transaction fees are high citizens will choose the path of least resistance. Secondary transactions taking place informally outside the land registry means the land registry quickly becomes out of date. A lack of integrity in land records is a major source of mistrust among citizens.

4) What is Blockchain?

Blockchain is a peer-to-peer, distributed ledger that is cryptographically secure, append-only, immutable, and updateable only via consensus or agreement among peers [5]. A blockchain is simply a public database that permanently records transactions once all parties agree, is extremely difficult to change and is secured by the laws of mathematics and physics. It is a public utility, and we can use this utility as an unbiased medium to share information between several parties in public view.

Blockchain powered land registry pilots have been launched around the world in an attempt to address the failures mentioned in section 3). The analysis of such pilots is the object of this paper.

III. Related Work

1) Blockchain for Financial Services

A 2017 review of enterprise blockchain use across financial services [6] found that the industry landscape at that time was dominated by experiments and short-lived proof of concepts (POC's) that had launched to great publicity and fanfare but subsequently failed. The reasons identified for project failure were

- No tangible benefits of the solution(62%)
- Privacy concerns (38%)

There was evidence of increased trust and efficiencies provided by the network, but they found that real digital transformation takes time and introducing new technologies that generate trust takes significant amounts of time. The median time required to get from POC into production was 25 months and some larger networks took up to 4.5 years to launch. The enterprise blockchain Hyperledger Fabric was the most popular platform (48%), followed by Corda (15%).

In 2019, an assessment report of blockchain adoption across different industries lists several patterns of development that participants should reference for achieving successful project deployment. A previous version in 2017 found the landscape at that time was dominated by short-lived POC's that fell away to leave behind a few genuinely sustainable blockchain networks. Some of the recorded reasons for blockchain project failure were:

- Unsuitable technology
- Technical issues
- Budget overruns
- Lack of executive buy-in.

The report also details how blockchain projects generally progress through several stages until they are equipped to run in a production environment. The typical lifecycle of a production network can be broken down into four main stages while the vast majority do not make it past stage 2:

1) Initial exploration
2) POC
3) Pilot
4) In Production.

2) Blockchain for Government Services

In a survey of seven active blockchain pilots within the European Union (EU) focused on public service provision [7] only one project (verification of academic credentials) was recommended for scaling up. There were positive results in the projects where blockchain was used to increase trust and efficiency in business processes such as secure record keeping, notarization, provenance and verification. Incremental benefits were witnessed such as decreased processing times, lower cost of transactions, and increased data integrity and security through the immutability nature of the underlying data. However, for the more sophisticated projects where decentralization and variabilities such as multi-party participation and complex business rules (smart contracts) play a part the risk profile greatly increases. There was also a growing need for a reconciliation mechanism to correct mistakes, something that is very challenging in an immutable registry. In some cases, such as the legality of digital signatures and notarization via cryptographic proofs, policy changes may be needed at EU government level in order to reach a compliant solution.

For government services to fully unlock the transformative power of blockchain additional time is needed for blockchain technology to mature [4]. Additional investment is needed in knowledge sharing, and guidance, developing more focused pilots, establishing a set of standards for security and privacy and the creation of shared infrastructures and data models for interoperability between citizen registries.

3) Blockchain for Land Registries

Building land registries to manage ownership and property rights is an expensive undertaking. Digital land registries have successfully resolved inefficiencies associated with paper based record keeping such as security, provenance, processing delays and certain types of fraud. However, cloud based solutions introduce new types of threats mainly unauthorized access and data destruction. A key feature of a trusted land registry is the authentication of all parties.

Authentication threats in traditional land registries could be tackled through blockchain-based authentication schemes [8]. For land records to be authentic transactions need to be approved by a member of an approving authority such as a land notary or a registrar. In a blockchain type network approvals would take the form of a signed transaction originating from the approvers wallet. This requires building an identity management and verification framework. If the ownership of a land parcel were tied to a coin / token then the existing owner could be verified by scanning the transaction history of the chain to retrieve the address associated with the unspent coin. If the owner's private key is lost or stolen, then this ability is lost. Therefore a robust key recovery strategy would be required such as that provided by public key infrastructure (PKI).

Data hashing and digital signatures in their basic form are not suitable for e-government use since they lack identity information of the key holders or contingency plans for lost keys [9]. PKI signatures on the other hand benefit from layers of infrastructure that includes a Certificate Authority (CA), know your customer (KYC) checks and key rotation services to ensure the identity of the key-holders is known. Hashing of data in the centralized database does not protect the data from being manipulated in the database. Without a link back from the corresponding blockchain record it is not possible to detect corruption meaning the presence of blockchain in this case provides no value in terms of security. One way to link data is a blockchain, therefore the use of blockchain for secure public administration implies not just hashing of data but migrating the registry itself to blockchain and the use of PKI for identification

4) Evaluation Frameworks for Blockchain projects

a) The Blockchain Decision Tree

The blockchain decision tree [10] is a revised version of a questionnaire [11] created by the same authors. It is intended to enable rapid initial analysis of whether blockchain is an appropriate solution for a defined problem.

b) Blockchain Land Registry Adoption Levels

In the paper [12] the authors identify a sliding scale of blockchain adoption levels beginning with no integration right up to a global land registry.

Table 1: Blockchain Land Registry Adoption levels

	Adoption level
0	No Integration
1	Blockchain recording (proof of existence)
2	Smart Workflow (Business Process Management)
3	Smart Escrow (Smart Contracts)
4	Blockchain Registry (Full Decentralization)
5	Disaggregated Rights (Trading of Land Rights)
6	Fractional Rights (Tokenization)
7	Peer to Peer Transactions (Zero Trip)
8	Interoperability (A global land registry)

Level 0: No Integration

Informal land registries, paper-based registries and digital land registries without any reference to blockchain fall into this category.

Level 1: Blockchain Recording

Creating a digital fingerprint of a digital asset (hashing) and recording these hashes inside transactions on a public blockchain creates proof of existence of an asset at a particular point in time. If the originating wallet belongs to a land official such as the registrar then the generated transaction signature and timestamp amounts to virtual notarization.

Level 2: Smart Workflow

Breaking business processes down into finite tasks to be processed in a specified order by multiple parties, recorded as separate transactions can create cryptographically secure shared source of truth. Business Process Management (BPM) can speed up collaborative tasks and increase transparency by publishing these transactions on either a private or public blockchain.

Level 3: Smart Escrow

Smart contracts can create efficient virtual escrow vaults with rules and conditions defined in code for the provision of escrow services between buyers, sellers and lending institutions involved in land transactions. A private or public layer 2 blockchain is required to support smart contracts.

Level 4: Blockchain Registry

Full migration from a centralized database to a decentralized ledger on a public private hybrid blockchain solution. Data storage would be stored on the private chain whereas the public blockchain would store transaction approvals.

Level 5: Disaggregated Rights

Verifiable approvals in public keep participants honest and foster trust between the land registry and its citizens.

Level 6: Fractional Rights

When land rights become tradable the tokenization of a right i.e. dividing up the right to water on a property among multiple parties becomes a possibility. Tokenization of ownership rights to property such as condos or large buildings is a common source of funding.

Level 7: Peer to Peer Transactions

With a decentralized registry and an active tokenized market of rights level 7 would enable the genuine peer to peer trading of property without the use of a trusted intermediary.

Level 8: Interoperability

Interoperability between different blockchain powered land registries enabling seamless property trading to anyone anywhere.

c) The Blockchain Land Registry Prerequisites

When integrating blockchain and land registries the same paper [12] identifies seven prerequisites that should be in place before you begin.

Table 2: Blockchain Land Registry Prerequisites

	Prerequisite
1	An identity solution
2	Digitized records
3	Multiple signature wallets
4	A private or hybrid blockchain
5	Accurate data before recording
6	Internet connectivity and a tech aware population
7	A trained professional community that interacts with the registry

IV. Methodology

This section describes the research methodology followed in this paper. The main steps were:

1. To select appropriate evaluation frameworks applicable for the Blockchain Land Registry problem.
2. To identify existing Blockchain Land Registry pilots.
3. To evaluate and analyze the success of these pilots by employing the selected frameworks in step 1)
4. To make recommendations for future Blockchain Land Registry projects.

1) Selecting the Evaluation Frameworks

The Blockchain Decision Tree

This framework was selected because it is a tried and tested way to filter out projects that are unsuitable for blockchain integration. In many cases the problem does not demand a blockchain and a more simplified centralized relational database is the best solution. Here we run the land administration problem through the blockchain decision tree framework.

a) Are you trying to remove intermediaries or brokers?

Yes - Land transactions today involve many third parties, estate agents, surveyors, valuers and notaries that can be substituted with virtual entities or eliminated completely with technology.

b) Are you working with digital assets?

Yes - With the move to digital land registries, title deeds and property rights are digitized, and assets are non-fungible meaning they are universally unique to that asset.

c) Can you create a permanent authoritative record of the digital asset in question?

Yes - A land registry is a permanent record of ownership of assets at a particular point in time and must include an auditable history of changes by authorized users.

d) Do you require high performance, rapid transactions?

No - Once a property is registered, subsequent transactions on a property are relatively rare.

e) Do you intend to store large amounts of non-transactional data as part of your solution?

No - Only signatures and proofs of documents (hashes) are stored on chain, all other associated information can remain within the private database.

f) Do you want/need to rely on a trusted party? (e.g. for compliance or liability reasons)?

Yes - There needs to be an identity provider and there will always be a need for a trusted registrar to give final approval.

g) Are you managing contractual relationships or value exchange?

Yes - Land tenure is a regime that defines who owns what property and for how long, which can be administered through contractual relationships between property owners and governing bodies. The value being exchanged is property rights.

h) Do you require shared write access?

Yes - Authorized participants such as notaries and registrars will participate in approving transactions independently. In the case of a global shared land registry, notaries and registrars from around the world will contribute to the same global approvals' registry.

i) Do contributors know and trust each other?

No - Often notaries are not government appointed trusted participants. In a global approvals registry participants will not know or trust each other.

j) Do you need to be able to control functionality?

No - The rules surrounding approvals can be set by individual land registries and they can be executed outside of the registry.

k) Should transactions be public?

Yes - Verifiable approvals in public keep participants honest and foster trust between the land registry and its citizens.

Blockchain Land Registry Adoption Levels and Prerequisites

These two frameworks were selected and combined because they focus explicitly on the land registry problem and identify the complexity and risks associated with the project. The higher the level of adoption from the beginning the higher the probability of failure, whereas the more prerequisites that can be met the higher the probability of success. In the next section we will review ten existing pilots under these frameworks.

V. Blockchain For Land - Evaluation of Existing Pilots

We evaluated ten recently active blockchain pilots across the world that were focused on land administration. The data has been sourced from freely available information online and various publications. The results are summarized in Table 3 below.

VI. Analysis and Results

a) Why do blockchain pilots crash and burn?

Out of the ten blockchain for land pilots evaluated only Estonia and Georgia are in production today while the pilot in Rwanda is ongoing. Georgia, the world's first viable blockchain land registry, recorded 1.5 million land titles on blockchain [14] while Rwanda was the first blockchain for land integration in Africa. All seven remaining pilots had some elements of success, but ultimately failed to make it past the pilot stage. Our analysis speculates the following reasons for failure:

b) Did not need a blockchain

While the Estonia solution X-road may be thought of as a successful blockchain pilot, according to the CTO of the Nordic Institute of Interoperability Solutions (NIIS) [42] there is no actual blockchain in X-road. Honduras was the first recorded attempt to use blockchain for land [15] leveraging a hybrid blockchain solution. A hybrid solution involves recording transactions on a private blockchain and then periodically anchoring to a public blockchain (Bitcoin). Canada and Sweden used proprietary private blockchains. It is questionable at best whether private blockchains are worth the effort when a regular relational database will suffice in most cases.

c) Identity, wallets, signatures, digitized accurate data

Integrating a blockchain for traceability and non-repudiation requires some form of identity solution. Accounts on a blockchain are provided to key-pair holders. A trusted wallet solution for the safekeeping and responsible key management of keys on behalf of participants is required. Information on KYC (Know Your Customer) checks for participants tying identities to key-holders is sketchy across the surveyed pilots but nonetheless difficult to achieve in a pilot.

The need for accurate data before recording is paramount. The primary goal of the Brazil and Rwanda pilots was the move from paper-based records towards paperless registration suggesting records were not digitized initially. Digitizing records before recording on chain is a risky undertaking for a pilot.

d) Internet stability failures

Putting land registries online brings many new risks to a platform such as cyber-attack, online fraud, and identity theft. A decentralized ledger can be very resilient in areas with poor internet access but the potential for short lived blockchain forks increases. Connectivity issues in remote areas of Rwanda proved initially challenging and demanded high levels of resilient infrastructure. Technical training of land registry officials and sensitisation of citizens, installing agents to support them is an ongoing requirement as technology evolves.

e) Blockchain land registry adoption levels were too high

The pilots in general were highly ambitious with many attempting to reach very high levels of blockchain land registry adoption from the outset. Brazil, Georgia and Sweden attempted to use smart contracts to automate some of their process flows.

f) No legal compliance

The Brazil and Wyoming pilots were run in parallel with the existing solution to assess feasibility. Brazil failed to achieve full legal compliance given there were different regulations in each county. Resistance to change, political bureaucracy and a lack of a local champion seemed to hamper many of the pilots. In Honduras there was a breakdown in communication between the provider and the government and the conflicting requirement to keep data private and sovereign within the borders of the country while also decentralized in public was a difficult balance to strike.

Legal recognition of user signed transactions is another cause for concern. In Sweden for example the law does not allow for the use of electronic signatures for real estate transactions

g) Ignoring stakeholders

Tim Robustelli (Policy Analyst, Future of Property Rights Program) discusses some common trends in blockchain for land pilots such as ignoring stakeholders needs, over enthusiasm about the technology and bureaucratic legal restrictions [16]. Blockchain and land administration are two very different domains, and he recommends getting experts from both fields working together while engaging with political, technical and socioeconomic stakeholders from the very beginning.

Table 3: Blockchain for Land Pilot Survey

#	Country	Year	Stakeholders	Provider	Result	Comment	Stage	Reference
1	Brazil	2017	Cartório de Registro de Imóveis (Real Estate Registry Office) in the municipalities of Pelotas and Morro Redondo	Ubiquity	Success	The first real estate transaction recorded on blockchain in Latin America.	Stopped	[24, 25, 26]
2	Canada	2018	Land Title and Survey Authority of British Columbia (LTSA)	Chromaway, Landsure Systems Ltd	Success	The pilot ran in parallel with a competing centralized solution that was ultimately selected.	Stopped	[27]
3	Estonia	2012	Estonian Information Systems Authority (RIA)	KSI Blockchain	Success	'X-road' ensures confidentiality, integrity, and interoperability between data exchange parties.	In Production[1]	[28, 29, 42]
4	Georgia	2016	Republic of Georgia's National Agency of Public Registry (NAPR), Hernando de Soto (economist)	Bitfury	Success	The first ever blockchain for land registry integration. 1.5 million land titles on blockchain	In Production	[12, 14, 30]
5	Honduras	2015	Honduras Government	Factom, Epigraph	Failed	Communication breakdown between parties hindered progress.	Stopped	[31, 32]
6	Rwanda	2020	Rwanda Land Management Use Authority, Rwanda Information Society	Medici Land Governance	Success	The first Identity, PKI and Blockchain integration for land in Africa.	Pilot	[33, 34]
7	Sweden	2016	The Swedish Mapping, Cadastre and Land Registration Authority	ChromaWay, Kairos	Success	Swedish law does not recognize e-signatures for property transactions.	Stopped	[35, 36, 37]
8	Cook County Illinois	2017	Cook County recorder's office	Velox RE, (IBREA), Hogan Lovells	Success	The pilot successfully designed a software-based workflow but ultimately decided not to record legal transactions on chain.	Stopped	[27, 38]
9	Carbon County Wyoming	2021	Carbon County recorder's office	Medici Land Governance (MLG), TylerTech	Success	Transfer existing digital land records to a blockchain-based registry. 1,386,550 txns (10 txns per record approx.)	Stopped	[39, 40]
10	Teton County Wyoming	2019	Teton County recorder's office	Medici Land Governance (MLG), Greenwood	Success	The first county in the USA with blockchain registered land. 1,099,774 txns (10 txns per record approx.)	Stopped	[39, 41]

1. X-road uses cryptographic techniques for recording data but there is no blockchain

h) Lack of local support

More recent research presented at an IFAD conference focused on securing land rights using innovative technology mentions the importance of local support and working with trusted intermediaries. [17] Both Wyoming projects in Teton County and Carbon County were halted when the integration between providers supplying the data to the blockchain recorder was suspended.

i) Pilot-itis

Speakers at the GSMA Mobile Health Summit in South Africa 2012 bemoaned the 'Pilot-itis' holding back mobile health in developing countries [18]. In a similar way the inability for pilots to make it past pilot stage is all too prevalent in blockchain, translating into missed opportunities and costing considerable time, energy, and resources of companies, entrepreneurs, and governments.

VII. Discussion

1) Access to Credit

In section II of this paper (Background) we touched on the importance of land tenure security and implied that secure and efficient land registries can help alleviate poverty by allowing citizens easier access to credit. In his book [19] the Peruvian economist Hernando de Soto argues that it is the lack of secure land titles that prevents the developing world from benefiting from capitalism. In an analysis of the

book by Williamson [20] de Soto's views on property rights can be distilled down into two separate testable hypotheses:

1. Secure property rights are positively correlated with access to credit and capital formation, which leads to economic development
2. Land titling programs provide the means to secure property rights.

Williamson finds that the first hypothesis is supported by both theoretical and empirical arguments, while the second lacks empirical evidence. However, a paper focused on Africa and the developing world suggests there is no evidence supporting the claim that land registration guarantees access to credit [21]. The authors found that when seeking credit, a registered land title is not always a requirement and that in practice in the absence of a land title lenders will accept unregistered documents as proof of land ownership. They also find evidence that land registration has not been able to secure land rights. Instead, they conclude that access to credit is much more complex where the cost of administration of small loans outweighs the value of the loans being administered.

2) Is an independently verifiable land registry a solution?

If land registries are centralized private systems that are regularly out of date can safely opening parts of the registry to the public help to address this? One way to achieve this is to record transaction approvals on a public blockchain.

Earlier in this paper we established that land administration is a good candidate for blockchain, and we have reviewed and evaluated existing blockchain pilots for land that failed to reach their potential. We now turn our attention to some promising blockchain pilots that appear to meet the blockchain land registry prerequisites and achieve a more modest level of blockchain registry adoption. The purpose of these pilots is leveraging a public blockchain to realize independent verification.

2) *Independent verification*

A fundamental pillar of any blockchain is public key cryptography. In order to participate in a blockchain transaction each participant requires a key pair. A public private key pair (mathematically related to each other) is generated by each participant and stored in a secure digital wallet. The private key is used to sign transactions and must be kept secret whereas the public key may be published in public. Anyone with access to the public key, the original data that was signed and the generated signature can verify that the signature belongs to the owner of that key pair. This verification can be used to guarantee non-repudiation that a transaction took place at a particular time and that a signature is genuine. Independent verification of land transactions is the key to unlocking paperless land registries and zero trip public services.

3) *Independent verification in Rwanda*

In 2019 Medici Land Governance signed an MOU with the Government of Rwanda to pilot paperless registration of conveyance land transactions [22]. The pilot was designed to solve three problems:

1. Prevent double selling of land
2. Prevent impersonation of sellers and buyers
3. Independently verifiable titles

The solution deployed during the pilot ‘Ubutaka’ augments the existing land registry, meets all of the Blockchain for land perquisites in Table 2 and achieves a blockchain adoption level of 1 in Table 1 (Proof of Existence).

Ubutaka receives land transfer information digitally via secure API from the government services portal Irembo [45]. Ubutaka integrates with the government national identity system (NIDA) to verify the identity of buyers and sellers in real-time. Ubutaka uses government-provided public key infrastructure (PKI) to guarantee the identities of digital wallet holders (notaries and registrars) on the platform. Information is verified by the notary prior to signing and registrar signatures are recorded on a public blockchain. The signature record on the blockchain is visible to the public and can be verified by anyone who has access to the registrar's public key.

Since a blockchain by itself is not searchable, an indexing service (Open Index Protocol) creates a user-friendly search engine for the blockchain that is available 24/7 to the public [23].

4) *Independent verification in India*

In 2022 the government of Maharashtra in central India announced it was using a public blockchain (Polygon) to issue verifiable certificates to citizens of the Gadchiroli district. Using the product LegitDoc developed by Crossforge Solutions the government is issuing 65,000 blockchain anchored certificates to combat forgery and enhance verification through the use of QR codes embedded on the certificate. LegitDoc hashes select details from the certificate and encodes them on chain meaning anyone who wishes to verify the authenticity of the certificate can scan the QR code to load the record from the chain and compare the hash proofs with the certificate entries. A live demonstration of this independent verification in real time is available online [43].

Neil Matris the founder of LegitDoc said during the launch of the programme that “while multiple other governments have run private blockchain pilots for securing land records, this is the first instance of an e-governance initiative being run on a public blockchain network (Polygon).” [44].

VIII. Conclusions and Recommendations

Over the last ten years blockchain for land registries has promised so much but delivered very little. In this paper we explain why land tenure security is important and determine that the land administration problem is a good fit for blockchain. The digitisation of land registries has introduced a new wave of security concerns around personally identifiable information PII. As land records become digital it can be tempting to introduce blockchain at the same time to solve some of the perceived problems that digitisation brings. Throughout this paper we have learned that digital land registries fail because they are not fit for the purpose of land administration and are not kept up to date. Blockchain has been touted as a solution to both problems but tackling both at the same time leads to a high probability of failure. Blockchain land registries fail not because of the nature of the land registry per se, but because of the additional prerequisites that an immutable ledger with zero trust

demands. Digital transformation takes time and introducing new technologies that generate trust takes significant amounts of time.

Technology works best in combination and to be successful with new technologies you need to build solutions incrementally. To build blockchain powered land registries with a high probability of success it is therefore recommended to ensure all the blockchain for land prerequisites have been met (Table 2), to aim for the first level of blockchain land registry adoption (Table 1) and to implement independent verification (via public blockchain) of records in your existing land registry. Following the blockchain hype and aiming too high is more than likely going to see your project end up with pilotitis in the graveyard of blockchain pilots (Table 3).

References

1. “Why Secure Land Rights Matter.” 2017. World Bank. 2017. https://www.worldbank.org/en/news/feature/2017/03/24/why-secure-land-rights-matter.

2. United Nations. 2015. “The 17 Sustainable Development Goals.” United Nations. 2015. https://sdgs.un.org/goals.

3. “Land.” 2019. World Bank. 2019. https://www.worldbank.org/en/topic/land.

4. Barbieri, Maurice, and Dominik Gassen. "Blockchain-can this new technology really revolutionize the land registry system." Responsible Land Governance: Towards an Evidence Based Approach: Proceedings of the Annual World Bank Conference on Land and Poverty, pp. 1-13. 2017.

5. Bashir, Imran, and Narayan Prusty. Advanced Blockchain Development: Build highly secure, decentralized applications and conduct secure transactions. Packt Publishing Ltd, 2019.

6. Rauchs, Michel, Apolline Blandin, Keith Bear, and Stephen B. McKeon. "2nd global enterprise blockchain benchmarking study." Available at SSRN 3461765 (2019).

7. Allessie, David, Maciej Sobolewski, Lorenzino Vaccari, and Francesco Pignatelli. "Blockchain for digital government." Luxembourg: Publications Office of the European Union (2019): 8-10.

8. Shuaib, Mohammed, Shadab Alam, and Salwani Mohd Daud. "Improving the authenticity of real estate land transaction data using blockchain-based security scheme." International Conference on Advances in Cyber Security, pp. 3-10. Springer, Singapore, 2020.

9. Konashevych, Oleksii, and Marta Poblet. "Is blockchain hashing an effective method for electronic governance?." arXiv preprint arXiv:1810.08783 (2018).

10. Mulligan, C., Scott, J.Z., Warren, S. and Rangaswami, J.P., 2018, April. Blockchain beyond the hype: A practical framework for business leaders. In white paper of the World Economic Forum

11. Maull, R., Godsiff, P., Mulligan, C., Brown, A. and Kewell, B., 2017. Distributed ledger technology: Applications and implications. Strategic Change, 26(5), pp.481-489.

12. Graglia, J. Michael, and Christopher Mellon. "Blockchain and property in 2018: At the end of the beginning." Innovations: Technology, Governance, Globalization 12, no. 1-2 (2018): 90-116.

13. Barbieri, Maurice, and Dominik Gassen. "Blockchain-can this new technology really revolutionize the land registry system." In Responsible Land Governance: Towards an Evidence Based Approach: Proceedings of the Annual World Bank Conference on Land and Poverty, pp. 1-13. 2017.

14. “Improving the Security of a Government Land Registry.” n.d. Exonum.com. https://exonum.com/story-georgia.

15. Collindres, J., Matt Regan, and G. Panting. "Using blockchain to secure honduran land titles." Fundacion Eleutra, Honduras (2016).

16. “Blockchain-For-Land: What We Are Getting Wrong and How to Fix It.” n.d. Uk.finance.yahoo.com. Accessed July 11, 2022. https://uk.finance.yahoo.com/news/blockchain-land-getting-wrong-fix-123900165.html.

17. “IFAD Innovation Day Side Event: APPLYING FRONTIER TECHNOLOGIES to SECURE LAND RIGHTS.” n.d. Www.youtube.com. Accessed June 25, 2022. https://www.youtube.com/watch?v=3jw4od3xtnc.

18. “Pilot-Itis: What’s the Cure?” 2012. BBC. June 20, 2012. https://www.bbc.co.uk/blogs/bbcmediaaction/entries/e00fc35a-0c0f-3e35-8280-38d048c34487.

19. De Soto, Hernando. "The mystery of capital." Finance & Development 38, no. 001 (2001).

20. Williamson, Claudia R. "The two sides of de Soto: Property rights, land titling, and development." The annual proceedings of the wealth and well-being of nations (2011): 95.

21. Domeher, Daniel, and Raymond Abdulai. "Access to Credit in the Developing World: does land registration matter?." Third World Quarterly 33, no. 1 (2012): 161-175.

22. “Rwandan Govt., Overstock Subsidiary Medici Land Governance Sign MOU to Implement Blockchain Property Rights, Land Governance Management – Medici Land Governance.” n.d. Mediciland.com. Accessed July 12, 2022. https://mediciland.com/rwandan-govt-overstock-subsidiary-

medici-land-governance-sign-mou-to-implement-blockchain-property-rights-land-governance-management/.

23. Medici Land Governance, “Rwanda Blockchain Records”, Medici Land Governance, April 1 2021, https://landrecords.mediciland.com/search/rwanda/rlmua/land

24. “Changing the World -One Block at a Time.” n.d. Accessed July 13, 2022. https://gbaglobal.org/wp-content/uploads/2018/02/Ubitquity-Brasil-Intro-Slides-English.pdf.

25. “Land Registry Blockchain Testing Starts in Brazil.” 2017. CoinGeek. April 7, 2017. https://coingeek.com/land-registry-blockchain-testing-starts-brazil/.

26. Allison, Ian. 2017. “Blockchain-Based Ubitquity Pilots with Brazil’s Land Records Bureau.” International Business Times UK. April 5, 2017. https://www.ibtimes.co.uk/blockchain-based-ubitquity-pilots-brazils-land-records-bureau-1615518.

27. Illinois Blockchain Initiative, “Blockchain in Government Pilot Database”, Illinois Blockchain and distributed ledger task force, Jan 31, 2018, https://airtable.com/shreIXQjzluCxam37/tbl7qVDFKKiEcFFrc

28. “X-Road® — E-Estonia.” 2017. E-Estonia. 2017. https://e-estonia.com/solutions/interoperability-services/x-road/.

29. “KSI Blockchain.” n.d. E-Estonia. https://e-estonia.com/solutions/cyber-security/ksi-blockchain/.

30. Shang, Qiuyun, and Allison Price. "A blockchain-based land titling project in the Republic of Georgia: Rebuilding public trust and lessons for future pilot projects." Innovations: Technology, Governance, Globalization 12, no. 3-4 (2019): 72-78.

31. Reuters. 2015. “Honduras to Build Land Title Registry Using Bitcoin Technology,” May 15, 2015, sec. Technology News. https://www.reuters.com/article/usa-honduras-technology/honduras-to-build-land-title-registry-using-bitcoin-technology-idINKBN0O01V720150515?edition-redirect=in.

32. Rizzo, Pete. 2015. “Blockchain Land Title Project ‘Stalls’ in Honduras.” Www.coindesk.com. December 26, 2015. https://www.coindesk.com/markets/2015/12/26/blockchain-land-title-project-stalls-in-honduras/.

33. “Medici Land Governance Launches Ubutaka: Piloting a Paperless Land Transfer System in Rwanda.” 2021. Www.businesswire.com. April 28, 2021. https://www.businesswire.com/news/home/20210428005538/en/Medici-Land-Governance-Launches-Ubutaka-Piloting-a-Paperless-Land-Transfer-System-in-Rwanda.

34. “Kigali, Rwanda – Medici Land Governance.” n.d. Mediciland.com. https://mediciland.com/projects/kigali-rwanda/.

35. Bennett, Rohan, Todd Miller, Mark Pickering, and Al-Karim Kara. "Hybrid approaches for smart contracts in land administration: Lessons from three blockchain proofs-of-concept." Land 10, no. 2 (2021): 220.

36. “The Land Registry in the Blockchain -Testbed the Land Registry in the Blockchain -Testbed a Development Project with Lantmäteriet, Landshypotek Bank, SBAB, Telia Company, ChromaWay and Kairos Future.” 2017. https://static1.squarespace.com/static/5e26f18cd5824c7138a9118b/t/5e3c35451c2cbb6170caa19e/1581004119677/Blockchain_Landregistry_Report_2017.pdf.

37. “Sweden Trials Blockchain for Land Registry Management.” n.d. ComputerWeekly.com. https://www.computerweekly.com/news/450421958/Sweden-trials-blockchain-for-land-registry-management.

38. Yarbrough, Karen A., and A. K. Mirkovic. "Blockchain Pilot Program Final Report." Deputy Rec. Deeds, Commun./IT, Cook County, IL, USA, Tech. Rep(2017).

39. “Wyoming – Medici Land Governance.” n.d. Mediciland.com. Accessed July 21, 2022. https://mediciland.com/projects/wyoming/.

40. Medici Land Governance, “Carbon County Blockchain Records”, Medici Land Governance, Accessed July 21, 2020, https://landrecords.mediciland.com/search/usa/wy/carbon

41. Medici Land Governance, “Teton County Blockchain Records”, Medici Land Governance, Accessed July 21, 2020, https://landrecords.mediciland.com/search/usa/wy/teton

42. “Nordic Institute for Interoperability Solutions — There Is No Blockchain Technology in X-Road.” n.d. Nordic Institute for Interoperability Solutions. https://www.niis.org/blog/2018/4/26/there-is-no-blockchain-technology-in-the-x-road.

43. “LegitDoc®.” n.d. Legitdoc.com. Accessed July 30, 2022. https://legitdoc.com/.

44. Soni, Yatti. n.d. “Bengaluru Startup LegitDoc Helps Maharashtra Issuing Caste Certificates via Blockchain.” Www.thehindubusinessline.com. Accessed July 31, 2022. https://www.thehindubusinessline.com/news/national/bengaluru-startup-legitdoc-helps-maharashtra-to-issue-caste-certificates-via-blockchain/article65274041.ece.

45. IremboGov. (n.d.). Retrieved August 1, 2022, from irembo.gov.rw website: https://irembo.gov.rw/