**BLOCKCHAIN AND PROPERTY IN 2018:
AT THE END OF THE BEGINNING**

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Abstract:

The paper seeks to provide an overview of the ways that blockchain is currently being used for real estate and land registries, and a sense of how its use may change in the future. After a foreword observing larger trends regarding the role of blockchain in the movement for an open and decentralized web, the introduction makes a broad case as to why blockchain makes sense for real estate.

The body of the paper has four sections.
1. The seven major prerequisites before blockchains are introduced into a land registry.
2. A conceptual framework of eight levels of blockchain integration with the registry, progressing from the most simple to the most radical.
3. Discussion of five different issues and impacts stemming from the interaction of blockchain and land, ranging from title insurance to regulation.
4. Finally, we consider six case studies of companies that are already active in the space, giving a brief overview of what they are doing and/or their recent history.

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Foreword: Decentralization and Society

Before considering the evolution of blockchain for land, it is important to consider wider developments in the blockchain ecosystem of which it is a part. Many of the technical and legal obstacles highlighted in this paper, such as the lack of interoperability and legal recognition of digital signatures, are being addressed for other use cases. And the widespread adoption of blockchain is not only a question of technical development, but of the degree to which society embraces the sort of decentralized governance models that it can orchestrate. Blockchain is unusual in that it is a social technology, designed to govern the behavior of groups of people through social and financial incentives. It is therefore inherently political in a way that few other technologies are. This quality has swept blockchain into the growing debate over reforming the power structures that govern the digital world.

It was the Russian interference in the 2016 US Presidential election that elevated this previously obscure issue to a prominent place in the public discourse. The fundamental problem that has been identified is that the consolidation of power in the hands of a few tech giants has become socially and politically dangerous. Proponents of this idea point to a variety of ills arising from the centralized control of data and of the attention economy in which it is generated, collected, and sold. These include the exploitation of social media marketing by political influence operations, the promulgation of extremist content, algorithmic bias,[1] and economic competition for societal attention.[2]

A few companies, notably Facebook and Google, effectively control the online marketplace of ideas. As a result, tech giants find themselves responsible for, among other things, policing speech on their platforms. But despite having accumulated powers previously diffused amongst the media, government, and civil society, these platforms are privately governed. And as for-profit enterprises, their interests are not aligned with those of the public, but with those of the shareholders to whom they are accountable.

Moreover, the problem is inherently difficult to correct. The ubiquity of these platforms makes it hard for even the most socially-conscious users to "vote with their feet" by leaving for platforms that better reflect their values. For many people, the cost of leaving Facebook is prohibitive, as they would have to leave behind the data that make up their online social connections and identity. It is similarly difficult for regulators to address the problem, as increasing compliance costs could lock the dominant companies into a permanent hegemony. At a recent New America event, ""Who's Afraid of Online Speech?," Sen. Amy Klobuchar and Rep. Ted Lieu discussed the difficulty of legislative solutions. As Rep. Lieu noted, the U.S. government could require social media platforms to review posts and ads for fake news and extremist content, but while Facebook and Google could bear the subsequent hiring costs, startups would be priced out of the market.[3]

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[1] Will Knight, "Biased Algorithms Are Everywhere, and No One Seems to Care," *MIT Technology Review*, July 12, 2017, https://www.technologyreview.com/s/608248/biased-algorithms-are-everywhere-and-no-one-seems-to-care/, accessed March 5, 2018.
[2] Center for Humane Technology, "The Problem," *HumaneTech.com*, http://humanetech.com/problem/, accessed February 27, 2018.
[3] "Who's Afraid of Online Speech?" YouTube video, 2:12:30, posted by New America, January 30, 2018, https://www.youtube.com/watch?v=q9FlATmYVcs.

One clear way to change this state of affairs is to decentralize control of the information economy, beginning with open protocols for personal ownership of digital identities and personal data. This would make personal data portable, allowing users to bring their data to the platforms of their choosing. More importantly, current advertising-based revenue models would be upended. Further decentralization of the internet, including the Domain Name System and file storage would have additional advantages, including increased privacy, censorship-resistance, and resilience against data breaches (e.g., the Equifax Breach) and Distributed Denial of Service attacks.

Though the movement to decentralize the internet has existed for some time --and has prominent advocates including Sir Tim Berners-Lee, inventor of the World Wide Web, internet pioneer Vint Cerf,[4] and the Mozilla Foundation-- it has suffered from a lack of resources, both financial and technological. In the decade since its introduction, blockchain has emerged as the best candidate to change that, both by attracting investment and enabling decentralized applications. As Steven Johnson wrote in a January 2018 New York Times Magazine article, "right now, the only real hope for a revival of the open-protocol ethos lies in the blockchain."[5]

Decentralizing the internet would involve solving some of the most challenging prerequisites outlined in this paper, such as digital identity. It would likely also involve a great deal of investment in blockchain infrastructure and standards, the lack of which is commonly cited as the greatest obstacle to the creation of an Internet of Value. Furthermore, it would necessarily be accompanied by an attitude shift towards comfort and familiarity with decentralized governance structures.

It is not certain that the open, decentralized ethos will prevail.[6] The repeal of net neutrality protections may be taken as a sign that the current political climate does not favor a move away from corporate control. And in 2017, Google became the largest corporate lobbyist in the United States, "allocating more than $18 million to lobby Congress, federal agencies and the White House on issues such as immigration, tax reform, and antitrust. It also spent money to weigh in on an effort by lawmakers and regulators to regulate online advertising, which is at the core of Google's business, according to disclosures filed to the Senate Office of Public Records." On the other hand, these trends could provide a powerful argument for accelerating the development of open protocols and decentralized applications.

There are signs that concern over the negative influence of the internet giants is creating pressure to change their business models. In February 2018, Europe's seventh-largest company, Unilever, announced that it would stop advertising on Facebook and Google if they did not take steps to become more socially responsible.[7] In a speech at the IAB Annual Leadership Meeting in Palm Desert, California, Unilever CMO Keith Weed said "it is acutely clear from the groundswell of consumer voices over recent months that people are becoming increasingly concerned about the impact of digital on wellbeing, on democracy

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[4] Klint Finley, "Tim Berners-Lee, Inventor of the Web, Plots a Radical Overhaul of His Creation," *Wired.com*, April 4, 2017, https://www.wired.com/2017/04/tim-berners-lee-inventor-web-plots-radical-overhaul-creation/, accessed February 25, 2018; Klint Finley, "The Inventors of the Internet Are Try to Build A Truly Permanent Web," *Wired.com*, June 20, 2016, https://www.wired.com/2016/06/inventors-internet-trying-build-truly-permanent-web/, accessed February 27, 2018.
[5] Steven Johnson, "Beyond the Bitcoin Bubble," *New York Times*, January 16, 2018, https://www.nytimes.com/2018/01/16/magazine/beyond-the-bitcoin-bubble.html?smid=tw-share.
[6] Hamza Shaban, "Google for the first time outspent every other company to influence Washington in 2017," *Washington Post*, January 23, 2018.
[7] "The parable of St Paul," *Economist*.

--and on truth itself," and that "2018 is either the year of techlash, where the world turns on the tech giants --and we have seen some of this already-- or the year of trust. The year where we collectively rebuild trust back in our systems and our society."[8]

This rhetoric accompanied the announcement that Unilever and IBM were partnering on "the first Blockchain solution for media buying,"[9] but its invocation of trust is still significant. It is true that the information economy is undergoing a crisis of trust. The question is whether trust will be restored by the tech giants reforming themselves to suit the demands of the current political climate, or if it will be created by the blockchain "trust machine."[10] If it is the latter, and it is decided that the digital world --in which our time, our money, and our social relationships are increasingly invested-- must be governed in accordance with the sort of open and democratic values we insist upon in the non-virtual world, then the result will be an environment that is better prepared to accommodate the more radical scenarios of digital value exchange.

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[8] "Unilever will not invest in online platforms that create division," press release, February 2, 2018, on Unilever website, https://www.unilever.com/news/Press-releases/2018/unilever-will-not-invest-in-online-platforms-that-create-division.html, accessed on February 15, 2018.
[9] Keith Weed and Babs Rangaiah, "How Blockchain is Bringing Trust to Digital Ad Buys," IBM, February 14, 2018, https://www.ibm.com/blogs/think/2018/02/45885/, accessed March 5, 2018.
[10] "The Trust Machine: The promise of the blockchain," *Economist*, October 31, 2015. https://www.economist.com/news/leaders/21677198-technology-behind-bitcoin-could-transform-how-economy-works-trust-machine, accessed March 1, 2018.

Introduction: Blockchain Makes Sense for Real Estate

Driven primarily by private sector investment, blockchain-based technologies are being developed to address a number of land and property related challenges. This paper examines how those technologies have been applied to land registries and real estate to date and considers how blockchain and registries will evolve going forward.[11]

High friction transactions are hardwired into the structure of modern real estate markets. As a result, legacy infrastructure in the sector is slow, expensive, and brittle. For the median home sold in the United States, transaction costs can constitute up to 10% of the total sales price. Entire industries have emerged for the sole purpose of capitalizing on the inefficiencies that exist around property transfers. The situation in less developed markets is often even more cumbersome.

Real estate transactions currently depend on a number of intermediaries, including brokers, government property databases, title companies, escrow companies, attorneys, inspectors, appraisers, and notaries. In the short term, sharing contracts and approvals in real time will reduce delays caused by mailing and delivery. Indeed, Goldman Sachs estimated that blockchain technologies could lead to an annual savings of $2-4 billion in the real estate title insurance market alone.[12] It would also eliminate the need for parties to reconcile documents, as all parties maintain an identical, immutable copy.

In addition, many time-consuming, expensive functions can be replaced with blockchain and smart contracts. Payments of rent, deposits, and fees could be automated. Escrow accounts could be redesigned around smart contracts and multisig wallets. The same infrastructure could be harnessed for other transactions that occasionally require resolution by a neutral party, such as disputes over rent deposits. In the longer term, blockchain-based registries could allow peer-to-peer asset transfers, reducing transaction times from months or weeks to minutes. Transaction costs could come down from thousands of dollars per sale to a modest service fee.

The ease and security of transactions could also permit the efficient[13] unbundling of property rights. A landowner could sell an easement to a neighbor quickly and cheaply. Investors could buy small shares in a rental property and receive their portion of the rent via an automated payment. In principle, this could allow individuals that cannot afford to buy entire parcels to invest relatively small amounts of money in real estate. This trend could have vast implications for financial inclusion, creating an international

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[11] Blockchain is a type of Distributed Ledger Technology (DLT). The World Bank defines DLT as, "a novel and fast-evolving approach to recording and sharing data across multiple data stores (or ledgers). This technology allows for transactions and data to be recorded, shared, and synchronized across a distributed network of different network participants" (See World Bank, "FinTech Note No. 1, Distributed Ledger Technology (DLT) and Blockchain," IV). While not all distributed ledgers employ blockchain technology, this paper refers almost exclusively to the blockchain model of DLT. Note also that there is no single, rigorous definition of blockchain. For more on this subject see Adrianne Jeffries, "'Blockchain' Is Meaningless," *Verge*, Mar 7, 2018, https://www.theverge.com/2018/3/7/17091766/blockchain-bitcoin-ethereum-cryptocurrency-meaning

[12] "Profiles in Innovation: Blockchain-- Putting Theory Into Practice," Goldman Sachs Group, May 2016, 7.

[13] There is an important distinction to be made between the two kinds of efficiency that blockchain can create. The first, which underlies most of the current real estate applications, comes from simplifying processes and removing intermediaries. Examples of this sort of efficiency include using using public chains to timestamp documents and eliminating the need for reconciliation of records through shared ledgers. The second kind of efficiency, which remains unproven, is in facilitating secure, high-speed, low-cost transactions at scale.

market for small real estate investments spread across multiple jurisdictions. Cross-border real estate investment is already projected to grow to over 50% of all real estate investment by 2020, and the emergence of blockchain could amplify this trend by introducing a class of real estate investors not limited by geography.[14]

Because it is decentralized, fault tolerant, and virtually immutable, blockchain offers security and resilience advantages over traditional transaction and record keeping systems. Records could be more resilient, as there would be no single, centralized repository vulnerable to destruction, as occurred in Haiti when "an untold number of title deeds and land registry records" were destroyed in the 2010 earthquake.[15]

Fraud and error created by new transactions could also be reduced with an immutable ledger that tracks all transactions. This opportunity will have significant implications for national land registries and title insurance. The need for title insurance will be reduced, as proof of ownership can be established indelibly on the blockchain. The creation of more complete and reliable property records will provide a hugely valuable tool for analysts, regulators, and land management officials. Ultimately, we believe the ability to promote property rights formalization, registry modernization, and the collection and analysis of land-related data makes blockchain a disruptive technology for land governance.

[14] Maria Angelova, "Real Estate cross-border transactions," Propy Inc., 2016, 5.
[15] Anastasia Moloney, "Unclear land rights hinder Haiti's reconstruction," ReliefWeb, July 5, 2010, https://reliefweb.int/report/haiti/unclear-land-rights-hinder-haitis-reconstruction.

Prerequisites for Blockchain Integration

As we wrote in 2017, there are a number of prerequisites that need to be in place before a registry can be integrated with blockchain technology.[16] Those are:

1. Accurate data
2. Digitized records
3. An identity solution
4. Multisig Wallets
5. A private or hybrid blockchain
6. Connectivity and a tech aware population
7. A trained professional community

Below we briefly review these points with some updates from the initial writing. Those already familiar with this work are encouraged to move to page 16 where we introduce the levels of integration we anticipate once these prerequisites are satisfied.

1) Registries should be as accurate as possible

One of the merits of a blockchain is that it is ostensibly immutable, so it is important to make sure that any existing data that is transferred onto the blockchain is accurate.[17] Jurisdictions looking to implement digital solutions are in one of three situations: they have a paper registry, a digital registry, or a registry that was destroyed.

All existing registries, whether digital or on paper, contain inaccuracies. Most causes of error are benign, but fraud and corruption always pose a risk to a registry's accuracy. Simple administrative errors and property owners forgetting --or avoiding for tax optimization-- to register changes also quickly cause outdated registries.

Ideally, the registry should be cleaned and current before it is put onto an immutable platform. The reality is that stopping to clean a registry risks creating disputes that would hinder a transition for years. How bad is it if messy data is imported into a blockchain? Pulling a registry into a platform that allows for more transparency and lower transaction costs could expedite and facilitate clean up. This is particularly true in the case of a paper registry. It is often challenging to find errors in the registry or cadastre until it is digitized --with a poorly managed registry it is difficult to cross-check claims.

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[16] Michael Graglia, Christopher Mellon, and Evan Akin, "Prerequisites for Incorporating Blockchain into a Registry," *FPR Blog (blog)*, New America, July 31, 2017, www.newamerica.org/international-security/future-property-rights/blog/prerequisites-incorporating-blockchain-registry/, accessed July 30, 2017.

[17] Angela Walch, "The Path of the Blockchain Lexicon (and the Law)," *Review of Banking & Financial Law* 36, (March 24, 2017): 715-765, papers.ssrn.com/sol3/papers.cfm?abstract_id=2940335, accessed July 30, 2017; Anthony Lewis, "A gentle introduction to the immutability of blockchains," *Bits on blocks: Thoughts on blockchain technology (blog)*, February 29, 2016, accessed July 30, 2017.

If a registry is in use, functioning as the public record, it should be on the best available technology. If transitioning to a new technology surfaces erroneous or conflicting records, they can be addressed in a systematic manner. Records can be flagged, and a process giving all parties a voice can be initiated without delaying implementation. If, however, the registry is riddled with errors, resources may be better utilized addressing those errors before incorporating blockchain into the registry.

2) Registries must be digitized (at least going forward)

A hash is a "is a mathematical algorithm that maps data of arbitrary size to a bit string of a fixed size (a hash) and is designed to be a one-way function, that is, a function which is infeasible to invert."[18] One of the properties of hashing is collision resistance, where is it is hard to find two inputs that produce the same hash.[19] Another quality of hashing is that even the slightest change to a digital file will produce a completely different hash --even file format has to be consistent.[20] By hashing a document and posting that hash to a public chain it is verifiably timestamped without being published. You cannot hash a paper document, though.[21] You can scan a document and then hash that scan; any subsequent scan, however, would have a different hash due to minute differences. Everyone would need the same copy in the same format in order for the hashes to agree. And it is hashing that empowers blockchains to mitigate against the alteration of records. So we recommend a registry be completely digital before blockchain is integrated. Note that both Sweden and Georgia had fully digitized systems before incorporating blockchain.[22]

3) An identity solution

Registries tell us who has what rights to which asset, so certainty around the "who" is critical. Land and buildings can be tied to a registry via maps, deeds and surveys. Those documents can be connected to the chain via hashes, but how to validate identity?

At the moment, we are only aware of one blockchain-based national ID system, SecureKey in Canada, which launched in 2017.[23] Certainly, with Ukraine and Dubai's stated intentions of having their entire government "on chain," they may also be developing something.[24]

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[18] https://en.wikipedia.org/wiki/Cryptographic_hash_function accessed March 1, 2017

[19] Shafi Goldwasser and Mihir Bellare, "Lecture Notes on Cryptography," Massachusetts Institute of Technology, July 2008, http://cseweb.ucsd.edu/~mihir/papers/gb.pdf, accessed March 2018.

[20] Craig Ball, "Deduplication: Why Computers See Differences in Files that Look Alike", *Ball in your court: Musings on E-discovery and Computer Forensics (blog)*, July 8, 2015, accessed July 30, 2017.

[21] The creators of dLoc, www.smartrac-group.com/dloc-a-breakthrough-solution-in-document-authentication.html, may point out that their product gets pretty close, and we agree, but the point remains. For more on hashing, see: *Wikipedia, The Free Encyclopedia*, s.v. "Hash function," accessed July 30, 2017, en.wikipedia.org/wiki/Hash_function.

[22] Joon Ian Wong, "Sweden's blockchain-powered land registry is inching towards reality," *Quartz*, April 3, 2017, qz.com/947064/sweden-is-turning-a-blockchain-powered-land-registry-into-a-reality/, accessed July 30, 2017; Michael Graglia, "Tbilisi agreement heralds significant expansion of blockchain to manage property registries", *FPR Blog (blog)*, New America, February 16, 2017, accessed July 30, 2017.

[23] "IBM and SecureKey Technologies to Deliver Blockchain-Based Digital Identity Network for Consumers," press release, March 20, 2017, on SecureKey website, securekey.com/press-releases/ibm-securekey-technologies-deliver-blockchain-based-digital-identity-network-consumers/, accessed July 30, 2017.

[24] Gertrude Chavez-Dreyfuss, "Ukraine launches big blockchain deal with tech firm Bitfury," *Reuters*, April 13, 2017, www.reuters.com/article/us-ukraine-bitfury-blockchain/ukraine-launches-big-blockchain-deal-with-tech-firm-bitfury-idUSKBN17F0N2,

Decentralized blockchain-based identity platforms are being developed and may soon be viable options for registries. These include Uport, Civic and, for those without personal devices, EverID. We do not suggest waiting for these systems, rather a registry must leverage an existing digital identity system. In the Swedish pilot, for example, the large telecom company Telia provided the digital keys to verify identity.[25] In India, the Aadhaar identity platform is a logical choice.[26] Estonia also has a robust system (which is not built on a blockchain).[27] In the US, one could imagine Login.gov, the Social Security Administration, or a state's DMV providing verification of identity to a registry.[28]

It is far better to use an existing, validated identity system than to create a new one just for a registry. This is both because identity management is a separate skill set and because using an established system or systems (if a federated identity verification approach is used) will result in higher quality information. Noel Taylor points out that while "verification of identity is certainly a paramount requirement for the system to work, imposing a digital ID requirement on all who transact in the system will impede progress into developing countries if equality is not addressed."[29] We agree, but insist that digital identity must be solved first. SDG 16.9 aims to provide everyone with a legal identity by 2030.[30] We hope this goal is met because it will get us closer to more people enjoying increased tenure security.

4) Multiple Signature Wallets

What happens if someone steals your key? What if you lose your key? What if someone holds a gun to your head and makes you give them title to your house with a click of a button without actually taking the key? The public-private encryption keys built into blockchain ensure that only those holding the associated keys can register or transfer a property. But if keys are lost or stolen, there must be recourse to recover the property associated with them. The issue of legal recourse is discussed in an upcoming prerequisite, but one clear mitigation, if not solution, is multiple signature ("multisig") wallets. These wallets require verification by a minimum number of keys, rather than a single key, before a transaction is completed. Instead of a seller simply pressing a "sell" button, a registry configuration could require both a seller and a banker (or registrar) to sign off on the transaction. Multisig can be configured in any number of ways, requiring, for example, two of two, two of three, or three of five designated signers.

accessed July 30, 2017; Nikhil Lohade, "Dubai Aims to Be a City Built on Blockchain," *Wall Street Journal*, April 24, 2017, www.wsj.com/articles/dubai-aims-to-be-a-city-built-on-blockchain-1493086080, accessed July 30, 2017.

[25] Lantmäteriet et al., "The Land Registry in the blockchain - testbed," Chromaway, March 2017, chromaway.com/papers/Blockchain_Landregistry_Report_2017.pdf, accessed July 30, 2017.

[26] Government of India, Unique Identification Authority of India, *About Aadhaar, 2016, uidai.gov.in/your-aadhaar/about-aadhaar.html.*

[27] Dave Birch, "Estonia, fake news and digital identity", *Tomorrow's Transactions (blog)*, Chyp, March 20, 2017, accessed July 30, 2017.

[28] U.S. General Services Administration, "login.gov - Homepage," login.gov/, accessed July 17, 2018; Social Security Administration, "How We Verify and Protect Your Identity," www.ssa.gov/myaccount/verifyandprotectid.html, accessed July 30, 2017.

[29] Michael Graglia, Christopher Mellon, Evan Akin, "Prerequisites for Incorporating Blockchain Into a Registry," FPR Blog, New America, July 31, 2017. https://www.newamerica.org/international-security/future-property-rights/blog/prerequisites-incorporating-blockchain-registry/, accessed March 9, 2018.

[30] World Bank, "Indicators and a Monitoring Framework for Sustainable Development Goals: Launching a data revolution for the SDGs," http://indicators.report/targets/16-9/, accessed July 30, 2017.

Some suggest a notary should be used as a second signer, but we remain unconvinced. There is no reason to shackle blockchain-based platforms to outdated systems already in decline.[31] Notaries are part of the system of middlemen and gatekeepers that are becoming less necessary in the face of technical innovation. In the United States, for instance, notaries were historically used to vouch for identity, which modern identity systems may not require. Other stakeholders who have a vested interest in valid transactions --bankers and registrars, for instance-- can act as second signers. Once identity is confirmed and all transactions are put in an immutable ledger, there is no need for a human notary in a blockchain enabled process, much less a justification for the associated costs.

Those who excitedly envision direct, peer-to-peer exchanges of real estate and unbundled property rights may groan at the suggestion of multisig wallets, but for most homeowners that dream is more akin to a nightmare.[32] Despite the Parity multisig hacks, which were due to poor coding, other multisig wallets seem secure.[33] We believe that multisig wallets will prevent more problems than they will cause by the modest delays associated with their use.

5) Use a private or hybrid blockchain

There is no universal format for blockchain-based registries, at least not yet, but we expect that they will all employ a private blockchain in some form. There are at least three good reasons for this:[34]

a. Both the Judiciary and Registrar need the ability to adjust the ledger
On a public chain (BTC, ETH) there is only a record of the transactions by two willing parties identified by their public keys,[35] as well as any comments they added to their transaction. Generally, if fraudulent data was entered and discovered, the only recourse for correction is another transaction reversing the prior entry. If a court rules that one spouse gets the house, but the other spouse does not want to transfer ownership, what happens? If someone loses their key or dies without communicating their key to another, how is ownership reallocated? What about expropriation of privately held lands for construction of public infrastructure? On a public chain, all of these questions are difficult to answer. But in a hybrid chain --where decisions are tracked on a private chain with hashes of key documents recorded on a public chain-- they can be addressed by granting appropriate authorities to the Registrar and Judiciary, which is critical when managing real assets.[36] This could take the form of a special variation of a multisig where an

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[31] "Breaking the seals," *The Economist*, August 22, 2012, http://www.economist.com/node/21560242, accessed July 30, 2017.

[32] Jeffrey Dorfman, "Creative Markets For Property Rights Can Solve Many Problems," *Forbes*, June 11, 2017, www.forbes.com/sites/jeffreydorfman/2017/06/11/creative-markets-for-property-rights-can-solve-many-problems/#751c0bfe4377, accessed July 30, 2017.

[33] Wolfie Zhao, "$30 Million: Ether Reported Stolen Due to Parity Wallet Breach," CoinDesk, July 19, 2017, www.coindesk.com/30-million-ether-reported-stolen-parity-wallet-breach/, accessed July 30, 2017; Jordan Pearson, "Someone 'Accidentally' Locked Away $150M Worth of Other People's Ethereum Funds," *Motherboard VICE*, November 7 2017, https://motherboard.vice.com/en_us/article/ywbqmg/parity-multi-signature-wallet-vulnerability-300-million-hard-fork.

[34] For an explanation of these terms, see Michael Graglia, "5 Myths About Blockchains," *FPR Blog (blog)*, April 14, 2017.

[35] For the latest blockchain and ethereum transactions, see "Bitcoin Block Explorer," blockchain.info/, accessed July 30, 2017; "Etherchain - The Ethereum Blockchain Explorer," www.etherchain.org/, accessed July 30, 2017.

[36] This is what Bitfury deployed in Georgia with their product Exonum. See "Exonum—A framework for blockchain solutions", exonum.com.

ombudsman has a key allowing it to create reverse transactions on the private chain. Accenture has made a similar observation in the context of financial services.[37]

What happens if someone abuses these authorities? While this is a risk, one of the appeals of the blockchain is that it is a registry of all transactions. So while we advocate for exceptional authorities to issue new keys and create reversing (as opposed to overwriting) transactions where mandated by law, we do not suggest this should be done in secret. Since all transactions will be recorded to the private chain and be visible to those with access, if configured appropriately, it will be far easier to identify and correct any abuse of authority.

b. Public chains cannot handle the volume of data involved
Registries contain deeds, titles, maps, plans, etc. All of these documents must be stored somewhere. Public blockchains cannot viably store such large amounts of data. Decentralized storage and transfer systems like IPFS, Swarm, Sia, Storj, and Maidsafe may solve the problem in the future, but are still in the early stages of development and therefore are not ready to be entrusted with a property registry.[38] Registries can store the documents on a regular server and post the associated hashes to a public blockchain, but if a blockchain-based record of the actual data is desired, registries will need to use a private blockchain.

c. Anonymity is not an option
Registries need to know who is registering or transferring property records. Public blockchains allow anyone with the correct keys to broadcast valid transactions, regardless of who or what they are. A private blockchain is needed if registries want to ensure only parties who have validated their identity to the satisfaction of the authorities are transacting. If nothing else, in jurisdictions with property tax, the tax authority may want more than a public key to hold liable for taxes.

6) Digital registries require connectivity and a tech aware population

Before a registry adopts a digital platform they should consider the costs and support requirements. An initial response may be that these additional costs make a project unattractive, but the counterargument is that a new system should eliminate a number of prospective operating costs.

Blockchain software is complex and the hardware requirements, substantial. It is hard to imagine that most public agencies could take these responsibilities in-house. This is well-understood beyond the world of registries, which is why we have seen Infrastructure and Software as a Service models (IaaS & SaaS) proliferate.[39] These models allow parties to purchase servers and software on a subscription basis instead of making substantial initial capital investments. We are seeing the same with Blockchain as a Service

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[37] David Treat, "Editing the Uneditable Blockchain," Accenture, www.accenture.com/us-en/insight-editing-uneditable-blockchain, accessed July 30, 2017.
[38] IPFS, "Peer-to-peer hypermedia protocol," 2015, GitHub Repository, github.com/ipfs/ipfs; Ethersphere, "swarm docs," github.com/ethersphere/swarm, accessed July 30, 2017.
[39] "As-a-service Solutions Drive Growth in Global Sourcing Market," press release, July 2017, on ISG website, http://www.isg-one.com/related-case-studies-detail/as-a-service-solutions-drive-growth-in-global-sourcing-market, accessed July 30, 2017.

(BaaS),[40] but this change in support model has budget implications. Namely that while the upfront cost is avoided, they are replaced with recurring costs. The maintenance and troubleshooting costs, however, shift to the vendor, which must be able to guarantee a very low rate of failure. And while public proof of work blockchains have proven robust, secondary software like wallets, exchanges, and smart contracts can be soft targets for hackers. A professional level of quality assurance and quality control will therefore be required.

In jurisdictions where connectivity is limited or consumers are not comfortable with digital transactions, a blockchain registry may not be optimal. If the system is not already digitized, we suggest starting there and then revisiting blockchain later. Registry digitization alone is a challenge. The Jamaican registry had to retrain employees and transform its office culture to make their new digital system work, and moving to a blockchain-based system will likely face similar challenges.[41]

7) Train the professional community that interacts with the registry

In the long run, some envision the blockchain disintermediating many parties. In the near term, this is unlikely. Lawyers will still bring suits, judges will hear them, and real estate agents will offer value added services to clients who would prefer expert assistance. All of these parties will need to be trained on the new system in order for it to function properly. The importance of engaging the professional communities who will interact with the blockchain early on in the transition cannot be overlooked. Blockchain lawyers such as Andrew Hinkes remind us that lawyers will need to understand a number of issues, including how to present records from the blockchain, how to interpret records, and how to harmonize evidence rules with output from the blockchain. To do any of those things, they will first need to be trained in the fundamental concepts, capabilities, and vocabulary of the blockchain. Even with a clear picture of the technical and structural requirements for a blockchain registry, a great deal of work will remain in the form of education and capacity building.

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[40] Microsoft Azure, "Blockchain on Azure," azure.microsoft.com/en-us/solutions/blockchain/, accessed July 30, 2017.
[41] Maya Gainer, "From the Ground Up: Developing Jamaica's National Land Agency, 2000-2016," Innovations for Successful Societies, January 2017, successfulsocieties.princeton.edu/sites/successfulsocieties/files/MG_Land_Jamaica_May2017.pdf, accessed July 30, 2017.

Framework for Blockchain-Registry Adoption

Once these prerequisites are satisfied, what does that integration actually look like? How will it evolve? What does it mean to put a registry on the blockchain? There are different ways you can integrate or apply blockchain to an immovable real property registry. Instead of simply enumerating each of these scenarios, we propose a progressive framework for how we see blockchain integrating with property registries over time. This progression is not envisioned due to limitations of the available technology --whether blockchain or a traditional database. Rather it is the complexity and resulting inertia of existing processes, compounded by implementation costs, that makes a progressive approach most likely.

In January 2014, SAE International launched the standard J3016 Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems.[42] According to Car and Driver, this was done to allow "automakers, suppliers, and policymakers to classify a system's sophistication," because, "no two automated-driving technologies are exactly alike."[43] A similar framework will benefit the developers and policymakers who are active in the space defined by the intersection of blockchain and land registries. The progression is not as clear in this case as it is with autonomous vehicles, and it is unlikely to proceed in as linear a fashion as the numbering may suggest. The levels represent increasing sophistication or complexity, as perceived by the authors.

We propose eight levels. The first four envision the two most commons forms of property transactions: sale and lease/rental. Starting with level five, blockchain is seen as facilitating the disaggregation of different types of rights as well as their fractionalization.

Level 0 - No Integration

Here we bucket everything from informal land where there are no legal titles, to paper registries, to computerized registries that rely on a centralized database. Clearly this category could be further subdivided but we are focusing instead on where blockchain is integrated with a registry.

Level 1 - Blockchain Recording

This is useful in situations where notaries are not available, or where trust in the existing system is limited.[44] Hashing is the process of taking any digital input --from a string of characters to a scan of a

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[42] "Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Driving Systems," *SAE International*, January 16, 2014. http://standards.sae.org/j3016_201401/, accessed on December 15, 2017.

[43] "Path to Autonomy: Self-Driving Car Levels 0 to 5 Explained: Just what does 'Level 5 autonomous car' mean?" *Car and Driver*, October 2017. www.caranddriver.com/features/path-to-autonomy-self-driving-car-levels-0-to-5-explained-feature, accessed on December 15, 2017.

[44] Here when we say "Notary" instead of the global definition of elevated attorney, we refer to the more American meaning of acknowledged signor.

Table: FPR Blockchain Property Registry Adoption Levels

Level	Name	Description	Example
0	No Integration	No use of blockchain	Most of the world
1	Blockchain Recording	Public blockchain used to record documents related to land transactions	Brazil, Georgia, Dubai[45]
2	Smart Workflow	Blockchain used to record progress of a transaction	Sweden, Dubai Properties (Landstream)
3	Smart Escrow	Smart contracts used for escrowing payment	Propy
4	Blockchain Registry	Central database replaced with a permissioned blockchain	Dubai, Georgia
5	Disaggregated Rights	Various rights to a single parcel are disaggregated and managed via blockchain	No known example
6	Fractional Rights	Rights for a given parcel are fragmented and managed via blockchain	Pangea[46]
7	Peer-to-Peer Transactions	Rights are transacted without intermediaries on Level 4 system	No known example
8	Interoperability	Different blockchain registries merge	No known example

legal document like a deed or lease-- and creating a unique output of fixed length.[47] The hash of a document is often referred to as the digital fingerprint, a unique identifier. By storing this hash on a public chain --such as BTC or ETH-- one creates an independently verifiable record of the existence of the document, in a specific condition, exactly when it was recorded via timestamps and ownership (or at least association) via public and private keys. In other words, the document has been virtually notarized and publicly recorded.[48] Some existing intermediaries are concerned by this practice; a group of European

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[45] Staff Report, "Dubai Land Department becomes world's first government entity to conduct all transactions through Blockchain network," *Gulf News*, October 7, 2017, http://gulfnews.com/business/sectors/technology/dubai-land-department-becomes-world-s-first-government-entity-to-conduct-all-transactions-through-blockchain-network-1.2102060.

[46] Andrew Keys, "How Ethereum Blockchain Technology Will Revolutionize Digital Asset Value," *International Business Times*, January 17, 2018, http://www.ibtimes.com/how-ethereum-blockchain-technology-will-revolutionize-digital-asset-value-2642311.

[47] "If you understand Hash Functions, you'll understand Blockchains," *Talk Crypto (blog)*, Talk Crypto, November 28, 2016, http://www.talkcrypto.org/blog/portfolio/if-you-understand-hash-functions-youll-understand-blockchains/, accessed on December 15, 2017.

[48] We say virtually because notarization in a legal sense includes authentication of signatures and indicates that the document is trustworthy. See National Notary Association, "What is Notarization," www.nationalnotary.org/knowledge-center/about-notaries/what-is-notarization. Hashing a document to a public chain only authenticates existence of the document in a certain condition at a given time. There is an open debate about if cryptographic signatures—using a private key on a personal device-- are comparable to digital signatures.

surveyors and notaries documented some of these concerns at the World Bank in March 2017.[49] Despite their concerns, we expect that the use of public blockchains to record key documents is likely to continue. In jurisdictions where corruption is a concern, introducing a public record of hashes can make it significantly harder to falsify records. On the other end of the spectrum, in countries where there are strong open data movements (Sweden, Estonia) or high degrees of transparency (the Netherlands), a public document registry may also be welcomed.

Examples: Brazil (Ubitquity) and Georgia (Bitfury) are using the Bitcoin blockchain to notarize the sale of properties.[50] The Netherlands is also using blockchain for leases. The Dubai Land Authority has the most advanced use case we are aware of. Per the Gulf News, the Dubai Land Department

> "*has created its blockchain system using a smart and secure database that records all real estate contracts, including lease registrations, and links them with the Dubai Electricity & Water Authority (Dewa), the telecommunications system, and various property related bills. Dubai's blockchain's secure, electronic real estate platform incorporates personal tenant databases, including Emirates Identity Cards and the validity of residency visas, and allows tenants to make payments electronically without the need to write cheques or print any papers. The entire process can be completed electronically within a few minutes at any time and from anywhere in the world, removing the need to visit any government entity.*"[51]

Level 2 - Smart Workflow

This is useful as a way to both speed up existing work processes and make them more transparent. Real estate development and transactions are often complex, involving numerous intermediaries and elaborate processes. By publishing the completion of each step of the transaction on a private or consortium chain and making those events visible to other participants in the transaction, timelines can be compressed dramatically. Along with mid-transaction transparency, hand-offs between parties become easier since everyone is using the same workflow rather than integrating numerous existing systems, which often introduces error.

In the case of a real estate transaction, the steps --bank approved credit line, offer accepted, deposit received, contract signed, etc.-- involve numerous entities who need to interact and be certain that each has done their part. Collaborating via a blockchain will allow them to collapse the timeline and realize significant efficiencies. Another benefit of this application is that more members of an ecosystem engage with blockchain and, as a result may become more comfortable with the technology, building support for deeper levels of adoption.

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[49] Maurice Barbieri, Jean-Yves Pirlot, Dominik Gassen, Hanns-Jakob Pützer, Raul Radoi, Nicola Maria Hoischen, Florian Lebourdais, "Blockchain – Can This New Technology Really Revolutionize The Land Registry System?" Presentation, presented at Land and Poverty Conference, Washington, D.C., March 22, 2017, www.conftool.com/landandpoverty2017/index.php?page=browseSessions&form_session=547&presentations=show, accessed on January 15, 2017.

[50] Ian Allison, "Blockchain-based Ubitquity pilots with Brazil's land records bureau," *International Business Times*, April 5, 2017, http://www.ibtimes.co.uk/blockchain-based-ubitquity-pilots-brazils-land-records-bureau-1615518, accessed on December 15, 2017; Michael Graglia, "Tbilisi agreement heralds significant expansion." www.newamerica.org/international-security/future-property-rights/blog/blockchain-for-property-rights-georgia/, accessed on December 15, 2017.

[51] Staff Report, "Dubai Land Department."

In the case of real estate development, the documents required to develop a project --sales and purchase agreements, progress reports, and master plans-- need to move back and forth between developers and approving agencies.[52] Having a trustless blockchain that can track these documents and increase visibility to all parties will expedite the process and reduce confusion.

Examples: Sweden with ChromaWay are using the Bitcoin blockchain to notarize transaction documents.[53] Westpac and ANZ, both Australian banks, are working with IBM to use blockchain technology for commercial leases. Their whitepaper on the project is informative.[54] For project development, Dubai Properties and ConsenSys have developed a proof of concept for a product called Landstream. It was presented at the Arab Land Conference in February 2018 and will go into production in March 2018.[55]

Level 3 - Smart Escrow

Smart contracts replace escrow agents in level 3. An escrow is "a deposit of funds, a deed or other instrument by one party for the delivery to another party upon completion of a particular condition or event."[56] When smart contracts were envisioned in 1995 by Nick Szabo, he defined them as "a set of promises, specified in digital form, including protocols within which the parties perform on these promises."[57] So instead of buyers, sellers and banks depositing deeds, down payments, and mortgage payments with a professional escrow firm, all of those things are digitized and entrusted to a small program that lives on a blockchain and transfers ownership when all conditions are satisfied.

Aside from the clear implications of replacing a set of professionals with code, level 3 blockchain integration is significant because, as Andrew Hinkes argues, the impact of blockchains on contract law may minimize litigation exposure as well.[58] Hinkes points out that oracles --external data sources upon which smart contacts may rely-- remain a vulnerability. Oracles are susceptible to fraud or manipulation and although many projects seek to address oracle information sources, they have many moving parts where they can break, be faked or be manipulated. Smart contracts open a Pandora's box of legal issues if they do not behave appropriately.

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[52] "Landstream Summary 2018 (Public)," Dubai Properties and ConsenSys, February 2018, docs.google.com/document/d/10B3C4YGDTHHS-P7x61g13YNfvyCQkTXgVvxYfNI1OKc/edit.

[53] "The underlying technology for this project is ChromaWay's two innovative products. First, Esplix the smart workflow middleware which enables processes and workflows to be described using code and then enforced by the participants in the system." See "Blockchain and Future House Purchases Second Phase Completed in March 2017," Chromaway, chromaway.com/landregistry/, accessed January 15 2018.

[54] Hariramchakraborthy Janakiraman, Chris T'en, Morag Home, and Rodolf Salem, "Distributed Ledger Technology and Bank Guarantees for Commerical Property Leasing, IBM, July 2017, www.ibm.com/industries/au-en/banking/downloads/Whitepaper-Bank_Guara.pdf, accessed on January 15, 2018.

[55] "Landstream Abstract," Dubai Properties and ConsenSys, February 2018, drive.google.com/file/d/1FmrSywflp9AqluypbD_OZF-xlziyWDtY/view.

[56] Real Estate ABC, "Escrow (Real Estate): What is it? Why do I need it? How does it work? Who chooses escrow?" www.realestateabc.com/homeguide/Escrow.htm.

[57] Nick Szabo, "Smart Contracts: Building Blocks for Digital Markets," University of Amsterdam, http://www.fon.hum.uva.nl/rob/Courses/InformationInSpeech/CDROM/Literature/LOTwinterschool2006/szabo.best.vwh.net/smart_contracts_2.html.

[58] Andrew Hinkes, "Blockchains, smart contracts, and the death of specific performance," Inside Counsel, July 29, 2014, http://web2.insidecounsel.com/2014/07/29/blockchains-smart-contracts-and-the-death-of-speci, accessed on January 15, 2018.

Example: Propy.com has used this approach to facilitate the purchase of an apartment in the Ukraine by a buyer in California paying with Ether and PRO tokens.[59] A detailed walkthrough of the transaction has been published.[60]

Level 4 - Blockchain Registry

The blockchain replaces the database in level 4. In all the previous instances, we imagined that the property registries existed as independent, centralized databases, which are supplemented in some way by the blockchain: in level 1 as a time-stamped signature, in level 2 as a shared source of truth regarding a process, in level 3 as smart escrow. In level 4, we imagine that a private permissioned blockchain replaces the central database and stores the actual records.[61] A private blockchain would be used to store the data for reasons of security, cost, selective privacy, and efficiency. The recording function, however, would still be performed on a public blockchain. This is not to say that all information would be private. Selective information from all transactions could made visible to a large number of participants, reducing the likelihood of fraud or other undesirable behavior. These observers could also be given permissions to suggest edits or updates to the dataset, creating a better-curated data set over time. This arrangement could include built-in incentives to reward useful contributions.

Examples: Dubai is doing exactly this for their real estate documents.[62] Georgia is in process of implementing such a system.[63]

Level 5 - Disaggregated Rights

From levels 1 through 4 the rights in question will be ownership and occupancy, but once a blockchain becomes the registry, other possibilities present themselves. In level 5, rights can be disaggregated and discretely managed via a blockchain. Various rights associated with a property would be freely negotiated, using a blockchain system to track those transactions. Examples of other rights include, but are not limited to air, water, subsurface, mineral, grazing, and easements.

Level 6 - Fractional Rights

Fractional rights are when a specific right is shared or divided between multiple users. This is frequently brought up in discussions about blockchain and real estate, but would be more difficult in practice without

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[59] "Propy Announces World's First Real Estate Purchase on Ethereum Blockchain," *Cision*, PR Newswire, October 2, 2017. www.prnewswire.com/news-releases/propy-announces-worlds-first-real-estate-purchase-on-ethereum-blockchain-300529474.html, accessed on December 14, 2017.

[60] Natalia Karayaneva, "How A Smart Contract replaced An Escrow Company in a $60k deal," *Hackernoon (blog)*, Medium, October 17, 2017, hackernoon.com/how-a-smart-contract-replaced-an-escrow-company-in-a-60k-deal-551ff7839044.

[61] For more information on why a private permissioned chain is most appropriate here, see Michael Graglia et al., "Prerequisites for Incorporating Blockchain."

[62] "In cooperation with DEWA, Smart Dubai, Emirates NBD, and the General Directorate of Residency and Foreigners Affairs," press release, October 11, 2017, on wasl Asset Management Group website, www.wasl.ae/press-releases/cooperation-dewa-smart-dubai-emirates-nbd-and-general-directorate-residency-and-foreigners-affairs.

[63] Per interview with Bitfury, January 16, 2018.

level 5 integration in place. Fractionalization of rights allows for numerous scenarios. In addition to rights of ownership or occupancy, rights to revenues resulting from different uses of the property could also be fractionalized and traded.

Fractional ownership in this context could be defined as multiple parties sharing the rights and responsibilities of owning a real asset (i.e., a house, a condominium, or a commercial building) much like multi-investor leases.

Fractional occupancy could mean a number of things, depending on if the right is divided in terms of space, time, or both. Examples of fractional rights include rights to a room in a house, or a bed in a room, or a time slot for a bed in a room, or rights to occupy an apartment, water rights being shared by multiple companies, or other third parties sharing the water on a land with owners, etc.

Beyond dividing how a property is used, both the governance and investment aspects can be allocated via blockchain. Buyers will purchase shares in an asset, which translate to a stream of payments, assuming the asset is leased (investment), and also provides certain rights or decision-making abilities (governance). This is technically possible without blockchain and has recently happened --see the Australian example of Brickx.com-- but with a blockchain, the costs of allocating, recording, and trading these rights would be considerably lower.[64] Therefore, we should expect various models for minting, trading, and discarding these shares. Blockchains may also facilitate the scaling of the Brickx.com model.

Example: ConsenSys has announced a project called Pangea, which will do what Brickx.com is doing via the Ethereum public chain.[65]

Level 7 - Peer-to-Peer Transactions

These exchanges can occur only after the adoption of a blockchain and the clarification of legal rights. Overall, until levels 1-6 materialize, it is difficult to imagine the possibility of genuine peer-to-peer transactions without the presence of intermediaries.

In the case of Brickx.com, the use of a blockchain to facilitate their model, instead of a centralized internal system, could offer a similar user experience but with faster clearing and lower fees. The real potential for this model becomes clear, however, when its potential is applied without an intermediary. For instance, if a homeowner desires capital, instead of securing a home equity line of credit (HELOC) from a bank, they could simply fractionalize the rights to rent their house and enter into a long term lease with themselves. The homeowner could then offer a fraction of the right to rental payments to any willing buyer via a smart contract. They would then be obliged to make payments to the owner of those rights (interest) until they paid off the initial cost (principal). Said differently, a level 7 registry with fractional

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[64] "Property Investment for Under $100," Brickx, https://www.brickx.com/, accessed January 15, 2018.

[65] "Stop Selling your Upside: How Blockchain Can Unlock Value in Real Estate Through Fractional Ownership," *Pangea (blog)*, Medium, January 4, 2018, medium.com/@pangeaGO/stop-selling-your-upside-how-blockchain-can-unlock-value-in-real-estate-through-fractional-b492400b47a; "Real Estate Needs a Revolution," *Pangea (blog)*, Medium, January 11, 2018, media.consensys.net/using-blockchain-to-expand-access-to-real-estate-4a2e3fb15f90.

rights would allow for a DIY HELOC or a crowd-sourced, peer-to-peer mortgage. In both cases it remains to be seen how these fractioned rights will be treated by the courts when failure to meet an obligation triggers a conflict.

Level 8 - Interoperability

This would be something of a Holy Grail --interoperability between multiple blockchain-enabled registries and levels of jurisdiction-- whether it is Santa Clara and San Mateo County, the Netherlands and Spain, or China and the US. It is important here to distinguish that we are not talking about level 3. Rather, level 8 would be an actual peer-to-peer transaction between two blockchains and enabled registries. From a technology perspective, this would require some standardization of what defines a property on a blockchain between registries and blockchain firms in order to have a unified definition for a physical space and its associated rights. As is almost always the case, the political and legal challenges to such transactions would be significant. The vision here entails the world's property being managed on a large hybrid blockchain that came together by virtue of its interoperability. Another scenario could involve someone creating a blockchain that is capable of managing all the property in the world. At first glance this may be what Patrick Byrne of Overstock and Hernando de Soto are considering.[66]

Beyond Colored Coins

The higher levels of our integration framework also require an appropriate digital instrument for conveying ownership. One solution for doing so on public blockchains is to use colored coins, cryptocurrency tokens marked with metadata linking them to off-chain assets. The transfer of colored coins can in theory be used to represent transfer of the assets associated with them, but some legal scholars have concerns. An analysis by Rod Thomas published in the European Property Law Journal identifies two major obstacles to trading property with colored coins in common law jurisdictions.[67]

First, he argues that colored coins may be unable to convey ownership of a specific property because they are based on currencies, which are fungible. Thomas argues that incorporeal interests, like easements or rights to rentcharges, could be transferred by coin, but property ownership should not. He argues further that there would be no adequate process for redressing loss of a specific asset like a house because if a transaction went wrong, damages could be claimed but ownership of the property could not be reassigned.

The second issue Thomas identifies is that "competing claims" and "off-chain interests" would need to be recorded in the colored coin in order for it to allow secure transactions, and the owner of the coin cannot be trusted to be the gatekeeper. An additional problem is that, depending on the implementation, colored coins may only store a very limited amount of data.

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[66] Evelyn Cheng, "Overstock.com shares spike after blockchain unit announces for-profit property registry," CNBC, December 13, 2017, www.cnbc.com/2017/12/13/overstock-com-spikes-after-blockchain-unit-announces-for-profit-property-registry.html
[67] Rod Thomas, "Blockchain's incompatibility for use as a land registry: issues of definition, feasibility and risk," *European Property Law Journal* 6, no. 3 (2017): 361-390, doi: https://doi.org/10.1515/eplj-2017-0021.

Some of the objections mentioned above are also mitigated by the use of private or hybrid chains with multisig wallets, which we argued in the prerequisites section were the best structure for blockchain registries. Similarly, given that the higher levels introduce some complexity, we believe that it would be preferable to create a standardized, purpose-built digital instrument for representing and conveying property ownership on chain. Instead of Colored Coins, such a system might be a robust digital identity system that gave identities to humans, parcels and building and then used the blockchain and smart contracts to record the relationships between them.

What is the Future of Blockchain for Real Estate?

There are a number of well-known technical and legal obstacles to overcome in order for blockchain to be widely adopted in the real estate and land sectors. These include the lack of standard protocols for interoperability and the fact that the dominant public chains may perish, for a variety of reasons including regulation of the cryptocurrencies that power them. Transaction speeds must increase without compromising data security. If we foresee a world with numerous micro-transactions there has to be adequate throughput speed to maintain it. This will depend in part on consensus mechanisms. Proof of Work has been very successful in large public chains but there are concerns around speed and energy consumption. Ethereum's Proof of Stake mechanism remains unproven. More US States are moving to recognize smart contracts and blockchain records, but early bills are occasionally compromised by the inability of lawmakers to define those technologies with sufficient accuracy.

The difficulty of these challenges should not be understated, but none of them are insurmountable and the potential for blockchain to improve land administration has generated a great deal of interest. In this section we explore five specific questions around the impact of blockchain: title insurance, legal reform, financial inclusion, big data and regulation. Each of these topics is too large to be explored in a single paper, so we have kept our remarks brief and focused only on key issues.

What does blockchain mean for title insurance?

Title insurance differs from other common forms of insurance in that it insures against past, rather than future, events. It can be expected, therefore, that if the historical property record can be made more reliable, risk will be diminished correspondingly.[68] This makes title plants a very natural blockchain use case.

A widely-cited analysis published by Goldman Sachs in May 2016 concludes that the impact of blockchain on title insurance will be to make title plants more efficient, leading to a decrease in the cost of premiums.[69] The greatest part of the cost of title insurance does not come from actuarial risk but from

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[68] Title searches usually start from the last known issued title insurance policy which, given the frequency with which properties are transferred, typically limits the period that needs to be searched to thirty years or less.
[69] James Schneider, "Profiles in Innovation: Blockchain, Putting Theory into Practice," Goldman Sachs, May 24, 2016, msenterprise.global.ssl.fastly.net/wordpress/2017/07/Goldman-Sachs-Blockchain-putting-theory-to-practice.pdf, accessed January 25, 2018.

fixed personnel costs, which "represent nearly 75% of industry premiums."[70] Title insurance companies can reduce these costs by using blockchain to create a thorough and accurate database of records, enabling more efficient title searches and reducing the number of defective titles they have to correct. Goldman estimates that total cost savings created by blockchain will result in 30% lower premiums for consumers. Interestingly, they project this will bring premiums across the US in line with those of the state of Iowa, which is unique in having a state-run title insurance monopoly.[71] While the Goldman report acknowledges that the use of blockchain will "clean" property registries over time, it does not envision a scenario in which title insurance becomes unnecessary.

The question of whether a sufficiently comprehensive and reliable registry --for example a blockchain registry that had been in place for decades-- could eventually remove the need for title insurance altogether is interesting. This seems unlikely to happen in the US without significant legal reforms, because in most US jurisdictions there are documents that affect security of title and do not have to be recorded. Furthermore, documents can contain defects because they are not reviewed and validated by a responsible party prior to recording. As long as off-chain information can impact security of title, professional intermediaries will be required to perform due diligence and mitigate against risk, which is a barrier to peer-to-peer transactions. Under these circumstances, disintermediation is not desirable for the transacting parties, who would assume the risk themselves. The situation is different in Torrens jurisdictions, where the registration of a certificate of title is guaranteed by the state as proof of ownership and title insurance is usually not required.

According to the American Land Title Association, the US title insurance industry "generated $14.3 billion in title insurance premiums during 2016 compared to $13.2 billion during 2015."[72] While there is broad agreement that blockchain will make the operations of title insurers more efficient, it is not clear what impact that efficiency will have on competition in the industry. The market is currently dominated by a handful of underwriters, with the top five companies having a 75% combined market share in the third quarter of 2017.[73] Early adoption by a major player could lead to consolidation in the industry as it outcompetes and acquires its rivals. Though it seems likely that early adoption will be by established companies migrating their existing title plants to the blockchain, it is also conceivable that private blockchain registry and workflow management providers could eventually compete with them. A company providing a parallel registry and managing document exchange between the buyer, seller, banks, registry, attorneys, escrow agent, notary, and brokers might accumulate enough records to start its own title plant over time and offer their own title insurance through their platform.

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[70] Ibid.
[71] Joseph Treaster, "Iowa Cuts Added Costs in Title Insurance Policies," *New York Times*, July 6, 2005, www.nytimes.com/2005/07/06/business/iowa-cuts-added-costs-in-title-insurance-policies.html.
[72] "2016 Title Premium Volume Up 8.7 Percent," American Land Title Association, March 21, 2017, https://www.alta.org/news/news.cfm?20170321-2016-Title-Premium-Volume-Up-87-Percent, accessed March 15, 2018.
[73] "Title Industry Generates $3.9 Billion in Premiums During Q3," American Land Title Association, December 14, 2017, https://www.alta.org/news/news.cfm?20171214-Title-Industry-Generates-39-Billion-in-Premiums-During-Q3, accessed March 15, 2018.

Is Torrens a better legal framework for a blockchain registry?

Most of the early blockchain-based real estate products have been oriented towards abstract title recording jurisdictions.[74] Complex tasks like recording transactions, managing workflows, and researching chain of title create obvious opportunities for cost savings from increased efficiency. It could therefore be argued that there is currently less of an economic incentive for Torrens jurisdictions to adopt blockchain. But the opposite may be true when it comes to the higher levels of blockchain integration proposed in our framework, which involve increased decentralization and liquidity of assets. At those later stages the security and simplicity of Torrens title may offer significant advantages.

In the short term, blockchain could reduce the time required to approve new title certificates in Torrens jurisdictions. In the long term, the adoption of blockchain registries and transaction tools could allow them to benefit from a greater degree of liquidity than could be achieved in abstract title jurisdictions, which include the majority of US states and counties.

Greater security of title is the primary advantage of the Torrens system. A certificate of title is a government-backed guarantee of ownership, and includes all encumbrances on the title document. This makes it easier to transfer ownership securely, and can greatly reduce the number of title disputes that burden the legal system, especially in places with unreliable or incomplete property records.[75] This security would be especially significant for peer-to-peer transactions. The indefeasibility of Torrens titles would allow buyers to know the validity of the seller's title and of their own claim once the transfer was registered, allowing title certificates to function more like bearer instruments.

When a legal claim is brought successfully against the holder of a Torrens title, the claimant receives monetary compensation from an indemnity fund and ownership of the property remains with the certificate holder.[76] This means that there must be a pool of money set aside for the purpose of compensation. In places like Australia, where the Torrens system originated, the government collects this money from title registration fees.[77] A blockchain-based registry could automate this function, collecting money for the compensation fund with transaction fees.

It is not clear that these potential advantages would be enough to drive adoption of the Torrens system in the US. It is used to a limited extent in a number of states, including Minnesota, Washington, and New York, but was never widely adopted after its introduction in the nineteenth century. This is largely due to the fact that the expense of migrating a property in the US to the Torrens system has usually been too

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[74] Jurisdictions in which evidence of ownership is provided by an Abstract of Title, a document detailing the chain of ownership of a property. In the sections that follow these are referred to as "abstract" jurisdictions and contrasted with Torrens jurisdictions, in which ownership is guaranteed by a government-backed Certificate if Title.

[75] For example, competing claims based on possession of the land, e.g. adverse possession, are not valid under Torrens.

[76] Shaun Watchie Perry, "Outline of the Torrens Act," *American Bar Association*, August 2005, https://www.americanbar.org/newsletter/publications/law_trends_news_practice_area_e_newsletter_home/torrenact.html.

[77] The government's liability is not limited by the amount of money in this pool, and they would be required to pay claims with other funds if it was ever exhausted.

great to justify. A sufficiently compelling reason may develop if property transactions become increasingly decentralized.

Because of the cost and complexity of transitioning properties over to Torrens title, this transition could not be done all at once. A more reasonable approach would be to move properties over to a parallel, blockchain-based registry over time. This could be achieved through incentivizing property owners to make the transition voluntarily, for example to gain access to an international market for fractionalized property or peer-to-peer sales to foreign investors. Alternatively, the transfer could be prompted by a triggering event specified by the registrar. The latter has been done in the United States before, if only at a small scale. In Hennepin County, Minnesota, the registrar converts properties to Torrens when they are repossessed for tax liens.[78] For our purposes the triggering event is less important than the effect, which would be to produce a gradual transition to Torrens titles on a blockchain registry.

The idea that Torrens titles could be transferred and registered more easily and securely on a blockchain-based system depends on the willingness and ability of the registrar to approve and register documents in a timely fashion. In their examination of the advantages and disadvantages of Torrens title in the United States, the authors of The Earthen Vessel point out that

> *"because the registrar's office is not particularly sensitive to market forces, the inherent delays of the time consuming review of the documents for legal sufficiency by the registrar's office can be an unacceptable burden for those engaged in transactions. On the other hand, for the registration of records system, where the examination of title is completed by private representatives of the parties to the transaction, market forces are a factor, and where necessary, the attorneys can complete the examination of title and the closing on a transaction, based upon the needs and expectations of the client, in a very short period of time."* [79]

It should also be noted that jurisdictions may be reluctant to embrace the Torrens system because of the cost of assuming liability and maintaining the indemnity fund. But as is the case in the title insurance industry, this risk could be reduced by improving the quality of property records. We should also reiterate that the argument presented here in favor of Torrens title is predicated on the idea that more liquid property transfers will be a great enough economic incentive to justify the expense and disruption of legal reforms. There are a number of scenarios why this would not come to pass. It is possible, for example, that the overwhelming majority of blockchain-based transactions will be of property-backed investments in which ownership is not transferred. The broader question raised is whether some jurisdictions will stand to benefit more than others based on the degree to which their land laws map onto the characteristics of blockchain.

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[78] Justin T. Holl, Peter Rabley, Mark Monacelli, and David Ewan, "The Earthen Vessel: Land Records in the United States," paper presented at the PRIA Annual Winter Conference, Washington, DC, March 2010.
[79] Ibid.

Will blockchain and land drive financial inclusion?

We should begin by emphasizing that, as Aanchal Anand, Matthew McKibbin, and Frank Pichel wrote in 2016, blockchain registries do not become significant for land governance until after land rights have been formalized:

> *"Simply put, blockchain does not resolve the primary challenge of land administration faced in many emerging economies – how to bring citizens and properties into the formal system. Blockchain will not help to identify who has what right and to where. It will not resolve property rights disputes as properties are brought into the formal system. Most importantly it won't resolve the tedious and time consuming process of collecting, verifying and bringing data into the system in the first instance."[80]*

This is an important point, and as we described earlier, there are other prerequisites to blockchain registry adoption in addition to the existence of formal records. We do see the potential, however, for commercially-oriented real estate platforms to speed up the formalization process indirectly through the promise of financial inclusion.[81] Low-transaction-cost, low-barrier-to-entry platforms for accessing international property markets offer a powerful incentive for both governments and private companies to invest in the creation of modern and reliable property registries. Blockchain-based real estate investment would be a major addition to the list of inclusion opportunities enabled by blockchain, which include remittance services, mobile money, and economic identity. A 2016 market overview by the technology services company Cognizant estimated the "revenue generated by banks by 2020 within emerging markets from unbanked populations" at $380 billion.[82] If blockchain-based real estate markets can help to activate dead capital in the developing world, this number will be radically increased.

There are already several companies positioning themselves to bring blockchain-based real estate solutions to the developing world. The most ambitious of these ventures may be De Soto Inc., though little has been made public about the company. According to Overstock founder Patrick Byrne, a partner in the venture, their goal is to put titles in the developing world on blockchain in a format that will allow them to be used as collateral for loans, with the resulting capital being traded on a tokenized market called tZERO.[83] It is unclear whether this is practicable, but it does indicate that serious business interests in the developed world are aware of the opportunity formalization represents and see blockchain as a key enabling technology. Byrne has even considered selling Overstock, which has a total market capitalization of roughly $1.5 billion, to fund De Soto Inc., telling the Financial Times "one of the possibilities is I sell the business and we have all the capital we need."[84]

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[80] Aanchal Anand, Matthew McKibbin, and Frank Pichel, "Colored Coins: Bitcoin, Blockchain, and Land Administration," Cadasta, http://cadasta.org/resources/white-papers/bitcoin-blockchain-land/.

[81] See World Bank, "Financial Inclusion," April 5, 2017, http://www.worldbank.org/en/topic/financialinclusion/overview, accessed March 1, 2018.

[82] Pani Baruri, "Blockchain Powered Financial Inclusion," (PowerPoint slides) Cognizant, 2016, http://pubdocs.worldbank.org/en/710961476811913780/Session-5C-Pani-Baruri-Blockchain-Financial-Inclusion-Pani.pdf, accessed March 5, 2018.

[83] tZero, "Home," https://www.tzero.com/#home, accessed March 5, 2018.

[84] Chloe Cornish, "Overstock Chief explores sale to fund blockchain venture," Financial Times, December 13, 2017: https://www.ft.com/content/d4a6d698-dfa6-11e7-8f9f-de1c2175f5ce, accessed March 9, 2018.

This presents an interesting counterpoint to the idea that blockchain registries should first be introduced in highly developed jurisdictions like Sweden. The argument for emerging countries being early adopters is twofold: first, addressing problems like corruption is a greater incentive for adoption than the desire to upgrade an already functional system; second, efficient access to foreign property markets is more significant for emerging countries than for developed ones. Inasmuch as corrupt jurisdictions can be expected to oppose increased transparency, it must be hoped that the promise of economic development will be the the stronger motivating force. It can also be argued that greenfield scenarios without legacy data that must be cleaned and uploaded will allow for faster and cheaper implementation. Moreover, in emerging markets even relatively slow public chains can make transactions faster, mitigating current throughput limitations.[85]

Will blockchain (finally) bring big data to land?

> *"Production, availability and accessibility of reliable data and statistics are of fundamental importance in monitoring and in taking evidence-based decisions for good land governance. The demand for data as evidence is increasingly focused to monitor global and national developmental status and targets."[86]*

In the long term we can envision the widespread adoption of blockchain registries leading to a revolution in the empirical study of land governance. In combination with a rich digital ID system including usage and demographic information, blockchain registries would create an unprecedented tool for studying the impact of land governance policies, bringing land into the era of big data. The consolidation of local property and transaction records into larger-scale national or supranational registries would be particularly valuable.

At least one of the companies that aspires to eventually create a global registry, Propy, seems to be aware of the value of this data. Touting itself as a potential "Amazon for real estate," it is positioning itself as both an online shopping platform and a provider of market data and intelligence.[87] From a development and governance perspective, this raises data ownership and registry privatization concerns which go beyond the scope of this paper.

In an interview published on May 5, 2018, Hernando De Soto and Patrick Byrne revealed that their joint blockchain venture would seek to document the actual occupation of land around the world rather than documenting formal titles, giving "everybody, including authorities, an idea of the volume, the enormous volume of people outside the legal system."[88] They have not revealed how they plan to accomplish this.

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[85] Charles Gallo, Anna Jumamil, and Pak Aranyawat, *Blockchain and Financial Inclusion: The role blockchain technology can play in accelerating financial inclusions* (Washington, DC: Georgetown University Press, 2017), 8.

[86] Pranab Ranjan Choudhury, Manoj Kumar Behera, Saumya Sharma, and Tajamul Haque, "Combining Administrative and Open Source Data for Monitoring Land Governance: Mapping Women Land Rights in the Context of UN's SDG in India," paper presented at the 2017 World Bank Conference on Land and Poverty, Washington, DC, March 2017.

[87] Bryson Masse, "'Propy' gets $15M on promise of digital currency real estate investment," *Inman*, September 25, 2017, https://www.inman.com/2017/09/25/propy-gets-15m-promise-digital-currency-real-estate-investment/, accessed March 5, 2018.

[88] Andrew Nelson, "De Soto Inc.: Where Eminent Domain Meets the Blockchain," *Bitcoin Magazine*, May 5, 2018, https://bitcoinmagazine.com/articles/de-soto-inc-where-eminent-domain-meets-blockchain/

At this point we should step back and ask why blockchain is being touted as the answer to these problems instead of existing, proven, cheaper technologies. As Peter Rabley of Omidyar Network reminds us, the problem with land registries,

> *"isn't that the technology isn't there — we already have a whole lot of enterprise solutions and database technologies to store the records. What we need is to accurately map the areas where people are living. In India, they used geospatial technology to uncover 500,000 inhabitants of a slum that previously nobody knew about. Once we've been able to identify where people are living that's the first step to ensuring that they have property rights."*[89]

We believe that where blockchain promises to distinguish itself from legacy technologies in its ability to coordinate the verification of data and transfer of value between large numbers of people without the need for trust. As we discussed in the preceding section, this allows blockchain not only to create secure property records but also to provide a transaction layer connecting those records to financial services. Furthermore, it can be used to organize decentralized data collection which, as we have argued elsewhere with respect to land surveying,[90] is a necessity given the vast amount of data that must be collected in order to enable mass formalization. In this domain blockchain can contribute by tracking digital supply chains and providing financial incentives for data collection and validation. Land Layby is testing a token-incentivized private registry in Ghana that "rewards users for adding correct entries to the blockchain and penalizes them for erroneous ones."[91] The FOAM Protocol adds an open source geospatial layer to the Ethereum blockchain and incorporates economic incentives to drive the creation of crowdsourced maps. According to FOAM's founders, this will "allow any coordinate to be turned into a blockchain wallet that can hold a balance and be tagged with crowdsourced data."[92] In combination with other tools like new earth observation technologies and digital ID, blockchain can become a core technology for property rights formalization.

How will blockchain for land be regulated?

In the foreword to this paper we discussed how concerns over the social impact of the centralization on the internet could help create norms favorable to the adoption of decentralized technologies like blockchain. But there are countervailing forces which we believe will lead government regulators to limit the decentralization of financial infrastructure. This would impact all assets traded with this infrastructure, though the impact on real property would depend on the degree to which blockchain increases liquidity.

[89] Dominic Wilson, "Why the blockchain isn't enough to fix land registries," *LinkedIn*, February 26, 2018, https://www.linkedin.com/pulse/why-blockchain-isnt-enough-fix-land-registries-dominic-wilson/, accessed March 9, 2018.
[90] Christopher Mellon and Michael Graglia, "Peering into the Future: How Dual-Frequency Satellite Receivers Will Democratize Land Surveying," *FPR Blog (blog)*, New America, March 23, 2017, https://www.newamerica.org/international-security/future-property-rights/blog/peering-future-how-dual-frequency-satellite-receivers-will-democratize-land-surveying/, accessed March 9, 2018.
[91] Kevin Mwanza and Henry Wilkins, "African startups bet on blockchain to tackle land fraud," *Reuters*, February 16, 2018, https://www.reuters.com/article/us-africa-landrights-blockchain/african-startups-bet-on-blockchain-to-tackle-land-fraud-idUSKCN1G00YK, accessed March 9, 2018.
[92] "Introducing the FOAM Protocol: The consensus driven map of the world," *FOAM (blog)*, September 22, 2017 https://blog.foam.space/introducing-the-foam-protocol-2598d2f71417, accessed March 9, 2018.

A fully decentralized financial system would have troubling economic and security implications. For the West, and especially the United States, influence over the international financial system is an essential diplomatic and law enforcement tool, which can be used to sanction state rivals and disrupt the financing of hostile non-state actors, most importantly terrorist groups.[93] The fear that blockchain could undermine this status quo was first raised by the advent of cryptocurrencies, which bear mentioning here before focusing on other blockchain-based financial applications.

The US government's assessment of the potential terror financing and money laundering threat from cryptocurrencies is still evolving. A House bill was introduced in January 2018 "to establish an Independent Financial Technology Task Force, to provide rewards for information leading to convictions related to terrorist use of digital currencies, [and] to establish a FinTech Leadership in Innovation Fund to encourage the development of tools and programs to combat terrorist and illicit use of digital currencies."[94] However, recent assessments by the EU and the UK Treasury have concluded that the threat of terrorist groups financing themselves via cryptocurrencies is not yet a serious one.[95] The June 2017 EU report, in particular, noted that terrorists still prefer fiat over digital currency.[96][97] There are at least two good reasons that cryptocurrency has not been treated as a major threat. First, the dominant crypto blockchains are only pseudonymous, and there are tools which can reliably reveal the identities behind the public keys of malicious actors.[98] Second, the pool of funds cryptocurrencies represent is simply too small to be significant compared to the larger economy.[99] Of course if or when large amounts of land are tokenized, this may no longer be the case.

A more significant threat to the current international order would be the creation of a decentralized value transfer system that would allow states to avoid international sanctions.[100] It is no accident that countries like Russia and Venezuela have been quick to demonstrate interest in state cryptocurrencies.[101] Venezuela has been a particularly dramatic example. During the ongoing economic crisis, Venezuelan citizens have turned to Bitcoin during a period of hyperinflation, while the government has created an oil-backed cryptocurrency in an effort to circumvent US sanctions.[102]

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[93] Keith Johnson and Elias Groll, "U.S. Sanctions Weapon Is Under Threat — but Not From Bitcoin," *Foreign Policy*, January 24, 2018, http://foreignpolicy.com/2018/01/24/u-s-sanctions-weapon-under-threat-but-not-from-bitcoin-blockchain-dlt-petro/.

[94] Molly Jane Zuckerman, "New US Bill Seeks to Fight Terrorist Use of Cryptocurrencies," Cointelegraph, January 17, 2018, https://cointelegraph.com/news/new-us-bill-seeks-to-fight-terrorist-use-of-cryptocurrencies, accessed March 5, 2018.

[95] Ibid; HM Treasury, *National Risk Assessment of Money Laundering and Terrorist Financing 2017* (London, 2017), 5, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/655198/National_risk_assessment_of_money_laundering_and_terrorist_financing_2017_pdf_web.pdf, accessed February 27, 2018.

[96] Zuckerman, "New US Bill Seeks to Fight Terrorist Use of Cryptocurrencies."

[97] There are several reasons for such proclivity. One is the lack of technological adoption, though this is likely due more to the availability of other funding sources than a lack of technical capability. It is certainly possible that this pattern will change. STEM-educated, technically proficient individuals --especially engineers-- are statistically overrepresented in jihadist groups to a high degree. Some researchers posit a link between the concrete thinking of engineers and the moral rigidity of religious and political fanatics. See Diego Gambetta and Steffen Hertog, *Engineers of Jihad: The Curious Connection between Violent Extremism and Education* (Princeton: Princeton University Press, 2016).

[98] See "Elliptic," https://www.elliptic.co/.

[99] Julia Kollewe, "Bitcoin: UK and EU plan crackdown amid crime and tax evasion fears," *Guardian*, December 4, 2017, https://www.theguardian.com/technology/2017/dec/04/bitcoin-uk-eu-plan-cryptocurrency-price-traders-anonymity.

[100] Johnson and Groll, "U.S. Sanctions Weapon Is Under Threat — but Not From Bitcoin."

[101] Nathaniel Popper, Oleg Matsnev, and Ana Vanessa Herrero, "Russia and Venezuela's Plan to Sidestep Sanctions: Virtual Currencies," *New York Times*, January 3, 2018, https://www.nytimes.com/2018/01/03/technology/russia-venezuela-virtual-currencies.html.

[102] Rene Chun, "Big in Venezuela: Bitcoin Mining, *Atlantic*, September 2017, https://www.theatlantic.com/magazine/archive/2017/09/big-in-venezuela/534177/; Popper et al., "Russia and Venezuela's Plan to Sidestep Sanctions."

The economic incentives of increased efficiency and international liquidity are certainly great enough to ensure the continued development of blockchain-based value transfer systems, but these systems can be expected to combine principles of decentralized exchange with traditional know-your-customer and anti money-laundering features. A February 2018 report from the Council on Foreign Relations notes that "many of the largest U.S.-based [cryptocurrency] exchanges, including Coinbase and Gemini" already comply with these requirements, making it "challenging for criminal groups to convert their cryptocurrency into hard currency."[103] It is also likely that multisignature wallets will be increasingly utilized,[104] as we have suggested is appropriate for land registries.

With respect to real estate, states will retain the power to regulate and tax land transactions, allowing elected officials to be responsive to the constituents who inhabit the land in question. Taxes may increase transaction costs, but these will be offset by efficiencies from disintermediation. The ability to regulate local land markets is needed to mitigate against unintended consequences such as asset prices skyrocketing in response to external capital flows. High degrees of liquidity and unrestricted property investment –facilitated by a blockchain enabled registry-- can drive up housing costs in areas favored by international investors. Foreign property investment from China, has created this dynamic in Australia. In 2015, legislation was introduced to limit such investment after middle-class Australians "complained about being priced out of the housing market" by wealthy Chinese investors.[105]

The need to retain sovereign control of property markets is one of the main reasons we argue for hybrid chains in the prerequisites, the authorities need the ability to regulate the economy and enforce the law. Further, as blockchains become integrated into registries at higher levels, national laws, taxes, fees, and regulations will have to be integrated into smart contracts.

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[103]Ankit Panda, "Cryptocurrencies and National Security," *Council on Foreign Relations*, February 28, 2018, https://www.cfr.org/backgrounder/cryptocurrencies-and-national-security
[104] Kowelle, "Bitcoin."
[105] Jamil Anderlini, "Surge in Chinese housebuying spurs global backlash," *CNBC.com*, February 25, 2015, https://www.cnbc.com/2015/02/25/surge-in-chinese-housebuying-spurs-global-backlash.html, accessed February 27, 2018.

Current examples of registries and blockchain

Below are six case studies of companies that have been pioneers in this space. We list them in alphabetical order. Their inclusion does not imply endorsement by the authors. The companies were selected, in part, because of access to their leadership. The six case studies are based on desk research, as well as on interviews and collaboration with the various companies' leadership. Broadly, all case studies includes a brief introductory section, followed by examination of the firm's platform(s) and project(s). Most cases conclude with discussion concerning the future of the individual company.

The case studies provide several key takeaways --both trends and obstacles. First, pilot programs must be launched with limited scope, integrating blockchain progressively and with an early emphasis on increased efficiency and lowered transaction costs. There is no easy or obvious path to the highest levels of integration, like international registries and peer-to-peer transactions.

There was no consensus amongst the interviewees that these higher levels of integration were achievable or even desirable. Several believe that blockchain's only essential role is to help produce a cleaner and more secure property record. Others see these early, limited use cases as stepping stones towards a radical reinvention of property registration and transaction.

On a technical level, the lack of common protocols and the limitations of existing public chains remain serious obstacles, along with the numerous legal and organizational challenges. There is an obvious need for legal and regulatory reform. Digital signatures must be recognized as legally binding in order to enable even the lower levels of integration.

Registry pilots must be responsive to local technological, political, and socioeconomic conditions. Different countries have different needs, as well as varying levels of existing property rights functionality. Moreover, implementing blockchain registries for land reform involves considerable risk of political interference. The transparent and immutable character of blockchain technology can be seen as a major threat to bureaucratic power, influence, and even wealth. When choosing a jurisdiction in which to operate, this fact must be balanced against the opportunity presented by the relatively low regulatory burden sometimes associated with operating in the emerging economies where land reforms are being undertaken. Perhaps counterintuitively, it is sometimes seen as simpler to implement blockchain technology in countries possessing inadequate or nonexistent property rights registry systems.

Most of these companies thought about whether to create a parallel, unofficial registry system, or integrate their product into the existing registry. In almost every case, a parallel registry was introduced, typically because of the limited scope of the projects. Public blockchains are typically used to "anchor" documents, with private databases used to store the documents themselves.

Case Study: Bitfury

Bitfury has taken on ambitious blockchain and registry integration projects in Ukraine and the Republic of Georgia. The product they developed in the course of this work is called Exonum. This case study is based on previous FPR articles and subsequent conversations with Rachel Pipan, Senior Communications Manager at Bitfury.[106] We are grateful for her time and insights.

Disclosure & Background

Disclosure: Bitfury, the National Democratic Institute, and New America co-founded the Blockchain Trust Accelerator (BTA) in 2016. BTA aims to connect governments with technologists and funders to hasten the adoption of blockchain for social good and governance. FPR is distinct and separate from the BTA.

Bitfury is a well-established firm in the blockchain space. Founded in 2012, the company began by focusing on Bitcoin mining.[107] At the time of writing, Bitfury represented approximately 2% of global mining power, known as hashrate.[108] In 2015, however, Bitfury was third globally with approximately 17% of the hashrate and was the best funded Bitcoin mining firm.[109]

Georgia

It was from this leadership position that Bitfury began a well-publicized pilot project with the National Agency of Public Registry (NAPR) for the Republic of Georgia to put their registry on the Bitcoin blockchain. The Memorandum of Understanding (MOU) was signed in April 2016 to pilot the use of blockchain in the process of buying and selling land in Georgia.[110] This project with Georgia was Bitfury's first departure from Bitcoin mining and hardware, moving into blockchain software.

Georgia is using a private permissioned blockchain to keep critical records and then using the public Bitcoin blockchain to publish hashes of essential documents. By hashing a document --which is generating a unique short set of characters based on that data-- and posting it into a field for extra data, one can use the public Bitcoin blockchain as a notary.[111] Since the chain is ostensibly immutable, once

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[106] Michael Graglia, "Tbilisi agreement heralds significant expansion;" and Michael Graglia, "Will Blockchain Work in Ukraine? Can putting Ukraine's property registry 'on the chain' significantly reduce corruption?" *FPR Blog (blog)*, New America, June 15, 2017, bit.ly/FPRBCUA1, accessed February 27, 2018.
[107] Valery Vavilov, "Happy Birthday Birfury," *Medium*, February 17, 2017, medium.com/@valeryvavilov/happy-birthday-bitfury-e98d2ddfe769.
[108] Blockchain, "Bitcoin Hashrate Distribution," blockchain.info/pools, accessed February 27, 2018.
[109] Rob Price, "The 21 companies that control bitcoin," *Business Insider*, August 13, 2015, www.businessinsider.com/bitcoin-pools-miners-ranked-2015-7#4-btc-china-pool-1374-118.
[110] Ian Allison, "Bitfury trumpets blockchain land registry with Republic of Georgia at Harvard and UN," *International Business Times*, November 9, 2017, https://www.ibtimes.co.uk/bitfury-trumpets-blockchain-land-registry-republic-georgia-harvard-un-1646616, accessed March 6, 2018.
[111] The extra data field is called OP_RETURN and it is much like the memo line on a check insofar as one can enter what they want there without restriction.

those hashes are published, the document is timestamped. This idea, first suggested in 2012, is not new. Our list of blockchain myths further explores the complementarity of public and private chains.[112]

The documents and associated transactions being stored are placed in a NAPR backend database on the private chain. So while the registry truly is blockchain-based, citizens still need to visit NAPR offices to complete transactions. Essentially, it is functionally a level 1 or 2 registry within the aforementioned framework, but could expand to level 4 and beyond if some constraints are relaxed.

Bitfury chose their first partner well. They entered Georgia shortly after years of investment by the World Bank and other donors to upgrade this registry. As a result, Bitfury is building on well-designed, recently reformed, and sophisticated registries with little corruption. Data from Transparency International and the World Bank, who rank corruption and cadastral practices respectively, support this assertion.[113]

In February 2017, Papuna Ugrekhelidze, Chairman of the NAPR, and Valery Vavilov, CEO of Bitfury, signed another MOU to expand Bitfury's work to support fixed property rights administration and other government departments with blockchain technology. According to Forbes, this will be the "first time a national government has used the Bitcoin blockchain to secure and validate official actions."[114]

Ukraine

Bitfury has also announced a partnership in Ukraine. In June 2017, *The Economist* noted that Ukraine "wants to become 'one of the world's leading blockchain nations.' The country's e-governance agency sees the technology as a way to address 'historic distrust of government'…[and] has plans for all kinds of blockchain-based registries, including of land and businesses."[115]

We expect that the approach in Ukraine will be different from the one taken in Georgia. Unfortunately, Ukraine has as an unenviable level of corruption. Transparency International ranks Ukraine as 130th in the world with a score of 30.[116] The World Bank ranks Ukraine's registration process at 64th, noting it contains seven procedures, takes 17 days, and scores 14.5 out of 30.[117]

Ukraine faces significant challenges, including a declining population, Russian interference, and stop-and-go reforms. Their ongoing change process is less than smooth. If Kiev anticipates that blockchain --or any technology-- will be a panacea, it may well be disappointed. The deputy director of

[112] See Graglia, "5 Myths About Blockchains,"
https://www.newamerica.org/international-security/future-property-rights/blog/5-myths-blockchains-registries/.
[113] "Corruption Perceptions Index 2017," Transparency International, February 21, 2018,
https://www.transparency.org/news/feature/corruption_perceptions_index_2017#table; "Georgia among Top Global Improvers, Says Latest Doing Business Report," The World Bank, October 16, 2016,
http://www.worldbank.org/en/news/press-release/2016/10/25/georgia-among-top-global-improvers-says-latest-doing-business-report.
[114] Laura Shin, "The First Government To Secure Land Titles on the Bitcoin Blockchain Expands Project," *Forbes.com*, February 7, 2017,
https://www.forbes.com/sites/laurashin/2017/02/07/the-first-government-to-secure-land-titles-on-the-bitcoin-blockchain-expands-project/#22836 5154dcd.
[115] "Governments may be big backers of the blockchain," *The Economist*, June 1, 2017,
https://www.economist.com/news/business/21722869-anti-establishment-technology-faces-ironic-turn-fortune-governments-may-be-big-backers.
[116] "Corruption Perceptions Index 2017," Transparency International.
[117] "Ease of Doing Business in Ukraine," The World Bank, http://www.doingbusiness.org/data/exploreeconomies/ukraine.

the Ukrainian e-governance agency said, "novelty and complexity have provided some cover: 'Most officials don't understand what we're doing, so they don't sense the threat.'"[118] At first glance, this suggests that expectations are high. Blockchain can help, but institutions must evolve in parallel, and they rarely change quickly. Such thinking also potentially underestimates the nuance and expertise required in dealing with registries.

Past performance is not encouraging, as demonstrated by the article, "26 Years of Land Reform: The Glass is Half-Empty or Half-Full."[119] The last paragraph begins with strong words from the ranks of the IBRD: "despite 25 years of reforms, a lot has yet to be done. Many of the above reforms are not related to highly politicized issues...and would depend only on the political will of the Parliament and Government."[120]

There are nevertheless reasons for cautious optimism that this project will work. First, Bitfury is large and well-established. They seem to be progressing in Georgia, they already have a strong presence in Ukraine, and it is reasonable that they would not have made a public announcement until after doing their homework. Second, Ukraine is a former Soviet Republic, and therefore similar to Georgia. There is neither a long cadastral history to sort through nor a detailed reconciliation process required before putting a registry on blockchain. Third, there is no shortage of technical talent in the Ukraine. A 2004 study indicated that Ukraine had the fourth-largest population of programmers after the US, India, and Russia.[121] Furthermore, Bitfury has offices and significant staff in Ukraine. Those programmers have a strong incentive to improve the quality of their government.

The most compelling reason for optimism is that Ukraine is implementing blockchain broadly. If the announcement had been that Ukraine was just putting their registry on the chain we would sound the alarm, given the degree of corruption and the preparatory work that is yet to be done. Since officials are considering all of the government, however, they may succeed. Not only will such scope allow Kiev to handle the issues of digital identity and payments, which are inextricably related to land registries, but it will also afford time to tackle this challenge. Bitfury and Ukraine may well need that time.

Platform: Exonum

Bitfury envisions itself as a full-service blockchain technology company --from mining to hardware to software. Accordingly, employees spent nearly two years pursuing the clear goal of creating a platform that offers "high-load security and efficiency."[122] In July 2017, Bitfury launched its new blockchain platform, Exonum. This was informed by their experience in Georgia described above.

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[118] "Governments may be big backers of the blockchain," *The Economist*.
[119] Klaus Deininger and Denys Nizalov, "26 Years of Land Reform: the Glass is Half-Empty or Half-Full," World Bank, October 17, 2016, http://www.worldbank.org/en/news/opinion/2016/10/17/26-years-of-land-reform-the-glass-is-half-empty-or-half-full
[120] Ibid.
[121] "Building The Muscle To Be A Tech Player," *Bloomberg Businessweek*, November 8, 2004, https://www.bloomberg.com/news/articles/2004-11-07/building-the-muscle-to-be-a-tech-player, accessed March 6, 2018.
[122] Valery Vavilov, "As Blockchain Changes The World, Bitfury's New Platform Exonum is About to Change Blockchain," *Medium*, July 16, 2017, https://medium.com/@valeryvavilov/as-blockchain-changes-the-world-bitfurys-new-platform-exonum-is-about-to-change-blockchain-cc13963f8501, accessed March 2, 2018.

The platform allows users to build their own cryptocurrency, store/exchange digitized assets, and code smart contracts for interactions with other entities. Exonum leverages the security of Bitcoin while also allowing for the privacy required for permissioned blockchains. It does so by anchoring the Exonum blockchain to the Bitcoin blockchain. As a result, the platform is decentralized, distributed, tamper-resistant, and secured with cryptography.[123]

Exonum is an open source Enterprise-grade blockchain framework. Bitfury stresses that its platform is based on Rust, "the most secure programming language to date."[124] The company also emphasizes its pertinence to a variety of companies, institutions, and governments.

Looking forward

The Use Cases section of Exonum.com suggests that Bitfury will continue to be ambitious with blockchain applications beyond land registries.[125] With that said, assuming progress is made in Ukraine, Bitfury will have two strong projects in former Soviet Republics and key staff --from the CEO to a significant number of programmers-- from the same region. As more opportunities emerge regionally, we would not be surprised to see Bitfury involved. At present we are not aware of other land related projects involving Bitfury.

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[123] Ibid.
[124] Ibid.
[125] See Bitfury, "Use Cases," Exonum.com, 2018, https://exonum.com/.

Case Study: ChromaWay

ChromaWay has initiated notable blockchain and registry integration projects in Sweden and the Indian state of Andhra Pradesh. Their tripartite platform includes Postchain, Esplix, and Token Technology. This case study is based on both desk research and interviews with ChromaWay's VP, US Business Development, Mr. Todd Miller. We are grateful for his collaboration.

Background

Founded in 2014, ChromaWay is a blockchain software company that provides technology infrastructure and applications to allow organizations to synchronize data, exchange assets, and control business processes securely. ChromaWay has offices in Stockholm, Tel Aviv, and Washington, DC. Their platform encompasses three primary products based on open source protocols: Postchain is a consortium database product that utilizes blockchain protocols to synchronize data among multiple enterprises, Esplix coordinates and verifies business agreements and workflows using smart contracts, and Token Technology enables enterprises and consortiums to facilitate asset exchange with digital tokens.

ChromaWay aims to simplify and shorten global real estate transactions through blockchain technology. Despite political, legal, and technological challenges, the company has engaged in numerous projects around the world.

Platform

Though ChromaWay is engaged in blockchain projects across many verticals, real estate is a major focus. ChromaWay real estate projects concentrate on the complete property acquisition and financing life-cycle, including origination, servicing, property transfer, and securitization.

ChromaWay focuses on four key problems in the real estate sector: Reducing the costs to consumers and businesses of real estate transactions, reducing paperwork and the time it takes to secure loans and property transfers, reducing the amount of fraud that occurs in mortgage lending and property transfer, and increasing security of tenure, particularly in the developing world.

ChromaWay argues that in order for blockchain technologies to gain traction, they have to be able to interact with existing land registry, mortgage, banking, and third party provider systems like loan origination systems. Therefore, to gain better adoption than solutions where the industry has to acquire a completely new platform and associated tech stack, ChromaWay created Postchain which they describe as a "consortium database."[126] This tech leverages blockchain protocols like consensus, linked timestamping, and signed transactions to facilitate the synchronization of blockchains among parties. ChromaWay describes their product design paradigm as modular so that it can integrate with both existing legacy

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[126] "Postchain," Chromaway. https://chromaway.com/products/postchain/. Accessed March 9, 2018.

systems and potential network service providers (e.g., identity, oracles, etc.) relatively easily. Their core platform is built around Postchain, which integrates with commercial databases (e.g., SQL).

Implementation

ChromaWay has implemented their platform with the Swedish Land Registry and the Land Registry of Andhra Pradesh (India). They recently completed a proof of concept project under the guidance of the UN Women Blockchain Lab in partnership with Cadasta and Abt Associates. The project focused on collecting land claim information in a refugee scenario. They have completed related projects in Estonia, Thailand, the US, and with the United Nations.

In Sweden, ChromaWay was invited to join a consortium of government agencies, banks, the nation's leading telecommunications provider, and other partners to develop a national mechanism to simplify and secure property transfer and other mortgage processes.

Sweden maintains a high-functioning land registry that helps power a leading Western European economy. The Swedish consortium sought to evaluate leading blockchain technology as a way to further accelerate development by streamlining processes, identifying new leverageable data sources, and developing deeper digital connections among government and financial institutions. For ChromaWay, the greatest challenges in a developed economy like Sweden's was accommodating --or changing-- laws and regulations around e-Signatures, smart contracts, and limits on data sharing intended to protect privacy. To move the project ahead the firm reports having worked with private sector and government partners to identify technical solutions to regulator limitations. Developing a global ID solution was also identified as a challenge.

In the Indian state of Andhra Pradesh, ChromaWay was asked to focus on developing a baseline blockchain solution to replace the technologies used at the land registry. This was an initial proof of concept and they are currently working with the government to move to an initial phase of development.

Disputed land ownership is frequently a cause of conflict in Andhra Pradesh. The current system, where land and property records are centralized in government databases, is inherently vulnerable to improper or unauthorized manipulation. This can make it difficult to reliably and unambiguously establish who actually owns a given property in the event that records are incongruent, absent, or otherwise suspicious. The government is exploring technologies like blockchain because they can help mitigate such risks by decentralizing data storage in such a way that records become difficult to manipulate without having the proper authority and following proper protocols.

The combination of Sweden and Andhra Pradesh was interesting for ChromaWay because they were able to see two very different governments engage with the same new technology. Virtually everything about these two use cases is different (e.g., legal systems, threats of fraud and tampering, financial resources, technical capabilities, human resource capabilities, etc.). As ChromaWay emphasizes --and we agree-- if blockchain is to be adopted across the world, solutions must be designed to fit a range of operating environments.

Last Thoughts

When asked what challenges remain, ChromaWay replied that "introducing a major change to a national land registry is a significant political decision. Whether in a fast-developing country like India or in an advanced economy like Sweden, stakeholders have to be willing to take some risks with regard to introducing a new technology and having the commitment to experiment and iterate on a decentralized framework for managing a major function of government."[127] ChromaWay also indicated excitement regarding their partnership with Cadasta and Abt Associates on using the blockchain to secure documented land claims. They believe this is an emerging opportunity to bridge the gap in the developing world between the formalization process driven by national land registries and a grassroots process through which individuals can secure the benefits of land ownership as a path to formalization.

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[127] Per interview with ChromaWay, January 5, 2018.

Case Study: ConsenSys

ConsenSys plans to use its Landstream application in Dubai to situate land registries on blockchain technology. They have also developed the Pangea platform for interaction with fractional ownership shares in real estate. This section is based in part on conversations with Corbin Page, Product Lead at ConsenSys and co-founder of Pangea, as well as on documents shared with the authors and publicly available reporting. We are grateful for Corbin's time and insights.

Background

Headed by Ethereum Foundation co-founder Joe Lubin, ConsenSys describes itself as "a global formation of technologists and entrepreneurs building the infrastructure, applications, and practices that enable a decentralized world."[128] ConsenSys became a major competitor in blockchain for land with the announcement of their partnership with the Dubai Land Department to build a blockchain platform to include all real estate contracts.

Landstream

The Landstream application is a digital signature system allowing Dubai Properties (DP), their customers, and business partners to manage real estate document signatures and approval interactions amongst the network.[129] The system cryptographically signs documents, such as sales and purchase agreements, progress reports, and master plans, on a blockchain, replacing the need for paper-based, manual signatures in Dubai's real estate ecosystem. Landstream will be one of the first live enterprise Ethereum applications in the world when it goes into production in March 2018.

ConsenSys says that "the ultimate goal of the blockchain initiative is to service Dubai Properties' end customers and make their purchasing experience as pleasant as possible."[130] In late 2016, ConsenSys and DP partnered to build a proof of concept app to track the development of a property from initial idea all the way through customer sale. As a result of the proof of concept's success, a production application is being built by ConsenSys this year. "While Landstream is an enterprise project with a commercial client, [ConsenSys] envision[s] that this product will be adaptable for other kinds of geospatial projects, including for NGOs."[131]

Pangea

Pangea is a Ethereum-enabled platform "to create, manage, and trade fractional ownership shares in real estate assets.. [ConsenSys'] mission is to democratize real estate investment allowing anyone, anywhere

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[128] "Home," ConsenSys, https://new.consensys.net/, accessed March 6, 2018.
[129] From documents shared with the authors by ConsenSys.
[130] Ibid.
[131] Ibid.

the right to own and invest in this fundamental shared resource of our planet."[132] There are three challenges of traditional real estate that ConsenSys seeks to address through this approach: the relative inaccessibility of home ownership for those in the middle or working class, the exorbitant transaction costs for middlemen involved in real estate transactions, and the illiquidity of real estate assets.[133]

By lowering transaction costs and the minimum amount of money needed to invest in real estate, ConsenSys aims to increase the liquidity and accessibility of property asset ownership. By converting the value of properties into tokens listed on the Ethereum chain, multiple owners can invest in a single property and, conversely, individuals can own shares in multiple properties. A set of tokens is created for each property, turning "common equity into transferrable and traceable shares on the blockchain."[134] These tokenized shares can be traded with other users in the Pangea marketplace "in exchange for their equity sold, allowing [customers] to use those funds for new investments, distribute dividends, or return capital."[135]

The ownership and transaction record is also publicly available to consult when creating or analyzing a proposed exchange, increasing pricing transparency and the ease of real estate transactions. In other words, property values on the ConsenSys system would be more dynamic and incentive-driven than in traditional real estate.

According to ConsenSys, some potential uses of their platform could include distributing shares to mall-goers to incentivize shareholders to shop at that mall and increase foot traffic, paying property managers in shares to enhance performance metrics or, to increase residential occupancy and greater participation, distributing shares to office space renters to create a collaborative working environment, or selling shares to renters so they have clear incentive (profit stake in occupancy) to rent in your building and maintain upkeep of the property.[136]

Dubai

In 2016, ConsenSys partnered with Dubai Properties, a leading real estate development organization to build a proof of concept application for a land registry as part of Dubai's push to record all government transactions on the blockchain.[137] The application was designed to track every step of the history and development of a property, from its conception through its sale to a customer. It does so by aggregating all documentation required to manage a property (e.g., lease registrations, property-related bills) into a single platform that all people involved can access and use when needed. Because all of the documentation and actors work within the same platform, all required documentation is available and

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[132] Description of Pangea from job posting, retrieved at https://boards.greenhouse.io/consensys/jobs/1044418
[133] "Real Estate Needs a Revolution," *Pangea (blog)*, Medium, January 11, 2018, media.consensys.net/using-blockchain-to-expand-access-to-real-estate-4a2e3fb15f90.
[134] Stop Selling your Upside: How Blockchain Can Unlock Value in Real Estate Through Fractional Ownership," *Pangea (blog)*, Medium, January 4, 2018, medium.com/@pangeaGO/stop-selling-your-upside-how-blockchain-can-unlock-value-in-real-estate-through-fractional-b492400b47a.
[135] Ibid.
[136] Ibid.
[137] Sindu Hariharan, "How Dubai's Blockchain Advisor ConsenSys Is Creating A Community For The Emerging Tech," *Entreprenuer*, December 6, 2017, www.entrepreneur.com/article/305701.

administrative processes move quicker with less friction. Lastly, Emirates Identity Card information and residency visas can be securely incorporated, allowing tenants to pay electronically, instead of having to write checks or visit any government entity.[138]

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[138] Staff Report, "Dubai Land Department."

Case Study: Epigraph

Epigraph previously attempted to create a blockchain-backed property registry in Honduras. The company has also pursued development of open APIs for registration integration. This case study is based on both desk research and interviews with Epigraph founder and CEO Matt Regan. We are grateful for his time and guidance.

Background

In 2014 Epigraph founder and CEO Matt Regan had experience in fintech --he had spent time at Accenture, JP Morgan Chase, and US Bank-- but knew little about blockchain. This was not unusual at the time, as people were just starting to think about blockchain use cases beyond cryptocurrency. He had seen property registries suggested as a use case, but mostly by technologists who were not land experts and naively thought it was low-hanging fruit.

In November 2014, Matt received a call from entrepreneur Abhi Dobhal, who had worked for a Bitcoin mining hardware manufacturer before joining Texas-based blockchain company Factom. Abhi had become interested in property registries after speaking with Guillermo Peña Panting, of the Fundacion Eleutera, at the 2015 Texas Bitcoin Conference.[139]

Peña explained that Honduras, faced with pervasive fraud and instability, particularly needed a secure and modern registry.[140] The country was also entering a window of opportunity, as the new government was introducing land reforms to stimulate the economy by expanding access to credit and attracting foreign investment through Zones for Employment and Economic Development.

There were some considerable problems to overcome --the Factom block size would have to be changed and the company lacked expertise in property and law. But, encouraged by the prospect of high-level government access through the new economic zones, and believing that Factom's existing blockchain technology was well-suited for property registries, Abhi reached out to Matt for his land and title expertise. Epigraph was founded in December 2014 to build a blockchain-backed property registry system in partnership with Factom.

Platform

Epigraph designed an end-user facing SaaS application that provided rigorous workflow controls using blockchain's technical strengths to protect the property registry work product from tampering at each step in the instrument submission, review, and recording process. The application would then allow property records to be authenticated as original when fetched from the registry by confirming their contents matched hashes written to the blockchain at the time of recording. Epigraph's solution used Factom as its

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[139]Jorge Constantino Collindres, Matt Regan, and Guillermo Pena Panting, "Using Blockchain to Secure Honduran Land Titles," International Property Rights Index, 2016, s3.amazonaws.com/ipri2016/casestudy_collindres.pdf.
[140] For more data and references on the degree of corruption in Honduras see Michael Graglia, "Tbilisi agreement heralds significant expansion."

blockchain layer to provide the application's desired immutability and auditability. Factom's platform functions as an information exchange layer above the Bitcoin blockchain, allowing a wide range of applications to notarize to a blockchain ledger.[141]

Similar to the Bitcoin blockchain, the Epigraph process of recording transactions would rely upon a network of nodes fulfilling various roles, such as acceptance of information from the network of full nodes. In this design, no single node is ever fully in charge, with decisions and behavior always visible and frequently changed. This arguably renders the recording process less vulnerable to manipulation and/or attack.[142]

Honduras

The Epigraph project was Honduras' latest attempt at reform and modernization. In 2003, the state established a new national system for property management (SINAP-- Sistema Nacional de Administración de la Propiedad). In turn, SINAP provides the platform modules for Honduras' unified registry system (SURE-- Sistema Unificado de Registros). Launched in 2004 via a large World Bank loan, SURE aimed to digitize Honduran property records.[143] Unfortunately, as noted by Victoria Lemieux, these systems may be unreliable and have been vulnerable to manipulation involving land title fraud.[144]

Additionally, the Land Administration Project in Honduras --known by its Spanish acronym, PATH-- began in 2004 under the lead of the newly-created Property Institute (IP). The objectives of PATH included improving land administration services, tenure security, and the transparency of property information. PATH focused on "updating cadastral information, land titling and protected areas delimitation, the recognition of indigenous land and territorial rights, and strengthening land administration institutions."[145] The IP also created a publicly available digital system of property data and registration.[146]

The second phase, or PATH II, which began in 2011, involved a study to determine the degree to which supporting the security of tenure improves livelihoods in poor households.[147] According to a 2017 assessment conducted by the Food and Agriculture Organization of the United Nations, the program ultimately improved land tenure security for 40,000 households increased property values an estimated 30%.[148]

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[141] Paul Snow, Brian Deery, Jack Lu, David Johnson, and Peter Kirby, *Business Processes Secured by Immutable Audit Trails on the Blockchain* (Austin: Texas, November 17, 2014).

[142] Victoria Lemieux, "Evaluating the Use of Blockchain in Land Transactions: An Archival Science Perspective" (Unpublished Report, University of British Columbia, February 2018).

[143] Jorge Constantino Collindres et al., "Using Blockchain to Secure Honduran Land."

[144] Lemieux, "Evaluating the Use of Blockchain in Land Transactions: An Archival Science Perspective."

[145] Fabrice Edouard and Sherry Ordoñez, "A project in Honduras assesses the positive effects of land titling on livelihoods in poor households," Food and Agriculture Organization of the United States, May 31, 2017, http://www.fao.org/in-action/herramienta-administracion-tierras/news/detail-events/en/c/889420/.

[146] Jorge Constantino Collindres et al., "Using Blockchain to Secure Honduran Land."

[147] Fabrice Edouard and Sherry Ordoñez, "A project in Honduras assesses the positive effects of land titling on livelihoods in poor households."

[148] Ibid.

These projects were intended to document all property in Honduras, with the entire system built and housed domestically. But in spite of roughly $100 million in sunk costs, by 2015 the data was rendered obsolete from lack of upkeep and the IP had reverted to using paper.[149]

First contact between Epigraph and the Honduran government was through a series of internet calls arranged by Peña. Officials appeared interested, and invited Matt and Factom President Peter Kirby to Honduras. Traveling at their own expense, the pair met with government officials at the Presidential Palace and at the Property Institute in January 2015 to learn more about the local situation and to brainstorm solutions.[150] Epigraph also met with the PATH team to learn about their systems and how PATH interfaced with notaries, as well as other groups involved in the creation and management of property records. Matt and Peter observed how information was transferred from office to office, and discussed the challenges related to maintaining old data and handling new legal instruments.

On their final day in country, Matt and Peter visited with Ebal Jair Díaz Lupian, the government's chief of staff and Executive Director of the Property Institute, to propose their blockchain solution.[151] The pitch was well received. After a second pitch to a group of advisors, but without a formal agreement with the Honduran government, the pair departed from Tegucigalpa expecting a letter of intent (LOI) and a pilot program.

Delay

Epigraph leadership had to decide on a structure for the anticipated pilot. There was no established method of building a blockchain registry. Epigraph drafted a proposal and sent it to the Honduran government, expecting a quick response.

However, political instability shook Honduras in Spring 2015. A corruption scandal involving President Juan Orlando Hernandez and his party triggered the crisis. Roughly $350 million was allegedly stolen from the Honduran Social Security Institute by corrupt officials. Leaked documents revealed that embezzled funds were provided to the Hernandez campaign.[152] Likely preoccupied by this crisis and subsequent protests, the Honduran government devoted little attention to the Epigraph proposal.

During this delay, Matt and Abhi wrote a white paper on blockchain-based land registries for the World Bank. The paper, *Immutability and Auditability*, examined the problem of inaccurate and corrupt registries and described Epigraph's registry solution. Its 2016 presentation at the World Bank drew so much interest that the pair was asked to give a second, informal educational session for World Bank staffers the next day.

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[149] Jorge Constantino Collindres et al., "Using Blockchain to Secure Honduran Land."
[150] Ibid.
[151] Gertrude Chavez-Dreyfuss, "Honduras to build title registry using bitcoin technology," Reuters, May 15, 2015, https://uk.reuters.com/article/usa-honduras-technology/honduras-to-build-land-title-registry-using-bitcoin-technology-idINKBN0O01V720150515, accessed February 28, 2018.
[152] Nina Lakhani, "How hitmen and high living lifted lid on looting of Honduran healthcare system," *Guardian*, June 10, 2015, www.theguardian.com/world/2015/jun/10/hit-men-high-living-honduran-corruption-scandal-president; Gustavo Palencia, "Honduras president: graft-linked companies helped fund my campaign," June 3, 2015, www.reuters.com/article/us-honduras-corruption/honduras-president-graft-linked-companies-helped-fund-my-campaign-idUSKBN0OJ26B20150603.

While departing from the conference, Epigraph also signed its LOI with Honduras. Matt recalls how that day was the high point of their optimism and excitement: it was "all downhill from there."[153]

The Pilot

The LOI declared that the pilot would commence within a couple months of the signing. Epigraph therefore began by working with IP staffers on the framework. Initial challenges included debate over introduction of a parallel registry or creation of a completely new system, as well as considerations about the proper instruments to utilize. Overall, though, work was entirely organizational, and not technological, at this stage. Nonetheless, a Fundacion Eleutera paper demonstrates that the Epigraph solution was to utilize blockchain, be designed as a SaaS, allow mobile access, and ensure data management and access.[154]

With Epigraph and Factom working remotely, major problems existed from the outset. Relevant officials demonstrated little interest in the project. Contacts in Honduras rarely responded to emails or attended scheduled Skype calls. Dialogue often occurred with minor officials possessing no decision-making powers. This stonewalling prevented Epigraph and Factom from deciding critical organizational questions and moving the pilot forward. Without the engagement of lower IP stakeholders, Epigraph fruitlessly resorted to high-level outreach. At this time, however, the registry pilot ceased to be a priority. The government was in re-election mode.

As the project stalled in 2016, Matt and Abhi turned to other projects. While both remained interested, nothing practical happened. As Matt notes, "the point [was] to put a system in place that could survive a political transition,"[155] and they had run out of time.

Lessons learned

Matt believes that several reasons potentially contributed to the lack of cooperation in Honduras. IP officials' job security may have been at risk through embrace of reform, or the bureaucrats may have feared a loss of power under the new system. Matt also suspects that the failures of SURE and PATH had an impact. Doubts about feasibility of the project, combined with a general air of uncertainty surrounding the election, also may have undermined any pressure on IP officials to engage with Epigraph.

This lack of enthusiasm was not confined to the Honduran government. According to Matt, other influential parties --including some at the World Bank-- "did not trust the entrepreneurial spirit of Factom and Epigraph" and were suspicious of the fact that Matt and Peter had bypassed the usual bidding process.[156] Matt says that Factom and Epigraph had decided that the pilot would be done at cost, as the pair believed it was very unlikely for anyone to bid on blockchain and land in 2015.

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[153] Per interview with Epigraph, December 19, 2017.
[154] Jorge Constantino Collindres et al., "Using Blockchain to Secure Honduran Land."
[155] Per interview with Epigraph, December 19, 2017.
[156] Per interview with Epigraph, December 19, 2017.

Procedural issues aside, doubts existed concerning President Hernandez's motives in seeking land reform. His policies were accused of being too favorable to business interests, while also exposing working and indigenous people to exploitation.[157]

Matt later identified two strategies that might have changed the outcome of the pilot:

First, Epigraph and Factom should have been physically present in Honduras. A tangible presence would have allowed them to demonstrate their commitment to the project and win over individual stakeholders through direct engagement. Building relationships and ensuring local, personal investment was necessary might have resulted in better cooperation from IP officials.

Second, the companies could have identified an angel investor. Substantial funding would also have proved serious engagement, helping to positively influence perceptions of the project. Matt and Abhi considered this option, but decided against it because they acknowledged that engagement with Honduras was a long game with bad odds. The two did not want to expend money without immediate return, and knew investors would be skeptical that the project would turn a profit in a reasonable amount of time.

Looking Forward

Epigraph's focus continues to be on title software. The partnership with Factom is no longer active and the current Epigraph API is being built on Ethereum.

In addition to its normal business operations, Epigraph is working on OpenTitle --an open API for recording property rights on blockchain-- on the back burner.

The API is being developed as an industry-specific middleware application that sits on the Ethereum network. It is designed to work with existing land registry programs, such as Enola, allowing governments or NGOs to secure registries to the blockchain without building an entirely new blockchain registry system. OpenTitle is intended for grassroots projects and PoCs, and is not meant to be legally binding. The API was created with the goal of building a more practical understanding with people still struggling with the ground-level idea of what a blockchain property registry really means and looks like.

In approaching the future of blockchain, Matt continues to view the technology as protection for the centralized application to guarantee that data is pristine and secure, which is reflected in Epigraph's more centralized approach. On this theme of growth and governance, Matt made an analogy to the Internet, which grew very slowly from a small pool of central resources. It did not have to be the Internet as we view it now all at once; rather, it took time to develop and spread before its explosive growth. In contrast, the hype surrounding blockchain has put pressure on blockchain developers to provide transformative solutions and products in too narrow of a time frame. A better option is to use blockchain to improve the security of paper documents, not revolutionize everything all at once.

In regard to the possibility of eventual registry consolidation and interoperability, Matt believes that combining government registries into a consortium where each individual registry is a node is the most

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[157] James J. Phillips, *Honduras in Dangerous Times: Resistance and Resilience* (Lanham, MD: Lexington, 2015), 46.

realistic possibility, though this would require common standards to be defined and adopted across different industries and governments. By building a blockchain platform that encompasses all registries, each individual government registry would also serve to protect the security and validity of other government registries.

Case Study: Propy

Propy has initiated blockchain and registry integration pilots in Ukraine and Vermont. The Propy platform displays property listings, manages transactions, and serves as a registry. This case study is based on desk research and interviews with Propy's Head of Research, Dr. Vasilios Vutsadakis. We are grateful for his time.

Background

Founded by CEO Natalia Karayaneva in 2015, Propy's ambition is to become the "Amazon for real estate,"[158] facilitating investment in foreign properties and bringing the liquidity of land in line with that of other major asset classes. They foresee this liquidity having advantages for both business interests and financial inclusion, creating micro-investment opportunities for the developing world and simplifying transactions in mature markets.[159]

Propy's ultimate goal is for peer-to-peer transactions to be conducted entirely remotely and via smart contracts, with the Propy Registry serving "as the legal ledger of record for real estate title transfers in a given jurisdiction."[160] The company's business model is to approach this goal incrementally as it addresses regulatory and infrastructural limitations. In the short term, the company hopes to attract customers to the platform for the increased efficiency and security provided by both online workflow management and the anchoring of transaction documents to the blockchain.

Propy launched its online real estate marketplace in 2016, held its ICO in August 2017, and its transaction tool went live in December 2017. Their goal is to allow peer-to-peer transactions by 2020. Propy is based in Palo Alto, California, with offices in Bulgaria and Ukraine.

Platform

The Propy platform is intended to be a one stop shop where an investor can "research, pay for, and reliably secure and record ownership of international property online."[161] To that end, they are building a three-part system on Ethereum to display property listings, manage real estate transactions, and serve as a property registry.

The current version of the Propy transaction tool, which is in full alpha, allows users to purchase properties in San Francisco with cryptocurrency, while properties in Beijing, New York, and Dubai can be bought via offline fiat payments.

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[158] Bryson Masse, "'Propy' gets $15M on promise of digital currency real estate investment," *Inman*, September 25, 2017, https://www.inman.com/2017/09/25/propy-gets-15m-promise-digital-currency-real-estate-investment/

[159] Brett Hershman, "Propy, A Blockchain Real Estate Startup, Could Change How You Buy Property," *Benzinga*, December 13, 2017, www.benzinga.com/news/17/12/10899303/propy-a-blockchain-real-estate-startup-could-change-how-you-buy-property, accessed February 8, 2018.

[160] Propy Team, *Global Property Store with Decentralized Title Registry* (Palo Alto, 2017), 8.

[161] Propy Team, *Global Property Store*, 4.

Once a transaction has been initiated, the online tool allows the various parties to manage workflow through smart contracts. According to Karayaneva, this allows deals to be completed in half the time that traditional methods require.[162] Smart contracts replace paper ones to the extent that laws allow, and can be signed digitally online. Every step of the transaction is hashed to the blockchain. "Users receive an electronic title deed with a blockchain hash within a day and within hours the transaction could close. The hard copy from the recording office will be received as usual," notes Karayaneva.[163]

Propy's plan is to have their registry mirror the official one in relevant jurisdictions until significant regulatory changes are made. Digital signatures and e-deeds must gain legal recognition to allow for completely digitized transactions, and to enable peer-to-peer transactions the Propy registry must be designated as the legal registry. For the time being, all relevant documents are recorded in the Propy registry and hashed to the Ethereum blockchain. Propy Registry only handles real estate title ownership and other data is stored in Propy's central database. The company may replace this database with decentralized storage later.

PRO Coins

Use of the platform also requires PRO Coins, tokens issued by Propy that unlock smart contract functions.[164] In their white paper, Propy says that the coins are necessary for two reasons: they provide a single settlement method independent of any fiat currency and also create a barrier to entry for attackers who might otherwise overload the network with spam. The total number of PRO coins is fixed at 100 million. 50 million were issued at the initial token sale, 35 million were reserved to spur network growth by rewarding new users, and the remaining 15 million were set aside to help fund the "improvement of blockchain infrastructure so that it can also meet the transactional requirements of Propy and the Propy Registry at scale."[165] Once all of the tokens have been distributed, new users will have to buy them from third parties.

Some elements of the transaction tool, notably PRO Coin fees, are set manually for each transaction. There will be automated dynamic pricing in the future once a value algorithm has been decided. Propy will also take a percentage fee from the broker in fiat, as well as a small percentage of the property value.

Jurisdictions

With a focus on cross-border sales, Propy designed its platform and smart contracts to be adaptable to different jurisdictions. This has required serious investment in researching national and international property laws. There is a common perception that early registry implementations are best attempted in secure and orderly jurisdictions like Sweden. However, Vutsadakis points out that developed countries are the most complex and regulated jurisdictions, and that "everything after California is easier."[166] As a result, "Propy is working with the governments of several emerging countries where, due to systems'

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[162] Gill South, "Propy launches blockchain pilot in Vermont to record real estate transfers," *Inman*, January 24, 2018, www.inman.com/2018/01/24/propy-launches-blockchain-pilot-in-vermont-to-record-real-estate-transfers/, accessed February 22, 2018.
[163] Hershman, "Propy, A Blockchain Real Estate Startup, Could Change How You Buy Property."
[164] Propy Team, *Global Property Store*, 26.
[165] Ibid., 29.
[166] Per interview with Propy, December 20, 2017.

inefficiencies, corruption, and the lack of regulatory complexity, a transition to a new system is expected to be more straightforward."[167]

As Propy begins laying the groundwork for engagement in a new jurisdiction, the firm reaches out to local professional communities to determine how much change can be tolerated. Each communities' desires and goals must be understood and accommodated. Propy considers the education of current stakeholders, often worried about blockchain's disruptive impact on their industries, as an essential component of capacity building. Brokers and registrars are naturally concerned that their jobs might change or be devalued. In response to this unease, Propy states that they are simply providing new enabling tools that are secure, immutable, and low-maintenance. From this perspective, blockchain is merely the latest addition to the set of modern tools already embraced by brokers and other real estate professionals.

Propy is currently targeting the US, the UK, and the UAE for business. It aims to introduce the Propy Registry in parallel to help brokers process international transactions more efficiently. Another targeted legislative environment is jurisdictions already utilizing blockchain to manage real estate titles. Propy could then enter to "provide a sole, decentralized source of validation for real estate transactions."[168]

Ukraine

In August 2017, Propy announced a pilot partnership with the State Agency for eGovernance of Ukraine to allow foreign buyers interested in real estate to invest by means of blockchain technology.[169] Following a massive decline in housing prices in 2014 and 2015, the Ukrainian government is aiming to leverage Propy's technology in order to facilitate online real estate sales.[170] Officials hope to boost a recovering economy by attracting fresh capital from foreign property investors, with a particular focus on China.[171]

In October 2017, Ukrainian developer Mark Ginsburg used the Propy platform to sell a Kiev property to Michael Arrington, co-founder of the tech news site TechCrunch, for $60,000.[172] Payment was made in Ether and PRO Coins.[173] Overall, the transaction was the first peer-to-peer cryptocurrency payment for real estate and ownership transfer on blockchain approved by a government.[174] The transfer was also registered on paper in the legal registry, though the official deed included the blockchain address to which the transaction was hashed.[175]

[167] Ibid.
[168] Propy Team, *Global Property Store*, 10.
[169] Jeremy Nation, "Propy Partners With Ukraine, Offers Foreign Investors Real Estate Opportunities," *ETH News*, August 15, 2017, www.ethnews.com/propy-partners-with-ukraine-offers-foreign-investors-real-estate-opportunities, accessed February 22, 2018.
[170] Richard Kastelein, "Ukraine Government to Allow Foreign Investors to Purchase Real Estate Online with Propy," *Blockchain News*, August 16, 2017, http://www.the-blockchain.com/2017/08/16/ukraine-government-allow-foreign-investors-purchase-real-estate-online-propy/, accessed February 22, 2018.
[171] Anthony Cuthbertson, "Blockchain Used to Sell Real Estate for the First Time," *Newsweek*, October 12, 2017, http://www.newsweek.com/blockchain-sell-real-estate-first-time-ethereum-682982, accessed February 22, 2018.
[172] Ibid.
[173] "Propy Announces World's First Real Estate Purchase on Ethereum Blockchain," *Coinspeaker*, September 30, 2017, www.coinspeaker.com/2017/09/30/propy-announces-worlds-first-real-estate-purchase-ethereum-blockchain/, accessed February 22, 2018.
[174] Hershman, "Propy, A Blockchain Real Estate Startup, Could Change How You Buy Property."
[175] Ibid.

Oleksandr Ryzhenko, head of the State Agency for eGovernance, asserts that, ultimately, "our ambition is for Ukraine to be one of the world's foremost nations in establishing a comprehensive blockchain ecosystem, and the real estate sector forms an important part of our overall blockchain strategy."[176] He believes that the technology will foster greater transparency, efficiency, security, and compliance within the Ukrainian market.[177]

Karayaneva has similarly noted the potential of her company's technology to attract foreign investors in Ukraine, while also providing the necessary security for real estate transactions.[178] As the potential of the technology becomes evident, Karayaneva stresses that the Ukrainian government, "is figuring out what laws they need to change."[179]

Vermont

Propy and the City Clerk's Office of South Burlington, Vermont announced a pilot project in January 2018.[180] The pilot will use Propy's platform to record real estate conveyance documents, with the aim of developing a more efficient and secure ledger for real estate transactions. There is an additional goal of evaluating the extent to which a blockchain-based platform will reduce the costs of storing land management data in comparison to traditional systems.[181]

The project is limited in scope at the time of this paper. Propy wants to begin with low-level integration into South Burlington's process of recording real estate transactions. According to South Burlington City Clerk Donna Kinville, in the first stage of the pilot Propy will sell properties through its platform and deliver paper deeds to the city with the blockchain address of the transaction record.[182] The last of four stages of integration would be for Propy to replace the city's current land records software. Through early February 2018, the city has not received any deeds from the company.[183]

Vermont was not a particularly suitable partner from the perspective of technical readiness. Zero towns in the state currently use E-recording.[184] In comparison, all fifteen counties in Arizona embrace such technology.[185] Overall, over half of all US registries utilize E-recording.[186] Propy chose Vermont for its pilot largely because the state was a friendly legislative environment.[187] A 2015 law related to economic

[176] William Suberg, " Ukraine Set to Offer Blockchain Real Estate to Foreign Investors," *Cointelegraph*, August 15, 2017, https://cointelegraph.com/news/ukraine-set-to-offer-blockchain-real-estate-to-foreign-investors.

[177] Kastelein, "Ukraine Government to Allow Foreign Investors to Purchase Real Estate Online with Propry."

[178] Ibid.

[179] Douglas Heaven, "A House Has Been Bought on the Blockchain for the First Time," *New Scientist*, October 11, 2017, www.newscientist.com/article/mg23631474-500-a-house-has-been-bought-on-the-blockchain-for-the-first-time/, accessed February 22, 2018.

[180] South, "Propy launches blockchain pilot."

[181] Nikhilesh De, "Vermont City Pilots Land Registry Record With Blockchain Startup," *Coindesk*, January 23, 2018, www.coindesk.com/vermont-city-pilots-land-registry-record-with-blockchain-startup/, accessed February 22, 2018.

[182] Ben Miller, "Vermont City, Real Estate Startup Try Out Blockchain for Recording Property Transactions," *Government Technology*, February 5, 2018, http://www.govtech.com/biz/Vermont-City-Real-Estate-Startup-Try-Out-Blockchain-for-Recording-Property-Transactions.html, accessed February 22, 2018.

[183] Ibid.

[184] "E-Recording in Vermont," Simplifile, simplifile.com/services/e-recording/e-recording-counties/e-recording-in-vermont/, accessed February 22, 2018.

[185] "E-Recording in Arizona," Simplifile, simplifile.com/services/e-recording/e-recording-counties/e-recording-in-Arizona/, accessed February 22, 2018.

[186] "E-Recording Counties," Simplifile, simplifile.com/services/e-recording/e-recording-counties/, accessed February 22, 2018.

[187] South, "Propy launches blockchain pilot."

development mandated that a report be made on the uses of blockchain for the government.[188] There is now a major blockchain bill under consideration in the state legislature; it would allow blockchain startups to create LLCs that would be taxed by the state in any coin of its making at a low rate.[189] The Vermont Agency of Commerce and Community Development additionally states that it is closely monitoring the pilot to evaluate how blockchain usage can be expanded in the future.[190]

Karayaneva expects other Vermont communities to join the program, as officials there are willing to listen and interact directly. Registries in the state exist at the town and city level; as a result, there are over 250 land registries and no common indexing and metadata standards. These municipalities may individually elect to create a parallel registry (i.e. a mixed presence of blockchain and traditional registries), replace an existing one, or remain independent.

Looking Forward

Propy's long-term goal is to allow peer-to-peer transactions, and one of the first steps towards this goal is the tokenization of real assets. Vutsadakis does not regard such tokenization as a novelty or even a particularly serious challenge, pointing out that it is already common to trade securities electronically. Propy believes that tokenized real estate will allow them to create something very similar to a traditional REIT but with reduced structural and setup costs. As with many other blockchain applications, the ultimate promise of this system would be to pass the savings from reduced overhead along to consumers, opening the market to micro-investors from cash-poor communities.

Vutsadakis says that this would require careful structuring to optimize tax and security laws, and would not necessarily be chartered as a REIT. Propy continues to conduct research into regulatory issues to figure out the optimal structure.

Peer-to-Peer

The aim is to allow people to trade properties remotely --without ever having to meet with another person. Propy believes that it will eventually be possible to trade real estate peer-to-peer in a similar manner to the trading of securities. However, that will require more work and possibly more legislation. Propy is currently investigating ways to approach the problem within existing laws, and eventually intends to build country-specific rules and regulations into its smart contracts. Current Propy smart contracts --which include title, deed, and identity contracts-- are only valid in California. Propy is developing additional contracts to store legal agreements and digital signatures, and others to manage payment and escrow.

Becoming the Legal Registry

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[188] Molly Jane Zuckerman, "Vermont Proves 'Blockchain Friendly," Hosts Real Estate Pilot Program," *Cointelegraph*, January 23, 2018, cointelegraph.com/news/vermont-proves-blockchain-friendly-hosts-real-estate-pilot-program, accessed February 22, 2018.
[189] Elizabeth Zima, "Vermont Bill Aims to Draw in Blockchain Business and Study Remote Citizenship," *Government Technology*, January 19, 2018, http://www.govtech.com/computing/Vermont-Bill-Aims-to-Draw-in-Blockchain-Business-and-Study-Remote-Citizenship.html, accessed February 26, 2018.
[190] Ben Lane, "Vermont city partners with Propy to bring blockchain to real estate transfers," *HousingWire*, January 26, 2018, www.housingwire.com/articles/42382-vermont-city-partners-with-propy-to-bring-blockchain-to-real-estate-transfers, accessed February 22, 2018.

Propy's ultimate goal is widespread, official adoption of the Propy Registry. There are currently two plans through which to approach differing legislative environments. If legacy registries remain the only legal option for recording ownership, Propy will continue mirroring government records while managing transaction workflows.

In a more pliable environment, Propy would become the "sole, decentralized source of validation for real estate transactions."[191] Eventually, one jurisdiction at a time, a global title deed registry would be created. Various national laws would be enforced through smart contracts. Development of this registry would include the building of universal metadata standards for storing deeds on blockchain technology.

According to its white paper, "Propy aims to develop the Propy Registry with the ultimate goal of becoming a global registry for title deed ownership information, which would be made available to worldwide entities, similar to a DNS system for website domains."[192]

Vutsadakis says that caution must always be exercised when debating replacement of an existing registry. For one thing, it is impossible to ascertain the future of any particular blockchain, or the technology in general. From a guarded perspective, it is more practical to use blockchain as a backup solution to existing registries while blockchain technology develops. Beginning with parallel registries is therefore pragmatic and probably unavoidable.

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[191] Propy Team, *Global Property Store*, 10.
[192] Ibid., 13.

Case Study: Ubitquity

Ubitquity's platform utilizes colored coin tokens to store property documents and transfer records on blockchain. The company recently completed a registry integration pilot in Brazil. This section draws upon desk research, as well as on interviews with Ubitquity founder Nathan Wosnack and Marina Reznick of Atlantic Sotheby's International Realty.

Background

Ubitquity founder Nathan Wosnack was drawn to blockchain and real estate in 2015 after working on a blockchain-based governance services program called iNation, which primarily focused on digital identity. A colleague, aware of his interest in non-fintech blockchain use cases, advised him to look into the land and title industries, leading to the founding of Ubitquity in September 2015. In 2016, Nathan partnered with Marina Reznik, of Atlantic Sotheby's International Realty, for her real estate expertise.

Nathan states that Ubitquity's "long-term goal is to digitize titles to all assets (in this case real estate) and provide an immutable record of clear ownership in perpetuity, powered by the Bitcoin blockchain."[193] The founder asserts that his company's service model sets it apart from others in the industry. "Some of these competitors have announced pilots with municipalities like we have…none of them that I've observed seem to be building a SaaS platform that focuses on B2B (Business-to-Business) with a focus on e-recording and title companies."[194]

Their core customers are municipalities seeking a SaaS E-recording platform, but Ubitquity also aims to reduce costs for title plants by making title searches more efficient.

Platform

The Ubitquity platform records property title documents and transfer records on the Bitcoin blockchain using colored coins. The Ubitquity registry operates in parallel to the legacy recording and tracking systems --whether paper, digital, or both. Information is entered through Ubitquity's web front end. Hashes of records are published to the Bitcoin blockchain, but the records themselves are stored as PDFs off-chain in a back-end database. Ubitquity currently uses the Colu colored coin protocol to record property information submitted through the web interface on the blockchain, though according to a case study by Victoria Lemieux of the University of British Columbia they are moving to the Colored Coins Open Assets protocol.[195] Ubitquity's platform is blockchain agnostic, and also supports Ethereum, Hyperledger, and Multichain.[196]

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[193] Avi Spielman, "Blockchain: Digitally Rebuilding the Real Estate Industry," master's thesis, Massachusetts Institute of Technology, 2016, http://dci.mit.edu/assets/papers/spielman_thesis.pdf.

[194] Jack Fitzgerald, "Ubitquity Interview: A 12 month update on blockchain and real estate," *Disrupt Property (blog)*, Disrupt Property, May 7, 2017, http://disruptproperty.com/blog/blockchainrealestateupdate/.

[195] Daniel Flores, Claudia Lacombe, and Victoria Lemieux, "Real Estate Transaction Recording in the Blockchain in Brazil," RCPLAC-01 (Vancouver: University of British Columbia, 2018), 12.

[196] Ibid., 25.

Ubitquity announced in July 2016 that it had completed the Bitcoin blockchain's first property ownership transfer.[197] It was also the first property transfer utilizing blockchain technology to occur in the US. Although the transaction was recorded on the Bitcoin chain, it also had to be recorded with municipal authorities in the usual way. Ubitquity launched a private alpha in March 2016 and completed a pilot project in Brazil from May to September 2017.

Brazil

Ubitquity implemented the first public pilot of its SaaS platform in 2017. The project was based in the Pelotas and Morro Redondo municipalities of the Brazilian state of Rio Grande do Sul. Rafael Mezzari, of the local Cartório de Registro de Imóveis (Real Estate Registry Office), initiated the partnership by approaching Ubitquity in late January 2016. Mezzari became interested in blockchain technology while exploring alternative land record management system. There is a widespread need for registry improvement in Brazil, which recently "introduced the SRE - Electronic Property Registry System project to modernize the current paper-based land registry system."[198]

Overall, Brazil lacks an integrated system of land management, and registering property can involve 13 separate steps. The cadastral database and the registration databases are not integrated, and different identifiers are often used for the same parcel of land. There is also the absence of an electronic database for examining encumbrances. The general system is susceptible to corruption and abuse by wealthy landowners.[199]

Against these significant challenges, the Ubitquity pilot aimed to introduce a parallel platform replicating the existing legal structure of property ownership and transfer recording. The goal of the project was to help lower costs, while also improving accuracy, security, and transparency. Ubitquity used the Colu Colored Coins protocol on the Bitcoin blockchain to establish "the link between a given blockchain record and its originating transaction"[200] The pilot was a remote engagement, and handled half a dozen records. Mezzari ultimately concluded that the service was too expensive, and discerned that blockchain technology would be possible for use in a "distant future."[201]

Victoria Lemieux, of the University of British Columbia, conducted an in-depth case study of Ubitquity's experience in Brazil. The scholar emphasizes several issues concerning wider application of the pilot program. First, Lemieux questions the possibility of the legal acceptance of digital signatures in Brazil. She stresses that such technology threatens officials because the Bitcoin blockchain is not vulnerable to political pressures, "disintermediating enormous government power."[202] Lemieux also emphasizes the

[197] Joseph Young, "Bitcoin Blockchain's First Property Ownership Transfer Settled by Ubitquity," *Merkle*, July 14, 2016, themerkle.com/bitcoin-blockchains-first-property-ownership-transfer-settled-by-ubitquity/.
[198] Flores et al., "Real Estate Transaction Recording in the Blockchain in Brazil," 7.
[199] Ibid.
[200] Ibid., 28.
[201] Ibid., 8.
[202] Ibid., 16.

need for private key security and identity management.[203] Finally, her report notes that blockchain technology does not guarantee accuracy of land transaction records in the original registry.[204]

In conclusion, Lemieux contests the long-term availability of access to blockchain records in Brazil, as well as their very evidential quality. The scholar asserts that such issues could "have a significant negative impact upon transparency and public accountability, and deprive individuals of their entitlement to land."[205] Changes to the legal, administrative, and procedural rules may be necessary for such systems to operate effectively.

Lessons

Ubitquity observed the two Cartório de Registro de Imóveis as very cooperative --despite remote working conditions. Each of the approximately 3,400 local Cartórios is an independent entity, which allows innovative officials to pursue experimental tech solutions.[206] Merrazi's interest in blockchain, and his subsequent partnership with Ubitquity, is a strong example of such flexibility.

Ubitquity benefited from early publicity provided by Avi Spielman's influential MIT thesis.[207] As a result, prospective customers have reached out to them; Ubitquity's leadership says that all of its engagements have been initiated by the customer. Nathan and Marina note that the rhetoric of blockchain advocates can create friction with potential partners. The focus on disintermediated transactions is both premature and counterproductive. Peer-to-peer exchanges remain only a distant possibility --promoting these transactions indirectly characterizes notaries, registrars, and brokers as unnecessary impediments to progress. In dealing with land officials, Ubitquity stresses that it can simplify their work, reduce their operating costs, and create high-tech jobs within their communities. When speaking with realtors, the company similarly stresses that blockchain will exist in the background, utilizing API links to complete simple tasks. The technology does not replace these individuals --it makes them more effective.

Future

Ubitquity does not foresee the introduction of peer-to-peer transactions in the near future, primarily because blockchain technology does not eliminate the need for professional due diligence, which remains necessary and is worth the cost given the degree of risk involved. Nathan also notes that, while smart contracts hold great potential, they are not always legally binding, and flawed code can make them susceptible to hacking. In combination, these concerns may outweigh the benefits of reduced transaction costs.

Ubitquity considers blockchain as a way to create a secure and clear record of documents, reducing the number of title defects over time and leading to a corresponding decrease in the cost of title insurance.

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[203] Ibid., 24, 28.
[204] Ibid., 18.
[205] Ibid., 31.
[206] Karla Mendes, "Can blockchain save the Amazon in corruption-minded Brazil?," *Reuters*, January 25, 2018, https://www.reuters.com/article/us-brazil-property-blockchain/can-blockchain-save-the-amazon-in-corruption-mired-brazil-idUSKBN1FE113.
[207] See Spielman, "Blockchain," http://dci.mit.edu/assets/papers/spielman_thesis.pdf.

Regarding national-scale land registries, Ubitquity says it will focus on small items first before considering expansion. Creating the right user interface and user experience will help with adoption; it must be point and click. Nevertheless, there are different obstacles in different jurisdictions. In Brazil, for example, some stakeholders do not want a national land registry, as local equivalents fear loss of either their independence or their profits.

Within North America, Wosnack highlights the International Organization for Standardization (ISO) Technical Committee 307 on Blockchain and Distributed Ledgers. The committee aims to develop a terminology database, "which supports international efforts to arrive at a common understanding of blockchain concepts and terms."[208] The CEO also spoke about Ubitquity's discussions with the Property Records Industry Association (PRIA) concerning best practices and standards for blockchain and real estate.[209] Wosnack believes that such developments foster the possibility of a blockchain-based national title plant. However, with more than 3,000 municipalities in the US, each with different rules and requirements, he concedes that it would be very difficult to create a national registry using blockchain.

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[208] Jack FitzGerald, "Ubitquity Interview: A 12 month updated on blockchain and real estate," *Disrupt Property (blog)*, May 7, 2017, http://disruptproperty.com/blog/blockchainrealestateupdate/, accessed January 17, 2018.
[209] Ibid.