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BLOCKCHAIN-BASED LAND ADMINISTRATION
FEASIBLE, ILLUSORY OR A PANACAE?

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Abstract

October 31st 2015, the Economist wrote an article about the use of blockchain as a 'Trust Machine', stating: "*The spread of blockchains is bad for anyone in the "trust business" (…), such as (…) government authorities that are deemed sufficiently trustworthy to handle transactions*".

In this paper the possible use of blockchain technology in Land Administration is described, with an overview of some recent developments in the field of blockchain technology - e.g. technical maturity, (hard) forks) and Governance. The relationship between Person(s), Right(s) and Object(s) in a Land Administration system is the basis for the definition of required functionality, given the complexity within these three elements: identity of a person, legal diversity ('bundle of rights') and the diversity in objects (including the possible use of 'bitsquares').

The paper analyses if some of the principles of Good Governance in Land Administration (transparency, accountability, security, rule of law) are being met with blockchain technology. In this context it is concluded that the technique does not seem to be mature enough for application in land administration *in this moment.*

Key Words:
Blockchain, Land Administration, Cadastre, Land Registry, IT, Good Governance, Transactions, Fit For Purpose Land Administration

1. INTRODUCTION

October 31st 2015, the Economist published an article[1] about the use of blockchain as a 'Trust Machine', stating: "*The spread of blockchains is bad for anyone in the "trust business" (…), such as (…) government authorities that are deemed sufficiently trustworthy to handle transactions*". It was stated that Land Administrations across much of the world are "badly kept, mismanaged and/ or corrupt". Blockchain technology should prevent the insecurity and injustice that are part of these Land Administrations. The shared ledger technology should bring trust.

What kinds of trust are necessary for a well-functioning Land Administration and can the blockchain bring this trust? In this paper we discuss the possibility to replace a well-functioning existing land administration system by an alternative based on blockchain technologies. The complexity and expenses of such current well-functioning Land Administration system is taken into account.

The authors describe what blockchain technology entails, if it will be useful for Land Administration (cases) and if so, what may be the (possible) use of shared ledger technology in Land Administration. Could this technology (completely) replace the current Land Administration systems? We describe the (possible) use and best practices of blockchain technology in Land Administration, in various existing legal and Land Administration systems.

While drafting this paper the most actual information that is available has been consulted, using the descriptions of the current state of play of various proofs of concept in countries that are piloting a blockchain-based Land Administration and by relating these developments to the practices of well-functioning modern Land Administrations. It has to be noticed here that developments are growing on a rapid pace and (blockchain) technology is changing almost all the time. This paper therefore gives a temporary overview of the recent developments and possibilities.

Before describing the blockchain, we define what Land Administration is about. After defining the term Land Administration, we describe the functionality and global requirements of Land Administration – as

[1] See: http://www.economist.com/news/leaders/21677198-technology-behind-bitcoin-could-transform-how-economy-works-trust-machine (Last accessed on March, 2. 2017).

identified by the authors based on literature and international experience built up in land administration projects and also in standardisation efforts as (ISO, 2012)[2].

2. GLOBAL REQUIREMENTS FOR IMPLEMENTATION OF LAND ADMINISTRATION

After defining the term Land Administration, we describe the functionality and global requirements of Land Administration in this section. Those requirements are identified by the authors based on literature reviews and international experience built up in land administration projects and also in standardisation efforts as (ISO, 2012)[3].

Definition

Amongst other definitions, the definition of United Nations Economic Commission (UN ECE) for Europe is widely used. In the 'Land Administration guidelines', the UN ECE defines land administration as follows: "Land Administration is the process of determining, recording, and disseminating of information about ownership, value and use of land when implementing land management policies" (UN ECE, 1996)[4].

In ISO (2012) Land Administration is described as the process of determining, recording and disseminating information about the relationship between people and land. This definition is being used in this paper – it brings the option to go beyond property and ownership rights and allows the inclusion of customary and informal land use rights. If ownership is understood as the mechanism through which rights to land are held, we can also speak about land tenure. A main characteristic of land tenure is that it reflects a social relationship regarding rights to land, which means that in a certain jurisdiction the relationship between people and land is recognised as a legally valid one. These recognised rights are in principle eligible for registration, with the purpose being to assign a certain legal meaning to the registered right (e.g. a title).

[2] ISO 19152,International Standard, Geographic information - Land Administration Domain Model (LADM). © ISO, 2012, Geneva, Switserland, 118 pp.

[3] Ibid

[4] UNECE, (1996). Land administration guidelines. With special reference to countries in transition. Geneva, Switzerland, United Nations/Economic Commission for Europe: 112 p.

It should be noticed that the presented definition of Land Administration includes Land Registry and Cadastre.

Functionality and Global Requirements

Looking 'from a distance', one will observe that the functionality of different Land Administration systems is in principle largely the same: they are all based on the relationships between people and land, linked by (ownership or use) rights, and are in most countries influenced by developments in Information and Communication Technology (ICT). Furthermore, the two main functions of every land administration (including cadastre and/or land registry) are:

- keeping the contents of these relationships up-to-date (based on regulations and related transactions); and:
- providing information from the (national) registers.

To create an overview of global requirements for Land Administration we use the terminology of Global Land Tool Network (GLTN).[5] It is described as "the governmental responsibility to provide security of tenure and information about tenure issues for property markets and governmental and private business activities."[6] This means that governments need to make the tenure information available so society can benefit from this in every possible way. For this, the government needs to institutionalize the provision of land information, including a geographical component. There is a need for policy and legislation, for some form of organisation for implementation of policies and for enforcement of the legislation and for the dissemination of information.

[5] See: www.gltn.net (Last accessed on March, 2. 2017).

[6] See: http://www.gltn.net/index.php/land-tools/themes/land-administration-and-information (Last accessed on March, 2. 2017).

The World Bank and FIG jointly promote the fit-for-purpose land administration approach that enables appropriate land administration systems. This approach is also promoted by the GLTN[7, 8] and is integrated in the UN-GGIM Addis Ababa declaration and in the Draft Version of the New Urban Agenda[9].

Fit-for-purpose approaches in land administration mean that the land administration systems should be designed for the purpose of managing current land issues within a specific country or region – rather than simply following more advanced technical standards. The fit-for-purpose approach is participatory and inclusive. The fit-for-purpose approach is a realistic approach that is scalable and could make a significant difference in the intermediate timeframe. A fit-for-purpose approach includes the following elements: – Flexible in the spatial data capture approaches to provide for varying use and occupation. – Inclusive in scope to cover all tenure and all land. – Participatory in approach to data capture and use to ensure community support. – Affordable for the government to establish and operate, and for society to use. – Reliable in terms of information that is authoritative and up-to-date. – Attainable in relation to establishing the system within a short timeframe and within available resources. – Upgradeable with regard to incremental upgrading and improvement over time in response to social and legal needs and emerging economic opportunities.

Land Administration: Object – Right - Subject

The common pattern for Land Administration (systems) consist of a triple[10, 11]: Object (spatial unit) – Right (rights in rem and /or personal rights) – subject (the title holder of the right that is related to the object). This triple is the basic structure for all well-functioning systems. It is not without coincidence that – amongst others – the key principles of the Domain Model for Land Administration, the Social Tenure Domain Model

[7] Enemark, S., Bell, K.C., Lemmen, C.H.J. and McLaren, R. (2014). Fit-for-Purpose Land Administration. FIG publication, Volume 60. International Federation of Surveyors (FIG).

[8] Enemark, S., McLaren, R. and Lemmen, C.H.J. (2015) Fit-for-purpose land administration guiding principles: reference document: e-book. Global Land Tool Network (GLTN), UN-HABITAT, Kadaster, 2015.

[9] See clause 35 in http://habitat3.org/wp-content/uploads/N1639668-English.pdf retrieved from https://habitat3.org/the-new-urban-agenda/ (Last accessed on March, 2. 2017).

[10] Lemmen, C.H.J., (2012). A Domain Model for Land Administration. Delft University of Technology, Delft, The Netherlands (PhD thesis).

[11] This triple is also known as the 'ABC-structure', as this structure has been identified by the IMOLA project. The European Land Registry Association (ELRA) has worked closely with other associations and networks concerned in the area of Land Administration. With this project ELRA aimed to produce a model for standardised land registry output, connected to explanatory material in different languages.

(STDM)[12], for building a legal and regulatory framework are a continuum of land rights (rights, restrictions and responsibilities), a continuum of land use right claimants (persons and groups or entities) and a continuum of spatial units (land, objects and units) (Lemmen et al 2015). Using 'continuum approaches' requires the introduction of quality labels, for example the legal meaning of certain information or the geometric accuracy of a geometric description of a spatial unit or parcel. Or a label proving that the attribute is linked to its source.

Things start getting complicated in case of plurality within each of these three parts. The most complex, yet not inconceivable situations are the cases where two or all three items within the triple are complex and extraordinary. The 'bundle of rights' can cause complexity, especially when combined with different shares in various rights. An example of this complexity is a case where there are multiple persons, each entitled to different shares in various rights (e.g.: a right of bare ownership, encumbered with the right of usufruct and a building right), with a mortgage right on the right of ownership or another right, with regard to a building on a plot of land (parcel), which building has been divided into apartment rights. This implies that subjects, rights and objects can be grouped. A group of objects for example is called "Basic Property Unit" in some countries. It means that the ownership of a group of objects is considered as a whole. There may be groups of groups. The the technical and administrative demands with regard to those situations should be met in a blockchain-based Land Administration.

It should be noted that data sets represented in the triple may be maintained and managed in an environment with distributed mandates and responsibilities.

Good Governance

Good governance has 8 major characteristics – it is participatory, consensus oriented, accountable, transparent, responsive, effective and efficient, equitable and inclusive and follows the rule of law. It assures that corruption is minimized, the views of minorities are taken into account and that the voices of the most vulnerable in society are heard in decision-making. It is also responsive to the present and future needs of society[13].

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[12] Lemmen, C.H.J. (2010) The social tenure domain model: a pro-poor land tool: e-book. Copenhagen, International Federation of Surveyors (FIG), 2010. FIG publication 52, ISBN 978-87-90907-83-9.

[13] See http://www.unescap.org/sites/default/files/good-governance.pdf

3. LAND REGISTRY PRINCIPLES

One of the specific aims of every Land Registration system is to try to break the usury cycle. Twaroch and Muggenhuber[14] point out that a Land Registry system is successful when all partners involved (owners, banks, Notaries, et cetera) have trust in this system. This is independent from legal and technical solutions. For having trust a third dimension the organisational or institutional aspects of the system have to be taken into account.

In some (developing) countries people do not always trust the current system. In some cases there is fraud and corruption and in other cases there is a lack of quality. A blockchain-based Land Registry system may seem to bring a solution for these problems, although in reality it perhaps does not. The real challenge for these countries will probably be the initial identification of right holders and the creation of actual titles. Once it is known who is the actual owner of a certain parcel, the ownership of the parcel can be transferred. This initial phase will not be realised by using blockchain. Blockchain is designed as a '*shared single source of trust*', to exclude (mistrusted) governmental parties and banks, but it demands an empty stage which everyone can agree on as a starting point. This stage will be put in the first phase of a blockchain, the Genesis block. This starting point may be the problem in the case of these countries, because there is no trust and so there will be no consent by all interested parties. In those cases a blockchain-based Land Registry will not work.

The principles of Land Registration are often[15] [16] divided into four:

1. Speciality principle: the concerned object ((immovable right regarding an) immovable property) and subject (the person (also the person behind the legal entity) must be unambiguously identified in Land Registration and consequently in the documents that are submitted for registration. In the blockchain the identification of a person currently is rather difficult. The technology was built *not*

[14] Twaroch, Ch. and Muggenhuber, G. (1997). Evolution of Land Registration and Cadastre; Case study: Austria, In: Lecture material Workshop F, JEC GI, Vienna p. F.3 - F.16 (p.5).

[15] Kurandt, F. (1957). Grundbuch und Liegenschaftskataster [Land book and parcel cadastre], Sammlung Wichmann, Band 18, Berlin: Herbert Wichmann Verlag (German)

[16] Henssen, Jo (1995). Basic principles of the main cadastral systems in the world, In: Modern Cadastres and Cadastral Innovations, Proceedings of the One Day Seminar in Delft on May 16, 1995, FIG Commission 7 and University of Melbourne, p. 5-12

to share these data with the participants in the blockchain. In the blockchain, the object is expected to be a digital asset. The goal of the blockchain is to create digital value by solving the double spending problem. In land administration, the object is physical in nature. Registration is in many countries related to identification of a spatial unit (based on boundaries) in the field – by means of surveys, identification on imagery or based on textual descriptions. Therefore a mapping between the physical objects and the objects in the administration must be created and maintained. This does not seem to be standard in the current generation of blockchains. Who will identify the persons involved (or issue a digital identity, preferably by issuing qualified electronic signatures) and who will map the physical and digital object? This person, organisation or entity has to take responsibility (and therefore liability) in case there is no match. This responsibility is only of value when responsibility implies liability.

2. Booking principle: until the change or the expected right is booked or registered in the Land register, the change in real rights on an immovable property is not legally effectuated. The blockchain logs all validated transactions in a sequence. This means the system can be fit for checks on ownership, titleholders and so on in many, yet not all, cases. This means blockchain possibly can be in accordance with this principle. It is a matter of filling the empty first stage with assumptions which everybody can agree on. In title systems the certificate of inheritance has to be recorded prior to the contract of sale (or deed of transfer). This is not necessary in a deeds system. Not knowing who the heir(s) is (are) or a contract of sale or a deed of transfer signed by the heir(s) may lead to problems in case of a fully digitized process of transfer.[17]

3. Consent principle. This principle implies that the real entitled person who is booked as such in the Land Register must give his consent for a change of the inscription in the Land Register. Using a blockchain based Land Registry system, this principle possibly can be met, since the owner of the asset has to sign the transaction in the blockchain, before it is uploaded to the network and put in a block. Note: First the owner of the asset has to be identified. Secondly, it is questionable whether digital signing by the owner is enough for consent. In some cases, it is difficult to decide whose consent is necessary. Based upon the information available in the blockchain this might even be impossible, especially in situations where people (the owners of a plot) are mislead, deceived or forced to participate in a transaction. In many countries a middleman (Notary or licensed

[17] This is also the reason why the in chapter 5 mentioned system of stylesheet-based deeds in the Netherlands cannot be processed automatically.

conveyancer) is introduced to prevent misuse of the weaker parties. By using blockchain technology it is stated that the role of the middleman is diminished.

4. Principle of publicity: this principle implies that Land Registers are open for public inspection (in some Land Registry systems inspection can be done by anyone, in other systems only by persons with a legitimate interest). There is third party protection, a protection by law, for third parties in good faith. A blockchain is a shared database that logs all validated transactions in a sequence. It is a public register that is not to be changed and therefore indisputable. It is a '*shared single point of truth*', trusted by the users, but there is no third party protection.

In the "Torrens System" there a division of principles related to the registration of titles. These three fundamental principles, identified by former chief land registrar, Theodore Ruoff [18] are:

(i) the *mirror principle.* It states that the register of title is a mirror that reflects completely and accurately the current facts pertaining to the title. It reflects ownership and requires all rights to be registered. Although, in Land Registries sometimes there is a 'crack in the mirror' because of certain third-party rights (or 'overriding interests') that may affect a piece of land even though they are not registered and because in some cases unenforceable or obsolete rights continue to be registered. These specific situations can only be put on a blockchain in case they are identified. This means that all possible situations should be recognized and put into computational code (smart contracts).

(ii) the *curtain principle,* which means that the buyer can rely on the content of the registers and does not need to assure himself whether there are specific elements that are not shown. He or she does not need to investigate trusts and equities or search behind the title as depicted on the register. In case of a blockchain based Land Registry system meeting the curtain principle is only possible when the transactions are put on the blockchain by a (group of) person(s) who is/are designated to upgrade or enrich the content to a certain level of trust. This means the introduction of a Trusted Third Party or a Middleman, while blockchain was meant to replace these Middlemen.

and

(iii) the *insurance principle.* Anyone who suffers loss because of a wrong reflection of the title through human frailty, must be put in the same position, so far as money can do it, as if the

[18] Ruoff, T.B.F (1957), *An Englishman Looks at the Torrens System,* Law Book Co of Australia, 1957, p.8.

reflection were a true one. In other words, the accuracy of the register is guaranteed and any person who suffers loss as the result of the inaccuracy is indemnified. In blockchain based systems there is no guarantee or compensation. The only means are the contribution of each of the participants; there is no insurance against mistakes or malfunctions.

4. BLOCKCHAIN

In 2008 an a paper[19] was published on The Cryptography Mailing List at metzdowd.com by a (group of) member(s) under the pseudonym[20] Satoshi Nakamoto, describing the bitcoin digital currency. In 2009 the first Bitcoin software was launched. Although the real identity of Nakamoto is still not known, the used technique is open source. That is the reason why it does not seem to be very important who Nakamoto really is[21], although Nakamoto owns a *wallet* containing roughly one million bitcoins.[22] This used technique is called blockchain technology. It is often said banks, governmental parties, Chambers of Commerce and Land Registry authorities will be challenged (or even be replaced) by this 'disruptive technology'.[23] Various interested professional parties[24], including banks[25] and Land Registry organisations[26], are examining and exploring the possible practical use of this technique.Changing or liquidating an

[19] The text of the original publication, "Bitcoin: A Peer-to-Peer Electronic Cash System", can be found here: https://bitcoin.org/bitcoin.pdf (Last accessed on March, 2. 2017).

[20] S., L. (2 November 2015). "Who is Satoshi Nakamoto?". *The Economist explains* (The Economist), Davis, Joshua. "The Crypto-Currency: Bitcoin and its mysterious inventor.". *The New Yorker*.

[21] A brief overview of articles and other sources, conducting research on the identity of Nakamoto can be found at https://en.wikipedia.org/wiki/Satoshi_Nakamoto (Last accessed on March, 2. 2017).

[22] Owning a wallet with this amount of bitcoins could form a risk. Since it is such a high percentage of the total amount of bitcoins, the owner of this wallet could influence the value by selling the whole package of bitcoins.

[23] Although the technology is described as being disruptive, the used techniques themselves are not new. The technology exists of a mixture of five elements, that are already existing since the `70`s, `80`s and `90`s of the previous century. Yet, no one had combined these techniques in this particular way. The novelty is its architecture and the design characteristics that make it work.

[24] For example, the US state of Vermont is testing a blockchain to store government records, while the central American nation of Honduras is testing a blockchain for property transactions.

[25] The most well-known initiatives initiated by financial institutions is the R3 consortium, see: https://r3cev.com/ (Last accessed on March, 2. 2017).

[26] Amongst others, Sweden, Georgia, Honduras, Ghana and Chicago`s Cook County, are developing, testing or creating a blockchain-based Land Registry.

organisation is not a matter of but introducing new technology. Changing or replacing an organisation is also a matter of policy, governance, legislation and insurance.The blockchain is a type of distributed ledger that records transactions between parties, without the need for a trusted third party or trust within the group. All transactions of a certain time period are stored in a block and connected (chained) cryptographically to the previous block. This makes the ledger resistant to change or tampering and therefore insures that all parties can trust the history as recorded on the blockchain. Business rules ensure that only valid transactions are stored on the blockchain, ensuring that parties can trust the contents of the blockchain [27].

The aim of the blockchain is to ensure the digital transfer of value from one party to another. One of the problems of digital information is that it can be copied: when someone has a music file and sends it to another person, both persons have a copy of the music file. For the sharing of information this works just fine, although there is no licence and the artist[28] does not receive any payment. When it comes to the transfer of value, it can´t be copied (easily). When someone gives a certain amount of money to another person, it isn´t enough for this person to receive a copy of the money, the ownership of the money must be transferred. The traditional way to solve this is to have a trusted third party, who keeps track of the money: mostly a bank. The blockchain solves the problem of double spending by keeping an immutable ledger of all transactions that is available to all participants in the network. The software ensures that all transactions are checked by all participants in the network. This is a ´consensus mechanism´ of checking transactions. When the majority of the network agrees with a certain transaction, it is executed. This process is automated with open source software, so all participants can check the software but do not have to check each individual transaction in person.

Having a consensus mechanism makes to blockchain invulnerable to localized attacks. No single participant can influence the blockchain by changing the stored transactions or by validating invalid transactions. To be able to do so, one has to have control of the majority of the network. In general[29] this is prevented in public blockchain applications since decentralized storage of information is done by every node on the network. Each node maintains and continuously verifies a complete copy of all transactions. In private

[27] See: https://www.forbes.com/sites/bernardmarr/2017/01/24/a-complete-beginners-guide-to-blockchain/#23fd1326e607, https://en.wikipedia.org/wiki/Blockchain_(database), https://hbr.org/2017/01/the-truth-about-blockchain

[28] That is also why some artists are starting a pilot, publishing their new songs on the blockchain. See: https://ujomusic.com/ and http://rightsshare.com/?tag=blockchain, regarding the inefficiencies in the music industry.

[29] In theory it is possible to influence the functioning of the blockchain or the value of the digital asset that is transferred by using the blockchain. In case of a majority of minors in a specific region or country, it would perhaps be possible to delaying transactions.

blockchain[30] applications validating transactions is done by one party or a group of parties. Because of the poor number of *nodes*, the validation rules can be adjusted easily. In case there is only one entity using the technology, consensus is met in an instance. This makes the system very flexible. In case there are more parties using the blockchain, the consensus mechanism can be used to harden the blockchain against hackers. The consensus mechanism makes sure hackers must hack more than half of the parties to gain control over the blockchain.

Consensus mechanisms

There are several types of consensus mechanisms [31] in use in different blockchain applications. The original consensus mechanism used in Bitcoin is called ´Proof of Work´. This mechanism relies on a combination of consensus and mathematical puzzles, making it computationally hard to validate transaction. This makes it expensive to add validators or ´miners´ to the network and therefore limits the chance of a 51% attack. The downside is that it makes this consensus mechanism expensive. It has been calculated that the blockchain network consumes the same amount of energy as a small country, even if it only processes 300.000 transactions per day [32].

To solve this problem other blockchain networks use other consensus mechanisms. In general, these mechanisms use less energy but also make the network less resistant to attacks. This is solved in two ways: by increasing the stake of the participants in the network or by controlling who can validate transactions. The first option leads to a ´Proof of Stake´ type of consensus mechanism. This mechanism gives participants with a bigger stake in the network a bigger vote when validating transactions. The reasoning is that if you have a lot of assets in the network, you want to protect these assets by ensuring the trustworthiness of the network and therefore you will validate transactions correctly. In a proof of stake model, it is not the number of computers but the size of the stake that defines the consensus. Because of this, these networks generally use substantially less computing power and therefore less energy.The downside of this type of consensus mechanism is the (possible) control of a limited (group of) entities with a large share (stake) in the network.

[30] More extensively on the possible use of private, public or hybrid blockchain in Land Administration systems, see: J. Vos, *Blockchain-based Land Registry: Panacea, Illusion or something in between? Legal interference of Registrars in the e-conveyancing process*, in ELRA, 7th Annual Publication, available via https://www.elra.eu/publications/elra-annual-publication/ (last accessed on March, 2., 2017).

[31] See: https://www.linkedin.com/pulse/consensus-mechanisms-used-blockchain-ronald-chan

[32] See: http://motherboard.vice.com/read/bitcoin-could-consume-as-much-electricity-as-denmark-by-2020

Several other mechanisms rely on methods that are less computationally intensive. This makes it easier to validate transactions but, as a side-effect, it makes it easier to attack the network. This is countered by making the network private and controlling who can validate transactions. Because the network is no longer public, it is argued that these methods introduce a Trusted Third Party into the system: the party that can grant access to the network. This is a valid concern. The resulting situation can still have benefits in comparison with the classical situation where the ledger is not distributed and transactions are validated by one party. Because the ledger is distributed and validating transactions is done by multiple parties, the network is more resilient to attacks from the outside and fraud from within one party in the network.

Vulnerabilities of the blockchain

In the past, we have seen several types of hacks of blockchain based applications. Even though the blockchain itself has not been hacked, there have been incidents that have had impact on the trustworthiness of the administration by allowing transactions to be recorded that were not approved by both parties involved.

51% attack

The main attack vector for the blockchain itself is the 51% attack, although this has never been successfully executed. This attack is a theoretical possibility that once one party controls 51% of the miners in the blockchain network, this party validate or invalidate transactions at will and may even be capable of rewriting past transactions. Recently, a scheme has been published, that can accomplish more or less the same by isolating part of the blockchain network [33]. This balance attack by a messaging delay is also a theoretical option, but may be easier to accomplish and exploit. When the mining power gets concentrated into a small set of participants, blockchain might not be as resilient to against mistrust as was intended.

Private key

In practice, attacks have not been aimed at the blockchain itself, but at the edges of the system. In the current generation of blockchains, assets that are stored on the blockchain can be accessed by using a cryptographic key. That means that ownership of the assets on the blockchain is defined by ownership of the key. Several

[33] See: https://www.theregister.co.uk/AMP/2017/01/16/boffins_balancing_miners_borks_bitcoins/

attacks have been aimed at these keys; if you can steal someone's key, you can control his assets on the blockchain. A related problem is that if you lose the key, you will lose control of your assets. To be able to use the blockchain more widely and reliably, connecting assets on the blockchain to verified digital identities is paramount. We expect future generations of blockchains (have) to accomplish this.[34]

In simple domains, like the bitcoin, the blockchain uses a simple, universal validation function. Basically: if you have enough money in your account, your transaction validates. In a lot of other applications, most notably land administration, the validation function for transactions is much more complex and can be specific for individual transactions. To be able to handle these types of situations, smart contracts are added to the blockchain. A smart contract is a piece of code that defines under which conditions a transaction can take place.

Smart contracts

Because these smart contracts can be quite complex and difficult to fully comprehend, they may introduce vulnerabilities into the system. A notable case where such a vulnerability was exploited, was the DAO hack .[35] This hack resulted in assets being transferred to another account, without the necessary consent. In a way, the system worked correctly as it was coded. But it didn´t work as designed, because the transactions were not approved in the way it was intended.

This DAO hack is not only interesting because of the hack itself, but also because of what happened afterwards; it sparked a debate on the question whether these unwanted transactions should be reversed or not. Reversing would mean tampering with the blockchain and in a way not very different from the 51% attack: the majority of the community had to implement code to change the blockchain in a specific way, removing the offending transactions. Another opinion was that the blockchain itself worked perfectly fine and that the users of the faulty smart contract should take their losses as they had agreed on using the smart

[34] Comparing blockchain with the internet, as blockchain is seen many times as the 'next internet', both technological inventions do not solve the lack of proof of authenticity (in all cases). On the current internet people do not trust their counterpart in all cases. Once they exchange additional attributes or (qualified) electronic signatures that are inseparably linked to individuals, there is (more) trust. This is no different than the blockchain; once digital identities are created on a high level of trust, blockchain will be more trustworthy. Perhaps biometrics can help to enhance confidence and assure this way of transferring ownership of (digital) assets. Using a token (creditcard/ USB device), combined with a password and a iris recognition could help to solve the uncertainty and low level of trust.

[35] http://www.coindesk.com/understanding-dao-hack-journalists/

contract themselves and could have been aware of the vulnerabilities. Eventually, this led to a fork[36] (split) in the blockchain. One group uses the blockchain as it was after the hack, the other group has repaired the transactions. Even though this split seems to work, it would be devastating if something like this would happen in land administration.

Lack of Governance

The DAO hack has also unearthed a governance problem. During the hack, nobody had the authority to stop what was happening. Since the blockchain is a distributed system, nobody has control of the system. There was no emergency scenario to defend the system from this hack. The hack itself has been active for several days before the community finally agreed to close down the system entirely. After that, the system has been down for a period of time, while the community discussed the solution to be implemented. This type of governance by consensus may be very democratic, but is also ineffective in case of emergencies as this example clearly demonstrates.

Different concepts

The blockchain introduces several concepts and combines these to create a new way to ensure the validity of transactions:

- the organisation of trust. The blockchain creates trust by decentralising the processing of transactions and creating transparency about this process. In our current society, we organise trust by creating trusted parties that we trust to process transactions and implementing checks and balances by other trusted parties. These are fundamentally different ways of organising trust in a system. Note that in most systems, there is more trust than what the blockchain provides. E.g. the bitcoin has no central authority managing the value of the currency, while for most national bank backed currencies this is the case and we can trust this system to keep the value of the currency relatively stable;
- a design concept. The blockchain using a network based design instead of a chain based design. The basic approach of the blockchain is that all nodes in the network have the same information and consensus defines what the new status of the network is. In traditional chain based design, at

[36] A more detailed description on this matter and a closer examination of the principle of a 'fork', see:

any moment one party in the chain is in the lead and knows the current status of the process is and decides what must be done next. This one party decides what the next step is. And:

- a technological concept. The blockchain combines and orchestrates several technologies in a specific way, to create added value different from what other systems can do. To create functionality like the blockchain in a more traditional way, is possible, but is also difficult and expensive. Even though the blockchain technology isn´t mature yet, the expectation is that the technology will be a standardized and easy to use solution in the future.

Bitcoin is the first and most known application of blockchain technology. It combines all three characteristics, it diminishes the role of the traditional banks and it ensures that the reliability is organised into a network and it provides a technological solution.

Blockchain characteristics

Blockchain (technology) has the following characteristics:

- shared databases: a blockchain is a shared database, copied on multiple databases that are all connected to each other. In the world of Land Registry it is common to use one source, one database with some back-up facilities;
- multiple writers: in a blockchain each and every transaction can be put in each version of the database. In the world of Land Registers, the transaction is updated in only one system. A copy of this transaction will be recorded in the back-up systems;
- distributed trust: unlike existing Land Registry systems where the administrator is trusted, you don`t need to trust the administrator of a copy database. Blockchain is also described as ‘shared single source of truth’;
- disintermediation: it is possible for anyone to keep a copy of the database and execute a transaction on that database. In the current Land Registry systems there is always a trusted third party that updates the registration;
- transaction dependency: in a blockchain it is possible to create a dependency on another transaction. The blockchain can monitor the fulfilment of this dependency;
- timestamping: in blockchain it is possible to securely keep track of the creation and modification time of a document or transaction. No one, not even the owner of the document, is able to change the (content of the) document or transaction once it has been recorded, provided that the integrity of the timestamp facility is never compromised;

- transaction rules: to prevent any undesirable transactions taking place, blockchain can check whether the transaction is valid or not. In traditional (Land Registry) systems the Trusted Third Party is monitoring the validity of the transaction.
- validation: blockchain logs all validated transactions in a sequence. It is a public register and unchangeable and therefore indisputable. In current Land Registry systems all transactions are part of a ledger and are traceable using an audit trail of some kind (validation); and:
- scalability: the Blockchain is easily expandable. Everyone who would like to upload a transaction on the blockchain can do so.

Anand et al[37] recognize (most of) these characteristics as applications in the context of land administration, although there are limitations to the use of blockchain technology in land administration. As Anand et al, we address many of the potential applications of blockchain by using existing and easy available technology 'for land information management combined with improved governance and better standard information technology (IT) practices'.[38]

The technique of Blockchain

The beginning of this 'history of transactions' is a first block which is called the *Genesis-block*. This first block is basically an empty state which everyone can agree on. This block (and all the transactions that are made afterwards) is saved in the 'database'. The database is shared on various computers that are linked ad random to other computers. These computers are called *nodes*.

Once a transaction is created, it is broadcasted through the P2P-network by using the nodes. Because of the P2P-technology it is very difficult to find out who sends the transaction. This is where the technology differs from most registrations: trust is not needed (at this stage), the technique itself will bring trust by mining the transactions. The transaction will be added to a pool of pending transactions. Because of the

[37] Anand, A. (2016, March 17), McKibbin, M., Pichel, F., *Colored Coins: Bitcoin, Blockchain, and Land Administration,* from www.conftool.com%2Flandandpoverty2016%2Findex.php%2FAnand-594-594_paper.pdf%3Fpage%3DdownloadPaper%26filename%3DAnand-594-594_paper.pdf%26form_id%3D594%26form_version%3Dfinal&usg=AFQjCNF6uSaWC4dhkbX73QG3MuOEndBY6w&bvm=bv.147134024,d.d2s

[38] Ibid, p. 3.

(bitcoin)protocol the balance of the wallet cannot be retrieved at once. For this, older records in the blockchain have to be collected.

Blocks that are containing pending transactions are created approximately every ten minutes. It is done by creating a *hash* value on the pool of transactions. This is called *mining*. When adding a block to the network an order to the various transactions within the block is established and a cryptographic signature is added to the block. A cryptographic signature has two main characteristics. Both are critical to the security of the database. First of all, the signature establishes a link to the preceding block. The second important characteristic of the signature is the non-repudiation: if the order or a transaction itself within the block would change, the signature will not be the same any longer. This will be noticed within the network that encompasses this block. If any transaction in a block – or perhaps in the Genesis-block –changes, the signatures from all blocks following that change will also be(come) invalid. This means that blockchain establishes an unchangeable permanent record of changes to the database.

When a new *node* appears in the network, it connects to the other *nodes*. These existing nodes update that new node with the history of the database, so the new node is capable of presenting the history of all transactions, coming to the same conclusions as all other nodes in the network.

The opportunities of Blockchain

It is known that the number of bitcoins is limited to twenty one million. Each bitcoin contains one million units (bits). Each *bit* is separately identifiable and programmable. That means every unit can be given specific properties. So, in theory it is possible to use the Blockchain technology for trading in Eurocents, in shares of companies, in Kilowatt of energy or votes for elections.

It is also possible to 'smarten' these specific units (e.g.: to employ the vote during elections for 2016 or to pay with the bits only for repaying tax debts). In such a case compliance will not be verified afterwards, but it will be programmed *in* the units and the system itself and therefore compliance can be checked in advance. It is also possible to program the units to automatically return to the issuing authority in case the unit is not used. One example could be sending back an unused vote during elections, in order to prevent misuse or incorrect counting.[39] Furthermore it is possible to use the technique for earmarking the money (e.g. in case

[39] Although, in theory – depending on the (political) system and its developers (in specific countries) – the voting ballot perhaps can also be programmed not to considered valid in case the vote has been used in favor of the opposing candidate.

a grant is awarded by the European Commission or in case taxes have to be paid). This can save a lot of overhead costs.

The programmable and open nature of Blockchain allows to rebuild or innovate the financial or administrative processes. Processes can be made more efficient and more transparent.

5. BLOCKCHAIN AND LAND ADMINISTRATION

Now that we have described the Global Requirements for Land Administration (Chapter 2), the Land Registry principles (Chapter 3) and the technology of Blockchain (Chapter 4), it is time to combine all of these elements and to find out whether blockchain may be of help in or possibly can replace existing Land Administration procedures.

Content of the Land Administration blockchain

It is important to recognize how transactions are stored on the blockchain. Will this be done by putting a document (depending on the legal system this might be a contract of sale or a deed of transfer) or can it be 'just' a small set of data? In some systems, the (licensed) conveyancer is allowed to update the Land Register by updating information/ putting new data in the system. In such a system, it is advisable to introduce certification requirements.[40] In most Land Administration systems currently a deed has to be sent to the Land Register. Depending on the system, this deed will be scrutinized for any substantive failures (title system) or for formal requirements (deeds system). After acceptance of the deed, the deed will be recorded and/ or the Land register will be updated with the essential data from the deed. In a title system the deed itself has only limited value, the essential data will be put in the Land Register. In a deeds system, the deed itself is of importance to examine the legal status of the registered object. For this reason, the data (the contract or deed) cannot be encrypted, since it will not be readable for the persons taking an inquiry.
Because of computational limitations it is questionable whether the complete Land Administration can be stored on the blockchain. Putting large documents (deeds) on the blockchain does not seem to be possible. Storage of data in a transaction on the blockchain is limited. Even if it is possible to store a complete contract on the blockchain, it will have a negative effect on the availability and performance of the blockchain. Therefore, the use of data with regard to the transaction does seem to be the best option right now. To

[40] See Rod Thomas, 'Fraud, Risk and the Automated Register' in David Grinlinton (ed), *Torrens in the twenty-first Century* (2003), 349, 366-367 and Thomas, Rod, Low, Rouhshi, & Griggs, Lynden (2015) Designing an automated Torrens system — baseline criteria, risks and possible outcomes. New Zealand Law Review, 2015(3), pp. 425-453.

prevent any tampering, this data should include the hashes (or pointers) of the actual contracts or deeds. If only these hashes are put on the blockchain, the original contracts should be kept safe on aa system that (still) cannot be altered. It is advisable not to store the document on a single database, since this database can or will be proven the weakest link. In future the database might be corrupted, broken or tampered with. For storage (and sharing) purposes there are permanent and decentralized methods of storing and sharing files. The InterPlanetary File System (IPFS)[41] is a distribution protocol, where nodes in the network form a distributed file system.

Actual and complete information

Once a transaction is stored on the blockchain, it is part of the (public) information. People have to rely on the information on the blockchain. It is important to present the current and complete situation with regard to the owner and the (various) right(s) with regard to an object. There is a risk of presenting information that does not represent the actual information. This can be the case during the *mining*-process. This process may take up to ten minutes. A more time-consuming uncertain period of time is the situation of a *fork*. In such a case there is uncertainty about the title-holder, since there seem to be multiple title-holders at the same time, until the fork-situation is solved. In a 'classical' well-functioning Land Registry system there is certainty after the document has been received and the time-stamp has been placed.

To introduce a Land Registry blockchain in a country with a well-developed Land Registry system, it seems necessary to know and incorporate all existing *rights in rem* and all existing Land Registry objects in the first block, the so-called *Genesis* block. If not all rights in rem and objects are incorporated in the system, there is no possibility to represent the actual situation with regard to the objects and *rights in rem* concerning all immovable objects.

There should be consensus (in some way) about the content of the Genesis block. This means that, in case of a public Land Registry blockchain used by everyone (and not solely by Registrars and other professional parties), there should be consensus on the current situation. With regard to filling the Genesis block, existing and well-functioning title systems and Torren`s based Land registry systems would perhaps seem to be more fit for using the blockchain technology. In case (such) a Land Registry system is not complete – in many countries there are still first entries to be made – the blockchain might perhaps be less suitable. In those cases it can only be used for the registered parts of the parcels and objects. Of course there is the possibility to divide the content of the Land Registers into smaller units on a geographical basis (eg. Villages

[41] See: https://en.wikipedia.org/wiki/InterPlanetary_File_System (Last accessed on March, 2nd. 2017).

and cities[42]), on the basis of the various rights in rem[43] or any other way of division (eg. cables and pipelines in the soil or apartment rights or condominium).

Data Retrieval

Once all transactions and data are put on the blockchain, for transparency and publicity purposes, it seems advisable to create the possibility to have multiple search entrees. In most Land Registry systems it is possible to have an inquiry by using the parcel identification number, the name of the title holders, the address (if present) of the parcel or building or by using the Cadastral map. This may be one of the most complex elements or possible issues a blockchain based Land Administration pilot system has to overcome. Depending on the way the content of the Land registers is divided, each (sub)division perhaps could (or even: should) be put in a new blockchain, some kind of a sidechain to the 'parent chain'. The parent chain could deal with (information regarding) transfer of ownership of a Land Registry object, where sidechains could be used for realising apartment rights or for the transfer of other *rights in rem*. In a sidechain it is possible to transfer an asset from the (original) parent chain to a sidechain, possibly onward to another sidechain, and eventually back to the parent chain, preserving the original asset.[44] In Bitcoin terms: a bitcoin (in a sidechain) would remain a bitcoin (as derived from the parent chain), since any coin moved from Bitcoin could be moved back. Sidechains are able to support their own asset (eg. 'Eurocoin').

The use of sidechains would make it possible to divide a parcel (parent chain) into a set of apartment rights (sidechain). It would also make it possible to move back the object in the sidechain (apartment right) to the 'parent chain' (parcel), as an apartment building may be restructured or a usufruct or lease may end under specific circumstances (eg. death or passing of a period of time). The parcel (parent chain) cannot be changed or sold, since it is being preserved. It is 'locked'. This also seems very useable in Land Registry matters, since a building cannot be divided into apartment rights in case it already has been divided into apartment rights. If one or more of the existing apartment rights should be subdivided into new apartments, there should be created a new sidechain with regard to the original apartment right(s) that now will be subdivided. Another possible solution could be the use of colored coins.

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[42] As is the case in Honduras, where it is (or was) planned to begin recording land title records on the blockchain by organizing a proof of concept for La Ceiba, the fourth largest city in Honduras. The most actual status is presented at http://www.coindesk.com/debate-factom-land-title-honduras/ (Last accessed on March, 2. 2017).

[43] Although the division on the basis of the various rights in rem does not seem to be suitable, since it should be possible to divide ownership in 'bare ownership' and usufruct, a building right, a lease or any other existing right in rem.

[44] Back, A. (et al) (2014), p.6.

In a country where there is no *numerus clausus*, the introduction of a Land registry blockchain might even be more complex. In such a system new *rights in rem* can be created. Those specific rights should then perhaps be put in another sidechain. Another possibility might be the possibility to smarten specific units within the blockchain.

The Accuracy of the data

Blockchain is meant to 'eliminate' the use of a Trusted Third Party. "It offers a way for people who do not know or trust each other to create a record of who owns what that will compel the assent of everyone concerned. It is a way of making and preserving truths."[45] But what is to be trusted if the person who stores the data or transactions on the blockchain is not known, not trusted or does not have the (legal or geodetic) expertise that is needed to fulfil the transfer of ownership of an immovable? What if parties themselves transfer ownership? This can only be the case either if there is enough trust between the parties or there is enough trust in blockchain technology and smart contracts.

A man-in-the-middle, a Trusted Third Party, is still needed. We need trust to believe that the deed is a correct legal representation of the agreement, that buyer and seller are who they say they are and have the funds to execute the transaction. The data of the transaction, of the deed or contract should be extracted and put on the blockchain in a correct manner. Once this is not the case, the question arises who will be liable if something went wrong during the process of extracting or storing the data.

In some countries the parties have to show the surveyor the new boundaries (the Netherlands), in other countries it is the surveyor who shows the parties the exact location of the boundaries (Poland). In some countries it is possible for the parties to record the new boundaries all by themselves. In future, once the accuracy of Global Positioning System (GPS) combined with the use of smart phones will be more accurate, it might be possible to create exact boundaries with a high(er) accuracy.[46]

We need to trust that all steps in the process are executed properly and that officials involved will testify reliably in a court of law if things go wrong. Some elements and perhaps even the whole process of transferring ownership is possible by using smart contracts on a blockchain based Land Administration system. Yet, it is questionable who is able to recognize the (amongst others) legal effects of a transaction

[45] http://www.economist.com/news/briefing/21677228-technology-behind-bitcoin-lets-people-who-do-not-know-or-trust-each-other-build-dependable

[46] For example, GPS-enabled smartphones are typically accurate to within a 4.9 m (16 ft.) radius under open sky, but the accuracy will decrease near buildings and trees. See: van Diggelen, Frank, Enge, Per, "The World's first GPS MOOC and Worldwide Laboratory using Smartphones," *Proceedings of the 28th International Technical Meeting of The Satellite Division of the Institute of Navigation (ION GNSS+ 2015)*, Tampa, Florida, September 2015, pp. 361-369.

once it is stipulated (coded) in a smart contract. As was made perfectly clear by the DAO incident, it is not (always) easy to see through the code that is used in a smart contract and recognize the (legal) effect of the smart contract. It is the question who is able to connect the real world (the object itself, the parcel and its boundaries) with the digital world (the unique identification number and description of the object or the parcel).

Blockchain will not change a legal system

A Land Registry system cannot be changed from a deeds to a title or Torren`s system or vice versa by introducing a blockchain-based Land Register. It will not bring any changes in any system. What goes in, will come out. In case blockchain will be used in a deeds system, there will still not be issued any title by the Registrar. In case of a title system the title will be transferred by using blockchain; the title will not get lost.

Blockchain technology will not improve legal certainty with regard to the content and legal meaning of the first block. In a case where there is uncertainty with regard to the title holder,[47] blockchain will not bring any changes. Improvement of the quality and the completeness of the Land Registers can be realised by recording new transactions and/or – depending on the legal system – titles in the subsequent blocks or by uploading new transactions in the first block. This is similar to a 'classic Land Registry system': by recording new deeds or transactions, the Land Registers become more accurate and give an actual overview of the current state of play.

Complex transactions

In quite ordinary cases it seems very admissible that blockchain can be of great use and possibly replace the current activities of trusted third parties or middlemen. Once a transaction is more complex, this might not be the case. Content keeping and the provision of information are global requirements and (therefore) of the utmost importance for Land Administration systems. Once not all information can be stored, the Land Administration system will not function properly. It is without doubt that there should be no difference between (information with regard to) ordinary or complex Land Administration cases.

It is therefore advisable to examine whether it would be possible to have an intervention by an 'Oracle', an expert in the field of Land Administration, in complex cases. This expert will not intervene when a smart contract can auto-execute itself, but will take over in case the smart contract cannot be executed without

[47] eg. prescription cases that are not registered, disputes on boundaries and deceased persons where the heirs did not register a certificate of inheritance.

the (legal or geodetic) help of an expert. The distinction between a simple and a complex case, although hard to make, might be a solution to prevent very complex computerization processes.

In many cases there are preconditions that are of importance in the process of the transfer of ownership. It could be the spouse or co-owner who has to give consent to the selling of the marital property[48], the dissolving condition of funding or any other precondition parties agreed upon (transferring ownership, free of mortgages, seizures and other burdens). In a 'classic Land Registry system' it is the task of (both) the licensed conveyancer/ Notary (and/) or the Registrar to check whether the preconditions have been elaborated or not. In a blockchain system this scrutinizing of the deed will not take place by a person. It has to be done by the system itself. Within the blockchain infrastructure 'each *node* acts as a title registry and escrow, executing changes of ownership and automatically checkable rules governing those transactions, and checks the same work of other nodes'. The code is the contract or code is law. As we have seen during the DAO-hack, a flaw in the contract can cause a lot of (legal) uncertainty, especially when there is no Trusted Third Party involved who is entitled to resolve the dispute. In the Netherlands we have tried to automize the updating of the Dutch Land Registry. By using so-called stylesheets in the Dutch Land Registry system (since 2008), scrutinizing of the deeds, fulfilling the checks and requirements for registration purposes and to a certain extent checking on meeting specific conditions is done in a different kind of way, but with the same result. One might say that these stylesheets are also smart contracts (the code, with certain preconditions, to transfer ownership). It is only since 2016, after 8 years of hard work, that we receive half of the deeds in a way that we can update the Land Register automatically. It is estimated that this percentage could increase to 70 – 75 % of all deeds. The rest of the transactions are (supposed to be) too complex to automize. It is our assumption that this will also be the case in a blockchain based Land Administration system.

6. ONE STEP FURTHER

By taking a conceptual step in thinking, it is possible to move from bitcoins being transferred with blockchain technology to bitsquares being transferred by blockchain technology; squares of land replace coins as the units of transaction. Each square has a unique ID and the rights holders are now in a blockchain

[48] As is the case in the Netherlands, resp. article 88 of book 1 of the Dutch Civil Code (art. 1:88 BW) and in some specific cases article 175 of book 3 of the Dutch Civil Code (3:175 BW).

environment. Transactions on the land market can be followed visibly and openly in the blockchain. It is possible to identify illegal transactions for those areas where a land market does not exist – in case of customary tenure or in case of protected nature areas, for example. All this can be published in a completely transparent way to the world.

What3words[49]s is such a system: a grid that divides the world into 57 trillion 3m by 3m squares of land, each with its own unique three-word address. The related geocoder turns geographic coordinates into these three-word addresses and vice versa. The use of words means that even non-technical people can accurately find any location and communicate it more quickly, more easily and with less ambiguity than any other system based on street addresses, postcodes, latitude and longitude coordinates or mobile short links. There may of course be some georeferencing problems in overlapping conventional parcel representations but these can be overcome with the right attention. The accuracy of the division of the world by what3words is limited to 3m by 3m squares. In most modern land administration systems this dimension does not seem accurate enough. Sometimes the price of a m2, combined with the surface area, is an essential part of the agreement. There are legal systems and traditions where people buy a plot of land to build their house and they pay a purchase price per m2. In some legal systems the surface area has to be measured prior to the transfer of ownership, in other systems this can (also) be done afterwards. In those cases the final purchase price will be deducted from the surface area. In a situation where the complete transaction is coded (smart contract) and put on the blockchain, there might not be a (technical) provision to transfer money or m2 after the transfer of ownership took place (and was therefore finalized).

A possible other conceptual step in thinking might be the possibility to address a unique ID to a specific right in rem that is inseparably connected to an object. This object might consist of a parcel (an amount of m2), a building, cables or pipelines or another right in rem. For example, the unique ID number A1B2C2D1XYZ541 would refer to the right of ownership, charged with a building right, with regard to a parcel sized 120 m2. Once a change is made with regard to any of the elements involved (the size of the parcel, a new right in rem is established charging the building right or the right of ownership, or the building right has ended) this unique ID will be changed to a new unique ID that will refer to the previous unique ID from which object the new object arose. Possibly the use of Colored Coins or the use of so-called Sidechains can be of help. Both of these technical novelties are created to add various divisions or different meanings to an asset.

[49] See: http://what3words.com/ (last accessed on March, 2., 2017).

7. BLOCKCHAIN BASED LAND ADMINISTRATION PROJECTS

The last couple of years, several initiatives around the world have started to create a blockchain based land administration. We have followed these initiatives and have been in contact with the various projects. Because there are some interesting differences in their approach, we mention some of what we know of these initiatives here.

a) Ghana / Bitland. Ghana and Bitland have been active creating a land administration in a blockchain based system. Bitland started from scratch creating a system and is using multiple blockchains for different parts of the process. The intention of Bitland is to create a land administration for several countries they are working with besides Ghana. Bitland is using all concepts from the blockchain (organisation, design, technical) to create an efficient land administration system.

b) Honduras / Factom. The land administration in Honduras is decentralised and suffers from unreliable processes and incompleteness of the administration. The Factom project is aimed at creating a more reliable land administration by introducing land administration software to all local land administration offices. The transactions administered in the decentralised software are also registered on the blockchain, thus creating a complete and nationwide audit trail or track&trace function. The blockchain is used mainly on the technical level, to create an easy to implement and reliable system.

c) Sweden / Chromaway. In Sweden there is no civil-law Notary involved I the process of transfer of ownership. Therefore buyers and sellers themselves of real estate have an important role in the transaction process. This process can take up to six months and, as is stated by the project, this is no longer acceptable. In order to speed up the process, without introducing a new organisation to orchestrate the process, the Swedish land administration office has looked towards the blockchain. They use blockchain based smart contracts to orchestrate the transaction. In this way, all parties involved have complete information on the transaction and at any moment in time it is clear who is responsible for the next step in the process. This eliminates friction in the process and reduces the chance that errors are made. The expectation is that this will reduce transaction time to days or hours, rather than months. This way, they use the blockchain both as a design and as a technical concept. Lantmäteriet and Chromaway did chose not to use bitcoin facilities. Instead, they created a system without consensus mechanisms (Proof of Work or Proof of Stake).

d) Georgia / Bitfury. In Georgia the first pilot was to ensure the archiving functionality of titles on the blockchain. The pilot reportedly was successfully completed. The focus of the pilot was to leave the paper trail and to secure the process of issuing a title on the blockchain. The second phase of the pilot will focus on the (possible) introduction of smart contracts. By using smart contracts Georgia will try to automize the

actual process of the transfer of ownership. Georgia and Bitfury chose to use bitcoin and therefore for a consensus mechanism.

e) Cook county / Velox. In Cook County the focus on the current blockchain pilot is to leave the current paper process. For transferring ownership, the property owner creates a blockchain title, using a Bitcoin Colored Coin. Some metadata is included (e.g. the Grantor`s name, the legal description of the property and specific rights in rem and exceptions or reservations). When transferring ownership, the system creates a colored coin, including the conditions and the name of the Grantee. Grantor and Grantee establish their identity by using the services of a Notary or an eNotary. Both do sign the contract electronically and the Notary notarizes the deed. The Grantor executes the conveyance by sending the colored coin to the Grantee.

In the above examples, only the Ghana / Bitland initiative seems to use the blockchain at the core of the land administration. The other pilot programs use blockchain for its archiving functionality, for a track and trace function or in order to orchestrate the process of e-conveyancing. The land administration itself seems to be handled by more traditional systems.

In our view this reflects the possibilities of the current generation of blockchain systems and the complexity of land administration. All projects see possibilities to extend the use of the blockchain in land administration, once the technology itself has evolved and the real estate transactions processes have been sufficiently standardized.

In our opinion it is possible to use blockchain technology for archiving of the transactions. By using this rather new technology for securing the content of the transactions (and underlying deeds) by putting (meta)data with regard to the transaction (and the deed) on the blockchain, the history of transactions that have been fulfilled is tamperproof. In countries where there is no reliable electronic system of transfer of ownership, blockchain might be useful, although the more traditional systems of a database (with back-ups and logging) may still be sufficient. Supplemented with authorization and authentication facilities, the content of these databases may even be shared with other parties that are involved in the process of conveying properties. Using existing and easy available technology combined with Good Governance might be working just as well. Parties that are willing to take a (small) risk, certainly can try to explore the possibilities of blockchain. In our opinion the use of blockchain, given the current state of Information Technology and the Dutch system of stylesheets, where all kinds of business rules are coded in a technical document by which the notaries can draft their deeds of transfer, cannot be guaranteed in all possible situations.

The second part of the process where blockchain might be of use is the issuance of titles (or property information). To prove you are the owner of a certain plot at a specific moment in time, it seems possible to issue a title of ownership, provided with a time-stamp and a qualified electronic signature. The evidential value of this document is as strong as the signature of the signatory. If this signature is put by a computerized system, it is as strong as the evidential value that is awarded to this system. If the signature is put by a Registrar, whose duty is to provide an undisputed title and who is liable in case of a mistake, the title holder can rely on the Registrar (and his insurance).

The part in between the process of archiving a transaction (or deed) and issuing information (or a title), is the most complex part: the registration of the transaction. In many cases this is done manually by the Registrar. Besides making (typing) errors during the manual updating of the register and the translation of the content of the deed into the register, depending on the conditions and measures to prevent these mistakes, it is certain that all transactions can be handled. In case of a complex transaction, it is questionable whether blockchain technology, using smart contracts, can process these transactions as well. It might be that some of the parties involved in the current pilots are fixated on the more basic transactions and rely on gradually learning during the iterative process of building smart contracts for land registry purposes. Possibly, some of these parties underestimate the complexity of the 'triple': right in rem, object and subject.

It may be advisable to try finite solutions rather than attempt to completely dislodge an existing system. The technology should deliver the same functionality (or more/ better) and must be easy to adopt, otherwise it will not expand or evolve towards a replacement of existing procedures. Key to put the registration activities on a blockchain would be the standardization of (all elements of) the various parts of the conveyancing process.

8. DISCUSSION

Looking at Blockchain technology, many of the Principles of Good Governance in Land Administration can or will be met. The elements of transparency and efficiency as well as the history of transactions (chain of title) is present. It serves the same functionalities as a sound Land Registry system: it knows who owns what at a certain time, it ensures single-ownership and it knows when a certain transaction took place. It is possible to 'track back' and therefore it should be possible to guarantee title.

Compared with a 'classic land registration system', blockchain may even provide some additional certainty. Because of the shared databases there is security of back-ups. Trust is added by cryptographic proof and a decentralised database, especially in the case the current administrator (Registrar) is not trusted. It might safe costs because of remediation of intermediaries (Notaries or licensed conveyancers) or administrators (Registrars). It therefore can be judged as an alternative for the classical Land Registers.

Because of its transaction dependency, in the Blockchain, it is not possible for a non-owner to transfer ownership. Checks on ownership using Blockchain technology are processed automatically, using transaction dependency and transaction rules, whereas in current Land Registry systems checks on ownership are executed by the Registrar, mostly by scrutinizing the deed and comparing this information to the content of the land register in person. That means that in the majority of cases the data of the seller mentioned in the deed is compared in person to the data of the current owner in the land register.

One of the exceptions[50] to this manual process is the computerized processing of deeds by using stylesheets, where the data with regard to the seller that is mentioned in the deed is automatically compared with the current owner as mentioned in the Land Register.

The introduction of standardised texts and clauses, combined with stylesheets, is a proven technique, although there some pitfalls exist and points of attention need to be taken into account.

In case of the implementation of a blockchain-based Land Registry system, one should not underestimate the complexity of the legal system, the meaning of the *rights in rem* (*numerus clausus* or not), the complexity and variety of different transactions and the proceedings of the legal professionals in the chain of conveying immovable property. Without standardizing (parts and elements of) this process, the complexity may be the threshold to success.

This complexity would even grow when a cross-border Land registry blockchain would be introduced. In such a case there should be an empty state which everyone can agree on. This empty stage would mean the objects are known and registered, the various rights in rem[51] are known and registered and there is an

[50] Or perhaps the only exception.

[51] As is experienced during the IMOLA project (see: www.elra.eu/imola) it seems possible to realize a European Land Registry Document. This document will consist of a common structure for Land Registry information,

agreement on (differences between) common law and civil law principles and causal and abstract systems. At this moment it is not sure whether all preconditions can be met. One of the possible risks is the transaction speed, especially since in the current Dutch Land Registry situation a deed of transfer can be processed completely automatically, without the interference of a human, in tenths of a second.

Sometimes technicians and other enthusiastic decision makers express their opinion that modern techniques can replace legal and geodetic professionals quite easily. Much progress is being made; the first blockchain based Land Registry pilots have started. Suffice it to say, but change is coming, although it is questionable how fast and to what result. Without the cooperation of legal and geodetic professionals, who indicate the legal and geodetic meaning and its implications, the use of blockchain might not be applicable in the right way and might even backfire in the absence of knowledgeable (legal and geodetic) council. Implementation of such techniques could result in unforeseen circumstances .

To implement the blockchain technology in Land Administration, one does need the legal and geodetic expertise of the experts in the field of (electronic) conveyancing. For drafting deeds this is the (licensed) conveyancer or the Notary, for updating the Land Register this is the Registrar and for the provision of boundaries it is the surveyor.

New (disruptive) techniques can be of (great) help in many cases, as long as it does not compromise the principle of checks and balances. For this, we need collaboration between all parties involved, who all would like to find incentives. This is the tension when talking about a disruptive technology that was developed to ‘eliminate’ certain parties in the process. It requires due diligence, care and circumspection, with a healthy sense of vigilance.

accompanied with a thesaurus, certain placeholders and factsheets. With this information one could compare rights in rem to a certain level and know what is the true meaning of a foreign right in rem.