Blockchain as a Technological Solution in Land Administration – What are Current Barriers to Implementation?

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Key words: land administration, cadastral systems, blockchain technology

SUMMARY

Many countries have started initiatives to improve their cadastral systems to better meet the current and future needs of society. Especially blockchain technology has drawn the attention of land administration society during recent years. In contrast to the current centralized cadastral systems, blockchain offers a possibility to create a decentralized and transparent database. However, a thorough investigation of the possibilities and drawbacks of the utilization of blockchain technology for registering cadastral information is still missing. In this paper, we conduct a literature review of the operation and features of blockchain technology. Further, we study potential benefits and barriers related to implementation of the technology using a qualitative approach. Our findings indicate that at least technical, social and juridical barriers exist.

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1. Introduction

A common view is that a cadastral system is needed to ensure efficient exchange as well as suitable use of real property units (e.g. Enemark et al., 2005). The role of cadastral system is to act as the 'where' component of property rights system by providing accurate information of real property units, their location and interests related to them. This can be, of course, achieved under various technical solutions. In many countries, the current cadastral system regime is based on a centralized database maintained by a public authority. New solutions are gaining interest though. For instance, blockchain technology and its implications for land administration have been under discussion lately (e.g. Anand et al., 2015; Vos, 2016).

Blockchain is still an immature technology: no matter the application field, we are still discussing about 'use cases' and implications. There are many reasons why land administration field should not neglect the blockchain technology at this point. To begin with, similar to the banking industry, the main role of land administration authority is to act as a 'trusted third party' - exactly the role that blockchains promise to displace. Second, possibilities (as well as drawbacks) of a distributed ledger deserve more attention. Greater transparency and control over your own personal data, central features of a decentralized system, might be the future also for public data.

As the maturity of technology evolves, more solutions based on blockchains will become possible. The change is fast: since 2009 there have been huge leaps from the technology behind bitcoin to second generation blockchain networks, like Ethereum, which are faster and have more capabilities. Hence, we cannot underline enough the need to increase understanding of blockchain in the land administration industry. Lack of basic knowledge of the technology can create a huge barrier for horizon scanning and recognition of future possibilities.

In this paper we want to investigate what is the current state of blockchain technology and what kind of barriers relate to blockchain implementation. We define our research aim with following research questions:

RQ1: What can blockchain technology offer for land administration?

RQ2: What kind of issues need to be addressed if the plan is to apply blockchain technology?

The paper is structured in a following manner. First, in Section 2 we review literature on the blockchain technology and its basic terminology. We also review potential blockchain disruption from land administration point of view. Next, in Section 3 we present our empirical findings. We take a qualitative approach and ask more technically oriented experts about their views on implementing the blockchain technology. Section 4 concludes.

2. Blockchain technology - basic concepts and current state

In this section, we go through some basic concepts related to blockchains. In particular, we focus on the basic features of blockchain and present the ground components of the technology. We then speculate blockchain disruption in land administration, mainly based on its technical possibilities and what previous studies have proposed.

2.1. Technology maturity and terminology

New technologies come and go and it can be challenging - or impossible - to accurately predict which ones will have a large scale impact on society. One commonly referred source for the maturity level of different technologies is the annually published Garner's hype curve (Figure 1). The curve positions different technologies based on their 'hype' and expected time to mainstream adoption. First stage on the figure is called 'innovation trigger', a phase when a new potential technology breaks through and catches media attention. Next follows a phase called 'peak of inflated expectations' that includes for instance reporting of first use case examples. Third phase is called 'trough of disillusionment', a period during which the fascination towards technology starts to decline due to some unsuccessful examples and projects. Then comes a 'slope of enlightenment' that shows a returning interest that usually stems from a growing understanding of real benefits of the technology. In general, at this phase the market players start to realize the potential of the technology for their own businesses. Finally, the technology life cycle reaches the phase of 'plateau of productivity'. At this phase the technology is mature enough and its introduction is profitable.

As we can see from Figure 1, blockchains are currently on a transition from second to third phase, with expected 5 to 10 years to mainstream adoption. Indeed, we have witnessed several use case examples of blockchain in recent years, also in the field of land administration.

Blockchain can be given at least three interpretations. It can be defined as a societal phenomenon, as a technology pile or as a database structure. The Gardner's hype curve, for instance, presents the blockchain and its maturity as a societal phenomenon. Blockchain as a technology pile, on the other hand, means that the utilization of technology consists of several levels. For example application, platform, processing and protocol levels can be distinguished for blockchain. Often firms specialize on one of the aforementioned levels. Finally, blockchain as a database structure usually refers to the technical operations of blockchain and to the facilities that make possible storing of information (Mattila & Seppälä, 2017). Blockchain enables a platform for decentralized database that can be used for a constantly growing data register. This type of register is called a public ledger since it contains information on all transactions. Thus, blockchain can be used for instance for storing some sort of transaction accountancy or script of code.

Figure 1 Garner's Hype Cycle in 2017 (adapted from Gartner 2017)

In a blockchain, data is stored in blocks and each new block is linked to the previous block with a mathematically computed, mixed character string called hash. Certain data always produces a similar hash, which guarantees that data in (the previous) block is same for all users. The hash is also called a digital fingerprint since it embodies a time stamp of previous actions. Hence the date and time of each transaction can be traced from the blockchain. We illustrate the operational principles of blockchain in Figure 2. Here we can see graphically how each new block contains a hash from the previous block. The first row, or each block's own hash, is computed from the contents of the block.

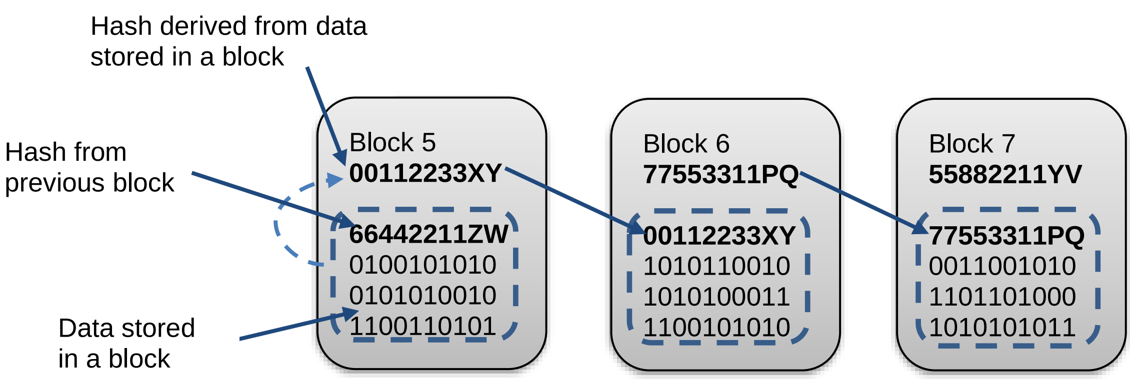

Figure 2 Blockchain mechanism illustrated, modified from Kotilainen 2017.

Node is another concept central to blockchain upkeep. Nodes denote host computers of blockchain administrators where blocks and their content are saved. Data is available for all contributing nodes, and thus transaction processes become more transparent when an objective intermediary is used as part of the process. Every node also has a full or partial copy of the blockchain and the stored transactions. This feature guarantees that an individual user cannot falsify information. If someone would try to finger the information stored into the blockchain, this would influence a hash as described above. Only a one character change in a hash would influence the following blocks, so other administrators would notice the attempt and they could interfere the situation.

The blockchain technology is based on a peer-to-peer network. Peer-to-peer network refers to a computer-based network where each computer can act both as a server and a customer device. For instance, in the Internet peer-to-peer networks are used for file and software sharing. In the blockchain technology an important component is a decentralized peer-to-peer network that is needed for consensus creation. In this context, a p-2-p network consists of several independent nodes maintaining the blockchain that follow certain rules. Nodes verify transactions happening in the chain following the rules. This is how consensus is reached in a p-2-p network and verified transaction can be stored into the blockchain. We can easily see how this mechanism could have implications to centralized organisations whose role is to maintain and secure transactions and related registers (e.g. Anand et al. 2015).

An important difference between a completely decentralized p-2-p network and a traditional database is how data evolves over time. In the p-2-p network participants may add data to the decentralized register, and a concensus mechanism is used to determine which version of database is the valid one. With centralized database, in contrary, there is only one trusted party who verifies the authentity of added data. Thus the role of consensus mechanism is to create trust and mutual understanding between blockchain network actors. Several consensus mechanisms exist but the most common ones are Proof of Work and Proof of Stake mechanisms. Proof of Work mechanism, which for instance the Bitcoin network utilizes, is considered to be easily verified. Biggest downside of Proof of Work is that the mining procedure that is needed for data extraction requires lots of computing power and, hence, lots of energy. (Anand et al. 2015; Lin and Liao, 2017.)

Another basic component of the blockchain technology is a public key infrastructure (PKI). The idea is that a user has both a public and a private key that are used to control access to data stored into blockchain. Private key is randomly created, and it usually consists of a long string of numbers and letters. Public key, on the other hand, is derived from the private key mathematically so that the keys together form a pair. Using again the Bitcoin network as an example, the public key is used for receiving bitcoins whereas the private key is used for user verification when a user wants to transfer or use bitcoins. (Antonopolous, 2014.)

Next concept that needs to be explained is a smart contract. Smart contract is a solution that utilizes the blockchain technology for creating contracts between two or more parties in a decentralized environment (Yli-Huumo et al., 2016). In its simplest form smart contract is a coded programme that is read and also executed automatically if certain pre-defined provisions are fulfilled. If contracts are made in a blockchain-based decentralized environment, they can be executed safely even without trust between contract parties. Smart contracts have then potential to lower transaction costs (using a trusted third party verification has costs) as well as to decrease frauds and other malpractices.

Finally, we note that several types of blockchains exist. First step in implementation planning is to decide what kind of actors are allowed to act as an administrator. Further, we can divide blockchains into public and private chains. Both types can operate in either a permissionless or a permissioned network. In a permissionless network participation does not require permission from a central body or other network actors. In a permissioned network, as the name implicates, a permission is required (Kinnunen et al., 2017).

2.2. Blockchain disruption in land administration

There are certain criteria or prerequisites studied by Mattila et al. (2016) when planning to utilize the blockchain technology for a certain purpose. We will present these prerequisites and after that compare them with an application to land registration. First prerequisite wells from the essence of blockchain technology basing itself to a peer network. Thus, the application purpose benefits from the decentralized database structure. Second prerequisite is that there is a need for several users to update the database at the same time. If there is no such need, the centralized structure of a conventional database should be enough. Third prerequisite is the consensus mechanism. If the database is updated simultaneously by several users, there is a risk that several versions of that database are created. Overlapping and simultaneous modifications must be able to unify. The potential applications for blockchain are decentralized databases with one correct version. Fourth prerequisite is that the modifications done in the database need to communicate with each other. The need for blockchain might not be justified, if there is no need for interaction with the data and if the modifications are not dependable or do not affect each other. The fifth criteria is trust, or the lack of trust. Trust is usually related to a situation where some party might benefit from deleting or forging data, or in the current system there are problems with keeping the data safe. Often these problems can be solved by using a trusted party, for example a land registration authority, to update a database. Still, sometimes the use of this trusted party is not reasonable due to high expenses, or some cases this trusted party does not even exist.

Thinking about the essence of land administration and especially the land register, we can tick the boxes of prerequisites for using the blockchain technology. Decentralized database together with the several users updating the register at the same time resulting to one correct version of the database are certainly essential features of land registers. Not to even mention the importance of interaction between the registered data, and trust. We can state that land registration fulfills the criteria set for using blockchain-based application. Let us next have a short overview of the actual use of blockchain technology in tasks related to land administration.

The purpose of using blockchain for land registration is rather easy to justify in a country where the land administration system is not trusted, either due to corruption, bad governance or just the lack of quality of that register (Vos 2016). Anand et al. (2015) rank land administration to be amongst the top most corrupted sectors in the world. There is no doubt that blockchain technology in these cases would be the answer for organizing land administration efficiently and trustworthy. Indeed, the use of blockchain in these cases is reasonable. But Vos (2016) poses a question: should we try to replace a well-functioning land registration by blockchain, and why?

Graglia and Mellon (2018) recognize eight theoretical steps towards integrating blockchains as part of society can be distinguished, starting from public blockchain for recording documents ending up with interoperability where different blockchain-based registers merge. Examples on the adaptation of the blockchain technology in land administration can be found on the first levels: Several countries have started to record either documents related to land transactions (Brazil, Georgia, UAE) and also to record the workflow, the progress of transaction (Sweden). Georgia has built its whole land registration basing itself on blockchain, and so has the city of Dubai in UAE. Still, most of the world is no yet at the stage of utilizing the blockchain technology, especially for land administration.

We can note that the use of blockchain in applications for land administration is not yet made its breakthrough. The success of existing and emerging pilot applications will show, how the future of blockchain and land administration will look like.

3. Empirical findings and discussion

In this study we apply a qualitative research methodology. As part of the research process, both primary and secondary qualitative data are collected. To answer the research questions we combine information from the literature and interviews. The literature is also used for identifying the adequate expert profiles to share their viewpoints about the second research question. At the second phase, eight interviews were conducted. In order to achieve broad enough knowledge base, the interview participants were selected from different backgrounds ranging from academia to business sector.

The interviews were semi-structured by nature and built around predetermined topics and key questions. Data collection method was flexible enough for the purpose of this study as it allows the researcher to develop new questions also during the interview session. Interviews were conducted either face-to-face or via Skype between October 2017 and November 2017. The interviews were recorded and they last between 30 to 80 minutes. The interviews started with a short introduction to present study and its goals, after which following topics were covered: (1) General questions about blockchain technology, (2) Technical implementation, (3) Introduction and use of (blockchain) technology, (4) Legislation, and (5) Future possibilities. For this study, we utilize only part of collected material.

We organize our findings and discussion into two sub-sections, according to our research questions.

3.1. What can blockchain technology offer?

The interviews started by charting the expert views about what new the blockchain technology could provide compared to the traditional technical configurations. The common impression among the interviewees was that from technical point of view the technology does not provide much novelty - in technical sense it is more about combining existing technologies into one solution. For example peer-to-peer networks or decentralized systems are utilized in many other methods as well, which means that some of the features provided by the blockchain technology could be executed with traditional database solutions as well.

Combining different techniques creates, however, new possibilities that cannot be achieved with other methods. Indeed, the promise of simultaneously decentralized and reliable database is perhaps the biggest reason behind excitement towards the blockchain technology, especially in governance. Decentralized architectures could be carried out with other solutions, yet the blockchain technology and the mathematical algorithms it uses enable preservation of trust among all parties as well. Trust remains since the data that is stored into a block is extremely difficult to forge. In addition, the blockchain technology can provide trust and transparency in an environment where there is no certainty about the reliability of other parties, nor about the permanence of stored information. Some interviewees pointed this ability to maintain integrity, reliability, and originality of data in situations where trust is missing between parties as the most important reformation of the blockchain technology. Few experts wanted, however, further stress that the new features provided by the blockchain technology depend strongly of the application field. Besides the mere facts of how and where the technology is applied, also previous solutions set many boundary conditions: for instance the type of blockchain (as presented in previous section) should be chosen considering the application field and existing technical solutions.

Besides the transparency and reliability aspects mentioned above, the experts saw some other potential benefits as well. One foreseeable benefit would be that with the blockchain technology, it is easier to produce such services that have been impossible to provide thus far due to a missing trusted third party. Lack of trust might have hindered the creation of business or services in some areas, but the blockchain technology could be part of the solution for such situations. Then, on the other hand, we could imagine a situation where a lack of transparency or the previous centralized solution has caused issues in past. Under such circumstances a need for new type of 'trust services' might arise. One possible horizon that was mentioned in the interviews was a solution that is no longer tied to a certain occupational group or controlling organization to act as a trusted party. Nonetheless, this suggestion should not be interpreted too extremely, said some of the interviewees. Getting rid of trusted third parties might cause unwanted consequences as well: their role as intermediaries in case of conflicts or faulty actions is indisputable and hence should not be undervalued.

Another potential benefit stems from the 'tracking feature' of blockchain. As explained in the previous section, with blockchain it is more difficult to falsify or eradicate information, or at least it is possible to trace down at which point of the chain information has been fudged. In addition, due to the decentralized structure, a blockchain based system has a high tolerance for faults since the maintained database locates at several servers simultaneously. This means that a single server is not alone in a critical position in case of possible attacks or other faults. Further, some of the interviewees pointed out the additional value from smart contracts. With smart contracts it is possible to programme and automate certain processes and thus create long transaction chains.

3.2. Barriers to blockchain implementation

3.2.1. General challenges

A fundamental challenge is whether blockchains will be used in a right way in right targets of application. Our interviewees stressed that the use of blockchains will never reach its potential benefits unless the chosen solution is a right fit for the application area. As mentioned above, some of the features can be achieved with more traditional solutions as well, and there should be an actual need or requirement for the added benefits so that implementation of the blockchain technology is the right choice.

Another general challenge is that the blockchain is not a feasible solution for storing large amount of data. Instead of data, it is usually more worthwhile to store important transactions related to the target of application. Moreover, it is possible to store the hash derived from the data instead. What comes to the 'actual data', it can be stored for instance into another decentralized system tailored especially for storing documentation. Documents can be found through the system and their originality can be checked from the hash stored to the blockchain. Thus, when considering the application of blockchain, it is advisable to assess what is going to be stored into the blockchain and whether it is feasible to do that. That is only way to avoid expanding the blockchain into a too large entity.

Also the complexity of technology and lack of knowledge were considered as general challenges. The blockchain technology brings many reformations related to both technological solutions and business models, but there are no common practices or standards for guidance available yet. Existing systems based on the blockchain technology are scarce in number, thus learning from historical examples is not an option either. Understanding the operations of blockchain technology, its application as well as the consequences of larger scale implementation will require expertise from several fields. It is imperative to raise the knowledge base at least to a level where people understand what the blockchain technology is all about and how it could be applied under different solutions. Furthermore we need more knowledge of impacts and risks related to the use of blockchain technology in long run. Currently the number of blockchain specialists is low and many of the interviewees suspected that lack of human resources is one factor hindering the implementation of the technology. There is, however, a growing interest towards the technology and its possible applications, which should eventually widen the knowledge base.

Few interviewees mentioned also the usability of blockchain applications as a challenge. For example in open Bitcoin network a mistake in writing the recipient's address or losing your own private key can lead to loss of assets. This results from the fact that in the Bitcoin network there is no central body that could be reached in problematic situations. If permissionless blockchain applications like that gain more ground, a solution for such examples is needed. This would require that some party is trusted over others. Due to problems related to everyday operations, more closed and cross-organizational versions of blockchain become more frequent first, since trust (at least to someone extent) is a built-in feature in them.

Finally, high energy consumption that results from the use of consensus mechanisms such as Proof of Work can be categorized as a general challenge. Especially for public and permissionless networks the energy consumption can become an issue.

3.2.2. Scalability

Already a quick review on the literature of blockchain reveals that scalability is a big issue in permissionless blockchains like the Bitcoin. Scalability problems relate to the ability of blockchains to handle large amounts of information. Our interviewees stressed that ensuring the scalability is a challenge especially for the permissionless and public blockchains. For the permissionless blockchains, it is difficult to evaluate beforehand how many users and network actors there will be. A growing number of actors makes the scalability a challenge since all data that has been accumulated into a net must be decentralized in a way that was agreed on in the beginning.

According to our interviewees, one fix to the scalability problem is to create such a governance model to the blockchain where the chain can be modified afterwards if there is a need for that. Thus the scalability is not necessarily only a technological barrier. Current view is that the technology may enable storage of several transactions into one block in the (near) future. So it is more essential to reach a consensus about governance of blockchain and whether it is possible to make changes to the current blockchain in order to support the scalability. The planning phase of a blockchain should include good technological choices that support the scalability but it is equally important to plan carefully the governance model and leave room for modifications as the technology inevitably continues to develop.

Another solution to the scalability problem is to leave older blocks out of the storage. Depending on the target of application, older events and transactions might not have such relevance that they should be stored in the beginning of the blockchain. For instance on top of the Bitcoin network some new technology has already been planned: this so-called lightning network would be a substantial help to the scalability issue. With the lightning network transactions could be executed faster and in higher volume than at the moment. The lightning network would create a separate channel for transactions happening between parties. Currently the Bitcoin network is burdened with ongoing transaction events and the lightning network would address this problem. What we can learn from this example is that technological advancements may help with the scalability problem but also the decisions of the network administrator as well as the governance model of the blockchain have important roles.

Another viewpoint that came up frequently in the interviews was that the scalability is not such a big issue for private and licensed networks. Such networks often have much less users and network actors, and the amount of storable data is not comparable to transactions happening in permissionless networks such as the Bitcoin. It is important, however, to acknowledge the restrictions on use already in the initialisation phase. As it was mentioned earlier, the blockchain is not a good solution for storage of actual data, but better suitable for recording transactions and hashes. Thus the scalability is less likely to turn into a serious problem if this is kept in mind since the very beginning.

3.2.3. Data protection and privacy

Data openness in blockchain creates many possibilities but also challenges related to data protection and privacy especially in permissionless and public blockchains. That type of networks usually have the whole transactions history and transaction paths available. However, alternative solutions where open data could be partly hidden are already under development. Different encryption methods also aim to prevent the ability to connect transactions to a certain person. Nevertheless, some evidence exists that with the current regime, it is not particularly difficult to connect transactions to certain accounts in the Bitcoin network. Again, this issue has been already addressed and a heavier encryption method that would increase data protection and privacy has been proposed. With this kind of add-ons there is a drawback also: the feature can become a subject of misuse and attract for instance actors with criminal goals.

Our interviewees emphasized that the challenges related to data protection and security as well as privacy are also connected to the governance model of the application. Further, what type of data is stored into the blocks and how it is encrypted matters too. Actors of blockchain network can be given for instance different kind of access rights to data by defining that certain actor only has access to data that is integral to his own actions. This type of feature could be utilized for example as part of a cross-organizational blockchain solution. According to our experts, it is not rational to store highly sensitive data into blockchains yet. In principle anything you store into a blockchain remains there till eternity, and even though different encryption methods could be applied, it is likely that in the future there is enough computing power to decrypt these encryptions. Another viewpoint that arose in interviews related to data security was that a possibility of attacks should be considered as well. It is important ponder beforehand different scenarios for attacks and how they could be prevented.

We further asked if it is possible to create a blockchain where part of the data is public and part of it is accessible only to a certain group of actors. The experts evaluated that it is technically possible to partially hide information with encryption methods and then define who has access to what information. For instance in the case of registries of cadastral system this kind of feature would be useful. According to the interviewees, personal information (such as personal ID) and other partly hidden information could be stored into a blockchain as some sort of identifier. These identifiers would then be used to trace down the original personal information from external database. A suggestion is that this would be possible only through a certified key so that predefined actors exclusively could perform this kind of connecting operations.

3.2.4 Social barriers

Our experts conceived that social barriers relate mainly to knowledge base and the usability of blockchain based systems. In addition, the overall understanding and acceptance of new technologies such as the blockchain technology was brought up as a social barrier. Few interviewees also wanted to emphasize that the blockchain technology will not magically solve 'deeply rooted' problems of register keeping. For instance, even though the blockchain technology could provide a reliable and functioning technology system, people in control of storing the information can still be bribed or forced into false entries. Further, it should be kept in mind that values and attitudes of authorities matter as well. We provide a simple fictional example: a blockchain based register could show reliably that a person owns the real property unit but another person is currently occupying the unit. If the authorities neglect the register information and leave the issue aside, the blockchain based register is as worthless as any other technical solution.

In addition to social challenges that where brought up in interviews, we note the importance of surrounding society and its values and attitudes should be considered as well. In some cases blockchains can help in increasing trust and transparency but the significance of social barriers should not be underestimated. Few of the interviewees even stated that thus far it seems that blockchain-based systems function best in societies that do not necessarily need such solution. We argue that explanation for signals like that call for wider perspective than just evaluation of technical and economic feasibility.

3.2.5 Juridical barriers

We addressed also the interviewees' perspectives on juridical barriers. Answering that question was, however, a challenging task since there is currently no legislation regarding the blockchain technology, at least in Finland where the study was conducted. Further, at the time the material was collected, there was no precedents either to give a form to judicial custom. To make the assessment of juridical barriers even more challenging, it is still unclear which laws should be taken into account when implementing the blockchain technology. Thus many of the interviewees perceived blockchains as juridically challenging environment and partly as a 'grey area' that hinders the introduction of technology.

There was a consensus among the experts that legislation should be included as part of the blockchain implementation, since new technological solutions and business models cannot be formed if they are illegal. This was seen as an imperative to include legal scholars into the development and application of the blockchain technology. Some of the experts thought that the legal barriers for the blockchain implementation are currently underestimated and the legal issues should be considered more thoroughly in different applications. However, the only way to find out how big changes different laws require due to the technology implementation, is to wait and see first how common and influential the technology will be.

Smart contracts fall also under juridical issues that need more clarification and clear guidelines in the future. If the smart contracts become common practice, there should be clear rules how they are formulated and how they fulfil their function. We also need clarity on the question whether transaction based on a smart contract is juridically secure. Then a question arises how far the current contract jurisprudence can be stretched to cover the smart contract transactions. We note that the smart contract as a name is a bit misleading since it does not always cover all the features of a contract. Also we know that there are many things in legislation that cannot be captured into a programmed code. Thus we need to first define which articles (and details related to them) can be automated with the smart contracts.

Another topical issue related to the legal barriers of blockchain implementation is the new European Union (EU) general data protection regulation (GDPR). Problematic part of GDPR in relation to blockchains and their technical mechanism is the so-called right to be forgotten which states that "the data subject can have his or her personal data erased if the data is no longer necessary or if legal grounds for processing no longer exist" (Castrén & Snellman 2015). This is in contrast with the principle that once a piece of data is stored into blocks, it cannot changed or erased afterwards. Another aspect of the GDPR that is open to interpretations is the question of whether we are maintaining a person register or not. The GDPR obligates those companies and operators that process personal data.

We summarize the findings related to the blockchain technology barriers in Table 1. The barriers are categorized into three groups: technical, social and juridical barriers. We emphasize that the barriers are in no particular order here, nor did we even try to assess their importance in relation to other barriers. We note, however, that even though we chose to interview experts with technological background, our results raise social and juridical perspectives as well.

Table 1 Blockchain technology barriers summarized.

Technical	Large data volumes
	Complexity
	Correction of errors
	Safety
	Usability
	Scalability
	Energy consumption
Social	Lack of knowledge
	Values and attitudes
	Surrounding society
	'Deeper' issues in register keeping
Juridical	Lack of legislation
	EU general data protection regulation
	Smart contracts and their juridicality

4. Conclusions

The blockchain technology offers a possibility to make a decentralized, transparent and reliable database. It is still unclear, however, how disruptive the technology will be for land administration industry. In order to get forward with this question, more research on potential uses and implications, but also on challenges related to introduction of the blockchain technology is needed. In this study we address this gap by examining new possibilities that the blockchain technology offers for land administration as well as barriers of implementation. Our approach was to interview experts that have proven expertise of the blockchain technology. We summarize our findings as follows: besides technical barriers, also social and legal barriers should be acknowledged when a blockchain implementation becomes topical.

Main contribution of this study is that it can be seen as guidance for future endeavours. The study has both academic and practical value since it combines basic knowledge on blockchains with expert views about blockchain implementation.

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BIOGRAPHICAL NOTES

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