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A critical review of distributed ledger technology and its applications in real estate

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List of abbreviations

ASTRI	Applied Science and Technology Research Institute
BIM	Building information modelling
BMI	Business-model Innovation
BOC	Bank of China
CIO	Chief information officer
DAG	Direct acyclic graph
DLT	Distributed ledger technology
JLL	Jones Lang LaSalle
HMLR	Her Majesty's Land Registry
ICO	Initial coin offering
IPO	Initial public offering
MLS	Multiple listing services
NASDAQ	National Association of Securities Dealers Automated Quotations
P2P	Peer-to-peer
PwC	PricewaterhouseCoopers
REIT	Real estate investment trust
SPV	Special purchase vehicle
STO	Security token offering

Glossary

Crypto exchange: Crypto exchanges allow the exchange of one cryptocurrency for another, the transaction of crypto coins, and the exchange of fiat money into cryptocurrency.

Directed acyclic graph: allows for multiple chains of blocks to co-exist and interconnect, which means that there is a wider range of possible confirmation options in comparison to blockchain structure.

Eclipse: In an Eclipse Attack, attackers seek to isolate and attack a specific user, or a group of specific users rather than attacking the whole network.

51% attack: this type of attack refers to an attack by a group of miners controlling more than 50% of the network's mining hashrate or computing power.

Fork: A blockchain fork is a radical change to the protocol and a permanent divergence from the previous version of the blockchain – nodes running the previous versions will not be accepted by the new version.

Hash: A hash is a function that converts an input of data into an encrypted output of a fixed length. A hash is created using an algorithm.

Holochain: blockchain adopts a data-centric approach and seeks to decentralise the transactions on the network. Holochains intend to make the interactions between nodes decentralised as well by allowing each node on the network to run its own chain.

Miners: Miners validate new transactions and record them on the blockchain. They compete to solve a difficult mathematical problem based on a cryptographic hash algorithm, and hence often require a dedicated computer and high electricity usage. Miners are often rewarded, for example, with bitcoins.

Node: DLT establishes a decentralised database spreading across several locations or among multiple participants, which are referred to as nodes. Each node can access the records of data and own an identical copy of it.

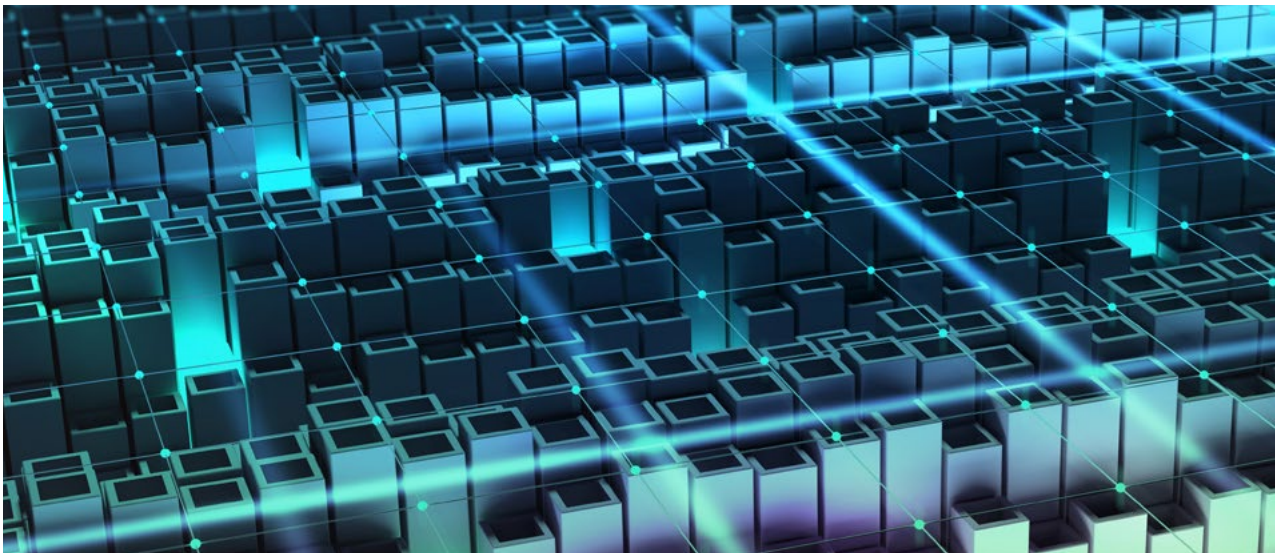
Nonce: In cryptography, a nonce is an arbitrary number that can be used just once in a cryptographic communication.

Private chain: A private blockchain only allows certain authorised entities to participate in a closed network.

Public chain: A public blockchain means that information is shared by all network nodes, updated by miners, monitored by everyone, and owned and controlled by no one.

Selfish mining: also known as a 'block withholding attack'. It occurs when a miner attempts to withhold a successfully validated block from being broadcast to the rest of the mining network.

Executive summary



Real estate transaction processes are considered to be inefficient, and real estate investments are often seen as 'lumpy' and illiquid. Triggered by the initial interest in Bitcoin, the distributed ledger technology (DLT), particularly in the form of blockchain, has drawn much attention from stakeholders in the real estate sector, as the technology has the potential to improve speed, efficiency, transparency and trust in transaction value chains. This study aims to critically review the current and potential applications of DLT in real estate and discuss how stakeholders in the industry will be affected.

The DLT seeks to resolve issues with centralised database management systems by using a decentralised database that spreads across several locations (i.e. nodes). Data or transactions can only be stored in the ledger when consensus among the nodes is reached. Blockchain is a particular application of DLT, where information is stored in chronologically and cryptographically linked blocks. The existing literature highlights the allegedly trustless, secure and immutable features of blockchain, but the technology also has limitations.

Applications of DLT in the real estate industry are dominated by blockchain solutions. The report examines the application of blockchain in real estate transactions, tokenisation, valuation and property listing platforms. With real estate transactions, a distributed database allows information referenced to the asset to reside on a ledger, which is available almost instantaneously to every actor in the network. The due diligence process of real estate transactions, therefore can be streamlined for buyers and lenders, and the potential for human error can be eliminated. Once terms and price are agreed, the exchange of the asset and the transfer of ownership can also be carried out via smart contracts in the decentralised system. Blockchain can also potentially enable real estate assets to be tokenised where tokens function as digital representations of the physical assets. Liquidity of the real estate investment market and access to global capital could be significantly improved if such tokens can be traded easily and globally. The valuation and property search process could benefit from a decentralised system, as data would be stored on a peer-to-peer (P2P) network, and information on properties would be transparent and up-to-date. Despite the advantages, the wider adoption of such decentralised transaction systems with self-executing features faces technical, legal and social challenges.

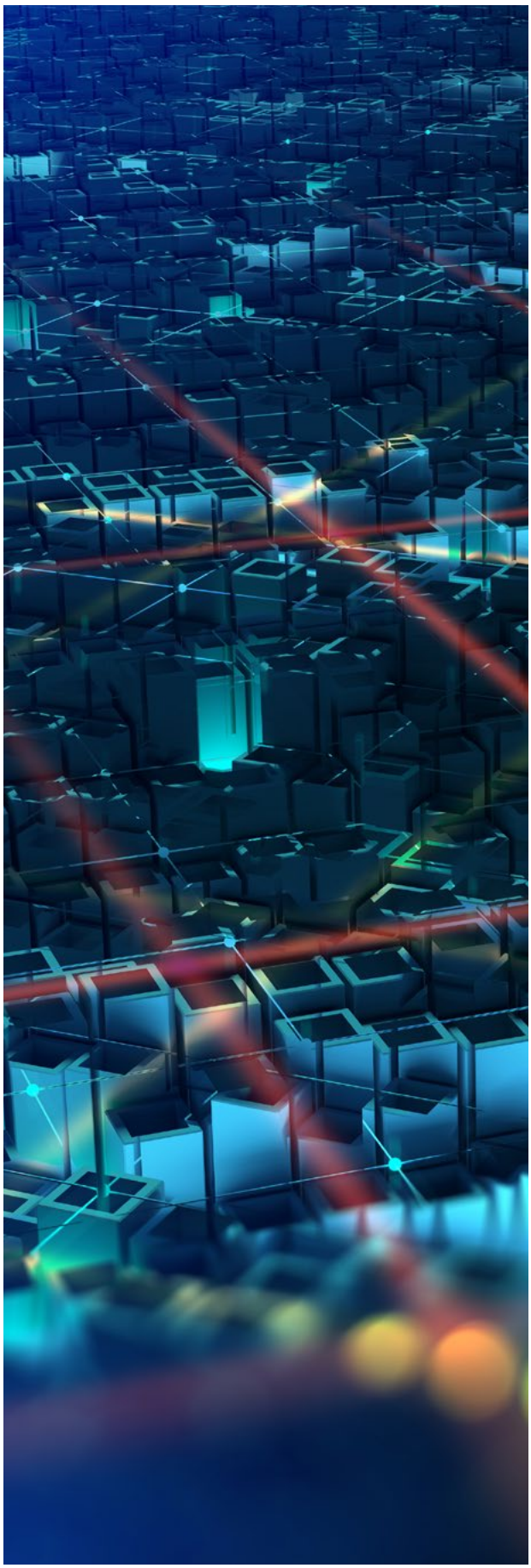
Main findings of the report:

- Blockchain-based systems are not completely trustless, with real estate transactions, intermediaries are still needed to verify sources of data in transaction value chains.
- Efficiency and scalability remain major concerns for industry and end-users.
- Legally, existing regulations and laws are still catching up with technological developments, and there are many uncertainties in the self-executing nature of smart contracts and the ownership and rights of tokenised assets.
- Socially, the pre-requisite for the technology to be applied successfully in the real estate sector is the participation and coordination of all stakeholders involved. Without guidance from the government and regulators, such coordination is difficult to achieve. The technology is still misunderstood.

Many have argued that DLT or blockchain has the potential to disrupt the industry, some regard it as a foundational technology that has the potential to create new foundations for our economic and social systems. Established disruptive innovation theories suggest that such technology may displace existing leading firms and eventually grow to dominate the market, thus firms have no other option but to accept and exploit it. On the other hand, since firms also face trade-offs and conflicts between new business models and legacies, the decision to adopt innovations still requires a thorough cost-benefit analysis. The report concludes that DLT is yet to mature, but its potential should not be ignored by the industry. Certain tasks may be replaced by the technology, but complete disintermediation is unlikely, as tenants, landlords, investors and homebuyers still require professional expertise and advice.

Recommendations:

- Stakeholders should work together, as a single group is unlikely to be able to drive the changes alone. Lessons could be learned from countries and jurisdictions, where regulators, industry players, and academic institutions have been purposeful and deliberate in nurturing blockchain technology innovation.
- The potential 'disintermediating' nature of blockchain can be a concern for intermediaries in the real estate industry. To co-exist with DLT and other technologies, real estate professionals should focus on adding value through their consultative role-based work.
- Existing firms need to invest in solutions or business models that could increase their competitiveness. Company executives should consider partnering with vendors and/or re-structuring their companies to have a good balance of staff with traditional real estate skills and knowledge of innovations and new business models.
- There is a need for governments to evaluate the impact of the technology and provide up-to-date guidance. Regulators need to protect the public interest while fostering technological innovation.
- The primary focus is on blockchain. Other types of DLT should be explored.
- The future of the real estate sector with DLT still looks unclear, but everyone needs to understand the potential of technology and be able to differentiate the 'good and bad' players.



1.0 Introduction

The development of various real estate activities is inevitably affected and shaped by the evolution of technologies. For example:

- innovations in building and construction methods allow buildings to be constructed more quickly and more energy efficiently;
- Building information modelling (BIM) has the capability to create a digital representation of physical and functional characteristics of a building, hence forms a reliable basis for decision making during a building life cycle (Saull and Baum, 2019);
- online platforms (such as CoStar and Zoopla) have been developed to combine information, analytics and marketing services to landlords, tenants, buyers and sellers;
- virtual tours of properties provide a new edge for marketing.
- 'Proptech' has become the buzzword in the real estate sector, and interest is growing among investors, tenants, regulators, governments, service providers, with regards to how these technologies will shape the future of the real estate sector.

As Saxena and Donati (2017) highlight, it is important for the real estate industry 'to wake up to the possibilities of deep property tech, and the possible risk for those stakeholders who fail to recognise its potential for the future' (p.4).

Notably, one could argue that certain fundamentals of real estate as an asset have not changed substantially: it is very difficult to directly own a fraction of real properties, and direct real estate investment cannot be shorted. Investments tend to be financed by debt, meaning that the price for real estate investment does not only reflect the demand and supply in the physical space but is also heavily influenced by the availability of capital.

With real estate transactions, intermediaries such as solicitors and brokers are needed to verify all the information involved in the transaction, and the due diligence process is lengthy and costly. Lease contracts are still paper-based, and rental payments and maintenance costs are usually enforced by third parties, which adds costs to the operation. Direct real estate investments remain 'lumpy', not sufficiently transparent and subject to high transaction costs, just as they were described in typical real estate investment textbooks many decades ago.

Triggered by the initial interest in Bitcoin, distributed ledger technology (DLT), particularly in the form of blockchain, has drawn much attention from a wide arrange of industries, as the technology promises increased speed, efficiency, transparency and trust in transaction value chains (Hileman and Rauchs, 2017). For example:

- the technology is cited to reduce friction and costs in the finance industry (Tapscott and Tapscott, 2017);
- in the insurance industry, blockchain has been exploited to increase the speed of claim processing as well as efficiency and accuracy in risk assessment and frauds prevention (Gatteschi et al., 2017);
- with food supply chains, the technology can contribute to establishing a traceable system that could effectively guarantee food safety (Tian, 2016).

Many have argued that DLT has the potential to disrupt the real estate industry (Veuger, 2018; Dijkstra, 2017). For example, many promoters of blockchain claim that the technology offers the only solution to the existing problems in real estate transactions, and others believe that the technology holds the keys to innovative ways of investing in real estate. There are also examples of enterprises that invested in and launched blockchain pilots, but could not convert them into operational deployment (Furlonger and Uzureau, 2019). With many use cases and a great deal of contradictory information, it is increasingly confusing to understand the true value of such technologies for the real estate sector. This study aims to critically review the current and potential applications of DLT in real estate and discuss how stakeholders in the industry will be affected.

2.0 DLT and blockchain

Traditional database management systems were designed around a centralised database server, which could cause a bottleneck when dealing with high volumes of transactions. Such systems are also vulnerable to cyber-attacks. DLT seeks to resolve these issues by establishing a decentralised database spreading across several locations or among multiple participants, which are referred to as nodes. Each node can access the records of data and own an identical copy of it. The design assumes the presence of malicious nodes in the network; hence, the database will be continuously synchronised and run even while such dishonest nodes participate in the network (Hileman and Rauchs, 2017). The process is achieved by consensus, as data or transactions can only be stored in the ledger when consensus is reached.

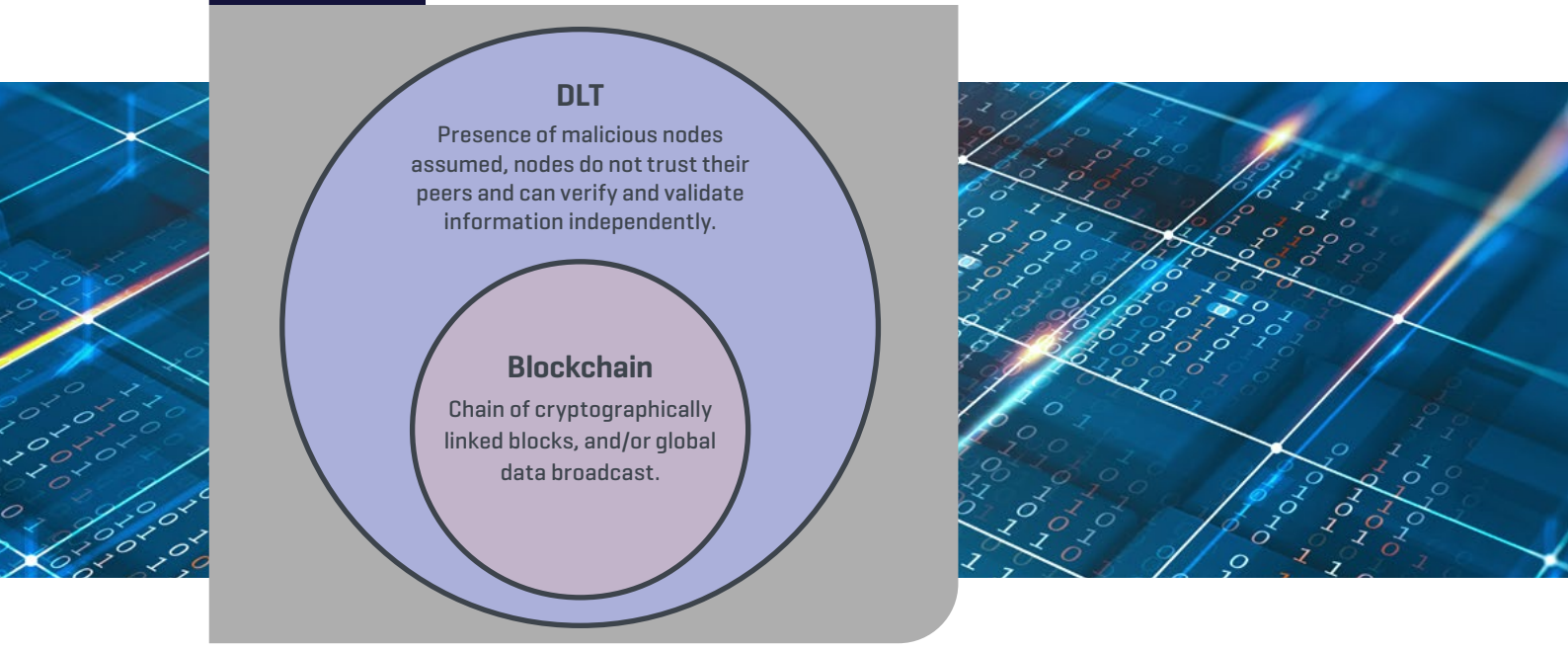
Blockchain is a particular application (or one type) of DLT that has been adopted in cryptocurrency and many areas such as supply chain, insurance, information sharing and cross-border transactions. In real estate, most of the current applications of DLT are also in the form of blockchain. A 'block' in a blockchain consists of multiple transactions that can be validated by the peer-to-peer (P2P) network using cryptographic means (Nofer et al., 2017). Each block also contains a timestamp, i.e. a hash value of the previous block and a nonce for verifying the hash. Hash values change if modifications are made to a block, thus making a blockchain very difficult to be tampered with without leaving a trace.

A protocol manages the initiation, validation, recording, and distribution of new edits and entries. A block can only be added to the chain if the majority of nodes reach consensus on the transaction. Hence the blocks are chronologically and cryptographically linked to one another, and cryptography replaces third-party intermediaries as the keeper of trust (Piscini et al., 2016).

Information is stored on the nodes permanently and cannot be removed once consensus is reached. All nodes are also able to track history, reducing the risk of manipulation and system failure. Therefore, blockchain is an authoritative data source of ownership claims. Participants' ownership of assets or data is achieved by controlling the associated private key, which cannot be transferred without the owner's consent (Hileman and Rauchs, 2017). Therefore, blockchain can facilitate the transfer of data and assets without the need of a trusted central authority.

The terms DLT and blockchain technology are often treated as synonyms in many studies and industries despite the difference (see Figure 1). The term blockchain is often referred to in this report, as use cases or studies discussed specifically refer to blockchain. The term DLT is used when the report discusses the technology based on decentralised ledgers in general.

Figure 1 **Blockchains as a type of DLT**



Source: Hileman and Rauchs 2017, p.23

It is worth noting the differences between a public and a private blockchain. A public blockchain means that information:

'is shared by all network nodes, updated by miners, monitored by everyone, and owned and controlled by no one. It is like a giant interactive spreadsheet that everyone has access to and updates and confirms that the digital transactions transferring funds are unique'

(Swan, 2015, p.1).

Bitcoin and Ethereum are, for example, public blockchains that can be inspected, verified, and downloaded by anyone.

A private blockchain, by contrast only allows certain authorised entities to participate in a closed network. One of the main benefits of a private chain is that access to data or certain functions can be limited, as not all companies or stakeholders want open access to confidential data (private data can be encrypted), hence consortia of organisations such as the banking industry tend to use private blockchains. In addition, since fewer nodes are required, private blockchains are more scalable and can process transactions more quickly compared to the public chains.

The scalability of public chains is questionable, as their structures restrict the number of transactions that can be processed and consume a large amount of computing resources. However, a private network is built and maintained by a consortium of players, not only making the system more vulnerable to risks of hacks and data manipulation, but also creating more of a centralised network, which is something that a decentralised system tries to avoid. A hybrid solution refers to a system where blockchain transactions are stored in an open ledger and confidential data are stored in off-chain storage (RICS, 2020). However such a system would still require a large amount of storage.

Trustless, secure and immutable are commonly highlighted features in existing blockchain literature, however many have noted that the technology has its limitations:

Trust: blockchain still requires a certain level of trust. Trust must be in place for the underlying cryptography. In the case of private chains, trust must be placed in the operators (Hileman and Rauchs, 2017). The split in the Ethereum community is an example, where some of the blockchain users continued to use the original blockchain after hackers stole cryptocurrency from a smart contract, while others decided to join a segment of the community that decided to fork (Abadi and Brunnermier, 2018). It is possible that individual nodes or nodes in collusion can independently maintain parallel forks in the blockchain of fraudulent transactions or altered reality (Baliga, 2017).

Furthermore, a blockchain cannot assess the accuracy of inputs; as far as the set conditions are met, the blockchain will consider any input as valid (Hileman and Rauchs, 2017).

Security and immutability: blockchains are secure in the sense that data storage and permissions are distributed, but private keys can be stolen and lost. The system is still vulnerable to attacks such as eclipse (Heilman et al., 2015), selfish mining (Sapirshtein et al., 2016) and 51% attack (Bastiaan, 2015); and malicious nodes can double-spend or cause disorder on a blockchain (Hileman and Rauchs, 2017). Data is said to be protected from deletion, tampering, and revisions (Iansiti and Lakhani, 2017), however transactions can be reversed if enough nodes decide to collude (Hileman and Rauchs, 2017).

Scalability: technically, the scalability of public chains is a major concern (Christidis and Devetsikiotis, 2016), and the validation time for Bitcoin transactions is much longer compared to the VISA system (Karamitsos et al., 2018), although others argue that the technology will evolve and scalability will improve.

Ownership versus possession: Distributed ledgers are useful for transferring ownership of assets, but they cannot guarantee the transfer of possession (Abadi and Brunnermeier, 2018). This is perceived as the main hurdle in the adoption of the technology in real estate, as it involves real assets. For example, the ownership of a property can be represented by a token, the blockchain writers would be able to transfer the ownership of the token from one person to another, but they would not be able to verify that the buyer is physically in possession of the asset. This is further explained in the context of smart contracts in section 4.1.2.

Legal framework: importantly, the legal infrastructure for blockchain is not yet in place (Christidis and Devetsikiotis, 201; Hileman and Rauchs, 2017; Deloitte, 2018). This has particular implications in exchanges that are enabled by smart contracts, as they are yet to be legally enforceable. The legal issues are discussed in more depth for each of the specific applications in section 4.

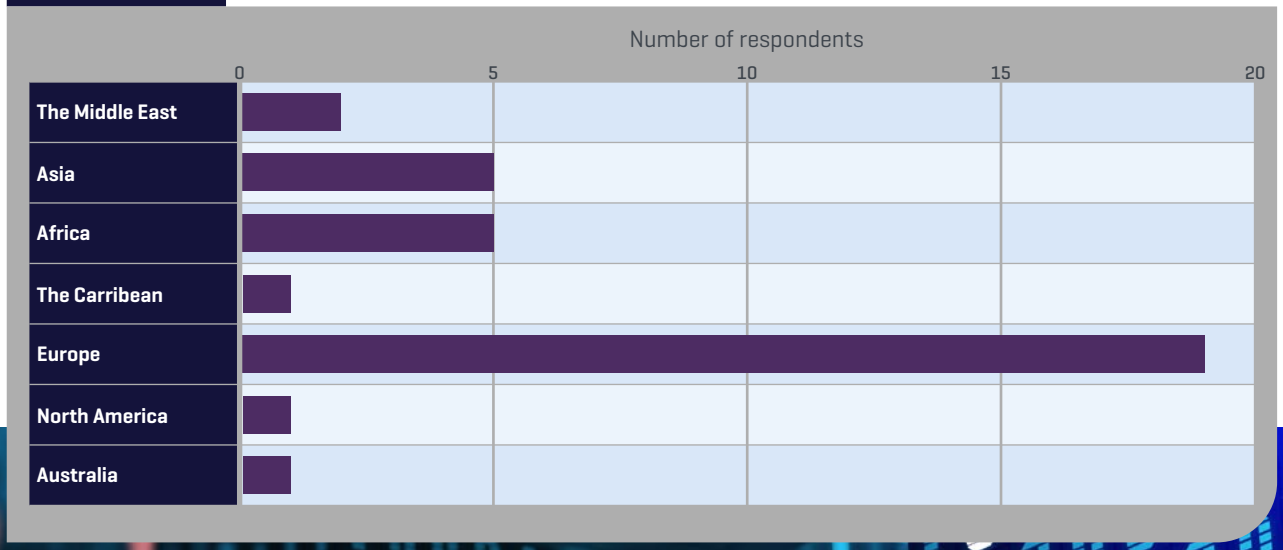
3.0 Research data

This research uses both secondary and primary data for the analysis. Secondary sources, including academic and market literature, are used to evaluate the current applications of DLT in real estate. The report uses examples of use cases to highlight the advantages and challenges in the adoption of the technology. A theoretical framework is adopted from the disruptive technology literature, which forms the theoretical basis of the recommendations. Primary data is collected through personal communications, informal interviews, and surveys. Informal interviews and personal communications were primarily conducted with start-ups and projects that specialise in DLT solutions to further understand how the technology can be applied in various areas in real estate. Due to commercial sensitivity, the report cannot reveal the identity of all the companies. Quotes are used in the analysis when consent was given.

In addition, the report uses information from presentations and panel discussions held at the Blockchain Summit, which took place in London, in June 2019. The primary data along with secondary data consisting of online blog articles and forum debates form the basis of the analysis of the report, which is presented in sections 4 and 5.

To further understand stakeholders' perception of DLT, an anonymous survey was distributed via RICS Twitter and LinkedIn posts in May and June 2019. Respondents could select multiple options when asked about the advantages and issues regarding different DLT applications. The response rate was unfortunately low (34 responses) due to how the survey was distributed and the restrictions of data protection regulations. Respondents came from a number of countries (Figure 2) with different real estate backgrounds (Figure 3). The findings of the survey are summarised in section 4.

Figure 2 **Geographical locations of survey respondents**



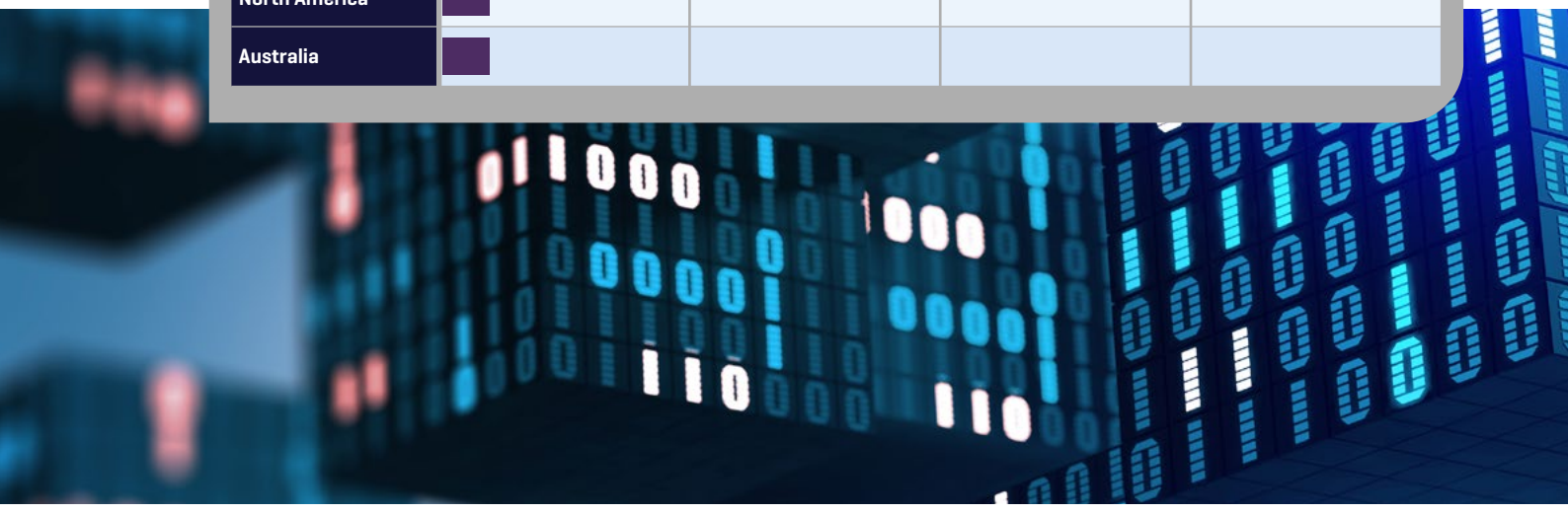
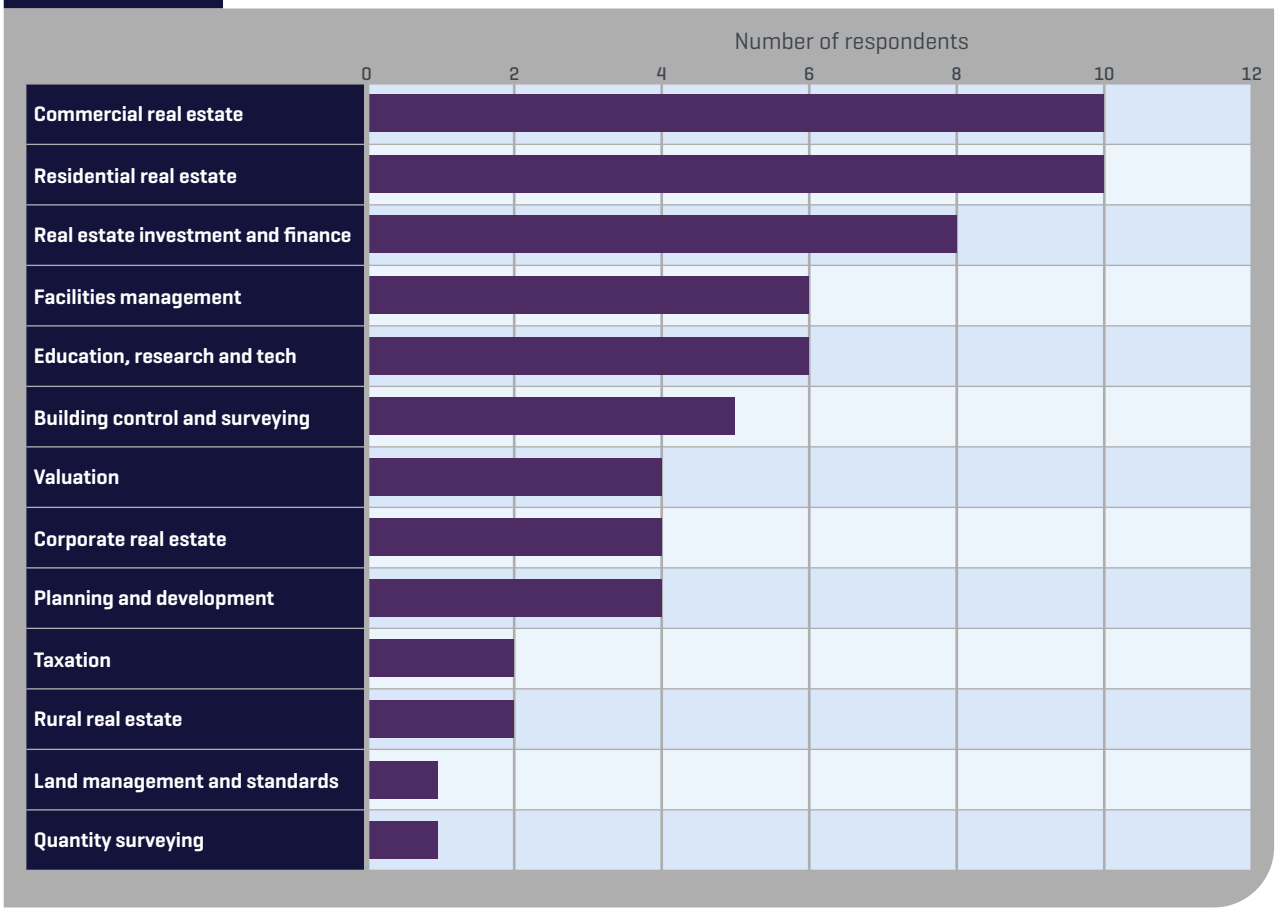


Figure 3 Areas of practice of survey respondents



4.0 DLT applications in real estate

As discussed, the transaction process of real estate assets is generally seen as inefficient and costly, and real estate investments are usually 'lumpy' (direct real estate investments tend to involve infrequent transactions with large transaction prices). Many argue that DLT, particularly blockchain as the dominating application of DLT, could improve transaction efficiency by reducing the complexity of due diligence and title registration.

In terms of real estate financing, blockchain is also said to have the potential to contribute to the simplification of crowdfunding and the improvement in the liquidity of real estate assets. Focusing on these aspects, this section of the report examines the applications of blockchain in real estate transactions and tokenisation. In addition, we also investigate use cases in real estate listing and valuation, as such applications have significance to many real estate professionals.

4.1 Inefficient real estate transactions: can blockchain be the solution?

The current transaction and conveyancing process of land and real estate requires validations from solicitors, agents, lenders, financial authorities, and appraisers/valuers; a complex and lengthy process that results in high transaction costs, including legal, brokerage, title registration and banker's fees. One of the main reasons for this is that information regarding the property, the seller and the buyer is stored in multiple private siloes.

The transaction process is also subject to a high likelihood of human errors. The high-friction nature of transactions is 'hardwired' into the structure of real estate markets (Graglia and Mellon, 2018), hence there is a need for a more efficient and transparent real estate transaction process based on openly accessible, up-to-date standardised property information in a single pool (Saull and Baum, 2019). Decentralised ledgers such as blockchain have been proposed as a solution (Deloitte, 2017b; Kairos Future, 2017; PwC and Urban Land Institute, 2018).

'Intransparency has caused data in real estate to become very valuable, as a consequence companies in the industry have created business models around resolving this data. Since there is no global standard or public ledger where all the data is registered, the industry has the need for third parties to verify the data more than once.'

Deloitte, 2017b, p.6

A typical commercial real estate transaction in the UK consists of the following stages:

- **Stage 1: head of terms.** Both the seller and buyer instruct their advisers (normally their agents). The seller and his/her agent review property information and the restrictions/limitations on the ability to sell. They then devise a strategy to deal with any issues. In some countries, the seller also needs to procure an Energy Performance Certificate. The buyer, in the meantime, considers the sources of finance and the timeline to secure funding.
- **Stage 2: pre-contract.** The seller carries out searches and makes a pre-contract legal package available, and the buyer starts the due diligence process and commissions surveys. Negotiation of the contract then takes place.
- **Stage 3: contract exchange.** Once the buyer has paid the deposit, both parties exchange contracts, and they are then committed to the deal. Before the deal is completed, there is a pre-completion period, during which the seller continues to manage the property and prepares for the completion statement and requisitions on the title deeds, while the buyer continues with due diligence such as pre-completion searches and finalises the mechanics for the transfer of completion monies.
- **Stage 4: completion.** The seller discharges the mortgage, and the buyer assumes responsibility. It is once the transaction is completed that the buyer will pay stamp duty tax and complete the title registration (Investment Property Forum, 2012).

Much of the process can be summarised into verifying information (current title deeds, financial status, contracts of purchase), validating transactions (title deed transfer, crediting) and cross-checking among the different parties to ensure all processes are being carried out. Some of these are repeated by different parties, as information is stored in multiple private siloes (Saull and Baum, 2019). The traditional due diligence process is also predominantly offline and labour intensive. The key to the improvement in efficiency, therefore, lies with how an openly accessible single pool of up-to-date standardised property information can be created.

'One investor explains that in a recent corporate transaction, due diligence took more than six months and accounted for 10 per cent of the total deal cost. Reducing both of these elements using blockchain could affect the value of assets and companies. "A 10 percent change is meaningful," they say.'

PwC and Urban Institute 2018, p.26

A distributed database, in theory, allows information referenced to the asset (the property) to reside on a ledger, which is available almost instantaneously to every actor. The due diligence process, therefore can be streamlined for buyers and lenders, and the potential for human error can be eliminated. Once terms and price are agreed, the exchange of the asset and the transfer of ownership can also be carried out in the decentralised system.

For such decentralised system to work, all the parties involved would need to put information into the distributed ledgers rather than into their siloed databases (Baum, 2017). To demonstrate this process, Box 1 explains a blockchain-based solution that was developed by Lantmäteriet, the Swedish mapping cadastre and land registration authority.

Notably, the process requires two main components: a single portal system, also known as 'e-conveyancing', where all documents needed for a transaction are accessible to all parties involved in the transaction, and a smart contract that automatically enables the exchange if pre-determined conditions are met.

4.1.1 E-conveyancing

The underlying principle of e-conveyancing is to create digital identities of buildings and people in a single system connecting all the agencies that supply information involved in property transfers (Saull and Baum, 2019). The idea is not new. As described in Saull and Baum (2019), in 2006 Her Majesty's Land Registry in England and Wales (HMLR) set up its own e-conveyancing platform called Chain Matrix which would allow buyers, sellers, solicitors/lawyers, agents and lenders to view the process of every transaction in a property chain. The rationale for the system was to highlight the causes of delays and promote a more co-ordinated exchange of contracts and transactions. The platform was trialled three times and was abandoned in the end due to a lack of adoption by conveyancers.

The main issue was that the absence of one party would result in all other parties reverting to paper-based processes. The heart of the problem was believed to be the disintegration between the new platform and the solicitors' own management systems. As data was inputted into both systems separately, the process was considered to be inefficient.

One could argue that current blockchain solutions, such as Lantmäteriet's project on Box 1, share the same principle of the Chain Matrix pilot. Does blockchain offer the solution to the problems encountered by HMLR? From an efficiency perspective, in theory, blockchain would make the conveyance process more efficient and less costly because information regarding the property and parties involved can be verified instantaneously by ledgers. However, Graglia and Mellon (2018) argue that title documents can contain defects if the information is not reviewed and validated by a responsible party prior to recording (i.e. garbage in, garbage out). As long as off-chain information can impact the security of title, professional intermediaries will still be required to perform due diligence (RICS, 2020).

Box 1

A blockchain solution to real estate transaction – testbed project in Sweden

The project was carried out by Lantmäteriet (the Swedish mapping, cadastre and land registration authority), Telia (Project manager for ID-solutions), SBAB (mortgage lender), Landshypotek Bank (investment bank), ChromaWay (blockchain technology company) and Kairos Future (business consultant) in 2016. The aim is to test the possibility of using blockchain as a technical solution for real estate transactions. It is estimated that the successful development and implementation of their platform could save Swedish taxpayers over €100 million a year (Fraser, 2018).

The process:

1. The buyers' and sellers' identities are verified using Lantmäteriet's app.
2. The seller commissions an agent to sell the property via the app. The agent does the due diligence and invites potential buyers. The due diligence does not need to be repeated again by other parties, as all information has been verified.
3. The buyer's bank also has access to the property via the app. The survey report can be included in or linked to the app. The bank can provide preliminary approval of the loan so that the seller can be confident that the buyer has the ability to pay.
4. All information necessary for the transaction from all parties is registered in the app. Signatures are provided using digitalised ID solutions, and all parties involved can retain a copy of the agreement and the verification record. The contract is also shared with Lantmäteriet.
5. The buyer instructs his/her bank to make payment to the seller, upon which land registry receives a notification to initiate the title transfer.
6. Once the title is transferred from the seller to the buyer, it is visible to all parties.

Source: Kairos Future (2017)

Hence efficiency associated with disintermediation is not completely possible, as transacting parties would need some insurance to mitigate the risk. Saul and Baum (2019) confirm that this is still the case in England and Wales.

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

Anand et al., 2016, p.1

There were four criteria proposed by Parabolic (a venture design studio focusing on crypto and blockchain) at the London Blockchain Summit 2019 to evaluate the implementation of blockchain in conveyancing and land and property title registration system. Parabolic argues that for blockchain to be applicable, the following four criteria must be met:

- there is going to be an exchange;
- there is a lack of trust;
- there is a need to share data;
- everyone in the network benefits from decentralisation.

Exchange can be justified easily as a real estate transaction involves an exchange of ownership and the rights of a physical asset. Regarding trust, the conveyancing process and land registry systems are different across countries and jurisdictions. Some are well established and generally trusted by the public (for example, solicitors and HMLR in the UK), whereas others are relatively immature and incomplete. In England and Wales, although HMLR is investigating blockchain-based applications such as smart contracts and digital signatures, it is very unlikely that it will move to a decentralised structure, as its current system is already well trusted (Tombs, 2019). In other countries, where land records are not complete and frauds to the land titles are more common, the advantage of a blockchain-based title registry system is more appealing, and the implementation of such decentralised land registry systems could be faster (Kshetri, 2017; Propy, 2017).

Sharing data is crucial to improve the efficiency of the transaction process. However, does everyone benefit from decentralisation? For buyers and sellers, there are incentives to share data if transaction time and costs can be significantly reduced, but they might also be concerned with privacy, as information on blockchain cannot be deleted. In addition, there are uncertainties in terms of how this could be applied in accordance with data protection law (RICS, 2020), which also brings the question of whether to use a public chain or a private chain. This report finds that most existing use cases adopt a private network. As discussed in section 2, while private networks may offer a higher level of privacy, such systems are more vulnerable to hacks and data manipulation, they also create a centralised network, which is contradictory to the principle of a decentralised system.

It is unlikely that certain market intermediaries can benefit from decentralisation. Hypothetically, if a decentralised network can successfully 'disintermediate', this innovative approach might, for example, replace lawyers and brokers who are involved in contracts for asset deals (Fairfield, 2014), and it could be expected to see resistance from these professionals. Even if intermediaries are still needed to ensure data and information are accurate in the first place, the cost of setting up a digitalised system that forms the foundation of a decentralised register can be high (Saull and Baum, 2019).

Furthermore, the current structure of real estate transactions incentivises and rewards agents to charge large fees (Fraser, 2018). However a streamlined process potentially threatens such fee-earning practices (Baum, 2017). The reluctance to adopt a decentralised system is evident. Some blockchain-based conveyancing processes (for example, a distributed ledgers pilot for a recorder of deeds in Cook Country, Illinois, USA, and pilot schemes in Pelotas and Morro Redondo municipalities of the state of Rio Grande do Sul, Brazil) were said to have fulfilled their intended outcomes but were not adopted due to the lack commitment from officials (who feared being replaced) and high implementation costs (Spielman, 2016; Lemieux et al., 2018).

4.1.2 Smart contracts

Smart contracts were first introduced by Szabo (1994; 1997) as a way of combining computer protocols with user interfaces to execute the terms of a contract. The principle of smart contracts is to allow contractual clauses to be translated into code, which can then be embedded in a hardware or software that can self-enforce the contracts (Chiristidis and Devetsikiotis, 2016).

'[A] car might be rendered inoperable unless the proper challenge-response protocol is completed with its rightful owner, preventing theft. If a loan was taken out to buy that car, and the owner failed to make payments, the smart contract could automatically invoke a lien, which returns control of the car keys to the bank. This smart lien might be much cheaper and more effective than a repo man. Also needed is a protocol to provably remove the lien when the loan has been paid off, as well as hardship and operational exceptions. For example, it would be rude to revoke operation of the car while it's doing 75 down the freeway.'

Szabo, 1994 p.1

As many have pointed out, smart contracts are not 'smart', but they execute exactly as they are programmed – 'if this happens, then do that.' The self-executing nature of smart contracts minimises the need for trusted intermediaries in transactions and the occurrence of malicious behaviours (Christidis and Devetskiotis, 2016). It is not until the creation of blockchain that smart contracts have become technically feasible.

With blockchain, smart contracts are scripts residing on the chain with a unique address. They use the network of nodes to validate whether aspects of the agreement have been completed. This makes smart contracts transparent and traceable by all the parties involved, hence making the automation of a large number of business processes across different entities possible (Hileman and Rauchs, 2017).

It has already been noted that smart contracts have the potential to disrupt the world of banking by facilitating global money remittance, legal electronic contracts, automated banking ledgers and digital assets (Peters and Panayi, 2016). In real estate, promoters claim that smart contracts are essential to solving the currently inefficient transaction process (Kairos Future, 2017). The Swedish land registry described in Box 1 for example, relies on smart contracts to carry out the exchange. Using the same case, Box 2 further compares the traditional way of signing real estate contracts and the Swedish blockchain-based project.

In line with the existing blockchain literature, the survey results show that most respondents consider 'improving transaction efficiency' as the main advantage of smart contracts (see Figure 4). Nearly half of the respondents also consider security, agent neutrality and being less prone to human errors as the key benefits of smart contracts.

Box 2

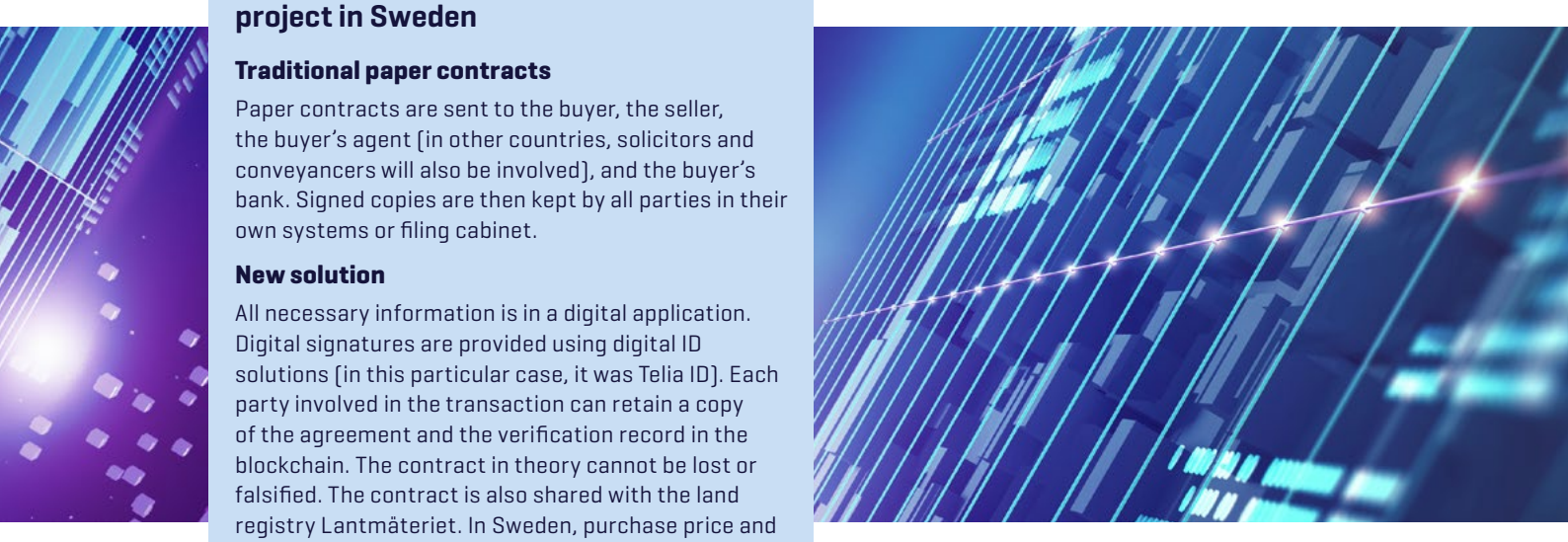
A blockchain solution to real estate transaction – smart contracts, testbed project in Sweden

Traditional paper contracts

Paper contracts are sent to the buyer, the seller, the buyer's agent (in other countries, solicitors and conveyancers will also be involved), and the buyer's bank. Signed copies are then kept by all parties in their own systems or filing cabinet.

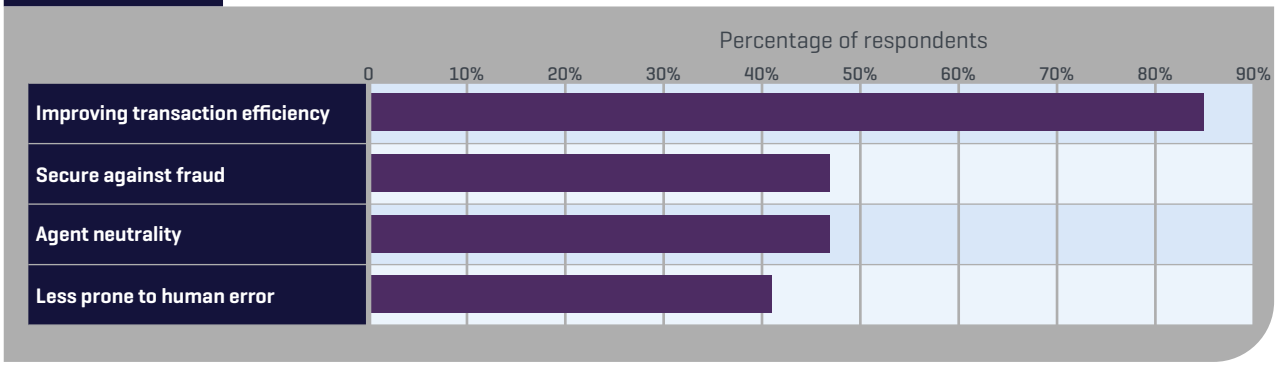
New solution

All necessary information is in a digital application. Digital signatures are provided using digital ID solutions (in this particular case, it was Telia ID). Each party involved in the transaction can retain a copy of the agreement and the verification record in the blockchain. The contract in theory cannot be lost or falsified. The contract is also shared with the land registry Lantmäteriet. In Sweden, purchase price and information on the property can be made public.



Source: Kairos Future (2017)

Figure 4 **Survey results on perceived advantages of smart contracts in real estate**



There are other areas that could potentially adopt smart contracts:

Management: a smart contract between the owner of a property and its tenants aims to ensure that the rental agreement is signed, the rental amount is paid on time, and the termination of the contract is executed correctly (Karamitsos et al., 2018). For example, the Australian firm Midasium has built a private blockchain-based property management system, where a smart contract could automatically initiate lease payments from the tenant to the landlord, as well as to any contractors that perform periodic maintenance, with the benefit of real-time settlement.

Renting: smart contracts could be used to make sure shared renting schemes are not abused (for example, Primalbase).

Investment: the same concept as smart contract-enabled conveyancing discussed above, but this can be applied to investment in direct or indirect real estate (for example, BitRent, Streetwire, Harbor).

There are uncertainties in the usefulness of smart contracts. One of the criticisms centres around the 'oracle problem'. Oracles in the smart contract context refer to those who validate data from the physical world, they can be machine-based or human. Because a smart contract has no knowledge of the physical world, it relies on 'oracles' to verify such information (Song, 2018). Such disconnection between blockchain records and the physical property raises concern (Veuger, 2018). Not only is it contradictory to the 'killer feature of trustlessness' of smart contracts (Song, 2018), it also damages the digital trust established by a decentralised system.

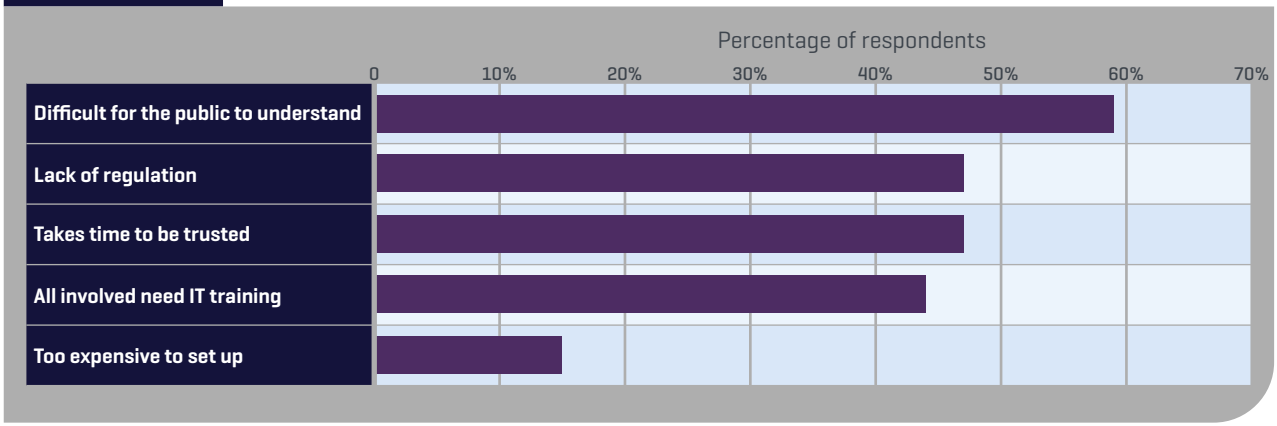
More importantly, oracles only validate the data but not the source of data, hence the 'garbage in, garbage out' issue can persist (Buterin, 2014). Given the importance of oracles, malicious or faulty oracles are the 'inherent choke points' for smart contracts (Koralewski, 2018). There are start-ups such as ChainLink that are experimenting in oracle designs to solve the centralised oracle problem by aggregating real-world data from distributed data sources. The success of such solutions depends on their adoption and traction in the smart contracts' ecosystem. For example, there has been no evidence of node activity or institutional partnerships, hence the value of ChainLink tokens is due to speculation (Koralewski, 2018). Others argue that the solution to the oracle problem is social rather than technical – the users of smart contracts need to understand who the oracles are, and how they can be held accountable (Tsankov, 2018).

In addition to the oracle problem, a blockchain solution can have a number of legal manifestations that can impact the legal enforceability of smart contracts. For example, with blockchain in general, there will be jurisdictional confusion over the appropriate cross-border action when a breach or failure occurs in such a decentralised system. Moreover, it is unclear how a claim would be brought against a blockchain system, as such a system is self-governing with no clear legal status (The Law Society, 2017). With smart contracts, there is also legal uncertainty on when digital signatures will become valid. In most countries, digital signatures are yet to be accepted by law. In other countries, legal acceptance is subject to interpretation. For example, in Sweden the law stipulates that the purchase of real property is done through a contract of sale which is to be signed by the seller and the buyer. However in a situation where condominium apartments are transacted, such formality is not specified, and it is possible to use digital contracts.

There are also uncertainties in how the legal systems can be changed to adopt such contracts and the cost associated with it. Because of the lack of legal enforcement, many existing use cases still rely on paper copy backups, a duplication of the process that eliminates the potential efficiency gains of this new technology (Saull and Baum, 2019). The study by Hileman and Rauchs (2017) shows that 40% of distributed ledger operators that were surveyed do not support smart contracts in their networks, indicating that there is still a long way to go until these businesses become fully automated and streamlined by smart contracts.

The survey results (Figure 5) also show that legality and trust in smart contracts are the main perceived issues of real estate professionals. The lack of understanding of smart contracts from the general public is another barrier

Figure 5 Survey results on perceived problems with smart contracts in real estate



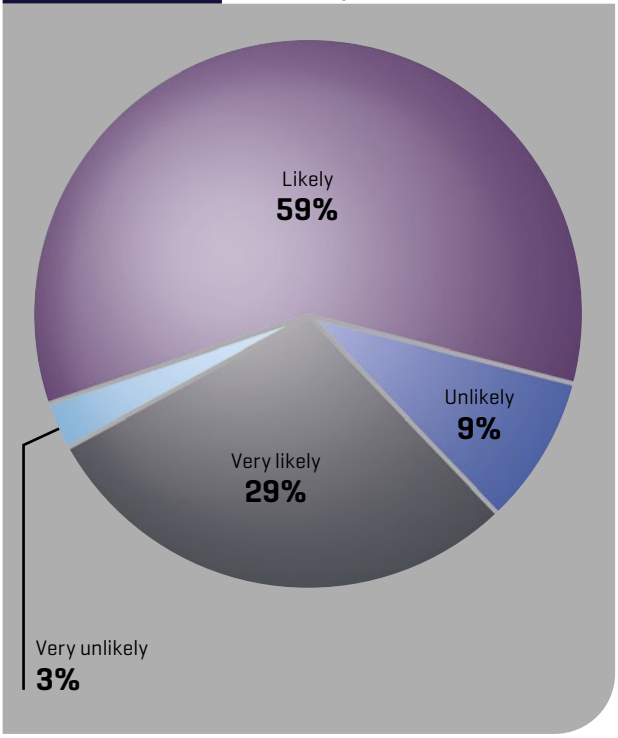
to the innovation being widely adopted. While not many respondents consider setting up costs to be an issue, nearly half of them consider that the IT training involved may be a major drawback. Interestingly, one respondent expressed that the 'contract terms and conditions are agile and difficult to maintain', highlighting the technical challenges with the technology. Despite these drawbacks, most respondents reckon that smart contracts are likely to be widely adopted by the industry (Figure 6).

It is clear that the current real estate transaction process needs to evolve, and new technologies such as DLT have the potential to facilitate such transformation. The authors share the view that this transformation process does not solely rely on blockchain (Saulle and Baum, 2019; Dijkstra, 2017). An infrastructure that consists of reliable digital identification of buildings, adequate legal systems and clear guidance from the government is the pre-requisite for the wider adoption of DLT. The authors contacted the Swedish land registry, and learned that since the testbed project was completed, there has been no further activity. Despite the fact that the technology was found to be a suitable solution to support a completely digital process for selling and buying properties, the project was only ever intended to be a proof of concept (Snäll, M., Personal communication, 21/08/2019).

'(…) there still are some issues regarding blockchain solutions. When a number of partners, keepers of nodes, and actors in a distributed system are to go to production and run a system like this; we still lack business and finance models, legal and policy framework, organizational standards and other parts of governance system in order to deliver a sound and stable service. We need to explore and solve this further (…)'

PwC and Urban Institute 2018, p.26

Figure 6 Survey results on perceived likelihood of adoption of smart contracts in real estate in the next five years



4.2 Improving liquidity – tokenisation

Transactions and other interactions on a blockchain involve the exchange of value, which comes in the form of tokens:

'Tokens might function as digital representations of physical assets, as a reward mechanism to incentivize network participants, or to enable the creation and exchange of new forms of value. They also allow private and corporate participants to control their data'

(Furlonger and Uzureau, 2019, p. 5).

The most discussed tokenisation process in real estate is perhaps the process of creating a digital representation of a physical real asset. Such digital representation can take the form of a fractional ownership interest in an asset, and many believe that tokenisation holds the key to increasing access to global capital and liquidity. This should be differentiated from the other function of tokens, i.e. a reward mechanism to incentivise network participants. The process starts with tokens in the initial coin offering (ICO), a commonly used process used by start-ups in recent years to fund their business or platform solutions. For example, companies (such as Atlant, Brickchain and AssetBlock) that aim to make real estate investments more accessible to investors through tokenisation all used ICOs to fund the start-up phase of the company. Such tokens are usually utility tokens, which provide token holders access to a future product or service but do not entitle the holder ownership (Deloitte, 2019).

The general ICO process involves the start-up creating a plan on a whitepaper that explains the project. An ICO campaign is then initiated, and supporters of the firm are encouraged to buy the tokens. These tokens could represent the digital rights of managing the platforms in the form of membership (Tapscott and Tapscott, 2017). Some also give token holders the right to vote for decisions, for example regarding property management. The concept is very similar to initial public offering (IPO), however due to their decentralised and unregulated nature, ICOs have a freer structure compared to IPOs. Such tokens are traded on crypto exchanges. Their values are determined by supply (normally fixed at the start) and demand (which tends to be based on the speculation of the successfulness of the underlying solution/business model). Many of the ICOs are open to the public.

Incubations are also taking place, many large companies that traditionally dominate the IPO (such as Goldman Sachs, NASDAQ, and the Intercontinental Exchange) have also become the largest investors in blockchain ventures (Tapscott and Tapscott, 2017). In the short history of ICOs, there have been many ICO frauds and unsuccessful business models. Many ICOs have experienced a dramatic drop in value and trading volume, which indicates reduced confidence from the public and investors. However, the potential for ICO to improve the efficiency of raising money in a global decentralised capital market should not be ignored.

A large part of the discussion in this section focuses on the functions of tokens as digital representations of real estate assets. It is worth noting that there are two distinctive possible structures to tokenised assets. One is that the asset is native to the chain, and the other is that the asset is a digital representation of an existing off-chain asset (Hileman and Rauchs, 2017).

A hypothetical example of the former is that the ownership of the underlying assets such as income-generating properties and development projects can be directly defined by the distributed ledger as tokens. Therefore the ownership of tokens represents the ownership of the underlying real asset corollary and any resulting profits from the asset. If the token is only a representation of an off-chain asset (the latter structure), the distributed ledger cannot enforce the exchange. Therefore, issuers of such tokens need to meet the requirement of rules and regulations. Whether these tokens need to be fully backed by existing assets also needs to be addressed. Hence off-chain tokenisation requires the reintroduction of trusted parties who can be responsible for guaranteeing these claims and can be held legally accountable (Hileman and Rauchs, 2017).

In the context of real estate, if tokens can be linked exclusively to the real estate asset and transferred to other users in exchange for payment, with the rights to the asset being recorded on an immutable, permanent, verifiable and auditable blockchain infrastructure, the underlying real asset will become divisible and more liquid. This means real estate investment would no longer be limited by geography (Saull and Baum, 2019).

In reality, however, tokenisation of real estate assets is established off-chain via a special purchase vehicle (SPV). The ownership of tokens therefore represents the ownership of a fraction of the SPV, not the property directly. This is due to a number of reasons:

- there are no land register systems that can incorporate tokenised ownership in title registration (and some land registries are investigating this issue);
- there will be legal issues with regard to property rights of such fractioned ownership (for example, how can the user rights be divided?);
- it is relatively easy to set up an off-chain structure. The process of such tokenisation structure is often referred to as referred as a security token offering (STO).

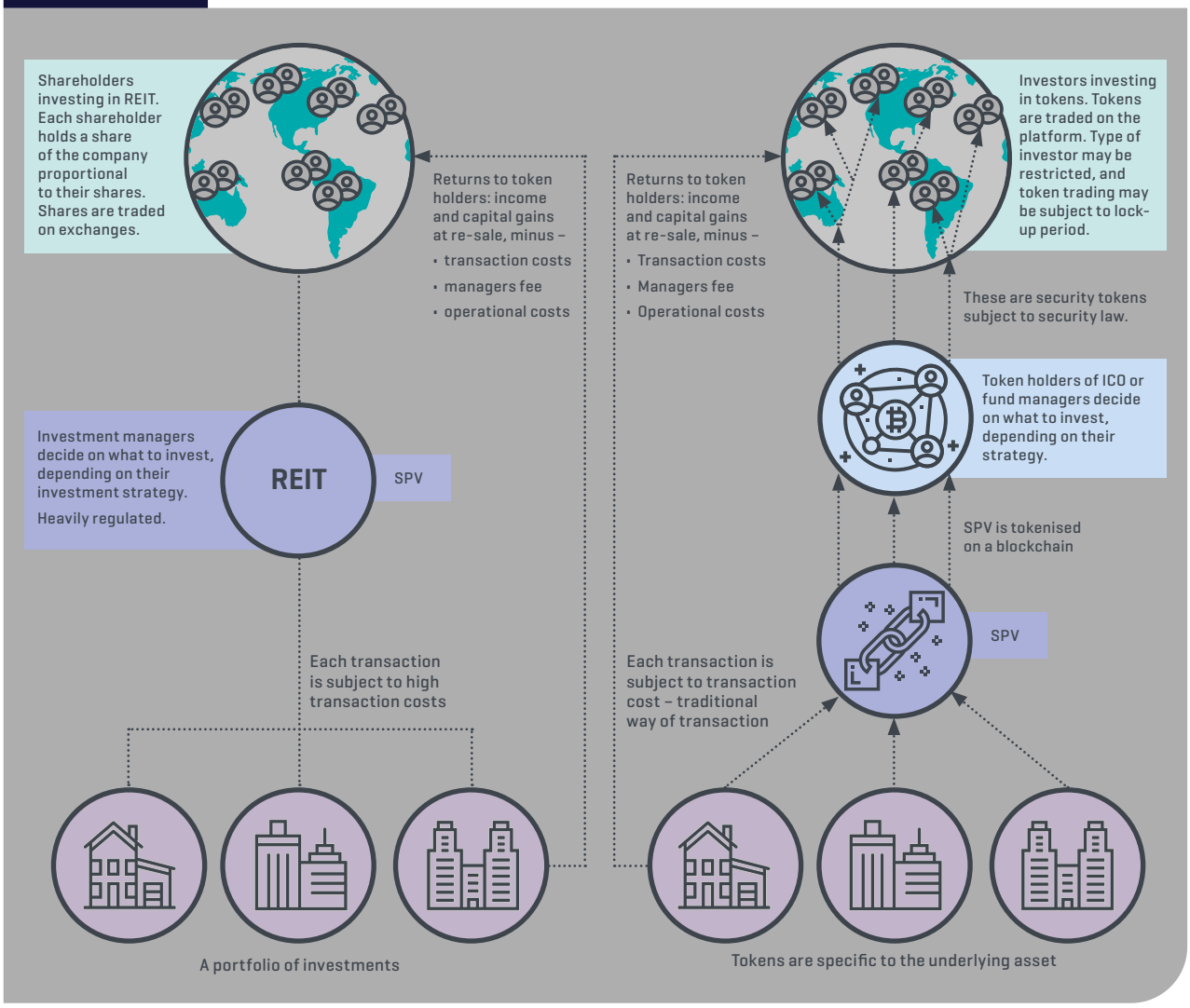
One could argue that the security tokenisation of real estate in the current format is not much different from the traditional indirect real estate investments such as real estate investment trusts (REITs) and private equity real estate funds. The processes of a tokenisation model and investment through a public REIT are illustrated in Figure 7.

Details of such STOs are different among issuers. In general, as securities, these tokens are subject to law and regulations of the jurisdiction where the SPV is tokenised. For example, tokenisation of properties in the USA was carried out under Regulation D Rule 506(c) of the Securities Act of 1933. Subject to regulations, some issuers adopt a democratised model where there are no restrictions on the types of investors (i.e. anyone could invest and re-sell), while others only allow accredited investors (i.e. high net worth individuals, companies and sophisticated investors) to participate with a lock-up period and minimum amount to invest. Voting rights also differ, token holders in the ICO have voting rights in investment decisions with some of the platforms, while investment decisions are executively made by internal or external fund managers with other solutions providers.

In comparison to REITs, such STOs are considered to be less costly to set up (Won, 2019), however the STOs could also have a complicated structure, for example, both debt and equity can be backed by tokens. Since there is no specific requirement on information disclosure, tokenisation potentially can offer a faster and easier procedure to raise funds. Most public REITs on the other hand, are required to disclose more information by security laws and Exchange Commission requirements.

A number of tokenisation cases took place in the last few years, for example, St Regis Aspen Resort was tokenised with an $18m security offering of tokens in 2018. A development of multi-unit luxury apartments at 13th Street in Manhattan was tokenised with a two-token waterfall structure ($17m in debt and $8m in equity) in early 2019.

Figure 7 **Example of tokenisation process via SPV versus REIT**



There are also unsuccessful stories, for example, the tokenisation platform Harbor's STO of a student residence in southern California was cancelled due to disagreement from mortgage providers on the lending terms.

For retail investors, tokens could potentially be more liquid than traditional indirect real estate investments as they are not subject to the opening hours of exchanges or cross-border transaction fees. However, liquidity is unlikely to be achieved instantaneously with the current tokenising infrastructure for the following reasons:

- creating a truly liquid market in real state requires a large transaction volume. Unlike stocks, which are traded on a few major exchanges, tokens are traded on the issuer's own platform. This is creating a highly fragmented market that further reduces liquidity (Freeman and Fetner, 2019).
- with stocks, all distribution channels have access to the exchanges. For example, investors can trade shares via online platforms, traditional brokers, or financial advisers. This is not yet possible for tokenised assets.

Retail investors also need to be aware of the specific risks associated with the underlying property. Most STO deals seem to consist of a single asset or properties within the same development. With limited information disclosure and potential lock-up periods, there will be uncertainty with the cash flows of the underlying incoming generating asset (Vogel and Moll, 2014). If token holders are not entitled to vote, they will have no direct control of the asset being invested. If the issuer adopts a 'democratised' model, how investment and operational decisions can be made among all token holders is unclear. Voting rights could be embedded within a smart contract, however such governing mechanisms are not yet in place and will take time to be developed (Freedman and Fetner, 2019; Hileman and Rauchs, 2017).

There are also concerns regarding the expected value of tokenised asset. It is unclear if/how the tokenisation process would impact the valuation of the underlying asset. For instance, how can liquidity risk be reflected in yield? There are also uncertainties in the value of tokens at redemption (Christidis and Devetsikiotis, 2016).

Opinions of survey respondents on the pros and cons of tokenisation are summarised in Figure 8 and Figure 9 respectively. Although the main perceived advantages of tokenisation include the possibility of fractioned investments, improvement in liquidity, efficiency, and security, the respondents also highlighted issues in the determination of token values, the lack of regulatory framework and public understanding, and the maturity of the token market. In addition, a few respondents were also concerned about the cost of the process (although the existing literature has suggested an STO is relatively cheap to set up compared to REITs), and the security and scalability of the tokenisation process.

Again, the four criteria for a blockchain solution to be necessary discussed section 4.1 are applied in assessing the need for tokenisation – namely a lack of trust, the need to share data, the existence of a transaction, and that all parties in the network must benefit. In terms of trust, there do not appear to be trust issues with REITs and private equity funds in well established markets. However, studies have shown that there might be agent costs and conflicts of interest associated with externally managed REITs, resulting in the under-performance of such REITs (Saglyn, 1996; Capozza and Seguin, 2000). Such issues are internal to the management structure of the funds and not related to the decentralised principle. Tokenisation might be more attractive in markets where REITs are not established, but the overall transparency in such real estate markets might still be a concern for investors.

Figure 8 **Survey results on perceived benefits of tokenisation in real estate assets**

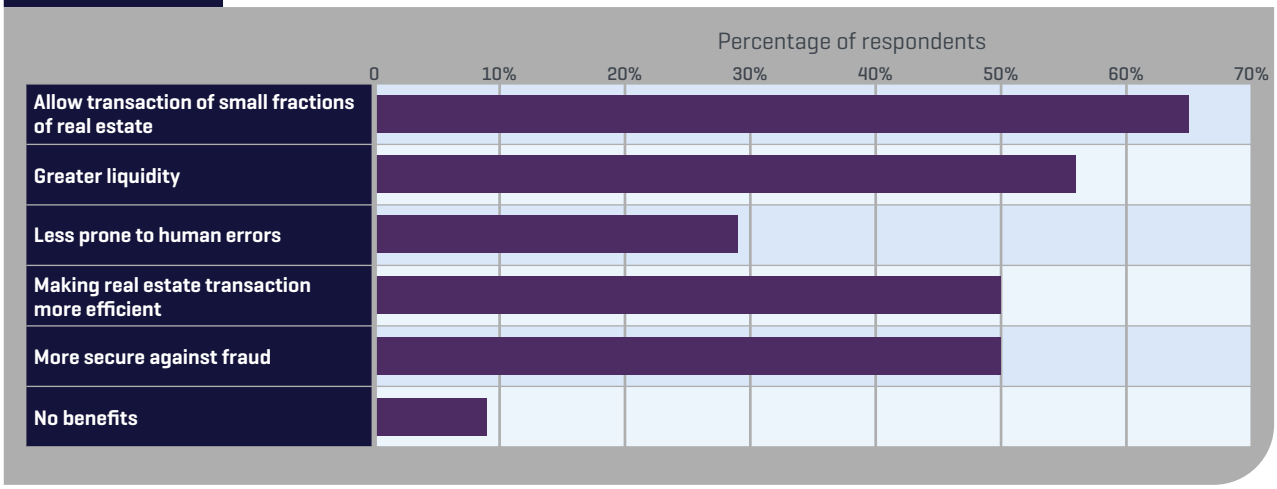
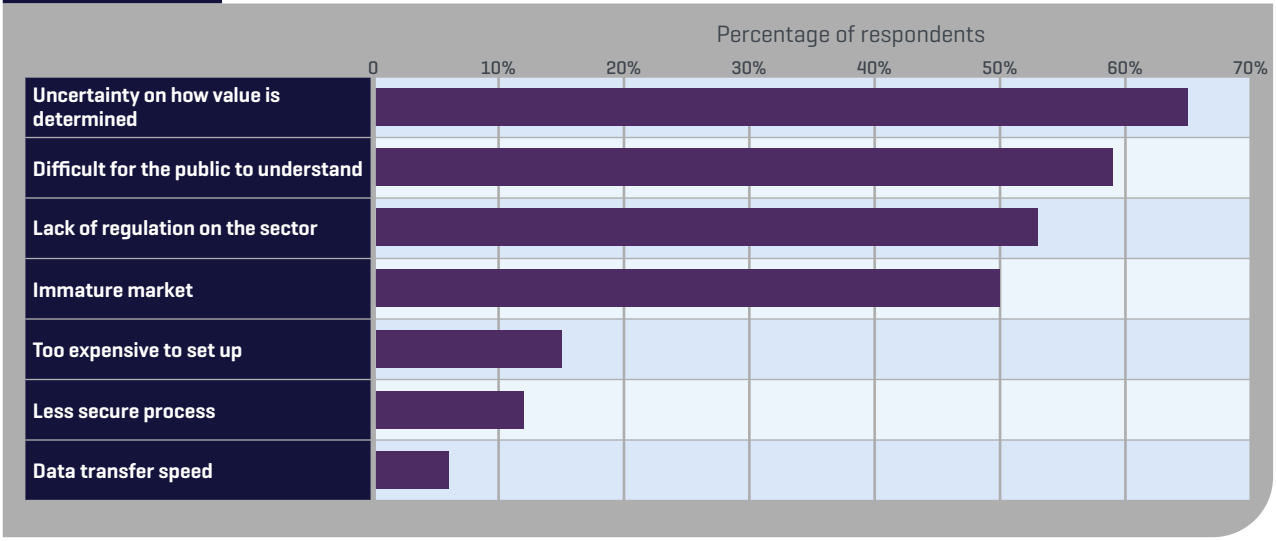


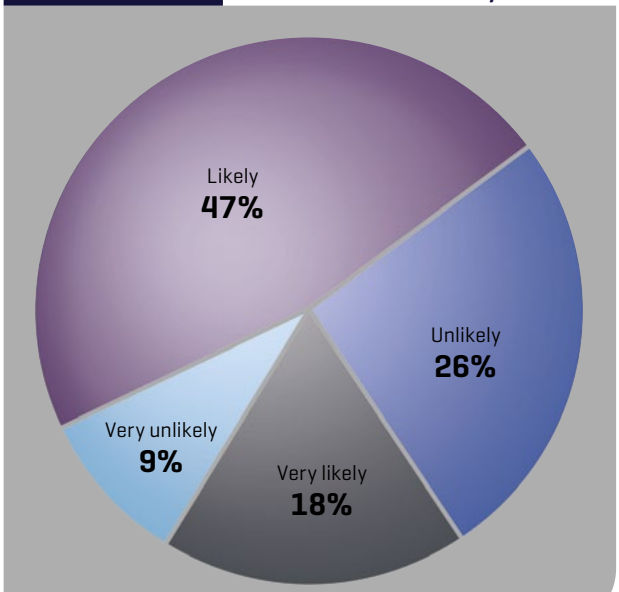
Figure 9 Survey results on perceived issues of tokenisation in real estate



While tokenisation certainly involves transactions, it is unclear whether there is a need to share data in such an indirect process for real estate investment. As mentioned, with STOs there is no specific requirement on information disclosure, whereas REITs have to disclose much more information under regulations. It appears that both issuers and investors can potentially benefit from a higher level of liquidity as a result of tokenisation, however the liquidity of such tokens remains uncertain given the current market capitalisation of tokenised assets.

Freedman and Fetner (2019) argue that not everyone would benefit from a more liquid market – sophisticated investors rely on illiquidity to make outsized returns. Similarly, Baum (2017) argues that if secondary platforms begin to capture real scale, real time pricing of assets becomes inevitable and the risk of the asset may rise. Token values may 'fluctuate according to their own laws quite independently of the movement of the value of the real capital' (Harvey, 2018). In other words, tokens may behave more like shares rather than the underlying asset. The legal issues with smart contracts, which are normally embedded in tokenisation, also apply. Hence, despite its potential, tokenisation currently appears to be no more than another way of crowdfunding real estate investment. The survey shows that 65% of respondents reckon that tokenisation will be widely implemented by the real estate sector, while the other 35% disagree (Figure 10). Compared to smart contracts, there seems to be less confidence in the wider adoption of tokenisation.

Figure 10 Perception on the likelihood of the wide adoption of tokenisation by the real estate sector in the next five years



4.3 Valuation

The Bank of China (Hong Kong) was reported to have applied blockchain to 85% of real estate appraisal, and blockchain was also used by JLL in their Spanish commercial real estate valuation in 2018. Figure 11 illustrates the property valuation DLT workflow by the Hong Kong Applied Science and Technology Research Institute (ASTRI): first, the bank requests a property valuation report from a surveyor. The surveyor does research, inspects the property and prepares a full report. Instead of giving the bank a hard copy or electronic copy of the report, the surveyor inputs the results and uploads the report via a user interface to the distributed ledgers. A network node generates a full report hash value and stores the property valuation information (including property address, a reference number for the property, the area, the age of the property, valuation date, the full report hash value, the name of the valuation company, and the property type) on the distributed ledgers. The bank then retrieves the valuation information from the network and uses the hash value to verify the report. If the bank does not approve the valuation, the valuer will need to review the report and resubmit information. Once the valuation is approved, the data is then shared among participating banks (ASTRI, 2016).

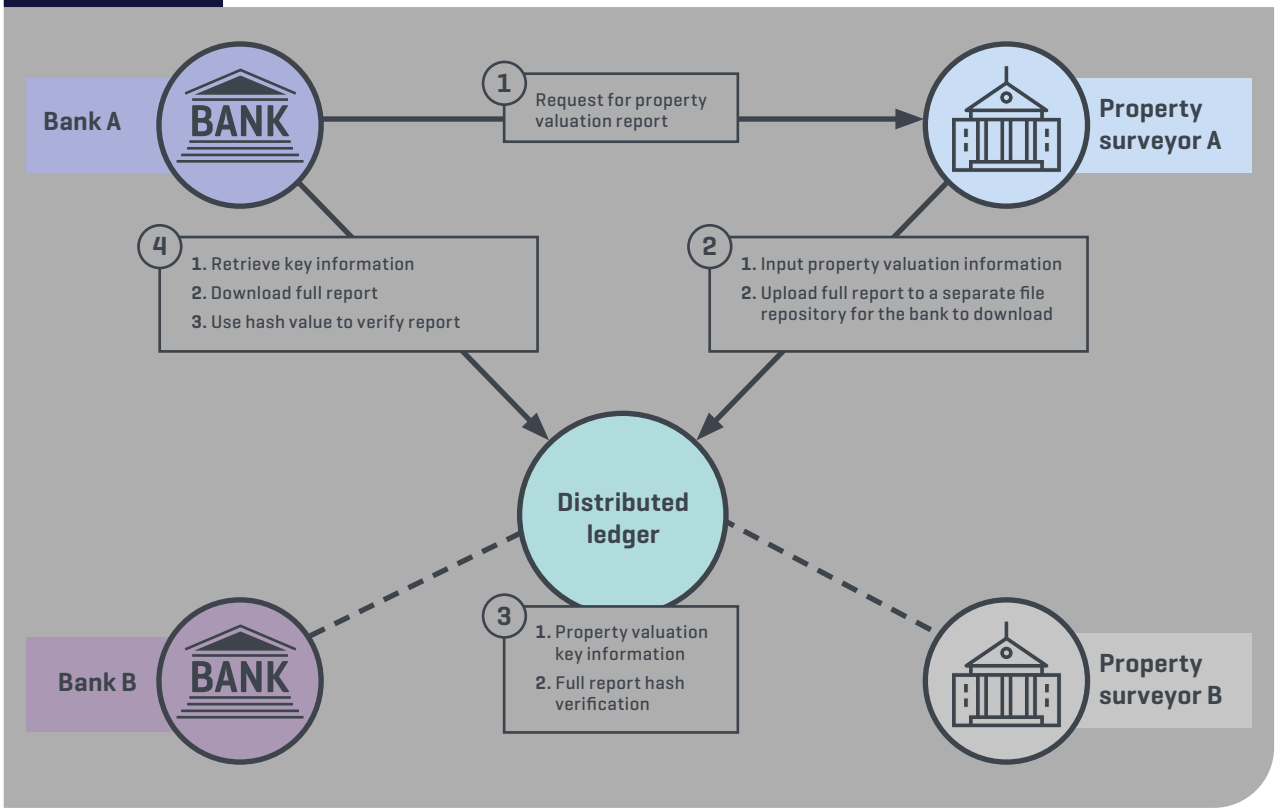
The main contribution of the technology is that the authentication of data is carried out automatically in blockchain, so that parties involved in a transaction would not be able to tamper with data. It also means that the validity of the valuation can be verified quickly and trustworthily.

'DLT based valuation platform 'allows multiple banks to access this network to download the property valuation report without contacting the surveyor individually. On the other hand, surveyors will no longer need to prepare a stack of paper forms for valuation reports each time when there is a request from banks. According to the Bank of China (BOC), they have improved the operational efficiency by more than 50% in the 4 months they have been using DTL. For example, it used to take more than a week to receive the property valuation report but now it only takes 2 to 3 days.

BOC is inviting more banks to join this initiative because the more banks that use this system, the more value it can bring out.'

Duncan W. in (Sia Partners, 2017), p.1

Figure 11 **Blockchain-based valuation process by ASTRI**



Source: ASTRI, 2016, p.63

The process would not affect valuation methods and standards (for example, surveyors will still need to physically inspect the property, and the valuation process will still need to comply with standards and regulations). The emphasis is on how data is collated, which depends on whether stakeholders are willing to share and coordinate the information.

ASTRI (2016) argues that since the valuation involves non-sensitive and publicly accessible information, coupled with the fact that it involves only two types of participants – the bank and surveyors – testing and implementation of private ledgers is more feasible. However, if more functions need to be embedded (for example incorporating lending into the structure), the process will become much more complex, as not only would it involve more parties, but also sensitive personal data and the need for legal enforcement.

The majority of survey respondents agree that blockchain could make the valuation process more efficient (see Figure 12). Over 50% also consider that the technology offers a solution to property valuation that is secure and less prone to human error and has the potential for global acceptance and recognition. In addition, some respondents mentioned the potential reduction in overhead costs. However, around 10% of respondents are not sure if the technology would add value to the existing valuation process.

Figure 13 shows that most respondents are concerned about the lack of regulation and the lack of understanding from the public. Less than a third of the respondents also consider that blockchain-based valuation is too expensive to set up and not a cost-effective system to implement. A small number of respondents raised the issues of frauds reported in the media. Interestingly, one respondent

Figure 12 Survey results on perceived benefits of valuation using blockchain

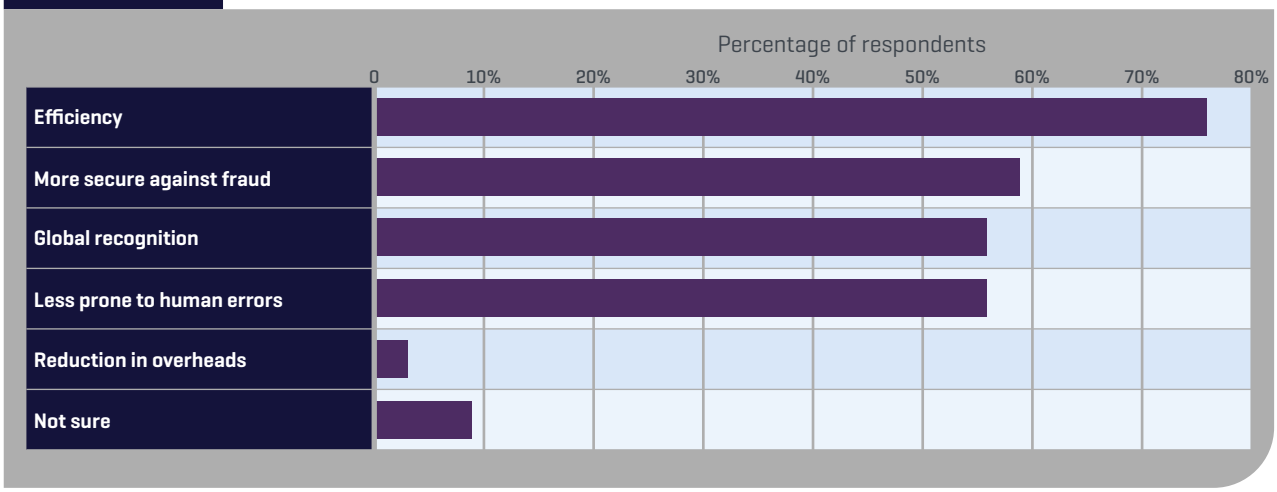
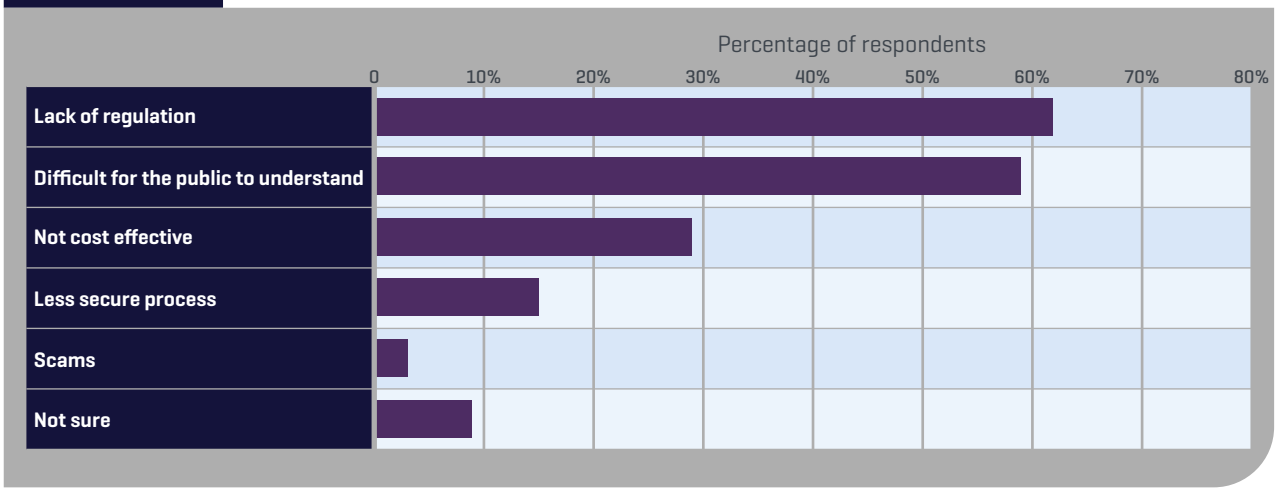
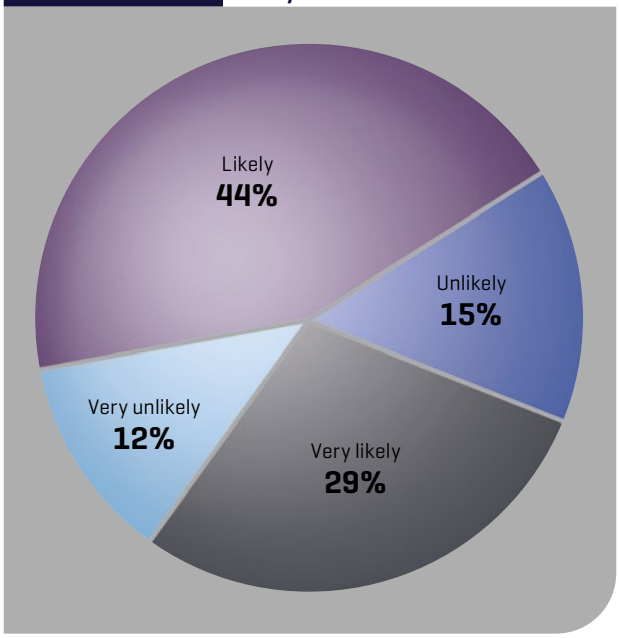


Figure 13 Survey results on perceived issues with valuation using blockchain



thought the process refers to automated valuations: 'not all properties are the same, people would have spent a ton of money doing their home, which would hold [a] certain value. When assessing the property for value, you can't just get a computer to do it.' Clearly there is misunderstanding around the application of blockchain in the valuation process. Despite these concerns, 73% of respondents think blockchain is likely or very likely to be adopted in real estate valuation (Figure 14).

Figure 14 **Perceived likelihood of wide adoption of DLT in valuation in real estate valuation in the next five years**



4.4 Blockchain in efficient and reliable property search

Property search is conventionally done via multiple listing services (MLS), which are typically subscription based with high access fees, at least in the case of commercial properties. Because the platforms rely on agents and brokers to supply information voluntarily, the accuracy and completeness of such information are not guaranteed. The search process is also considered as inefficient for landlords and tenants, as listing information is fragmented and often out of date across multiple platforms (RICS, 2020).

It has been suggested that a blockchain-based listing platform could resolve this issue. As data is stored on a P2P network, information on properties should be transparent and up-to-date. Brokers would have more control over their data, and end-users could benefit from such a system with more reliable and complete information at a lower cost (CBInsights, 2019).

One could argue that a reliable listing platform with good coverage of listings alone does not necessarily require blockchain (if transactions are not embedded in the system). For example, in Scottish housing markets, there are several well-established and trusted property solicitor centres that cover the majority of residential listings with valuation reports and energy performance certificates. Many blockchain-based listing platforms hence integrate smart contract-enabled transactions. Box 3 shows the models adopted by the start-up Propy. Such models utilise blockchain throughout the whole property value chain (from searching to transaction, to land registry). While such models combine all the advantageous features of blockchain discussed earlier, they also face complex functional, social and legal challenges associated with e-conveyancing and smart contracts.

Box 3

End-to-end transaction platforms – Propy

Propy was founded in 2017, with its headquarter in California, USA. The company provides three platforms for residential properties:

- A listing platform that allows sellers to list properties and buyers to search for properties (in the company's whitepaper, the company indicated the intention to adopt a decentralised system for the listing platform in the future).
- A transaction platform, where due diligence and transactions are facilitated by blockchain.
- A registry that stores all land records on the blockchain by implementing smart contracts.

4.5 Summary

The advantages of the key applications of DTL, particularly in the form of blockchain in real estate and the barriers for their wider adoption have been discussed. To conclude the section, the key findings are summarised using the eight-level framework (Graglia and Mellon, 2018) in Table 1. The framework starts with a level 0 that represents the non-blockchain systems, and as the level increases, the process becomes more sophisticated and complex.

At level 1, blockchain is used for recording data. In the real estate context, this could mean using blockchain to verify a sale or a lease. This would be particularly useful in jurisdictions where notaries are not available or cannot be fully trusted, as blockchain-based title recording systems would make it significantly harder to falsify records. Such systems may also be easily implemented in places where there are strong open-data movements or high degrees of transparency. Blockchain-based valuation can also be categorised into this first level. However, it should be noted that the current form of blockchain does not implement the full 'create, read, update, delete' model that is found in conventional database management technology, as the technology cannot delete data (Gartner, 2019). This may represent a major limitation of blockchain as a database management system.

The process of e-conveyancing described in section 4.1.1 is an example of level 2 – smart workflow. The main contribution of blockchain is speeding up the existing conveyancing process and making it transparent. With real estate, the level 2 application tends to be embedded in level 3 – (smart escrow), which aims to enable the automatic transfer of ownership or payments once all pre-specified conditions are satisfied (i.e. the application of smart contracts). This report has noted that smart contracts are facing challenges in legality and manageability. Gartner (2019b) suggests that the technology will undergo significant changes and will continue to mature over the next two or three years.

Level 4 requires a private blockchain that replaces the traditional central database for storing title records (although Graglia and Mellon (2018) argue that the recording function should still be performed on a public blockchain). Countries such as Dubai and Georgia are in the process of implementing such a system.

From Level 5 onwards, there are fewer user cases and applications. For example, level 5 enables disaggregated rights, which is not feasible yet with real assets. Level 6 refers to a specific right being shared or divided among multiple users – the principle of tokenisation. However, as noted before, the current models of tokenised real estate assets do not support true fractional ownership.

At level 7, P2P transactions can occur if legal rights are clarified. In real estate, the transaction of the real asset – the property – is still facilitated by intermediaries in all the applications of blockchain discussed in this report. Until the legal system can enforce smart contracts properly, solicitors and conveyancers are still needed in the transaction process. Lastly, level 8 refers to the interoperability of multiple blockchain-based systems across countries and jurisdictions. This is challenging from a technological as well as legal and political perspectives (RICS, 2020).

Table 1 **Blockchain property registry adoption levels**

Level	Name	Description
0	No integration	No use of blockchain
1	Blockchain recording	Public blockchain used to record documents related to land registration
2	Smart work-flow	Blockchain used to record progress of a transaction
3	Smart escrow	Smart contracts used for escrowing payment
4	Blockchain registry	Central database replaced with a permissioned block-chain
5	Disaggregated rights	Various rights to a single parcel are disaggregated and managed via blockchain
6	Fractional rights	Rights for a given parcel are fragmented and managed via blockchain
7	P2P transactions	Rights are transacted without intermediaries on level 4 system
8	Interoperability	Different blockchain registries merge

Source: Graglia and Mellon, 2018, p. 98

5.0 Blockchain in real estate: disruptor or foundational technology?

Many believe that blockchain will disrupt the real estate sector (Spielman, 2016; Dijkstra, 2017; CBInsights, 2019; Friedlmaier et al., 2018), but very few specify the nature of this disruption. Veuger (2018) suggests that the real estate sector will face two fundamental changes as a result of blockchain: the use of the technology in the sector itself (i.e. the applications discussed in this report) and the broad social impact resulting from the users of real estate. New types of users will emerge, existing institutions will change significantly or disappear and new participants will rise, but the author concludes that 'the true meaning of the blockchain technology for real estate still needs to be investigated' (Veuger, 2018, p.118).

5.1 The theory of disruptive innovation

The theory of disruptive innovation was first developed by Christensen (1997), who argues that such innovations enable the development of new markets, where the key attraction is cheaper, simpler, smaller, more frequent and more-convenient-to-use products. This is very different from sustaining innovations that aim to improve existing products for the existing consumers. A disruptive innovations, therefore is not a breakthrough that makes existing products better, but something that provides a product that is more affordable and accessible by a different (and potentially larger) market. The key conclusion reached by Christensen (1997), Christensen and Raynor (2013) and Danneels (2004) is that such innovations disrupt the existing market, may displace leading firms and products, and eventually grow to dominate the market. The only way to respond is to accept and exploit it.

Throughout history, however, some leaders of traditional business models have struggled to embrace disruptive innovation (Tapscott and Tapscott, 2017). Blockchain in real estate seems to fit Christensen's description of disruptive innovation to a certain extent, for example, tokenisation potentially makes real estate 'more affordable and accessible by a different market'. However, as the current tokenisation models do not fundamentally differ from other investment vehicles, tokenisation is merely another innovative way of real estate investment via crowdfunding. While the idea of digitalised land registry and smart contracts is relatively novel, they do not necessarily create a different market.

Markides (2006) argues that disruptive innovations should be further categorised under two headings, namely business-model innovation (BMI) and radical production innovation. The former refers to the discovery of a fundamentally different business model in an existing business (for example, e-books compete with traditional book stores in fundamentally different ways), while the latter are innovations that create new-to-the-world products. By definition, Markide's (2006) definition of BMI seems to be a better description of blockchain.

'BMI 'must enlarge the existing economic pie, either by attracting new customers into the market or by encouraging existing customers to consume more … It is important to note that business model innovators do not discover new products or services; they simply redefine what an existing product or service is and how it is provided to the customer'

Markides, 2006, p.20

The theoretical implication of Markides' BMI is that new activities may not be compatible with a company's existing business activities, and companies may face trade-offs or conflicts between the new way and the existing model of doing business. Such trade-offs mean that it is almost impossible for a company to compete in both positions simultaneously, as there will be risks of paying a high straddling cost and degrading the value of the existing activities (Porter, 1996). This is generally true for DLT as, for many industries and companies, it is unknown whether the existing business models and legacies hold more value in comparison to innovative ways based on blockchain.

Real estate is a slow-moving asset class, and the industry is highly conservative (Baum, 2017). One could argue that it might not be true that real estate companies 'are not good at strategy' (Baum, 2017), it could be that given the potential trade-offs and conflicts (i.e. more efficient process with disintermediation versus protecting the fee-earning practices), large well-established firms will, initially, have little incentive to adopt DLT or to respond to it (Markides, 2006).

New business models are not necessarily superior to existing ones, thus the decision to abandon the existing model in favour of a new model should be based on a thorough cost-benefit analysis (Markides, 2006). For example, Gartner (2019a) suggests that 90% of current enterprise blockchain platform implementations will require replacement by 2021. The lack of an industry consensus on product concepts, feature set, core application requirements and target market means that it is unlikely that a single dominant blockchain platform will emerge. In turn, the fragmented landscape of blockchain platforms makes it confusing and challenging for IT decision-makers.

Tapscott and Tapscott (2017) argue that how blockchain would disrupt an industry depends on how incumbents react. 'Blockchain is not an existential threat to those who embrace the new technology paradigm and disrupt from within' (Tapscott and Tapscott, 2017, p.5). Although most companies that specialise in blockchain are start-ups, the existing industry is not ignoring the technology. For example, large real estate service providers such as JLL, CBRE and Savills are all doing research in technologies for real estate. JLL has established a tech and innovation investment global venture fund – Spark – to invest in new technologies; blockchain has also been implemented in real estate valuation (JLL, 2018); Cushman and Wakefield facilitated the first tokenisation of a multifamily property in Brooklyn, USA (Cushman & Wakefield, 2018).

The potential disintermediating nature of blockchain can be a concern for intermediaries in the real estate industry. Although it is unlikely that intermediaries in the conveyancing process will be completely replaced by blockchain, it is possible that private blockchain registry and workflow management providers could eventually compete with the existing system (Graglia and Mellon, 2018). For example, a company providing a parallel registry and managing document exchange between all the parties involved in a real estate transaction could accumulate enough accurate records to start its own title plant over time and offer competitive title insurance premiums. Existing firms need to invest in solutions or business models that could increase their competitiveness, whether these are DLT-based innovations or others.

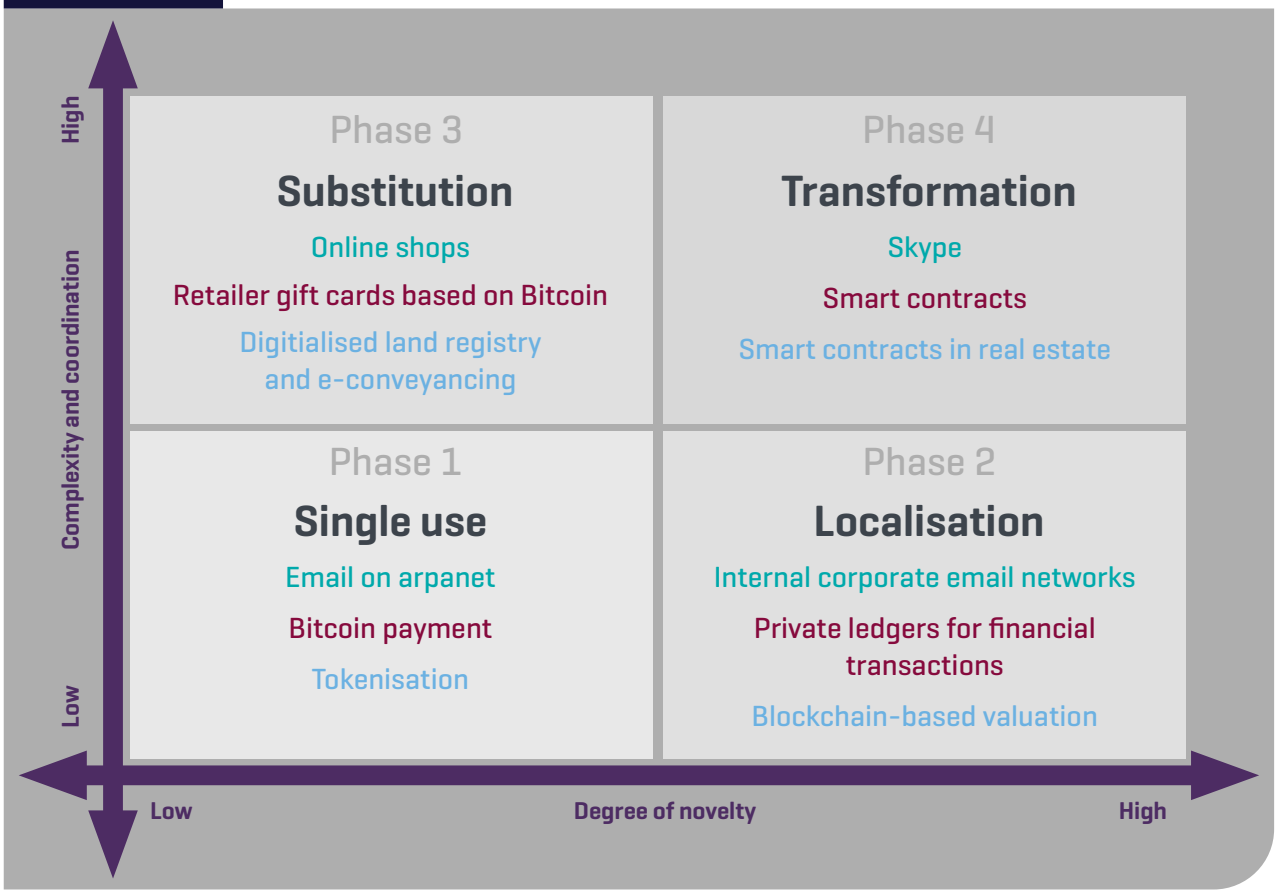
'If you look closely, blockchain really boils down to role-based work versus task-based work within the transaction process. The greater the orientation towards task-based work outcomes, the greater the reliance on technology and automation. In my opinion, any disintermediation in the CRE industry will come from the broker's reputational risk. Obviously, any bad or malicious behavior with respect to accuracy (intentional or not), will go away because the data will be contained in the blockchain.'

Bangia, 2018, p.2

With real estate brokerage, Bangia (2018) suggests that processes that are not associated with blockchain will preserve brokers/agents from disintermediation. For example, consultative tasks on market analysis, strategic planning, property information and negotiations will still require professional expertise and experience. Investors and home buyers still place tremendous trust in such services (Baum, 2017), and it is difficult to see how such services will be replaced by blockchain or other technologies.

On the other hand, it is also highlighted by Bangia (2018) that in processes where blockchain certainly has the advantage to improve efficiency – listing, due diligence, payments and the mechanical part of a transaction – the technology may put intermediaries at risk. As highlighted in RICS (2020), 'the risk to professional jobs and services may derive from technology convergence, rather than blockchain as a standalone technology' (RICS, 2020, p.29). To co-exist with blockchain, real estate professionals should let the task-based aspects be handled by the technology and focus on adding value through the consultative role-based works (Bangia, 2018). The same principle applies to surveyors, as DLT is unlikely to put the professional out of business, but has the potential to make the process more efficient and less prone to human error. It is essential for surveyors to understand the potential changes in their practices and the complexity of the process if more parties (such as mortgage lenders and buyers) are involved.

Figure 15 Framework for foundational technology



Source: Iansiti and Lakhani (2017, p. 7)

Furthermore, if the real estate market becomes more liquid as a result of tokenisation, valuation is then likely to be needed more frequently. It will be interesting to see if valuation methods change as property investments become more liquid and fractioned.

5.2 An alternative framework

Alternatively, the impact of blockchain on real estate can be analysed using Iansiti and Lakhani's (2017) framework on foundational technology (see Figure 15). They argue that blockchain is not a disruptor, but a foundational technology that has the potential to create new foundations for our economic and social systems.

Using two contextual dimensions – complexity/coordination and novelty – the framework maps the process and infrastructure that must be established to facilitate blockchain adoption. This framework can help stakeholders in real estate to evaluate their own blockchain capabilities and strategies. Figure 15 compares the general applications of blockchain (in red) with the specific applications in real estate (in blue) and the development of internet-based technologies (in green).

Phase 1 – Single use: refers to relatively low-novelty and low-coordination applications aimed at creating more convenient, less costly, and highly focused solutions. Bitcoin or other cryptocurrencies, for example, offer a new medium of exchange without the need for centralised verification. In real estate, tokens of tokenised asset can be traded on exchanges (similarly to shares).

As discussed in section 4.2, the potential impact of this is to make traditionally lumpy assets more liquid, however the current models seem to be very similar to REITs and private equity funds, which are neither very novel concepts nor do they require a high level of coordination.

Phase 2 – Localisation: refers to innovations that have high novelty but need a limited number of users to create immediate value. Using the internet as an example, this could refer to the internal corporate email networks adopted by large firms. If blockchain follows such paths, we would expect to see private networks of multiple organisations connected through distributed ledgers.

Such development has already started to take place in the financial services sector. For example, NASDAQ is working with tech firm Chain to offer financial transaction validation and processing technology. Others (such as Bank of America, JPMorgan, the New York Stock Exchange) are in the process of testing the application of blockchain as a replacement for paper-based and

manual transaction processing in areas of trade finance, foreign exchange, cross-border settlement, and securities settlement (Iansiti and Lakhani, 2017). In real estate, one example is blockchain-based valuation. As we have discussed in Section 4.3, a blockchain-based valuation process only requires the participation of surveyors and banks (with relatively low levels of complexity and coordination), the technology has the potential to make the valuation process more transparent, less paper-based, less costly and less prone to human errors.

Phase 3 – Substitution: the application of the technology has low novelty but involves wider public use, so it replaces the existing way of doing business. A hypothetical example would be that new currency systems are formed using cryptocurrencies, where every party that engages in monetary transactions would need to adopt them. Iansiti and Lakhani (2017) highlight the substitutional nature (i.e. new technology to replace old business models) of such innovations in this phase, but also point out that new technologies face more challenges in adoption. In real estate, this report discussed how paper-based property titles can be digitalised and the whole conveyancing system can benefit from a decentralised system. In line with Iansiti and Lakhani (2017), this study also highlights the complexity of such transformation and the resistance from the industry.

Phase 4 – Transformation: applications are not only highly novel, but also require coordination among many actors, therefore have wider implications across the economic, social and political systems. The adoption would require major changes in social and institutional settings. A self-executing contract is an example given in Iansity and Lakhani (2017), and it is compared to Skype: before the internet, video calls were not possible. Without blockchain, self-executing smart contracts are not feasible. Although technical, legal and social barriers prevent such contracts from being widely adopted at the moment, the benefits of smart contracts should not and will not be overlooked.

How should managers and executives of real estate companies evaluate blockchain for their organisations? Iansity and Lakhani (2017) suggest that the easiest place to start is the single-use application, as they tend to be the least risky. Tokenisation has been tested by institutional players, and we are expecting to see more and more cases around the globe. Another low-risk approach is to use blockchain internally as a database for storing and verifying information and transactions (for example a DLT-based valuation process). With the substitutional models, companies could focus on replacements that do not require end-users to change their behaviour significantly but present alternatives to expensive or unattractive solutions (Iansity and Lakhani, 2017). In the context of e-conveyancing in real estate, this requires better confidence in blockchain from the end-users. Perhaps the most challenging task is for the innovation to be absorbed and adopted by the real estate 'ecosystem', where part of the resistance lies within the industry.

Transformative applications are still far away, however companies should evaluate their possibilities and invest in developing the enabling technology. Given the limited experience of DLT among traditional real estate companies, Deloitte (2017a) suggests that executives should consider partnering with vendors – which is in line with Christensen's (1995) recommendations – while others recommend a good balance of staff with traditional real estate skills and knowledge of innovations and new business models (PwC and Urban Land Institute, 2018).

'Consider how law firms will have to change to make smart contracts viable. They'll need to develop new expertise in software and blockchain programming. They'll probably also have to rethink their hourly payment model and entertain the idea of charging transaction or hosting fees for contracts … executives must be sure they understand and have tested the business model implications before making any switch.'

Iansiti and Lakhani, 2017, p.10-11

6.0 Conclusion

This research investigates the application of DLT in the real estate industry particularly in the form of blockchain. Specifically, the report evaluates the application of the technology in the real estate transaction process, tokenised real asset, listing platforms and valuation. The report agrees with other previous studies that the technology has the potential to disrupt the real estate sector, but has yet to mature.

'For the real estate industry, distributed ledgers represent a risk because new services and applications can appear from nowhere to threaten the market's architecture. At the same time, distributed ledger technology represents an intriguing opportunity to build a robust infrastructure for future use by the industry.'

Baum, 2017, p.72

The report highlight the many challenges to overcome: the international legal infrastructure (i.e. the different levels of registration) and complications in taxation (for example, if a property can be tokenised on-chain, how does tax apply to transactions?) could be the first two hurdles to cross. The potentially lower transaction cost and lower barrier to entry offer powerful incentives for the government to invest in the creation of modern and reliable property registries (Graglia and Mellon, 2018).

Whether DLT is the only solution to such registries remains an unanswered question. Testbed projects of blockchain-based conveyancing systems have been introduced in highly developed jurisdictions such as Sweden, but even in Sweden the current legal and social infrastructure is not considered to be sufficiently mature to allow full implementation. It is expected that emerging countries will be early adopters, as DLT can address problems such as corruption and allow efficient access to foreign capitals (Graglia and Mellon, 2018). It is also important to note that governments need to regulate to avoid unintended consequences. For example, with tokenisation, would house prices be driven up as properties have access to more international capital?

For DLT to work in real estate, industry groups should develop common standards and protocols, exchange knowledge and best practices, and engage with innovative companies and regulators. It will also require competitors to work together, which could be challenging. While some stakeholders in the industry 'wait and see' if changes take place with the governments and regulations, others may be concerned that new activities associated with DLT may not be compatible with existing business activities. While it is understandable that firms may initially have little incentive to respond to the new technology, a technology with a disruptive or foundational nature should not be overlooked. Competitors with innovative business models will continue to emerge if new technologies can truly improve market efficiency and barriers can be overcome, and existing companies will have to adapt and transform.

Both the public and the relevant decision-makers need to be educated on DLT to recognise the advantages and shortcomings of the current state of the technology and its potential. Our findings show that misunderstanding of the technology among industry leaders is still widespread.

For example, Gartner (2019b) finds that many blockchain projects ignore key features of the technology and view blockchain purely as a database or storage mechanism. Some assume that interoperability standards exist and smart contracts are mature; others have not considered governance issues thoroughly, thus 'CIOs should monitor the evolving capabilities of blockchain platforms and align their blockchain project timeline accordingly' (Gartner, 2019, p.1).

It is important for the public to understand that DLTs are neutral and can be used for good or evil, and blockchain industry models therefore need to solidify and mature to allow both insiders and outsiders to distinguish between good and bad players (Swan, 2015). In the context of real estate, end users need to understand the services and products enabled by blockchain and other DLTs, and whether they offer competitive advantages over the traditional ones. They need to fully understand how their personal data is recorded, and how their rights are protected. The wider adoption of the technology also depends on the demand from the public.

Report findings:

- DLT such as blockchain has the potential to increase efficiency and transparency of real estate transactions, listing and valuation processes.
- Technically, the technology requires improvement in scalability, confidentiality, and interoperability. As highlighted by Graglia and Mellon (2018), the dominant public blockchains could perish if these technical problems are not solved.
- The interface between the digital realm and the physical world is still weak and damages the digital trust established by decentralised systems (Glaser, 2017). This is particularly relevant to the real estate sector, as it involves real assets and different types of user rights.
- Legally, there are many uncertainties in the self-executing nature of smart contracts and ownership and rights of tokenised assets.
- There is a lack of an industry consensus on product concepts, feature set, core application requirements and target market, so the current market for blockchain platforms is highly fragmented, making technology choices confusing for many decision-makers (Gartner, 2019).
- Socially, the pre-requisite for the technology to be successfully applied in the real estate sector is the participation and coordination among all stakeholders involved. Without guidance from the government and regulators, such coordination is difficult to achieve. Misunderstanding of the technology means that industry leaders and the public need to be educated further.

Despite these shortcomings and challenges, the potential of blockchain applications in real estate should not be ignored. As highlighted in this report, many believe that blockchain has the potential to disrupt industries. Our primary data also shows there is relatively high confidence in the technology to be adopted by various sectors in real estate.

Recommendations:

- Stakeholders should work together (Deloitte, 2017b; Baum, 2017), as a single group is unlikely to be able to drive the changes alone (Saull and Baum, 2019). Lessons could be learned from countries and jurisdictions where regulators, industry players, and academic institutions have been 'purposeful and deliberate in nurturing blockchain technology innovation' (Lim et al., p.1).
- The potential disintermediating nature of blockchain can be a concern for intermediaries in the real estate industry. To co-exist with DLT and other technologies, real estate professionals need to focus on adding value through their consultative role-based works.
- Existing firms need to invest in solutions or business models that could increase their competitiveness. For example, company executives should consider partnering with vendors, and start with single-use applications that require less coordination from other stakeholders. Leaders may also consider re-structuring their companies to attain both a good balance of staff with traditional real estate skills and knowledge of innovations and new business models.
- There is a need for governments to evaluate the impact of the technology and provide up-to-date guidance. On the regulation front, regulators need to protect the public interest, while fostering technological innovations. How regulations unfold could be one of the most significant factors in determining whether DLT will flourish (Swan, 2015).
- The report focuses on blockchain, as the applications of DLT are currently dominated by blockchain. Other types of DLT should been explored. For example, directed acyclic graph (DAG) and Holochain are being explored in terms of increasing efficiency and scalability.

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