Insight paper

RICS

Blockchain: an emerging opportunity for surveyors?

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Foreword

Every so often a revolutionary digital break-through emerges. In many cases the benefits are immediately apparent and widespread, while occasionally its effectiveness and applications are confined to a few specialists.

The internet provides a case in point. We are now almost totally dependent on the search capabilities of the internet for both personal and professional use. But in 1993 the internet server was only available to users by connecting to CERN (the European Organization for Nuclear Research) in Switzerland, and gave access to limited information resources. Indeed, a technical journalist commented at the time that in terms of searchability, 'the web remains mostly potential'.

We have, undoubtedly, come a long way since then, but a fundamental question still arises whenever professionals encounter new technological developments: how can we distinguish between the hopes of an enthusiastic technical community and the realisable long-term benefits that a given technology can unlock, at an affordable cost?

Blockchain has given rise to exactly this question. Blockchain came to public prominence as the digital architecture underpinning Bitcoin and other cryptocurrencies that blossomed following the financial crash of 2008. It soon found potential applications in other fields, including a wide range of sectors in which RICS members and RICS-regulated firms operate, with some speaking of blockchain transformational capabilities in the same breath as those of the internet. Others have counselled caution as to its potential impact and it remains to be seen who will be proven correct.

Can blockchain really deliver as a transformative technology? This insight paper aims to explore this question, introducing readers to the basic elements of the technology and exploring the range of its potential applications in the land, property, construction and built environment sectors. These include supply chain management in the construction industry, where the integrity of materials sourced from around the world needs to be verified before being used on construction projects. The registration of land titles is another process that is considered ideally suited to the application of blockchain, and countries such as Dubai have already started to use blockchain technology to register property transactions and ownership.

However, the paper should also alert built environment professionals to the potentially significant risks and costs associated with adopting blockchain capability. For example, a key application of blockchain technology is the smart contract. Blockchain enables the contracts to execute themselves autonomously once certain conditions are met, allowing credible transactions without the need for third parties. The supporting system is, however, expensive to set up, so businesses need to justify it – not just technically, but financially. Some legal uncertainty also remains over self-executing smart contract transactions and this has yet to be ironed out.

Built environment professionals must hold the public interest at the heart of their decision-making at all times. This is especially true when considering technology-driven solutions: there is sometimes a temptation to fixate on the ideal technical solution without giving appropriate weight to the real societal outcomes.

Who can imagine running a business today without access to the internet? We may well be asking the same question about blockchain in the future, so built environment professionals must be as ready to face that future and deliver confidence to the public.

I hope you find this paper useful and informative as you take steps into that future.

Tim Neal FRICS

RICS President

Glossary

Block	A block is a set of transactions to be recorded onto the blockchain following achievement of consensus. The block consists of two parts: a header and the transaction data. The header contains information that varies according to the blockchain protocol (see below). It is used to identify the block, including a timestamp, a unique code and the code of the preceding block in the chain, and often contains metadata drawn from the transactions in the block.
Blockchain ledger	A type of distributed ledger using blockchain technology.
Blockchain network	A distributed network running a blockchain protocol (see below).
Blockchain protocol	The set of rules governing how a blockchain ledger operates, including how consensus on the blockchain network is achieved, the components of a block, whether permissions are required to participate in the network and the speed at which new blocks are generated.
Consensus	When the validity of new transactions being added to the blockchain ledger is agreed by all participants. Consensus ensures the accuracy of the ledger and is achieved through a number of different mechanisms, including proof-of-work, proof-of-stake, proof-of-authority or selective endorsement. Consensus prevents double-spending of the digital asset being recorded by preventing conflicting entries from being made at different points in the network.
Cross-chain interoperability	The ability for different blockchain ledgers to interact and exchange data with one another.
Cryptography	A technique to encode data into an unreadable format to prevent unauthorised reading of the data. Encrypted messages must be decrypted before reading, using a key to decode the data.
Decentralised system	Authority is distributed across a wide range of participants with no single entity maintaining control over the system.

Digital identity	A unique online identity that may require proof of connection to a real person or organisation, depending on its usage.
Distributed ledger	A ledger stored across a decentralised network. No single participant is in full control of the ledger and new entries into the ledger must be confirmed as valid by all participants on the network, in a process known as achieving consensus.
Distributed network	A network with computer processing power and data spread over multiple participating computers.
Double spending	Occurs when a person transacts the same asset more than once. For example, if a property title is digitised and multiple copies of the same title are sold to different individuals at the same time. Blockchain can prevent this by verifying the validity of a transaction by achieving consensus on the state of the ledger before it is further appended. If the same asset is used in multiple transactions, the blockchain network will accept the first valid transaction and reject all subsequent ones. Once this transaction has propagated over the network, the transaction is considered valid.
Hybrid architecture	Multiple different technologies or systems that interact with one another. For example, a blockchain protocol may allow authenticated user access to a database that is separate from the blockchain, allowing a set of data to be represented on a blockchain without the need to store prohibitively large datasets or to share private or confidential information in a public space.
Immutable	Cannot be retroactively altered. This means that once an entry is made in the blockchain ledger, it cannot be changed.
Node	A participating computer in a blockchain network that stores, updates and broadcasts a copy of the distributed ledger.

Open blockchain	Open, permissionless blockchains are open for anyone to join. Participants in a transaction are identifiable through a digital wallet. There is no other connection to a digital or real-world identity, affording the participant a high degree of anonymity. Anyone can download the blockchain protocol and run their own node on the blockchain network. The ledger is open and readable by anyone. Bitcoin is an example of this kind of blockchain network.
Peer-to-peer network	A network in which participating computer systems connect directly to one another through the internet, allowing file and data sharing between widely distributed computer systems without going through an intermediate server.
Permissioned blockchain	A permissioned blockchain has an access control layer and requires user authentication to join. Users have a clear digital identity that, depending on the purpose of the blockchain, may require their real-world identity to be verified also. The blockchain protocol may restrict users' ability to read data according to their circumstances, most obviously in relation to their degree of involvement in a transaction and their ability to access private information relating to the transaction.
Private blockchain	A private blockchain is closed to the public and membership of the blockchain is controlled by a central, owning authority. The nodes in the blockchain network are defined (and usually controlled) by the owner. This distinguishes a private blockchain from a permissioned blockchain. The owner of the private blockchain can restrict access to participants, for example, by granting various levels of permission to read or write data onto the blockchain.
Proof-of-authority	A consensus mechanism in which the right to verify transactions and update the blockchain ledger is earned by participants with a strong reputation. Their reputation is then used as a stake (see proof-of-stake), with improper updates to the ledger resulting in a loss of authority.

Proof-of-stake	A consensus algorithm used to achieve consensus in blockchain networks. A node is selected to create a new block based on its stake in the system, often determined by several factors such as its wealth, length of participation in the blockchain network and an amount of random chance. There are several rationales for this mechanism: it is impossible to predict which node will create the next block ahead of time, which prevents criminal tampering and any node owner has a vested interest in maintaining an accurate and legitimate ledger due to their high stake in the system.
Proof-of-work	An algorithm used to achieve consensus, mainly on open blockchains. The mechanism works by creating a mathematical puzzle of arbitrary difficulty that must be solved to create a block's unique identifier. The puzzle is designed to be difficult enough to occupy the computing power of the network, but easy to verify once the correct solution has been found. In the Bitcoin network, the difficulty is set to take 10 minutes for the computing power of the network to solve. Once a solution is found, the successful node broadcasts its copy of the ledger and the new transactions to be appended. This is verified by the rest of the blockchain network to achieve consensus. The solution of proof-of-work cryptographic puzzles is known as mining.
Selective endorsement	A consensus mechanism used in private blockchains in business networks. The nodes in the network are selected by the owner of the blockchain to maintain and update the ledger, giving control over who verifies transactions. As a result, trust is centralised in the blockchain network much as it is in established institutions of trust, such as banks. This method of achieving consensus is more energy efficient than others as it does not need to guard against fraudsters joining the blockchain network – as in open blockchains.
Smart contract	An application programmed on a blockchain that is designed to execute automatically when a series of prerequisite criteria are met. This allows for automation of routine processes initiated through updates to a ledger.
Trustless environment	An environment that obviates the need for trust in interactions as the risk of malicious action is removed.

1 Introduction

Transaction records are part of the defining infrastructure of our economic and legal system and they make the construction and management of real estate possible. They support the design and construction of buildings and the operation of infrastructure and real estate assets throughout the real estate life cycle, from inception to decommissioning. Transaction registries, or ledgers, are an essential feature of the real estate industry, underpinning everything from the ownership of private property – the cornerstone of modern society – to the day-to-day management of buildings and the built environment.

These records are traditionally kept and managed by a trusted central authority, such as a bank for day-to-day financial transactions or a central land registry. This gives all users of the record systems confidence in the accuracy of the records and serves to protect the assets that are recorded in the central ledger of the record system. But this could all change as a result of an emerging technological development – blockchain.

The purpose of blockchain is to provide a distributed ledger that can record transactions between two parties in a verifiable and permanent way and does not rely on a trusted central authority for authentication or custody of the records.

Blockchain is advocated as a modern approach to maintaining these records that is digital, immutable, transparent, decentralised, frictionless and immediate. Although still in its infancy, blockchain technology is moving steadily into the mainstream and over the next two decades could change the underlying mechanism of how professional services are delivered, and how the real estate and construction sectors are transacted.

1.1 Aims

This insight paper aims to provide a balanced view of the outlook for blockchain, its application to the real estate, built environment and construction industries and what it could mean for RICS members and RICS-regulated firms. The insight paper will explore the technology, providing an explanation of how blockchain operates, its potential, its limitations – and the problems it can solve. Case studies are included to illustrate the potential of blockchain across each sector.

1.2 Context

Blockchain is a software technology with the potential to reshape the real estate industry, but it is also a technology surrounded by hype.

If blockchain distributed ledger technology achieves widespread adoption, it is expected to change the landscape of business, altering the way transactions are recorded and how records are kept (Lemieux, 2017). For built environment professionals there are undoubtedly opportunities and challenges from entrepreneurs and innovators who see a rosy future for blockchain as a disruptive technology.

But real estate is not finance. Unlike homogenous and incorporeal financial assets, real estate interests are represented by heterogenous corporeal assets and the physical nature of the built environment will lessen the full impact of blockchain as a technology. Many applications of blockchain that are vaunted as bringing transformational change for real estate and the built environment will face limitations caused by the need to inspect, catalogue and record information about a tangible physical asset, each with unique characteristics that may only being identifiable by a site inspection.

2 What is blockchain?

Blockchain is a record-keeping technology that enables a growing list of records to be kept in a digital ledger. The ledger is made up of individual blocks storing transactional data. These blocks are linked using cryptography (see Glossary) to form a chain, with each block inextricably linked to the preceding block in the chain. When people refer to 'a blockchain' they are often referring to the complete transaction history that is stored by that particular record-keeping system. The blockchain ledger can be added to but not edited, making it a trustworthy record of transactions and activity.

A typical block chain transaction would operate as follows (see Figure 1).

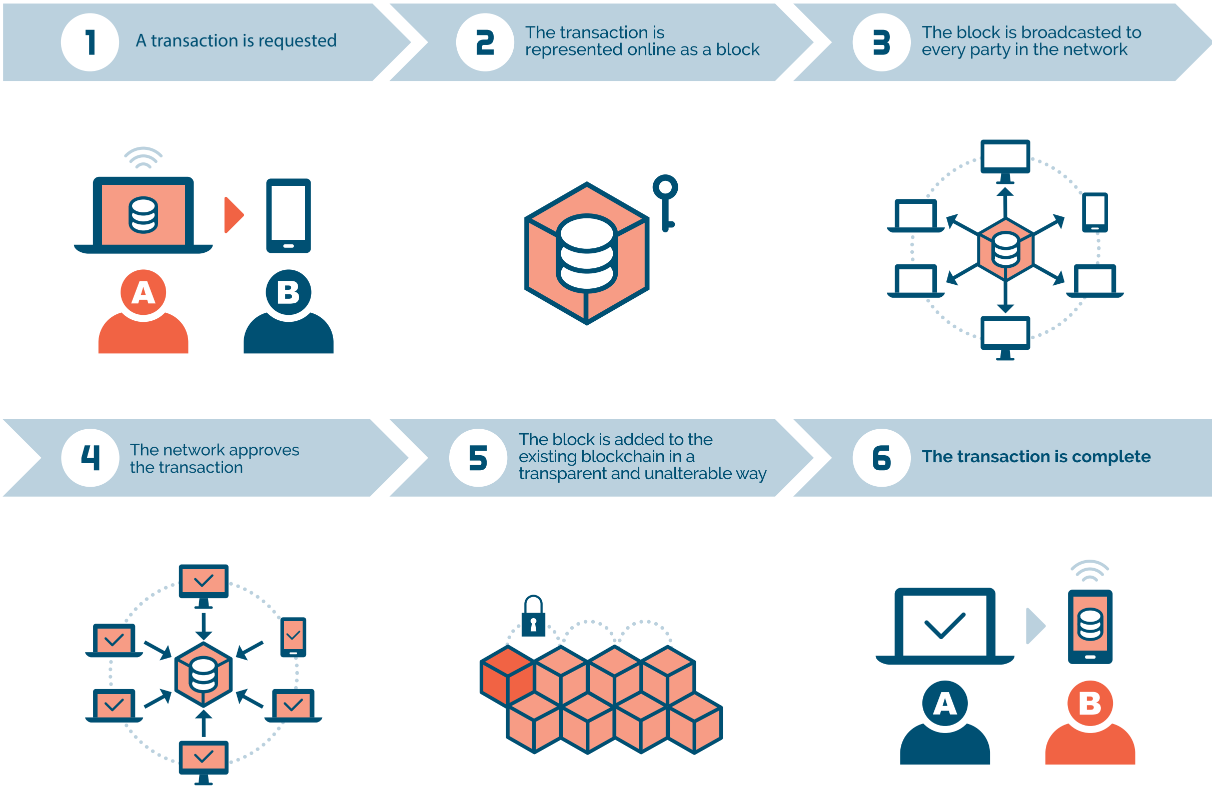

Figure 1: The process by which new transaction data is added to a blockchain (elenabsl/Shutterstock.com)

1 A wants to make a transaction with B.

2 This is achieved through the composition of a block, which consists of a unique block header and a list of transaction data. The block header is formed of components containing metadata that is specific to that block. These metadata link to the previous block by way of information relating to the current block, including a timestamp, and a data structure summarising the list of transactions in the block.

3 Once a transaction is made, the block is broadcast to each party in the network and the blockchain network proceeds to verify its validity and achieve consensus.

4 Consensus is achieved through a process known as mining. Miners take transactions from pools of unconfirmed transactions and add them to the new block being formed, in the process confirming the validity of a transaction in accordance with the history of the blockchain (i.e. that an asset is not being double-spent (see Glossary)). The network then works to achieve consensus through one of several proofing mechanisms. These are essential to prevent an attacker compromising the integrity of the blockchain. Examples include:

- proof-of-work – miners solve a cryptographic puzzle whose difficulty increases in line with the total computing power in the mining pool and
- proof-of-stake – the block generator is chosen through a combination of random selection and a high stake in the system (Kravchenko, 2018).

5 Once the block is approved, it is added to the existing blockchain and is transparent and unalterable. The distributed nature of the ledger makes it very difficult for data contained within a block to be tampered with or falsified: to do so would alter the chain's metadata and require a block's cryptographic signature to be reformulated.

This data structure of the blockchain provides a record of all the transactions that compose that specific blockchain. It is, however, possible to keep a ledger composed of only block headers to overcome space constraints: as a blockchain grows indefinitely it could become very large, depending on the data stored.

6 The transaction is complete. A blockchain network has no central authority and all information is recorded in a shared ledger, which is unchangeable (or immutable). The information in a given blockchain is open for all participants to see and this gives transparency and accountability; everyone who is involved is accountable for their actions (Al-Saqaf & Seidler, 2017).

2.1 Disruptive innovation

Blockchain is a disruptive innovation that could have a far-reaching impact on the wider economy and all sectors of government and industry. Disruptive innovations create new markets, new value chains and new business models, which eventually displace existing ones in the process.

Disruptive innovation is typically technology driven and is often the domain of pioneering start-up businesses. They emerge with a small customer base in a niche market that is enough to support the growth of the start-up, but that has been overlooked by incumbents with already high costs catering to a large market. From these niche markets, the customer base grows as businesses become more established and begin to take advantage of increasingly streamlined and efficient processes. Disruptive innovation usually takes advantage of low-value or new markets, moving into the higher value end as the business becomes increasingly successful.

Examples of disruptive innovation include Airbnb, which transformed the hospitality sector; Netflix, which overhauled the film rental industry; digital photography, which has largely replaced chemical photography; and smart phones, which are increasingly rendering laptops and personal digital assistants obsolete.

2.2 Implementation

Different types of blockchain have evolved since the first blockchain was launched in 2008 to support the cryptocurrency Bitcoin (see section 3) (Nakamoto, 2008). There is no universal agreement on the best way to implement a blockchain application and blockchain terminology is sometimes applied incorrectly (Gramoli & Staples, 2018). The most well-established blockchain implementations have been used for cryptocurrencies, such as Bitcoin and Ethereum, but blockchain has the potential for much wider record-keeping applications.

The decentralised structure of a blockchain distributed ledger (see section 2.3) has the benefit of efficiency, compared to conventional centralised systems, because the transaction costs in a distributed ledger are low (frictionless) and execution can be fast (immediate). The low transaction costs and fast execution speeds, however, need to be weighed up against the infrastructure costs, both for setting up the blockchain ledger and for maintaining it. If these costs are amortised across the life cycle and reflected in the transaction costs, the overall costs may be as high as a conventional ledger system.

If feasible over the long term, the real estate sector and construction industry – where transaction costs are high and timescales are long – can take advantage of the low transaction costs and fast execution speeds of a blockchain ledger. The implications are wide ranging, and could include the registration of land titles, day-to-day transaction records, contract administration, supply chain management, building management and many other areas of practice.

The initial set up of a real estate contract, for example, either for a sale, letting or development opportunity involves a lengthy due diligence process including identity and financial checks, legal process, and the need to establish the nature, extent and condition of the physical property. Checks concerning the property's relationship with neighbouring property, any legal restrictions, easements, rights of way, rights of light, planning constraints, and the legality of use or proposed use may also be necessary. The list is long, and it is unlikely that blockchain can solely replace this process for most real estate contracts.

For administrative processes (where the parties already have a contractual relationship, such as rent and service charge collection in a landlord and tenant relationship), however, adopting blockchain can be more feasible – but the advantages may be smaller.

Blockchain transactions can be financial transactions or non-financial transactions, with each transaction represented as a record in the blockchain network (see Table 1). Although, there are only a small number of blockchain networks in existence today, adoption is expected to grow as organisations recognise the innovative benefits that can be had.

Application area	Record type
Bitcoin cryptocurrency	Financial
Ethereum cryptocurrency	Financial
Land Registry records	Non-financial
Letting records	Mixed financial and non-financial
Identity records	Non-financial
Supply chain and materials records	Mixed financial and non-financial
Surveillance records	Non-financial
Asset maintenance records	Mixed financial and non-financial
Voting records	Non-financial
Employment history	Non-financial
Employee wage or salary records	Financial
Food safety and supply chain	Non-financial

Table 1: Examples of transaction types that can be stored in blockchain

2.3 Decentralised versus centralised networks

Blockchain uses a peer-to-peer computer network to achieve the decentralised ledger and this peer-to-peer network is essential to achieve trust without a central authority. This is because decentralised systems have no central authority to dictate the truth to other participants in the network (see Figure 2).

The decentralised peer-to-peer network distributes tasks and activities between peers on the network. Each peer is a computer participating in the network, known as a node. A copy of the blockchain ledger is stored across all the nodes participating in the system.

The nodes in a blockchain network achieve agreement on the current state of the blockchain using the blockchain protocol, allowing the participants to trust the information stored in the blockchain without having to rely on the centralising mechanism of a trusted third party, such as a bank, a financial institution or a central registry, e.g. a government land registry. This situation, where the need for a trusted intermediary is removed, is known as a 'trustless environment' (see box below).

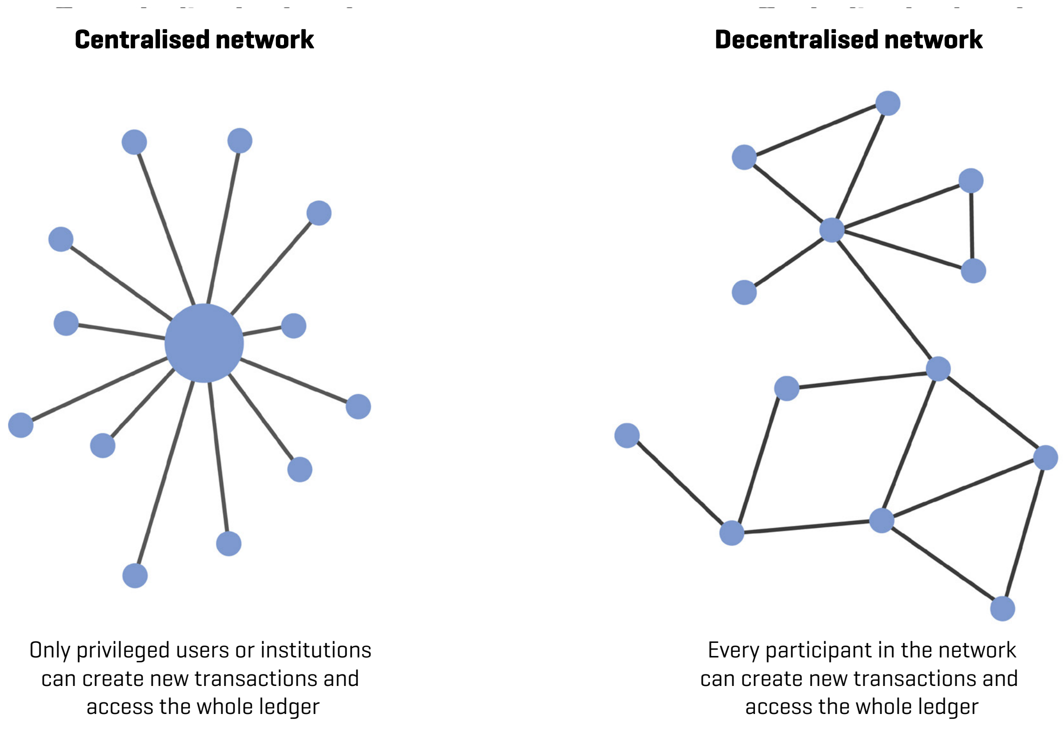

Figure 2: Centralised versus decentralised networks

The trustless environment

Trust (n.) – Firm belief in the reliability, truth, or ability of someone or something.

One of the claimed advantages of blockchain is the creation of a trustless environment. The word 'trustless' here refers to the absence of any central validating authority, not the absence of trust between the participants. Trust in any blockchain ledger is essential, but the trust is delivered by the architecture of the blockchain technology itself rather than through the validation of a trusted third party.

This offers the possibility of real estate transactions being made in a digital environment, with the potential to reduce the time, cost and friction involved in the legal processes, as well as removing the need for trusted intermediaries (Brock, 2018).

The trustless environment provided by blockchain could save time and money in real estate transactions by changing the roles played by intermediaries who are needed to provide trust within the process, but there are still many hurdles to overcome.

- How is the data entered on the blockchain ledger checked for accuracy in the first place?
- How are the identities of the parties checked before they enter the immutable blockchain ledger?

Unlike intangible financial assets, real estate is a physical asset. The due diligence process for real estate requires physical inspection of the asset and this is not possible using a blockchain ledger.

3 Types of blockchain

3.1 Open blockchain

Blockchain underlies the cryptocurrency Bitcoin, which is where the technology was first introduced. Bitcoin blockchain is a decentralised ledger containing all Bitcoin transactions and is an example of a fully distributed open, or unpermissioned (permissionless) general purpose blockchain. Anyone can participate in the Bitcoin blockchain network. The same rules apply to all participants and the whole process is open, so anyone can look at the transaction history on the Bitcoin blockchain.

The fact that anyone can join without having their identity verified means that a permissionless blockchain gives users a degree of anonymity. It is possible to identify all the transactions of a specific user, but it may not be possible to link that user to a specific person or group. This anonymity is frequently described as one of the chief advantages of blockchain, but it means that permissionless blockchains are not suitable for property transactions where the identity of participants is of paramount importance.

Another of the appeals of a blockchain ledger is that it is immutable. This means that changing entries previously made on the blockchain needs to be very difficult. The difficulty in modifying previous data is achieved though the aggregation of the computing power of participants on the network (the peers or nodes). In a permissionless blockchain, each time a new block is made, a cryptographic puzzle must be solved (known as a proof-of-work). This puzzle is essentially an encrypted code that must be decrypted to give a known result. The only way to do this is by brute force guesswork, which requires a large amount of computing power and the result is then validated by the rest of the network.

To conduct fraudulent transactions or to modify previous transactions, an attacker would need to maintain over 51 per cent of computing power across the entire blockchain network for a long enough time to propagate the changes in the ledger across the network of all users. Their open nature also means that permissionless blockchains can have large memberships. This is necessary because it makes the network more resistant to attempts to seize control and rewrite the ledger.

3.2 Private blockchain

A private blockchain may be run by either one organisation, or a consortium of organisations, and tend to be smaller. In the case of a single organisation, this means participants in the network may be separated by department (i.e. each department effectively functions as a node), whereas in a consortium, each entity functions as its own node.

Given the smaller scale of private blockchains, the methods used to verify transactions are different from the larger open blockchains. One approach to verification is selective endorsement, in which trusted nodes are delegated responsibility for controlling, verifying and confirming transactions on the network. This may occur over multiple nodes but remains more centralised than the consensus mechanisms used over open blockchain networks. It is also less tamper resistant than open blockchains as it would require less effort to compromise the network and fraudulently alter the ledger, for example by a hacker gaining control of the trusted nodes. However, even in the event of a security incident, the ledger would still be readily auditable by network participants or oversight bodies.

In real estate and many financial transactions there is a need for privacy, but private blockchain implementations undermine the chief benefit of blockchain, namely the absence of any central validating authority. It will still be digital, decentralised and frictionless but the principles of transparency and immutability may be compromised. Trust is needed between the participants and the level of security (in terms of transactional validity) is lower. These features mean that private blockchains often break with the classical definition of blockchains that centres around the process of decentralisation.

3.3 Permissioned blockchain

A permissioned blockchain offers a combination of features between the open blockchain, which allows anyone to download the blockchain protocol and run a full node, and a private blockchain, in which access is strictly controlled. An open permissioned blockchain allows anyone to apply to join, and following verification of their identity grants them an appropriate level of access to the network.

It is expected that many built environment and real estate blockchains will be permissioned, industry-specific blockchains, with an access control layer and participation rules set by a regulatory authority or an industry consortium. The participants in a permissioned blockchain still play a role in maintaining the blockchain as nodes in the peer-to-peer network, retaining the principle of decentralisation. This form of blockchain is of most interest in real estate applications that require the identity of participants to be known.

Permissioned blockchains can be customised to grant different levels of permission. They allow control of a participant's ability to read or write to the blockchain according to their role, and they can be used to prevent private information from being accessed by unauthorised participants. The wider access enabled by a permissioned blockchain, together with the ability to maintain control over the network, makes this type of implementation suitable for built environment applications that need broad access – yet must also maintain users' privacy. This is not possible on open blockchains, which allow all participants full access to the data, or private blockchains, which are centrally administrated and do not have outward-facing, publicly available interfaces.

The smaller scale and restricted authority to run nodes on a private or permissioned blockchain network mean that the energy intensive proof-of-work algorithms used to achieve consensus on open blockchains such as the Bitcoin network are not needed. The proof-of-work required on an open blockchain to prevent malicious activity is circumvented by the increased ability to trust participants, who can be vetted in permissioned and private blockchains or completely defined in private blockchains.

3.4 Hybrid architectures and off-chain storage

The need for data privacy is an important reason for considering a hybrid architecture rather than an open blockchain. No blockchain application should store private data (i.e. confidential or personally identifiable data) in the open blockchain database, even if it is encrypted. Once in the public domain it cannot be removed and even if it is stored in encrypted form, it may be decrypted in the future.

This is where off-chain storage in a private database may be needed and can be used in combination with an open blockchain to achieve a hybrid solution. In a hybrid system the blockchain transactions are stored in an open blockchain ledger and confidential data are stored in off-chain storage.

Off-chain storage is also suitable where the volume of data makes it impractical or undesirable to store the data in the blockchain database and for many real estate and construction applications this may be desirable. Obvious examples include land title information, which may include site plans and construction projects, which have building information modelling data, and requires large amounts of storage for even a small project.

3.5 Cross-chain interoperability

Cross-chain interoperability between different blockchains has not yet been resolved but is important if blockchain is to achieve the widespread adoption that is predicted. Cross-chain interoperability would allow blockchain ledgers to interact and exchange data, leveraging the value created by the blockchain ecosystem.

Disconnected blockchain systems run counter to the interconnected ethos of the internet and the digital world. Cross-chain interoperability is a prerequisite for enterprise level adoption of blockchain and the scaling up of blockchain adoption. This has the potential to create what has been called the Internet of Value, as financially and economically valuable assets may be exchanged entirely online (Polishchuk, 2017).

4 Smart contracts

A smart contract is a software program that runs on a blockchain network and may be the most significant innovation in blockchain systems. Built on a blockchain ledger, smart contracts execute themselves autonomously when certain conditions are met according to prescribed rules (Swan, 2015).

These are not contracts in the traditional sense, which rely on a number of trusted intermediaries and, for many real estate and construction contracts, a lengthy legal process to implement them. Once set up, a smart contract can execute automatically when pre-set conditions are met, but a blockchain-based smart contract requires considerable investment in both the technical infrastructure and the legal framework for execution and enforcement. This is often overlooked in the boosterism surrounding smart contract implementations.

While it is easy to see the opportunities afforded by smart contracts, they also entail a degree of risk and implementation has so far been problematic and expensive. There is a need for extensive testing of the computer code that delivers the smart contract mechanisms. In addition, smart contracts are a new target for cyber criminals and cyber security specialists are only now starting to understand what smart contract vulnerability looks like (Orcutt, 2018).

However, one of the big drivers for the adoption of blockchain technology in real estate is the role that blockchain can play in streamlining the transaction and conveyancing process. Property transactions such as the sale or lease of a property are time-consuming and expensive. They require extensive due diligence to ensure the legitimacy of a purchaser (or the reliability of a tenant). These issues are further complicated by the need to verify the identity of the parties involved. This information is traditionally supplied in writing and this slows down the process.

The distributed nature of a blockchain means that all parties have access to the same digital contract, so there are no delays in exchange of contracts or signing processes and smart contracts can execute automatically, contingent on meeting certain criteria (Deloitte, 2017). This can provide an additional layer of security for the parties involved: exchange of contracts cannot happen until all parties are satisfied that the conditions of the contract are met and agreed, making it more difficult to defraud a purchaser or tenant of their deposit money.

There are other, less holistic, applications of smart contracts that are relevant when the relationship of the parties is already established, such as landlord and tenant agreements and supply chain and labour relationships. A transparent, immutable record of tenant history with regards to making payments on time or fulfilling contract terms would be a useful way to conduct due diligence more quickly than would otherwise be possible.

5 Real estate opportunities

It is forecast that blockchain will generate more than US$3 trillion of business value by 2030 (Gartner, 2017) and it is easy to see that there are many opportunities for the use of blockchain in the real estate sector. Some of these opportunities will take the form of new organisational processes that streamline transactions (Plansky et al., 2017); others will be driven by blockchain providing a platform for new business models that results in increased liquidity and an opening of real estate investment to new stakeholders who would not otherwise choose to participate in real estate investment markets (Dijkstra, 2017). Additional opportunities will arise from blockchain providing the data storage mechanism to underpin other emerging technologies (Liu et al., 2020).

5.1 Land titles and property rights

One of the big drivers for the adoption of blockchain technology in real estate is the role that blockchain could play in streamlining the conveyancing process (Saull & Baum, 2019). Many of the conveyancing costs arise from the need to hire trustworthy professionals, such as surveyors, valuers and solicitors. These professionals are responsible for valuation, verification, and preparing and agreeing contracts and other legal documents that are part of a real estate transaction. These due diligence processes provide assurance to the buyer that the title to the property is free from defects, but add a substantial amount of time to real estate transactions.

Digitising this information and storing it in an immutable ledger using blockchain could reduce the amount of time, money and effort needed to establish title ownership and verifying the identities of involved parties. While it may expedite the conveyancing and legal due diligence process, however, it would not eliminate all due diligence activities, some of which require a physical inspection of the real estate asset.

For local government, blockchain can store information about zoning and planning permissions, previous works done on a property, or permits associated with a property in a publicly searchable ledger, increasing the transparency of property records and the reliability of searches that are part of the process of transferring a land title.

The use of blockchain for the title register could also reduce the ease of carrying out title fraud and if fraud is attempted, there would be a clear and readily accessible record of changes in the blockchain ledger.

Case study: HM Land Registry

HM Land Registry, responsible for registering land and property ownership in England and Wales, is currently conducting research and development for proof-of-concept applications that use emerging technologies such as distributed ledgers and smart contracts for property registration and conveyancing. The goal is to develop innovative methods that leverage data and technology to make property transactions quicker, easier and more efficient, saving time and money in the process. Transactions would still need to be verified by HM Land Registry, which would also expect to guarantee the title (Brown, 2018).

The Land Registry's Digital Street project began by consulting directly affected stakeholders to identify possible areas for application development. The project then trialled a digital register for a small number of properties of various types and tenures in South West England, incorporating data including title registers, title plans, coal and flood-risk data and other data sources. This was used to develop pilot software in a two-day hackathon (an organised event where programmers involved in software development collaborate intensively to develop a software application in a short frame of time), showcasing the possible uses of a digital property register. Three applications were developed from this exercise: the use of machine learning and natural language processing to answer questions posed by potential buyers; the assessment of lending risks to approve mortgages instantly based on applicant information; and the use of smart contracts, underpinned by blockchain technology to automate exchange and completion processes, including the transfer of funds and tax payments (Tombs, 2018).

Case study: Instant Property Network

Instant Property Network (IPN) is a project built on the technology company R3's Corda blockchain platform (R3 is a large consortium of financial institutions, technology companies, professional services firms and consultancies). Its goal is to lay out the technological foundation for a digital property marketplace to help participants deal more directly with one another to contain costs and reduce the lead time on property transactions.

Instant Property Network carried out a proof-of-concept trial of simulated property transactions across 23 countries. It found that a blockchain-based distributed ledger system could reduce the time taken to complete property transactions from more than three months to less than three weeks. The trial included over 40 companies, among them UK banks Barclays and Royal Bank of Scotland and law firm Clifford Chance, who are all members of the R3 consortium. This improvement could save billions of dollars every year (Ryder-McMullin, 2019) but must overcome the following barriers to adoption.

- Inputting the necessary data into the blockchain system is a large undertaking. It also requires significant investment, as data entered on any blockchain ledger is itself subject to a costly verification and validation process.
- Blockchain empowers IPN and its corporate partners as opposed to buyers and sellers. Smart contracts of this kind require a central authority to implement and validate transactions, which suggests a permissioned blockchain as a minimum and possibly a private blockchain, removing some of the chief benefits of applying blockchain technology.
- Even if the legal process could be successfully implemented using a distributed ledger technology to give a satisfactory level of assurance to the parties in a transaction, it is less easy to see how the same level of assurance relating to physical assets – such as real estate – can be delivered using blockchain ledgers.

IPN is an ambitious project with a credible list of partners. It has the potential for greater automation of routine activities and faster property transaction times, but there are still hurdles to overcome. If successful, this project could put a lot of professional services jobs at risk, but also offer the opportunity to make major savings in the time, effort and cost involved in transacting property.

5.2 Sale and asset transactions

High value transactions require high levels of trust and the sale of real estate is a lengthy process that includes many intermediaries. In addition to the buyer and seller, agencies, brokers, financiers and legal professionals can all be involved in the process and there is a need to agree on the value of the asset and to identify the complex nature of the legal interest in a property.

Information from a blockchain ledger can simplify the valuation process as it offers the ability to store information on the state of a building, previous valuations or sale and transaction details and information on similar properties and their values as part of a secure, distributed ledger (Church, 2019). This could reduce information silos and open a wider pool of information than has previously been available. It could also provide a platform for a unified record to improve the life cycle management of a building.

Blockchain could also cut transaction times and costs by reducing the need for intermediaries in the sale process. Robust, verifiable digital identities help create a trustless environment (see box on p.13) making some of the work conducted by intermediaries obsolete. The ability to programme smart contracts that execute once the agreed funds and deeds are ready for exchange, mitigates risks for both transacting parties and makes the process more efficient. It would not, however, eliminate all due diligence activities, particularly those that require a physical inspection of the real estate asset.

Case study: ChromaWay

Swedish start-up ChromaWay has been developing innovative new products and services based on blockchain technology since 2014. The company operates in a number of sectors, including real estate.

ChromaWay's focus is on the use of blockchain and smart contracts to facilitate property sales and transfers. The company has partnered with Lantmäteriet, the Swedish equivalent of HM Land Registry in the UK, and initiated a project to investigate the use of blockchain in real estate in 2016. In March 2017, pilots were conducted for a proof-of-concept showing the application of the technology and demonstrating a functional implementation. In June 2018, ChromaWay completed a full, verified transaction, with government-approved digital signatures and legal contracts created from a digital smart contract. The process was compliant with EU regulations, including the General Data Protection Regulation (GDPR) 2016.

ChromaWay began working with the Indian state of Andhra Pradesh in 2017 to build a blockchain pilot to provide a transparent and accessible land registry. Andhra Pradesh's current system of centralising land registry and property records in government databases is vulnerable to fraudulent or corrupt editing, resulting in frequent ambiguities and irregularities in records.

ChromaWay's objective is to interface their blockchain ledger with government databases, and to make these records publicly accessible and immutable. If a land title registration is illegitimately modified, the change can be traced through the history stored in the blockchain, along with the user or users involved in modifying a record, providing proof of wrongdoing to investigators. This does not solve the problem of verification for the data being entered into the blockchain. The validity of data when it is entered into the blockchain is an ongoing challenge for any blockchain ledger. The human element is also a potential risk, with one Andhra Pradesh official estimating that land registrars in India receive almost US$700 million in bribes annually (Bhattacharya, 2018).

5.3 Lease agreements and automated payments

Landlords and tenants could also benefit from blockchain. It provides security to the tenant when paying a deposit by helping to ensure that they are not being defrauded by somebody posing as a landlord, and it can also provide landlords with access to a tenant's history.

Smart contracts that are integrated with a blockchain ledger have wide application for the rental and leasehold real estate markets, where there is a lack of a pre-existing relationship between the landlord and the tenant, raising an issue of trust. Leases executed as smart contracts allow more trust to exist between parties and could also automate processes with heavy administrative burdens such as rent collection, deposit payment and return, and maintenance.

In the event of a dispute between parties, mediators would benefit from having full access to the terms agreed at the beginning of a tenancy and payments made under the agreement. Blockchain makes it possible to provide the digital identities and history of the parties involved to assist in negotiation or arbitration. It is also possible to include details of the state of the property before and after a tenancy to ensure fair settlement of a dilapidations claim.

Case study: Rentberry

Rentberry is a San Francisco-based company that uses blockchain and smart contracts to facilitate a smoother residential lettings process. Although the company was only founded in 2015, Rentberry held listings in more than 5,000 towns and cities within the US by the end of 2017. It now lists rental accommodation in more than 50 countries.

Rentberry's platform stores all the documentation and transactions required in the residential lettings process from both tenants and landlords as smart contracts. The software allows for the collection of tenant information and documentation, including a user profile, proof of income and references. When tenants apply to rent a property, they can customise their offer: providing details of how much rent and how large a deposit they are prepared to pay. These offers are anonymously published to show all offers on the accommodation. This increases transparency if, for example, two tenants wish to bid on the same property.

The system makes it simpler for landlords to list available properties and to manage their properties directly without having to rely on agents. Much of the due diligence work such as verifying identity, income and references – traditionally performed by letting agents – is automated through smart contracts. Once an agreement has been reached it can be digitally signed by participants and stored securely in an accessible, distributed ledger. During the tenancy, maintenance requests can be submitted through the system and third-party maintenance provided and paid by smart contracts. As a result, landlords reduce the effort involved in managing their tenancies, eliminating traditional costly agencies.

At present, Rentberry markets properties using conventional local listings, but as the user base increases, it aims to become a global database of rental properties.

5.4 Multiple listing services

Multiple listing services (MLS) are fee-charging services that assist in the operation of the real estate market. They allow real estate brokers to provide information about properties on their books to a wider range of marketing channels, typically other brokers with clients looking to buy properties. However, the system lacks efficiency and the format and information held in these MLS are not standardised. There are over 800 MLS in operation (Arup, 2019) and they are common practice in some parts of the world.

Blockchain offers a new way for brokers to collaborate by using a decentralised, standardised ledger (Arup, 2019). This can reduce the duplication of information that frequently occurs in multiple listings, where databases are fragmented and listings may be out of date. The distributed nature of blockchain and the more direct participation of stakeholders in the records system means that once a listing is no longer valid due to a sale or removal from the market, it is easy for it to be updated by the selling broker. It also avoids the need for brokers or individual sellers to pay multiple listing fees, reducing the cost of conducting real estate transactions and improving efficiency in search processes.

Aside from applications in real estate transactions and contracts, blockchain can also add value to management of infrastructure in the built environment. Utility provision, pollution monitoring and waste stream management and monitoring are all areas that stand to benefit from blockchain. Blockchain can increase transparency in all these areas and offers a secure medium for distributing data on the built environment to associated companies, regulators and customers.

6 Built environment opportunities

6.1 Waste management

Waste management is a key challenge in the built environment and an important aspect of a building's operational life. There is a regulatory burden in ensuring that waste is correctly disposed of and the disposal processes can be costly. It is increasingly important to establish environmentally and socially responsible credentials, creating demand for systems that can attest to the provenance and fate of waste. Blockchain provides a mechanism for facilitating waste management. The waste stream from a building can be recorded in a blockchain ledger to include disposal costs, contractors used and the destination of waste (Kouhizadeh & Sarkis, 2018).

Information about the construction of a building and materials used can be recorded through the construction management process (see Material passports on p. 26). When a building is refurbished or demolished the blockchain ledger can provide a record of the types of waste expected, the intended disposal options at the time of design and the actual disposal process used at end-of-life.

6.2 Water management

Water management is essential for maintaining healthy populations and a clean environment. Once water has been used, it must be treated before being returned into the environment to prevent harmful pollutants or other contaminants from entering the water system.

Blockchain can deliver the mechanism for maintaining records on water levels, water quality and consumption (Lazaroiu & Roscia, 2017). The deployment of sensors throughout the water infrastructure to monitor water quality, and water consumption and the types of wastewater being produced, can provide data which is then recorded in a transparent, open way.

The increasing use of smart meters in buildings, if combined with a blockchain ledger, would facilitate transparency in water billing by providing a billing platform and helping to discourage excessive consumption. Sensors can also be deployed to monitor wastewater discharge and identify any sources of hazardous contaminants. The immutable nature of blockchain records is especially important in this case as it enforces regulatory obligations and provides traceability.

6.3 Energy microgrids

Renewable energy is refocusing energy supply on decentralised energy networks rather than powerplants. This new pattern of electricity generation and distribution could deliver greater energy independence locally and help deliver energy security nationally as more energy is derived from decentralised renewable sources, as opposed to relying on fuel imports.

As a distributed ledger, blockchain lends itself well to this new pattern of supply. It allows transactions to be recorded across these multiple, small, interconnected grids, facilitating payment and billing for suppliers and consumers. This information is also useful for facilities and property managers who may be obliged to keep records of energy consumption for emissions reporting.

7 Construction opportunities

Construction projects are complex, with multiple stakeholders and difficulties in coordination and communication between stakeholder groups. Blockchain allows progressive iterations of design to be stored securely and may also include building information modelling data (see section 7.1) which can be referred to during the operational phase of a building's life cycle.

During the construction phase of a project, blockchain can provide a transparent purchasing process and smart contracts could be used to record the receipt of materials when they arrive on site, automating payment in accordance with the agreed terms.

After completion, blockchain also allows the ongoing monitoring of a building to assess how it functions in comparison to the design specifications and predictions.

7.1 Building information modelling

Building information modelling (BIM) is the creation of a 2D or 3D digital model of a building using data supplied by, for example, engineers or architects. It facilitates collaboration from different disciplines tasked with creating the digital design of new buildings, as well as informing decision-making throughout a construction project and beyond. BIM also benefits operational management of a building by providing the facilities management team with information about a building from the design and construction phases of a building's life cycle.

Blockchain offers a platform to improve the transparency of BIM: it allows changes made to the data to be traced reliably, greater granularity in the allocation of permissions and improved security (Nawari & Ravindran, 2019). One of the limitations of blockchain is that it is not a suitable medium for storing an entire BIM database as these databases tend to be very large. This is an example of where a private blockchain may be implemented and the BIM data may be stored off-chain in a separate database (see section 3.4).

7.2 Supply chains and procurement

Procurement is relevant at all stages of a building's life cycle, from the acquisition of construction materials to the ongoing maintenance of a building and the provision of consumables. The reliance on external suppliers as well as the involvement of a number of stakeholders means that buying materials or services requires careful management.

Blockchain technology can improve transparency in procurement processes by making the ledger of purchases visible for those with access permissions, as well as providing a means to verify the receipt of an order. Smart contracts can automate repeat orders, streamline the invoicing processes and mitigate the risk of fraudulent transactions.

7.3 Material passports

Material passports are data sets that accompany materials, components or products detailing their origin, providing in effect a 'digital birth certificate'. Material passports can provide a record of the provenance of a material and ensure regulatory compliance in the supply chain. At the end-of-life of a building or product, the material passports can inform reuse, recycling or disposal.

Blockchains can provide a record-keeping mechanism for material passports. Records stored in multiple systems can prove ephemeral and may be modified by fraudsters, for example to alter consignment weights to incorporate illegitimate materials into shipments of legitimate stock. The immutable nature of the blockchain can help to prevent these alterations.

Case study: SiteSense

Canadian-based technology company IntelliWave has been applying blockchain technology to construction processes. Their SiteSense software has been developed using a combination of Internet of Things sensors and cloud-based data repositories.

A lot of time is wasted on construction sites locating and collecting tools, materials and other essential equipment. SiteSense allows users to record the location of these items, using either coordinates or traditional patterns of storage layout, such as warehouse number, grid number and bin number. This helps to maintain stock records and for operatives to locate items quickly.

SiteSense is designed to reduce human error by automating data entry. This is achieved through the sensor layer that automates data collection, such as scanning barcodes and uploading images of stock and receipts, augmented by background data collection through geolocation and the goods handling processes.

The system automates procurement and distribution – a logical application for blockchain – and stores transactions sequentially. Once a purchase order is raised, it is approved and then the order is placed with a supplier. Included in the order placement are instructions on the labelling requirements for shipments, providing barcodes that can be scanned with a smartphone camera. Tracking information is part of the SiteSense process, and as the order moves along the supply chain, more detail is added to the blockchain showing where and when bottlenecks may be occurring. When the delivery is made, all materials are checked and accounted for and the materials receipt can be scanned, adding information such as the time, place and accuracy of the delivery.

Smart contracts are used in the SiteSense system. These automate the procurement processes, such as paying for goods. They enable monitoring of completion of a purchase order and the corresponding materials being delivered. Once a delivery has been verified and the material receipt is scanned, the smart contracts trigger a payment mechanism, notifying back office staff that a payment needs to be made to a supplier. This helps to automate time-consuming work, such as the identification of outstanding purchase orders or delays in delivery. The distributed ledger allows multiple parties to access this data.

Deployment of the SiteSense system has led to an 80 per cent reduction in phone calls to material management offices, demonstrating the improved information visibility that blockchain technology can bring to construction projects.

8 Risks and challenges

As with any emerging innovation, blockchain suffers from boosterism by blockchain evangelists, engineers and early adopters of the technology. The question is: how likely are today's professional firms and other industry players to take advantage of the opportunity that blockchain represents? Disruptive innovations, such as blockchain, pose a noteworthy risk in the industry, both to individuals working in the real estate sector and to organisations that fail to capitalise on new technology. Some commentators are predicting that blockchain could change the nature of the real estate industry completely; others are more measured in their analysis.

Innovations in the use of blockchain will undoubtedly change the way the real estate profession operates over the coming years. However, for those seeking to implement blockchain, the risks involved in developing a distributed ledger, the drawbacks to the technology and the barriers to adoption should be considered and understood.

8.1 Job security

Many of the gains from improved efficiency and cost savings will be as a result of a reduction in labour as an input and professional jobs are at risk as blockchain and blockchain-based smart contracts become more sophisticated. One of the persistent trends caused by technology is increasing automation – a hallmark of the Fourth Industrial Revolution (Schwab, 2017) – and automation is increasingly affecting areas of professional work that were previously viewed, at least by those within the professions, as safe from technologically driven unemployment.

The risk to professional jobs and services may derive from technology convergence, rather than blockchain as a standalone technology. Automation stemming from artificial intelligence, specifically machine learning if coupled with blockchain technology, could change the employment landscape for real estate professionals (Flood & Robb, 2018).

There are also risks for those working in administrative roles in other areas, such as the supply chain. This is due to the ability of smart contracts to automate the processes involved in ordering goods, materials and services – thereby cutting out the intermediary.

8.2 Cyber security threat

One of the biggest challenges facing blockchain is the cyber security threat. Since early 2017 hackers have stolen nearly US$2 billion worth of cryptocurrency, sometimes through the exploitation of vulnerabilities in the blockchain architecture itself (Orcutt, 2019). If the blockchain ledger can be hacked and altered, then the central pillar of immutability is compromised. This is not surprising, as blockchains are attractive to thieves because any fraudulent transactions inserted into the blockchain ledger cannot be easily reversed.

Small scale blockchain implementations are especially vulnerable because the computer power needed to rewrite the chain is low. Fully open to completely private blockchain implementations are all at risk from both internal and external threats.

There are additional security problems that cannot be easily designed out of the blockchain technology because, as with any digital solution, the problem is not limited to the technology itself but is affected by issues arising from user practices and behaviour. The fact that reversing or correcting blockchain transactions is so difficult increases the impact of compromised user accounts. Weak or reused passwords, downloaded malware or changes to the ledger, whether accidental or intentional, are all security risks to consider when developing blockchain implementation.

8.3 Resource intensive

Developing and deploying blockchains can be resource intensive. These projects require expert programmers to write the code for a blockchain-based application and, in some cases, may require specialised infrastructure such as dedicated server farms to develop the blockchain protocol.

8.4 Energy intensive

The sustainability credentials of blockchain are also questionable. Permissionless blockchain ledgers used for cryptocurrencies have been shown to consume prodigious amounts of electricity to maintain the security of the transaction chain. This is especially true in the case of public blockchains that use proof-of-work mechanisms to achieve consensus, for cryptocurrencies for example. It is estimated that the largest blockchain network, Bitcoin, consumes 74.87 TWh of electricity per year: to put this into perspective, the 37th largest national electricity consumer in the world, the Philippines, consumes 78.3 TWh and is home to over 100 million people (Cambridge Centre for Alternative Finance, 2019). This extraordinary energy requirement is unlikely to occur on the permissioned and private blockchains, which are the type that will be used in the real estate sector, but it is worth bearing in mind that larger, more secure networks can incur significant resource costs to run.

8.5 Reverse transaction difficulty

One of the appeals of blockchain is its immutability. However, the difficulty in amending a blockchain ledger could itself be problematic. If an error is made in the blockchain, the transaction may be inalterable. It could be reversed by a corrective transaction, but this would require the compliance of the beneficiary of the erroneous transaction. If a fraudulent transaction is made, for example, by an employee managing a company's blockchain ledger, it would be easy to trace the user responsible but not to reverse the transaction.

8.6 No track record in trust source

One of the claimed benefits of blockchain is its ability to reduce reliance on trusted intermediaries such as banks, lawyers and surveyors, but blockchain does not actually remove the requirement for trust in real estate transactions. Instead, it transfers trust from existing institutions to the blockchain technology and its controllers. If these blockchain applications are proprietary, the owner of the blockchain would take on a similar role to the established organisations that serve as a source of trust. Therefore, we may see a greater concentration of power, this time in the hands of technology companies and unlike current sources of trust, blockchain does not have a proven track record.

8.7 Cross-chain integration requirement

In today's connected and globalised world, interoperability and integration between IT systems is de rigueur. Cross-chain integration, which is needed to deliver interoperability, will be essential if the promise of blockchain is to be fully realised. This is not currently possible except for some embryonic proof-of-concept implementations.

8.8 Regulatory risks

Regulation is an important barrier, because a system that is intended to be trusted in the way that blockchain applications are promoted would need to satisfy stringent regulatory requirements. For personally identifiable information, GDPR would need to be applied. This would include the right to be forgotten and have data deleted from a database. The immutable nature of blockchain and the fact that successful modification of historic data could have knock-on impacts on successive blocks in the ledger makes the legislative hurdle especially difficult.

9 Summary

Blockchain provides a record-keeping technology, in which a reliable and verifiable record of transactions is maintained across multiple computers using peer-to-peer networking and cryptography.

Blockchain, and the smart contracts it enables, has the potential to revolutionise the real estate sector but this may take a couple of decades. Figure 3 – based on an analysis by Arup (2019) – sets out projected timelines for some of the applications discussed earlier. Only a couple of application areas, such as freight tracking and logistics in the construction industry, are expected to be commercialised in the near future, while automation of many functions of real estate agency and property data management could still be 15–20 years away.

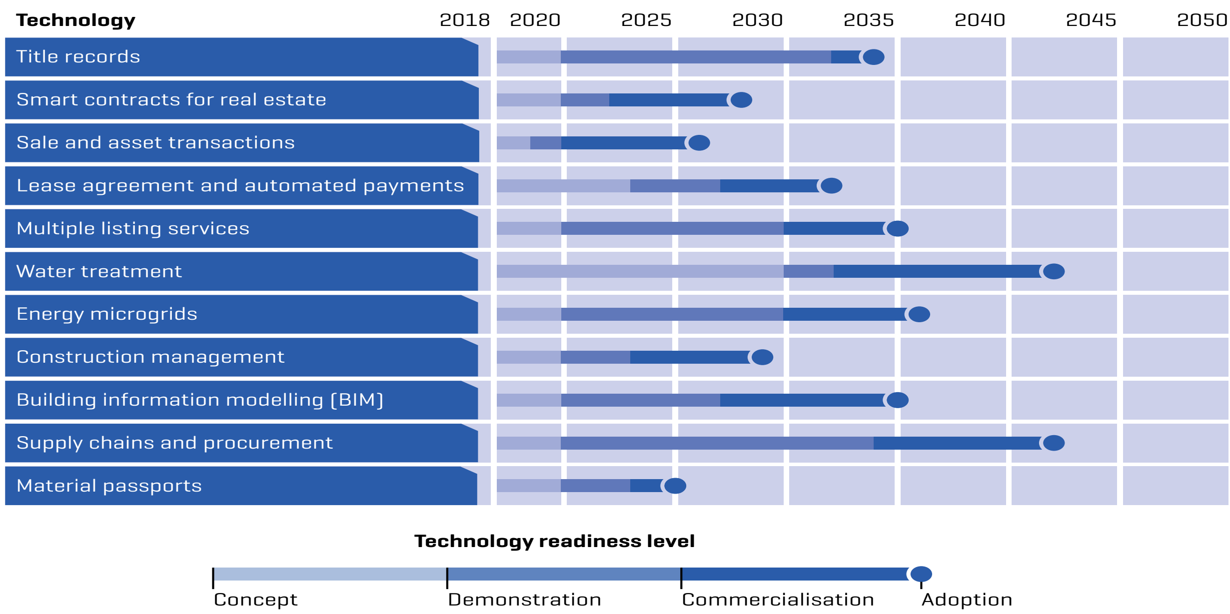

Figure 3: Blockchain technology timeline (adapted from Arup, 2019)

Blockchain is complex and there are many barriers to adoption, which makes it difficult to anticipate the time frames in which blockchain will realise its potential in the real estate sector. What is clear is that some of its envisaged applications will transform how business is carried out in the industry.

Blockchains can be used to store information about construction project management, building management, property management, utilities management, and even data drawn from the ever-growing network of sensors that are part of the Internet of Things.

A distributed ledger system can be used to register property ownership and land titles and this application has the potential for reducing the time required for the subject-to-contract process in the sales and lettings markets.

Smart contracts are the most significant development for real estate professionals. There are applications for smart contracts across the real estate sector, from lease agreements and conveyancing to supply chains, facilities management and property management. The use of smart contracts offers the opportunity to build a trustless environment without any central validating authority. Smart contracts running on blockchain could significantly decrease the cost and time involved in a number of real estate transactions.

Blockchain technology could have a large impact on the way that real estate services are delivered, but what works in the world of cryptocurrencies, banking and finance is not directly applicable to real estate, construction and built environment use cases where there is always a physical asset to be measured, inspected and reported on.

The trustless nature of blockchain is one of its most vaunted advantages, eliminating the need for a central authority in the form of a bank or land registry. It is argued that blockchain does not eliminate a need for trust, but rather replaces established sources of trust with trust in the technology and in the companies' operating blockchains.

The technology is neither mature, nor the all-encompassing engine of change that its staunchest advocates claim it to be. Real estate professionals need to carefully evaluate specific use cases of blockchain and determine whether it can add substantial value to their activities, or is simply a use of blockchain for its own sake.

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