



BLOCKCHAIN

Unblocking the roadblocks towards a collaborative construction industry

Abstract

The construction industry has always been slow in adopting new technology. Construction has always been a very collaborative industry and there might now be new ways to improve the ways of collaboration. Blockchain – a decentralized ledger of records – emerged from the global financial crisis of 2007-2008 and has proven successful in a number of industries. Activities such as voting, energy trading, water trading, storing identities are all currently conducted on the blockchain – including, a company that has incorporated BIM and blockchain. Could this be a start of a major technological advancement in the construction industry? While blockchain is still in its early stages of development and numerous risks remain unknown until it has been implemented, blockchain still has immense potential for various industries and the way business is conducted. This report examines blockchain technology, its advantages and its disadvantages and explores the potential it has for the property and construction industries. This report proceeds to interview six industry experts – a builder, a quantity surveyor, two property lawyers, and one finance expert and one blockchain expert – to discuss industry issues and how blockchain can assist in solving these issues. This report also provides a comparison between how technologies that had huge hopes for the construction industry – such as BIM – could be increasingly adopted using blockchain as a driver.

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CHAPTER 1 - INTRODUCTION

Construction is a highly “collaborative process involving a larger or smaller group of participants” (Turk & Klinc, 2005). Construction projects have increased in complexity over time, causing the traditional means of managing projects outdated. The use of traditional tools, processes and techniques that were once at the forefront of management technology have lately become insufficient; and in many cases, questionable (Morris,1994; Baccarini, 1996). While certain aspects of multiple projects may contain similarities, the processes, strategies, and tools that are required to deliver each of these projects have a large scope for variation. Similarly, despite the differences that exist between multiple projects, certain technological advancements provide solutions to problems that span numerous domains.

One of these problem arising domains is the issue of payment; this is an issue that has the potential to cause delays in projects at any moment from the design stage leading all the way up to the construction stage. According to Kartam and Kartam (2001), delayed payment is the second highest operational risk that leads to project delays, the highest being financial failure. The reason for this is that contractors heavily rely on said routine payments in order to finance various stages of the project and maintain compliance with a set schedule. Failure to make payments within stipulated timeframes mean that contractors would have to deviate from the planned schedule as well as incur additional financing and transaction costs, the latter of which increases their risk of insolvency (Odeyinka & Kaka, 2005). Another significant consequence of delayed payments is the slowdown in material delivery which, in turn, impacts labour productivity. In summary, delayed payments have a large role to play in both determining the success of construction projects as well as maintaining the survival of the construction industry (Cheng et al. 2009). Since payment is a realm of the construction industry where there is such a large scope for issues to arise, there is significant room for improvement.

Among the various issues that exist in the construction industry, one area of improvement present is the use of file storing. Before any project gains traction, there are various stages and parties it must first reach. Technological advancements over time have allowed construction projects to grow not only in size but also in its complexity. This brings forth the issue of storing data of such complex projects. Hard drives have, for a long time, been the prime means of storage. When dealing with files of complex nature and large sizes, however, it is often the case that storage devices are unable to carry these files along with other documentation equally important to the project. There may be a solution to this issue among others in the construction industry. All these issues could potentially be resolved rapidly via collaboration. The problem with this solution is that for collaboration to be efficient in any economic activity, trust is one of those little things that goes a long way. Most

people do not trust blindly; rather, they require some form of verification and/or reassurance, first, that the other party is worthy of their trust. In commercial settings, they often buy that reassurance from intermediaries, middlemen and women, go-betweens, and matchmakers who they feel are trustworthy (Dakhli and Mossman, 2019).

This report aims to examine one possible solution to these issues - a vision that is believed to revolutionize the way in which transactions occur and their impact that may be had on the construction industry. The solution being suggested here is one known as blockchain (Dakhli and Mossman, 2019). In this report, the technology of blockchain is explored as a tool to assist in managing projects more efficiently. This report will mainly explore the concept of blockchain as a broad topic, its advantages, and its current uses across various industries including property and construction. This report will then explore the further potential that blockchain has in the construction and property industries based on discussions with industry experts about industry issues and how blockchain may be able to solve them. This report will also briefly discuss some of the disadvantages associated with blockchain technology. Prior to engaging in further discussions, it is important to define some key terms:

Blockchain – Blockchain is a ledger of transactions that is decentralized and distributed in order to maintain a constantly increasing set of records. Most users in the blockchain network should agree and record their consent in order to store a transaction in the ledger. Sets of transactions are bundled together and are allocated a block in the ledger, which is chained to a series of other blocks. Blocks are linked together using a timestamp and a hash function to the previous block (Li et al., 2018)

Cryptocurrency – According to the ATO, cryptocurrency is “a digital asset in which encryption techniques are used to regulate the generation of additional units and verify transactions on a blockchain” (Australian Taxation Office, 2020a).

Encryption – “The process of hiding or encoding data on computers or related devices to prevent unauthorized persons from viewing or accessing the data in question. The process typically requires an encryption and reverse encryption program and a key.” (Bell, 2012)

Hash – The hash function validates the integrity and non-repudiation of the data inside the block [4]. The hash function “is a complex mathematical problem that miners have to solve in order to find a block.” The hash function is used as a search function for data in a database and are collision-free making it extremely difficult to find two identical hashes for two different messages. Blocks in the blockchain are identified through their hash

and this serves two main purposes – identification and integrity verification. Each block has a hash of the previous block all the way to the first block generated (Aitzhan & Svetinovic., 2018)

Smart Contracts – Smart contracts define the agreements in a mathematical language and are written in code that is understood and executed by machines, eliminating human expenses and error (Mack, 2019)

CHAPTER 2 – BLOCKCHAIN TECHNOLOGY LITERATURE REVIEW

“Blockchain is a database that maintains a continuously growing set of records” (Banafa, 2018, p.86). It is decentralized and no central administrator or computer that controls the network. New transactions are validated by the participants in the network through the application of an algorithm to verify the new transactions’ validity. Sets of approved transactions are grouped together and identified as a hash which is then sent to all nodes in the network and then they validate the block. Every block has a hash associated with it, which identifies itself from the previous block it is associated with it (Banafa, 2018) – refer to Figure 1. The name blockchain got its name from the information being recorded on each transaction as a ‘block’ that gets added to a ‘chain’ (Ramage, 2018) – in this manner, an incorruptible ledger of ‘blockchain’ is formed (San et al. 2019). Blockchain has a number of advantages – some of these include decentralized, anonymity, security, immutability, auditability, transparency, performance, and trust (Perera, et. al. 2020).

- Decentralized – One of the main advantages of blockchain is that it consists of a decentralised of decentralised peer-to-peer network. No central data storage mechanism and no central administrator exists that stores the main property of the blockchain distributed ledger (Walport, 2016). Through a decentralised network, traffic flow issues such as delays and a single point of failure is eliminated and it also provides robustness (Dorri, et. al., 2016).
- Anonymity – Blockchain transactions use public and private keys. This allows users to remain anonymous and protect their privacy while enabling third parties to verify their identity (Sun, et. al., 2016).
- Security – Encryption mechanisms that are used in the blockchain involving public-key cryptography allows to secure the validity of the information that is stored and to prevent fraud (Weernik, et. al., 2017). Privacy of private data is maintained through encryption and data integrity, authenticity and nonrepudiation are maintained through digital signatures (Lewis & Larson, 2016)
- Immutability – Information that is on a blockchain is unchangeable as it is secured by the peer-to-peer network of participants (Dorri, et. al. 2016). After records have been included in the blockchain, they cannot be reversed (Atlam et. al., 2018) – this leads to resulting the ledger to be an immutable record of all previous transactions (Lewis et. al., 2017). Only create and read (CR) operations are allowed in the blockchain (Lewis et. al., 2017).

- Auditability – Transactions that are in the blockchain are validated and recorded with a timestamp. This allows users to easily trace previous records through accessing any node in a particular network (Zheng, 2016).
- Veracity – The stored records in the blockchain are the same copy of the historical records of the ledger as it is stored in the network of nodes. This record is verified by consensus that improves veracity at a higher level. Faulty entries that are created will be identified and eliminated as they will not be able to reach consensus (Chartered Accountants Australia and New Zealand, 2017).
- Transparency – All transactions are transparent in a public blockchain and are also announced to the public (Yli-Huumo, et. al, 2016). The privacy of the records can be made public or private so that it is available to all market participants (Chartered Accountants Australia and New Zealand, 2017) (Lo et. al., 2017) or else the level of transparency can be controlled as required.
- Trust - Blockchain provides greater trust among its users (Woodhead, R., et. al., 2018). When adding data, a majority of the participants in the blockchain need to agree for it to become a part of the definitive blockchain (Lewis & Larson, 2016), (Yli-Ojanpera et. al. 2018). Once recorded, this data cannot be altered or deleted.

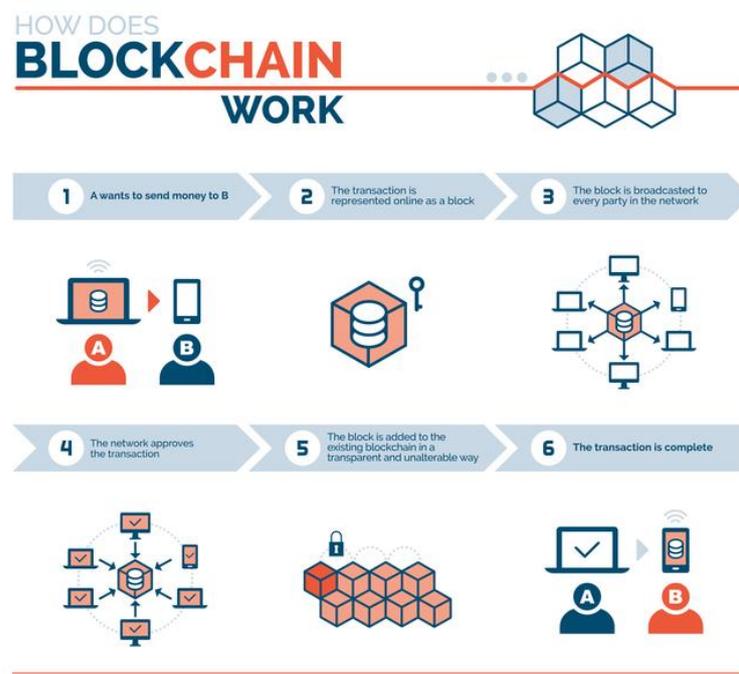


Figure 1: How Does Blockchain Work (n.d.) – (Coinmama.com, n.d.)

CHAPTER 2.1 – BLOCKCHAIN USES

Blockchain has proven itself successful in a number of industries. Initially starting with the financial industry, blockchain has continued its growth – and still continues to grow – among other industries. Some of the key industries and their projects are highlighted below including current projects that are undertaken:

Finance – Initially, the blockchain was developed in order to send data between two parties without an intermediary. This has been developed further to realize blockchain's fullest potential with the increasing development of various cryptocurrencies in recent years (Nawari & Ravindran, 2019). All major banks in the world have commenced exploring the application of blockchain technology in the banking sector to align with the rapidly changing technological advancements (Mingxiao, et. al., 2017). Currently, there is a collaboration between six of the world's largest banks (Barclays, Credit Suisse, Canadian Imperial Bank of Commerce, HSBC, MUFG and State Street) in order to work on cryptocurrency to improve the financial markets (Arnold, 2018).

Santander, a UK bank, was the first bank to conduct international payments with the introduction of blockchain technology. Santander has also predicted that the by using blockchain technology, significant reductions can be achieved in the infrastructure costs of banks relating to cross-border payments, securities trading and regulatory compliance – a reduction of between USD 15-20 billion per year by 2022 (Belinky et. al., 2015). As blockchain technology increases efficiency and productivity, the issue of double spending could be avoided as the transactions need to be verified by a majority of the nodes, for a valid transaction to be recorded (Mingxiao et. al., 2017). Rapidly changing technology and highly competitive and volatile markets require banks to innovate with blockchain and huge data in order to not lose their competitive edge (Hassani, 2017). Currently, a blockchain-enabled stock exchange system is under development called The Australian Securities Exchange (ASX) and will be launched by Australian Stock Exchange in 2020 (Perera et. al. 2020).

Voting – Some of the major issues faced by community and politicians of many countries is low voter turnout and voter fraud. One of the solutions to this problem is online voting as it boosts the number of active voters and addresses security and integrity issues in elections (Violino, 2018). Horizon State is an organisation that offers powerful and reliable digital ballot box systems for shareholder voting to official government elections of all scales (Horizon State, n.d.). According to Jamie Skella of Horizon State, if a blockchain could incorporate a digital ballot box, it would be unable to change or reverse the votes. This would make it a trustworthy process based on a system which is not owned by a single entity (Thompson, 2018).

Transportation (ridesharing) – A blockchain-based ridesharing platform, Arcade City, matches passengers and drivers without involving a third party (like Uber). Through the use of blockchain to facilitate trust-less peer-to-peer models, Arcade City improves sharing economies (Arcade City, 2018) and has introduced 'Arcade City Token as the cryptocurrency to be used in transactions. Arcade City has suggested the introduction of a “decentralised transportation ecosystem, where people can use the same token to ride on a bus, rent a bike or carpool, without any central authority to organise its operation” (Hamida et. al., 2017).

IID protection – Blockchain can be a means through which identity theft may be prevented. Initially, this information – known as Decentralised Identifiers (DIDs) need to be stored online in a blockchain. This information including personal details such as name, date of birth and social security number can be accessed through a QR code that the user receives which is stored in the digital wallet. Instead of repeatedly entering information, details are readily available when one signs up for an application. An identity wallet has been created in order to allow individuals and companies to own, control and manage their digital identity – SelfKey (Selfkey, n.d.). Another similar development is ShoBadge developed by ShoCard – ShoBadge is another secure digital identification enterprise that is based on the blockchain. In ShoBadge, it is possible for a user to prove their identity when using the digital wallet by selecting an identity recognition form out of forms such as QR code, fingerprint, iris scan, face recognition among others (ShoCard, n.d.).

Food and agriculture – Products such as meat, fruits, vegetables, seafood and various others form part of the food and agriculture industry. A well-managed supply chain results in a high quality of food produced in the agriculture industry. In today's world, consumers are disadvantaged as they do not have any way of verifying the source and origin of the food or agriproducts that they consume. By storing data in a decentralized manner in food and agriculture blockchain, each consumer can have the ability to read or trace information such as operations from origin to sale and subsequent recycling. (Hackius & Petersen, 2017; Popper & Lohr, 2017). Other developments include a blockchain-based e-agriculture system in order to manage data on pesticide use, production costs, local weather, energy use, soil quality, and others in Taiwan. Also, National Taiwan University developed GCOIN, blockchain-based decentralised system to manage irrigation data collected by remote sensors (Lin et. al., 2017). Other developments include Walmart working with IBM to develop a food tracking solution to track movements of pork from small Chinese farms (Popper & Lohr, 2017)

In Asia, beef from Australia is highly in demand and there is a significant amount of counterfeit Australian beef in the market. In order to solve this issue, CSIRO's Data61 is developing a blockchain adopt blockchain and reduce the costs of food fraud in Australia (CSIRO'S Data61, n.d.). Instead of payment and other supplier concerns, blockchain-based supply chain innovations are focussing on enhancing clients' necessities such as product quality and compliance (Hackius & Petersen, 2017; Popper & Lohr, 2017).

Foreign Aid – The aid to assist refugees and displaced persons have numerous issues and exist in the current systems. Third- party costs, mismanagement or theft make up about 30% of all development funds that never reach its intended party. Transaction fees are made up of 3.5% of most international relief aid (Paynter, 2017). A third party (intermediary) can be eliminated to connect the donor with the intended final recipient. “Usizo is a crowdfunding platform in South Africa, that has been planned to be launched where a Bankymoon meter that is blockchain-aware will be installed in rural schools and donors around the world can make payments directly to the meter using tokens and fund energy or water the school needs” (Mulligan, 2015). This would enable the donors to notice exactly where their contributions are headed towards.

In recent times, the United Nations developed a project in order to aid the refugees in Jordan who moved from the conflict zones in Iran and Syria. Through the use of an Ethereum blockchain, funds are sent to a certain few shops/merchants in the neighbourhood of the refugee camps. The refugees can then obtain the funds by going to these shops by proving their identity. The identity of refugees can be proven through Iris Scan, which has identity details of refugees stored in the blockchain network (Perera et. al., 2020).

CHAPTER 2.2 – BLOCKCHAIN IN THE PROPERTY AND CONSTRUCTION INDUSTRY

The disruption of a number of industries through blockchain technology is imminent and this also includes the property and construction industries. Some of the highlighted blockchain developments across the property and construction industries are highlighted in this section.

About 78% of the land in Ghana is unregistered - hence leading to many land disputes. This has led to a company like Bitland into developing a land registry that will be based on the blockchain (Kshetri & Voas, 2018). Similarly, Bitfury (a Bitcoin mining company) and the government of Georgia are in the process of developing a land registry using blockchain (Higgins, 2016). In Ukraine in 2017, a transatlantic electronic bargain occurred on agreement of real estate exchange with the use of smart-contract on blockchain Ethereum. An American citizen purchased an apartment in Kiev while the object seller was located in New York using a decentralised marketplace of real estate Propy (USA) (Unified Register of Builders, 2017). Ethereum is a blockchain cryptocurrency, similar to Bitcoin.

Construction brings together builders, construction experts, vendors, sub-contractors, and several other teams with different expertise. Construction industry has frequently been known as a fragmented industry that significantly needs to improve its efficiency and productivity, and to embrace the opportunities presented by emerging technologies, such as blockchain (Safa et. al., 2019). Through blockchain's ability to maintain a distributed ledger, blockchain offers a high level of security. Through blockchain's decentralized peer to peer network and its many nodes and public witnesses to each verified transaction make it much more difficult for cyber-attacks to be successful. An easier collaboration platform for all participants in the construction process is allowed through blockchain technology because it allows all members to have current and continuously updated access to building plans. Additionally, it is clear who owns the document due to tracing ability (Safa et. al., 2019). Blockchain users can either operate in a public network, a private network or a hybrid network (Dragonchain, 2019)

While blockchain was initially developed for the financial industry to send and receive funds, it is being tested across various other industries to realize its fullest potential. There are a lot of aspects to a collaborated construction effort. Based on examples seen above, it should seem as no surprise that in the construction sector, there is immense potential for blockchain to be a solution to many industry problems that are currently occurring. Here are a few examples of current developments below of how blockchain is assisting the construction industry and built environment:

File sharing for document management – Technological advancements has allowed complex projects to be developed that require a number of different types of documents. Construction projects are typically composed of large amounts of data and several organisations struggle in storing this data with storage space. Similarly, past project data management and storing is also a common issue faced by several organisations. While it is good practice to store past project data for future purposes, the massive storage space that is required to store this data is a challenge. A solution to this issue is file storage sharing in the blockchain. Massive amounts of unused data space that are currently available in data allow for this data to be sold for any users who are in need of it. Filecoin was introduced as a digital storage and retrieval system that allows users to rent space on their disk for data storing purposes (Filecoin, n.d.), where cloud storage is converted into an algorithmic market (Protocol Labs, 2017). The users of the data storage will use Filecoin as a cryptocurrency to pay the data storage providers in the decentralised network. A blockchain-based digital storage and data retrieval system such as Filecoin can be used in order to store data of construction projects (Perera et. al., 2019).

Energy Management – Trading energy at the local grid level between individual producers and consumers can also be performed using distributed ledger technology (Hamida, et. al., 2017). With the increased adoption of solar panels and other green energy sources in generating energy, blockchain has the ability to allow producers and consumers to pool and exchange energy for transparency, traceability and other benefits. A blockchain-based solution for the energy industry is available with Power Ledger (Power Ledger, n.d.). Power Ledger has partnered with BCPG (a company conducting renewable energy business in Thailand) to develop the world's first peer-to-peer renewable energy trading trial at the 577-urban precinct in Bangkok, Thailand (Power Ledger, 2018). Energy transactions are monitored across 18m points between participants while enabling peer-to-peer trading and ultimately evaluate the trading positions of individual participants (Perera et. al., 2020).

Water trading – Depending on supply and demand, users are allowed to buy and sell water resources. Government agencies usually manage this with their own processes and rules which leads to transparency issues (Nguyen et. al., 2019). A possibility to eliminate such issues and intermediaries exists while improving transparency – smart contract enabled transactions. American water treatment technology provider, OriginClear, is currently working on a blockchain protocol called WaterChain. Through the use of smart contracts and cryptocurrency, WaterChain is aiming to create transparency and efficiency in the water treatment industry (Pee et al., 2018).

The full potential of blockchain is still being discovered as it is applied and tested with different functions and tasks. The construction industry is ranked as the second lowest sector to have adopted information technology (Eadie et. al., 2013), and it had remained so for the past three decades (Ashworth & Perera, 2015). Productivity in the construction industry is one of the least productive sectors globally as productivity increases stand at 2% (Barbosa, 2017). However, significant increases are evident in the rate of investment in construction; it is predicted that by 2030, 8 trillion USD of global market growth will be achieved (Betts & Robinson, 2015). Blockchain provides a ripe environment for the impending digital disruption in the construction industry. Major changes were expected to be visible through technologies such as BIM in the construction industry in the last decade but, its adoption is yet to be visible (Dave et. al., 2018 & Perera et. al., 2017). One of the main reasons for this is because it only impacts construction procurement marginally as it is a technological change (Ashworth & Perera, 2018). However, the construction procurement process can experience significant change as blockchain provides this enormous potential. Therefore, exploring possible applications of blockchain is extremely important for the construction and built environment (Perera et. al., 2020).

BIM and Blockchain – Construction projects can be simulated in a multi-dimensional digital model and provide several benefits from project inception to its occupancy. This process is known as Building Information Modelling (BIM) (Perera et. al., 2017 & Fountain, 2018). BIM is treated differently to the construction supply chain and that affects the final construction product quality. The construction process activities combined with the data for facilities management during design, operation and post-construction stages can be improved by integrating BIM with the construction supply chain (Hijazi et al., 2019; Volk et al., 2014). In order to deliver one-off projects, the construction supply chain stakeholders typically collaborate. The construction supply chain that can be operated in a blockchain will address issues of transparency and allow for better integration during the lifecycle of the project (Kinnaird et. al., 2017). A technology start-up business, BIMCHAIN, designs bridges in France using BIM and blockchain. Various documents are shared on a platform using digital signatures as validation by the project stakeholders. Additionally, the smart contract that is embedded in the platform validates models and processes payments – enhancing the blockchain-enabled proof of consistency, publication and approval (Nguyen et. al., 2019).

Smart Contracts – Resolution methods of payment issues in a chained payment settlement culture and default settlement durations in the construction industry are much higher than other industries (Ramachandra et. al., 2011). Furthermore, payment delays are also significant in the construction industry (Danuri et. al., 2006) and there are also considerable partial payments and non-payments in the construction industry (Ramachandra et. al., 2011). The resolution of all these issues also requires additional costs causing the contract price to be inflated to cover the cost of finance. Numerous companies and businesses – mainly small and medium sized enterprises (SMEs) – cannot tolerate the upfront costs without continuous payment and healthy cash flows (Penzes et. al., 2018).

A solution to the above problems is smart contracts. Smart contracts enable trusted transactions and the exchange of money, asset, or anything of value to occur between all key stakeholders. The environment of construction is changed from document-driven to data-driven enabled by smart contracts. Smart contracts require a set of rules to be set up once they are agreed and also enforces those rules in order to complete the contract (Safa et. al., 2019). By implementing a smart contract enabled blockchain payment application, more trust can be provided in the transaction because automation allows for greater enforceability of the contract. Clients can directly purchase products or services from suppliers by making an initial payment at the ordering stage. After the products are delivered to site, the remainder of the payment can be made to the supplier in an automated process – all of these are initiated and controlled through a smart contract (Perera et. al., 2020).

Engaging the right employees, suppliers and contractors with the right skill set and supply capability is vital to any construction project. To address this issue, it has been proposed that with blockchain technology, workers with suitable skills and qualifications can be identified by a Digital Identity Card (ID). This ID card can then be linked to the relevant authorizing body. For example, a chartered engineer that is involved in a project would be required to undertake a screening process that was possible by blockchain technology. Their ID would have to be authorized by a board of engineers of the relevant geographic location that they are working in. The same can process can be undertaken for suppliers – with digital ID's, the proof of membership to relevant professional bodies or proof of reliability in providing services are readily available, parties interested to engage the services of a worker or supplier within the construction industry can do business more efficiently (Amaludin & Taharin, 2018)

CHAPTER 2.3 – BLOCKCHAIN ADVANTAGES AND IMPACT IN THE CONSTRUCTION

INDUSTRY

Blockchain offers many advantages that could be beneficial in the construction industry. Some of the key advantages are highlighted below:

Workflow and time efficiency – Construction productivity can be improved in the construction industry with the application of blockchain technology by using smart contracts (i.e. between a subcontract and a supplier). Automatable payment can be made to the subcontractors and suppliers via smart contracts when the job is done. Delays that arrive from the discrepancy of BIM models and conflicts between design consultants during various stages can also be mitigated through the use of blockchain. The use of private blockchain application in BIM is recommended so that only relevant project stakeholders (architects, engineers, consultants, quantity surveyors, project managers, and client representatives) are allowed to validate and access “blocks” into the blockchain environment. In the pre-contract stage, various design consultants will create and modify BIM models for tender purposes in the blockchain platform. All project stakeholder participants that are in the private blockchain have visibility to the BIM model and can validate the modifications that were completed prior to updating information into the drawings known as “blocks” that is then added to the “chain”. All participants in the private blockchain have access to the latest and updated information along with timestamps of all the changes being made in the BIM model to view when and where drawings were amended. This should resolve a number of issues conflicts between design consultants that are caused by wrong versions of drawings. Quantity surveyors also benefit from these features as their preparation of cost plan, bills of quantities and tender addendums, if any, are up to date depending on the version of drawings they are using. The decentralized structure (flatter organizations) and less centralized logic (less top-down) will decrease latency (Alcazar, 2017) in preparation of drawings. In the post-contract stage, the blockchain application in BIM will allow easy traceability of the changes in order to prepare variation – this is due to the ability of the blockchain technology providing a growing necklace of information records, historical transaction transparency and chronological fulfilment (Ramage, 2018). Ultimately, the client is informed of the potential cost implication of the design changes during construction and workflow and time efficiency are achieved with the blockchain application in BIM. Furthermore, administrative load on reporting, governance, monitoring responsibilities and risk transfer will be significantly reduced (Hughes, 2017) by using blockchain application and platform in project funding

management, real estate management, supply chain management, and electronic document management (Kiu et.al., 2019)

Cost efficiency – Centralised intermediaries usually process transactions made by the client in the construction industry. These intermediaries charge clients a certain amount of fees for processing their transactions by providing their facilities and services. Blockchain, in the construction industry, allows for the elimination of these intermediaries and their transaction costs (Blockchain Technology: Will It Make a Difference? (2017); Hughes, 2017). Information and payment can be made directly from the project client with design consultants, suppliers and direct contractor with the use of . Using smart contracts will assist in cost reduction for administration of contract documents. It is also possible that clients can sell their property using the blockchain platform eliminating the fee that is charged by property agents or brokers.

Efficient resolution of payment disputes is a major issue in the construction industry as they are frequently lengthy and expensive when settled in the court. The application of blockchain in a construction contract allows for the cost of settling a construction dispute to be saved because no issue of late payment or non-payment will occur within smart contracts. Time and cost are significantly saved with the application of blockchain because all the processes are automated and neutral (Wang, et. al., 2017). Additionally, BIM and blockchain together allows for more accurate and correct drawings to be produced which also allows for cost estimates and bills of quantities to be created much more cost effectively (Hughes, 2017). Hassles such as wrong quantities and wrong drawings will be eliminated and also the cost of developing variations during the construction stage will also be reduced (Kiu et.al., 2019).

Transparency and trust – Participants in networks have the ability to see the chronology of monetary and non-monetary transactions (i.e. drawings, land or property transfer) by the application of blockchain in the construction industry. The blockchain allows all information in a transaction – whether financial or data exchange – is visible to everyone who is participating in that particular transaction (Ramage, 2018). Additionally, blockchain technology's decentralised features allows all participants in the transaction to have the same information across the application and it cannot be deleted – only the sender and receiver has more information than other participants (Wang et. al., 2017). The traceability and immutability record in the system creates transparency for other users. With transparency available in the network, this encourages participants to enter into the binding smart contract as a result of trust towards the machine. The application of blockchain in the

construction industry eliminates any trust issues as their established trust relationship is in the automated system itself (Wang et al., 2017).

Data Security – Common construction industry practise stores construction data in a centralised database and platforms – this compromises the security of the data that is being stored. One major risk to this data is the risk of being hacked by a hacker with negative intentions to claim monetary ransom in order for the owner or client to retrieve their data. Complex construction projects require a lot of documentation and data security is extremely important with any project. Blockchain technology's unique feature lies with ensuring data security because every piece of information in this database is linked to the rest of the information through a digital signature or private key (Koutsogiannis & Bernsten, 2017). The decentralised feature in the blockchain system allows all participants to own the same information across the system – this is a massive advantage for construction business and activities. Information in a blockchain network is replicated across a peer-to-peer network and this makes it extremely difficult to corrupt or extinguish the files (Alcazar, 2017), (Peck, 2017). Once information in blocks has been validated and an immutable record has been developed in the system, this secures the data from being modified or deleted by any participants or hacker. This improves data security immensely and safety for all participants.

Blockchain has been successfully tested and is continuing to grow in the finance industry. In most other industries, blockchain is a new hype that is proving to be more and more of a reality across various industries. Through blockchain technology, construction teams eliminate a number of issues such as the discrepancy between what information was included at what stage in the documentation, and document storage issues. Technology such as smart contracts allow automation of law in the construction industry without expensive lawyer fees and lengthy legal processes. Ultimately, this builds a level of trust and security in the industry. However, not everything in blockchain has been explored. Similar to currently existing technological advancements, not everything is perfect. A number of questions exist about the technology of blockchain and the potential it has.

CHAPTER 3 - METHOD

The initial research was conducted and as the research progressed, several questions arose. In order to seek answers to these new questions, interviews were conducted with industry experts. To ensure thoroughness of the results of this study – i.e., to avoid entering a narrow-minded view of the subject in discussion – it was ensured that these experts were from differing occupations. Relevance of these occupations to the concept of blockchain was also taken into consideration. The experts selected for this study included a builder, quantity surveyor, two property lawyers, finance expert, blockchain expert.

The builder and quantity surveyor both provided great insight on issues that they have noticed in the construction industry. They were also able to point out how the industry has changed in the last few years along with expertise on how it is going to continue to change, and what industry professionals would be wise to prepare in advance for. The property lawyers provided insight on issues and resolution methods in the construction and property industry. The finance expert provided insight on deeper details on blockchain along with how blockchain can alter the way business is conducted. The blockchain expert provided insight on the technology and addressed further questions that arose from the initial research performed in this study.

An overview of the questions that were discussed with industry experts are shown below. More questions arose during discussions and interviews. The experts that were interviewed included a builder, a quantity surveyor, two property lawyers, a blockchain expert and a finance expert.

- Discussion questions with quantity surveyor
 - What are the major issues in the construction/property sector?
 - Are these issues worsening or getting better or has it changed at all in the last 10 years?
 - Where do you think future issues are going to be in the construction/property industry?
 - What role do you think banks are going to play in the future with construction payment(s)?

- Discussion questions with builder
 - What are the major issues in the construction/property sector?
 - Are these issues worsening or getting better or has it changed at all in the last 10 years?
 - Where do you think future issues are going to be in the construction/property industry?
 - Do you have any issues with payment in the industry?
 - Are you seeing any improvements with these issues in the payment industry? How?

- Discussion questions with property lawyer
 - What are the major issues in the construction/property sector?
 - Are these issues worsening or getting better or has it changed at all in the last 10-15 years?
 - Where do you think future issues are going to be in the construction/property industry?
 - How are these issues solved?
 - Do you have any experience in cases surrounding blockchain and law?

- Discussion questions with property lawyer
 - What are the major issues in the construction/property sector?
 - Are these issues worsening or getting better or has it changed at all in the last 10-15 years?
 - Where do you think future issues are going to be in the construction/property industry?
 - How are these issues solved?
 - Do you have any experience in cases surrounding blockchain and law?
 - Are there property/land ownership disputes? How are they resolved right now - advantages/disadvantages of these resolution methods?
 - What are some of the main issues with leasing/rental agreements (if any)? How are they resolved right now - advantages/disadvantages of these resolution methods?
 - Have contractors/clients come to you with their disagreements at the end of the project and told you that there are disagreements on the final account - what's the resolution process here? (one example - feel free to add more based on experience)
 - What are other issues that you are experiencing right now in property sector? How are they resolved?

- Discussion questions with finance expert
 - What role do banks currently play with construction industry payments?
 - Why do banks hold on to the money for so long? How do you think this is going to change in the future?
 - How do you think blockchain is going to affect banks?
 - Smart contracts – what are their pros and cons?

- Discussion questions with blockchain expert
 - How does blockchain work in the sense that one wants to send information and the other wants to send money? Is there a link to each of these blocks? I.e., if a payment is made to an engineer to obtain a set of drawings – do these blocks somehow get linked to each other?
 - What determines what block gets added to the chain?
 - Is there a way for smart contracts to have multiple international law applied to them – advantages and disadvantages?
 - Who governs/controls the blockchain? What happens if there is any issue in the chain/system?
 - How is it possible to have so many currencies on the blockchain concept? What moves their cost(s) up and down?
 - What's the process to send money from one person to another? What's involved in between and how long does it take?
 - Where do you see the future for blockchain technology?
 - How do you think this technology impact our work and daily life? Business?
 - How are things like taxes determined given volatility?
 - What is the difference between blockchain and cryptocurrency?

CHAPTER 4 – RESULTS

CHAPTER 4.1 – DISCUSSIONS WITH A BUILDER

One of the experts that was interviewed was a builder with over 15 years of experience. This particular builder has significant experience working in residential, civil, commercial, and education sectors and also in new builds and refurbishment types of projects. This particular expert now owns and manages their own construction company and mainly is involved with the residential sector.

Some of the biggest challenges in the construction industry seem to be management of trades and payment issues. These issues have always been around in the industry but have worsened over the last 5-10 years. While tradespeople are skilled to do the work, they are unable to see how their tasks fit into the greater construction project schedule. Some of the problem can be tied into education and qualification of trades who lack how to manage businesses and trades. This results in a huge gap in their knowledge between what they were taught and what industry reality is.

Firms manage these issues by trying to predict these issues before hand on site and issue any charges or back-charges associated with these issues. Usually, most issues occur because clients want something fast but then quality is sacrificed as tradesmen lack the training due to their lack of knowledge or access to the codes or training standards. Tradespeople also require continuous professional development in order to prevent the construction industry from stalling or repairing existing errors and issues.

Payment schedules seem to have an effect that impacts the industry in many more ways than just a contractor not being paid – there almost always are much more follow-on effects further into the system and ultimately impacting the construction industry negatively. Companies and mainly, banks are very well known for delaying payments as much as possible resulting in a number of unhappy suppliers and contractors. One of the solutions to these problems is that builders should be provided with cash flow throughout a project weekly as is deemed enough to cover what they're doing. A weekly cashflow would prevent them from being held up on cash and they can always proceed with the project. While there is some balance held and will be resolved in the end, this could proceed the work in a much more efficient manner. A requirement to have a minimum project cost could also prevent payment issues in projects. From a builder's perspective, a certain amount of work completed per month requires owners and developers to pay them a minimum amount – this prevents the builders from being completely out of payment.

It would also be extremely beneficial if the property and construction industry had a credit rating system that is very similar to a credit rating system that is available to consumers. It would have to somehow be introduced by a governing or certifying body. The credit rating system would depend on several factors – industry certifying bodies could validate contractors and subcontractors' skills and continued professional development on an ongoing basis, the credit rating system could also be used for development companies and owners and based on their payment histories, etc. If implemented successfully, this would result in a two-way system that could significantly improve the construction supply chain.

CHAPTER 4.2 – DISCUSSIONS WITH A QUANTITY SURVEYOR

An interview was also conducted with a quantity surveyor with over 10 years of experience. This particular quantity surveyor also has significant experience working in multi-unit residential, commercial, and education sectors among many more. This particular expert also has experience working in New Zealand and Australia and now is an associate director in a large multinational quantity surveying consultancy firm.

Some of the issues in the construction industry that are visible today are shortage of skilled labour including consultancies such as quantity surveyors and project managers. Trades such as tiling have encountered with significant experiences where labour increased by up to 100% (\$125/square metre to \$250 square metre). Among other common shortages are in trades are those that are utilised across all projects – such as structural trades (concrete, formwork, etc.). Quantity surveyors are always required to know what the market is doing in order to allow for shortages of trades, or rise in costs of trades, etc.

Quantity surveyors are required to focus on what is specified. While it can depend on what stage of the project the project is in, it is also dependent on how specific the item is and where it is being procured from. Quantity surveyors are always required to be cognizant of what that means and how it impacts the bigger construction picture. It may also mean that material substitutions may have to be made and what impacts that may have this particular project.

More shortages may be experienced in the construction industry, especially if major events such as The Olympics come to Brisbane. There would be more infrastructure projects to be delivered which may bring migration from other cities and states. In turn, the cities that these labourers may arrive from may experience shortages for a certain period of time. Construction is always a cyclical process. However, there never is going to be a surplus of any trades or skills in the construction industry. Professions such as quantity surveyors and project managers are always on the long term in the skills occupation list and this and may not be disappearing from skilled shortage list anytime soon.

In Queensland's building environment, there is a requirement with a progress claim that needs to be completed where a statutory declaration is issued that states the employees, suppliers, subcontractors have been paid - this is becoming a bigger issue. There are supposed to be audited project bank accounts which should have the ability to audit all funds going in and out of that account but this requires another level of bureaucracy and, essentially cost which is to be ultimately be borne by the client.

Australia has quite strict rules on immigration but there are things like skilled shortage list that allows to bring skilled people from overseas in case of a shortage provided that they can be attracted to Australia.

Educational offerings such as that at Bond University allows for some of the skills for newcomers to develop into what they are interested in and work in a field that is currently experiencing shortage.

Business in construction industry may not change significantly in the near/short-term future. Business is going to be continuing as it has been in the construction industry for a number of years. Banks will continue to remain to be a means through which funding and funds will be processed. A lot of the future remains unknown including what direction the industry will proceed to head towards. Jobs (such as quantity surveyors) and institutions (such as banks) will continue to evolve with technology and time. For example, technological advancements in the construction industry such as building information modelling (BIM) continue to improve and allow for more accurate measurement –financial institutions may go through a similar evolution process.

Developments in the blockchain may include where blockchain is able to link a BIM take-off or bills of quantities (BoQ) and eventually, when the project commences on site, tracking contractor progress claims can be linked to items in the BoQ which becomes easily quantifiable and trackable.

CHAPTER 4.3 – DISCUSSIONS WITH A PROPERTY LAWYER (A)

One of the industry experts that was believed to have significant experience and knowledge regarding the issues relevant to the property and construction industry was property lawyers. This particular property lawyer started their career as a contract administrator for a construction builder and proceeded towards becoming a lawyer in the construction and property industries.

Currently, main issues in the property sector are:

- The supply of credit (particularly in a low-interest rate environment) has a lot to answer for in terms of affordability of residential and commercial property. Property, construction and dwelling prices have sky rocketed over recent decades, and has become extremely competitive as a result, which makes margins low in a highly-leveraged environment.
- There are also recent instances of building quality being below par, which is perpetuated through high cost, high competition and low regulation.
- Another factor is high minimum wage and low technological development generally, which would allow buildings to be built for less with less human capital.
- Land ownership disputes are less common than disputes relating to the property generally. The majority of disputes from my experience relate to disputes with neighbours, planning departments or warranties given by sellers to buyers during a property purchase (i.e. the water allocation associated with the property is [x] mega litres per year, when in fact it is [y]), which may trigger a contractual claim for damages.

Currently, these issues are resolved legally through administrative or contractual claims. The advantage is that an independent court /arbitrator is ultimately available to resolve any dispute if the parties cannot agree. The disadvantage is that this process can be very costly, and uneconomic to pursue a just outcome for the wronged party. There has been the emergence of alternative dispute resolution (for example mediation), which is cheaper and has been beneficial, but is not 100% successful.

Residential leases generally favour the landlord, and most states do not have strong rent protection mechanisms (for example, the right to a minimum term, or cap on rent increases). Commercial leases are negotiated on more of an arms' length basis, and the issues generally arise later and are fought on the terms of the agreement (which are overwhelmingly prepared by lawyers).

End of project disputes (particularly regarding final payment and damages for loss) are common, and are the most controversial and heavily litigated. The resolution process generally follows the terms of the contract, which are agreed at contract commencement. Often the process is agreed that first, the parties must meet and negotiate for a period of time to resolve the dispute in good faith followed by mediation or an expert followed by the parties will be free to go to court.

CHAPTER 4.4 – DISCUSSIONS WITH A PROPERTY LAWYER (B)

Similar to the previous property lawyer, another property lawyer believed to have significant experience and knowledge regarding the issues relevant to the property industry was also interviewed. This particular property lawyer owns and manages their own law firm and is mainly involved with property law, planning and development law, commercial leasing, retail shop leasing among others. The experience of this lawyer also provides a perspective that is unique from other experts.

Queensland used to have a paper deed for property ownership and that would be proof of land ownership. Queensland has now transitioned into a digital system where the ownership or transfer of ownership is still done via paper and lodged with the land registry department who then update the digital title – it makes getting a physical title deed impossible and if there is a paper deed, it is not recognized. However, this process generally does not create for many issues.

Property transactions methodology has changed in Queensland. As an example, settlements are usually conducted with signed cheques and documents being passed around to banks and other relevant parties. This is now being done digitally online which integrates with the title office. Some documents are signed through paper documents and others digitally and this could become an issue for some.

Councils storing past records or details of properties has always been an issue. Events such as a fire occurring in a council office resulting loss of records prevents new owners from having access to prior information on their specific property.

Developers and builders becoming insolvent has always been an issue. Builders becoming bankrupt with unfinished work or incomplete developments has been an issue for property sector. This issue seems to be worsening over the last 10-15 years and there are some laws that have been implemented to deal with this issue (illegal phoenix activity). Illegal phoenix activity is when a company is established to carry on the business of a previous company that has been purposely entered into insolvency to avoid paying its debts, taxes, creditors and employee entitlements – this affects the overall economy significantly (Australian Taxation Office, 2020b).

Owners and developers have fears when signing any contractor for a job if they are going to go into insolvency during the course of their project. Contractors have several overheads and rely on progress payments from clients to fund their projects – something smart contracts may be able to address. Blockchain allows for transparency that is required in this space. Companies can be searched online and details such as

their risk rating are also available online but it is not very accurate. It only takes one job to damage a contractor's risk factor/rating. This rating system also goes both ways with contractors having the ability to see what their clients' ratings are with details such as financial position, is the client making timely progress payments, etc. Transparency is key and is an aspect no one thinks about until significantly damaging errors are made.

One of the most common issues in the renting space is falling behind in rent. Other issues such as rent reviews and make good of the premises when leases have ended are also common. Residential rental issues are more small scale but commercial rental issues are more significant in the tens or hundreds of thousands of dollars. Rent arrears are generally dealt with finding out a reason why rent is in arrears and require them to pay the rent immediately. If that fails, notices of breaches will be issued and eventually, locking the doors of the premises.

CHAPTER 4.5 – DISCUSSIONS WITH A BLOCKCHAIN EXPERT

Finding blockchain experts is not easy. One of the industry experts interviewed here is the co-founder of a bank. This particular industry expert understands how blockchain works, and how it is different to the traditional banking methods that are used today.

Transferring funds internationally is mainly conducted through banks or money transferring agencies. Currently, this process takes a number of days or even weeks depending on business operating hours and days. It is also dependent on which banks in the sender's country are affiliated with which banks in the receiver's country. If the sender's bank is linked to the receiver's bank, the transfer is much quicker – almost instantaneous. If the banks are not affiliated, then the funds need to go to a bank that has an affiliation in that country and then be released to the sender's accounts. These processes take a few days or even weeks to complete.

Cryptocurrencies are generally held in digital wallets called e-wallets. E-wallets typically have the tendency to let users purchase cryptocurrencies and transfer these cryptocurrencies among users. These transferring transactions are then recorded on the blockchain. This system is a separate ecosystem from the traditional banking ecosystem and has allowed concepts like decentralised finance which takes money out of the centralised finance system and becomes peer to peer. Blockchain is a decentralized validation of transactions – either monetary or data – and this serves as a source of truth and record. Buying, transferring and selling cryptocurrencies is all done in exchanges and e-wallets and these transactions are all recorded in the blockchain.

Blockchain data cannot be altered or deleted – it is permanent. Any additional data that gets added to the blockchain becomes an addendum.

Given proper implementation, a whole host of operations such as payments, clearing/settling of contracts, trading, loans etc. could be effectively undertaken without the need for security offered by an impartial intermediary (such as banks). Not having to use a middleman means less costs from fees and charges, and potentially, given good enough processing speed in the blockchain, faster processing times.

In many cases, a bank is the middleman in these transactions. They are large and trusted organisations that have huge reserves of capital at their disposal to ensure payment and facilitate trade. If blockchain is developed to a sophisticated enough level, the degree of involvement for banks, and therefore their revenue, will decrease substantially.

There could be some concerns with blockchain affecting banks negatively through removing the level of involvement, and therefore the profitability of historically bankable products. The concern from a banking perspective is that if the blockchain technology becomes sophisticated enough, it could effectively remove the need for banks in a wide slew of their most cost operational activities, as they will be outclassed on a cost basis as well as a speed on.

If there is a finite number of cryptocurrencies like Bitcoin and wallets, it is essential to know where the funds were transferred from and to. Cryptocurrency values are based on supply and demand and are not linked to number of blocks in a chain. Smart contracts are a way to automate contracts in the construction industry. Smart contracts are more like a system that is built on top of the blockchain that facilitates contractual arrangements with a bunch of conditions incorporated in it.

CHAPTER 4.6 – DISCUSSIONS WITH A FINANCE EXPERT

One of the industry experts interviewed here is a finance expert with over 10 years of experience. This particular industry expert currently works with blockchain technology. This particular expert also has a deep technical understanding of how blockchain works, but also offers a perspective on risk and how blockchain has evolved to what is visible and evident today.

When transferring funds from one person to another, usually a third party is used – banks – and other technology such as SWIFT codes, pay ID, etc. Both parties need to have bank accounts and banks check if enough funds exist to transfer from one party to another and once this is confirmed, only then it is processed and the completed. Typically, this electronic process works for smaller values. Larger values of transactions require human intervention to look at if enough balances are available, etc. Blockchain has the ability to allow users to send digital currencies from one bank account or crypto address to another and no third party (such as banks) is involved. This can be explained in the simplest way as a ledger where each person in the network has their balances written down and recorded. When funds are transferred from one person to another, questions such as how much did a sender have and if they have enough to send the requested money will be posed to validate the transaction – this validation is known as mining process.

When transferring money through banks, no one (except the bank) knows how much money the sender has in their bank account. With blockchain, if people are able to match the crypto addresses to a person, they would know how much digital currencies they have or are holding but no one can spend more than they have. Bank transfers are becoming instantaneous with time and also provide security, but do not provide a decentralisation element. Blockchain sacrifices speed for decentralisation. Sending money on the Bitcoin blockchain – even with the largest currency, most amount of resources and highest market capitalization – a transfer of Bitcoin from one address to another would take about 10 minutes. Blockchain is much slower than proper secure bank transfers. Banks would never want to give up their centralization power as they have built their processes, finances, economics and can control what is and isn't going to happen.

Crafting a transaction in blockchain is similar to a message that dictates what action(s) happen in the wallet. This message then gets broadcasted into the network. Numerous actions that occurred during the last few minutes are pooled together and software developers (known as miners) run mining nodes. About 6-7 years ago, these processes could be done on an Apple Mac laptop. About 3-4 years ago, these processes could be done on a good gaming PC and today, there are specific computers called ASICS developed strictly for the purposes of Bitcoin mining. These messages are written in a cryptographic language and then miners need to

solve a mathematical problem. This mathematical problem looks for everyone's transactions in the network and validates each of these transactions (no one is spending more than what they have or no one has put the same transaction twice, etc). Once this is solved, everyone's diaries and books are updated with these ledger entries and the process is repeated with the next set of transactions.

Issues with blockchain transactions are extremely difficult to solve. Any transaction with issues needs to be undone, with all the following transactions undone including an updated ledger of these undone transactions. The way this works is 50% of the blockchain miners have to agree to this but then the miners whose transactions were validated would complain. Miners would then decide that they would go back two blocks and remove the blocks that has issues (as long as 50% of miners agree) and update everyone's ledgers based on that. While this is a simple process in theory, the decentralizing aspect of it makes it much more difficult to actually process.

Governments have the ability to tell a bank to seize all funds from a particular company because for several reasons such as they have not paid their taxes, etc. This aspect is removed in blockchain technology. Smart contracts allow for transparency that does not allow for any modifications or tampering that is written into it. Minor changes such as adding a full stop has a waterfall effect. Smart contracts involve a hashing mechanism called SHA 256 that spits out 56 letters through which even a book can be written in code.

The future of blockchain lies in a few visions:

Capital raising – it was not really intended for this but it just evolved over time and that just became a way people raised capital; also through crypto exchanges which allow people to transfer coins from one coin to another in exchange for a small fee since becoming an economics and a stock market in itself.

Blockchain is something similar to digital gold and the decentralized aspect allows for not one person or one group of people to manipulate it. While blockchain is something similar to digital gold, it may even replace digital gold but never replace currencies of countries.

CHAPTER 5 – ANALYSIS

CHAPTER 5.1 - SUMMARY OF ISSUES

Shortage of labour and trades, payment issues and maintaining property records seem to be some of the common issues across the property and construction industry. Issues of labour and trade shortage and payment issues in the construction industries can be major contributors to damaging a builder's reputations and can have further repercussions such as obtaining future projects and the ultimate success of the construction industry. Issues with keeping property records can also be an issue. While technological advancements – such as storing records online digitally – are being conducted, there might be a way to take that further into a better way of storing and accessibility.

Builders' reputations – especially financially – are always dependent on if payments are made in a timely manner. Builders' financial status deteriorates if clients and owners make late payments or incomplete payments. Builders have overheads and suppliers that they depend on progress payments for including continuing to the completion of the project. Failure to pay on time or incomplete payments can have negative impacts on the project, supply chain and ultimately, the construction industry.

While companies do try and take measures where they can to prevent some issues, some issues are inevitable. Several of these issues are mainly resolved by administrative or contractual claims. Both parties pay significant legal fees to get a result through a lengthy and expensive process where only the lawyers seem to be the winners.

So, is there a way to address all these issues? How can blockchain assist with these issues?

CHAPTER 5.2 - BLOCKCHAIN CREDIT RATING

One of the recommendations made to industry issues this paper in '*Chapter 4.1 – Discussions with a builder*' was to have a credit rating system that allows owners and developers to see details about the builder – their skills, continued professional development, details of recent projects completed, risk rating/factor, etc. This allows owners and developers to make better decisions prior to engaging a builder on their project. The same credit rating system would also allow builders to view details on owners and developers – payment histories, ongoing legal issues, details on past projects, etc. Ultimately, this allows everyone involved in the construction industry to undertake better informed decisions whether it is a developer engaging a builder for a project or a builder deciding whether they should work on a particular developers' project or not.

It is in a developers' best interest to engage the right builder for the right job. One of the ways this can be done is through blockchain. In '*Chapter 2.2 – Blockchain in the Property and Construction Industry*', the concept of a digital identity card was mentioned. A digital identity card created for every major industry organization with various details – such as professional bodies they are associated with, continued professional development that they have undertaken, details of past projects and how successful the project was, risk/rating factor, etc. – stored behind them could improve the way business in the construction industry occurs. This concept would not only be between developers and builders, but could also be extended as far down as manufacturers and suppliers to help owners choose right products for projects. As an example, in recent times after the 2017 burning of Grenfell Tower in London, flammable cladding has been a major issue in the construction industry. Sourcing a supplier or a builder that specializes in rectifying the existing flammable cladding with the right material for the right price and the right duration, could be an example through which a digital identity card could be extremely resourceful.

There could be significant details that could be stored on these digital identity cards through the blockchain and the criteria on which the builders are scored. However, there are also disadvantages with this proposal. One of the biggest disadvantages with this proposal is some builders will succeed in obtaining a strong portfolio of projects for a few years and other builders will not. This proposal would have to be governed by a building commission or body to assist builders with a lower credit rating in improving their scores in order to obtain more projects. This would eliminate issues such as skilled labour shortage as it would be a way for builders that do not have a good reputation for good quality of work would improve their skill level. Overall, this would benefit everyone in the construction industry to make better informed business decisions.

CHAPTER 5.3 - BLOCKCHAIN DRIVER

Earlier in this report in '*Chapter 2.2 – Blockchain in the Property and Construction Industry*', the collaboration between blockchain and BIM was discussed. While BIM allows the collaboration of various project stakeholders to represent characteristics of a project digitally, blockchain allows for better integration during the lifecycle of the project (Kinnaird et. al., 2017). Companies such as BIMCHAIN share documents on a platform for their projects using digital signatures for validation by the project stakeholders. BIMCHAIN also uses smart contracts that are built into the platform to validate models and process payments (Nguyen et. al., 2019). If this technology and this integration were to be examined further and implemented successfully, it could change the way business is conducted in the construction industry.

From the early design stages, designers and engineers could have a project modelled in BIM that is validated in blockchain. This BIM model of the project can then be linked to a smart contract which will get validated or go through revisions until it meets all the conditions of the smart contract – regardless, the end result of this stage is validation by the project stakeholders in the blockchain. Once the model has met all the criteria of the smart contract, it could then be shared with quantity surveyors to develop a project budget – also linked to a specific version of a drawing in the blockchain. This model could also be shared with head contractors to develop their project budgets and various suppliers to obtain the right product for the right job. Value engineering exercises may also be conducted. After engaging a builder, certain suppliers for a project and the construction of the project begins, quantities and costs in the contract may be linked to quantities in progress reports as the project goes on. As projects near completion, a record of all information added, recorded is stored in the blockchain. This would result in a building having a storyline of what events occurred on what day at what time and blockchain becomes a single source of truth, which would eliminate a number of issues in the property and construction industries. This could even be incorporated with a smart contract where as stages become more and more complete in a project, the associated and relevant payment is also processed after being validated successfully.

One of the biggest issues in the construction industry is end of project disputes – usually involving money. Blockchain issues a date and time stamp to any activity that occurs. This eliminates a number of construction industry issues of when documents or change orders (variations) were issued or when a certain event occurred. Also, since blockchain issues a record of all activity and stores all documentation with the right time stamp, it becomes a record-keeping system. For example, a quantity surveyor working on a cost estimate

for a set of contractual set of drawings can link their estimate to this particular set of drawings in the blockchain. If the designers and engineers issue an addendum set of drawings to this contract while the quantity surveyor is working on the original set of contractual drawings, the designers and engineers believe that the contract set of cost estimate is inclusive of the addendum when it is not. Blockchain also allows the elimination of any party using the wrong set of drawings for a wrong task – i.e. using 100% design development set drawings for a contractual estimate, etc.

CHAPTER 5.4 - BLOCKCHAIN STORAGE

Storage of complex construction data and even storing of property records has been, and still is an issue in the property and construction industry. Companies like Filecoin offer storage space using blockchain technology and this can solve many issues that currently exist. First, a lot of data such as suppliers, the details of the project can be stored permanently for reference later on. Secondly, details of construction projects – mainly, when a particular event occurred – can be recorded by using the date and timestamp feature in blockchain. Third, at the end of the project, after the construction project is complete, the relevant details of the project can be stored by local and relevant councils (also in the blockchain) for future reference and record keeping. This would be stored in a database that could lead to a number of advantages – mainly, allow people to see what sort of restrictions exist in a particular area. Additionally, this would also allow developers or owners to know if what their project is feasible and realistic in the area of interest based on restrictions and neighbouring projects in the area.

CHAPTER 5.5 – BLOCKCHAIN DISADVANTAGES

While blockchain technology has a lot of advantages, there are also a number of disadvantages. Technology is not always perfect and blockchain is no different. There are limitations and there are risks associated with blockchain. Some of the largest issues with blockchain include:

- Large energy consumption – blockchain miners try to solve trillions of solutions per second to validate transactions consuming a significant amount of computer power (Niranjanamurthy et al., 2019).
- Cost – while blockchain does offer significant savings in transaction costs, the initial capital required could be high (Niranjanamurthy et al., 2019).
- Control, security and privacy – while blockchain does address some privacy and security concerns, there are still other cyber security concerns such as user identity theft, fraudulent sender and receiver, etc (Niranjanamurthy et al., 2019).
- Redundancy – Blockchain transactions operate as a network and must be processed by every node in the network. There is a lot more work involved here for the same end result as in a centralized database transaction (Niranjanamurthy et al., 2019).
- One of the risk items associated with the construction industry is while it is possible for blockchain to assist greatly with a number of issues, there are limitations as well. Currently as blockchain is still its early stages, there might not be too many issues to deal with. As it becomes more widely adopted, the issues (and the scale of the issues) become unknown including threats such as fraudulent sender and receiver, identity theft, etc.
- Another major risk item associated with blockchain could be that it may be trying to solve a number of issues all at once. One of the questions here to be asked is how much is too much.

CHAPTER 6 - CONCLUSION

As technologies continue to evolve, some of the disadvantages with blockchain may be improved upon, which will lead to them no longer being disadvantages; although with new improvements, there may also be new disadvantages. As blockchain continues to disrupt traditional methods of business and procurement in various industries, their disadvantages will also improve and become more advantageous – i.e., blockchain may improve its security features or may find better energy efficient ways of using computers to validate transactions in the blockchain. Blockchain does allow users to operate in either a public network, a private network or a hybrid network (Dragonchain, 2019). When BIM was first introduced into the construction industry, it solved a number of issues, but failed to become widely used. Lack of a legal framework, additional resources and expenses, increased level of risk and liability, lack of skills and training, are some of the reasons why BIM is not widely used in the industry (Batarseh et al., 2018). However, as adoption of new technologies in the construction industry is quite slow, blockchain could be the main driver of BIM adoption in the industry among also adopting other new emerging technologies.

One of the major impacts blockchain can have is that it can become a middle layer for various technologies to operate together efficiently (Perera et al., 2020). Incorporating details of developers, builders and suppliers into the blockchain through a digital identity card – details such as previous projects each company worked on, the risk ratings associated with each company, the financial position associated with each company - could also be greatly beneficial to the construction industry. This would allow owners and developers, builders and contractors, and suppliers and manufacturers to make better informed business, and even industry, decisions with the aid of blockchain. Overall, this technology has the potential to change the way business is conducted in the construction industry today. Blockchain allows the ability to store information that cannot be changed or deleted, with date and timestamp of activities in the blockchain. This feature would act as a single source of truth for various construction projects. Blockchain can offer an unchangeable, transparent and trustworthy means to record, store and communicate project information in the property and construction industry. Disagreements in the construction industry resulting in payment issues because certain tasks were claimed to be left incomplete would be greatly decreased. Additionally, projects would not experience significant delays, allowing for expensive and lengthy resolution processes in the construction industry to be immensely reduced, if not eliminated. Furthermore, this would also result in the reduction in risk of builders entering insolvency, and ultimately, would be a step towards the successes of the construction industry. Employee workloads could also be effectively managed through the use of smart contracts in the construction industry by

automatically executing the tasks that usually require large human involvement and input. Beyond the construction stages of the project, details of the project could also be stored with local relevant councils for record keeping. This would allow future owners and developers to know if their project is feasible or not based on local restrictions and the like. A growing collaboration method of BIM and blockchain technologies – along with incorporated features such as digital identity cards - may be a giant leap forward towards the beginnings of a less fragmented construction industry and more collaboration with the property industry.

Blockchain has already begun to emerge successfully in the property and construction industries with property transactions, energy management, and water trading occurring in the blockchain (Perera, et al., 2020). There are also companies that are using smart contracts – which is, a blockchain based contract with several contractual conditions written in computer code that can execute the conditions of the contract without human involvement - for leasing agreements in residential rental properties (Hutly, n.d.). Blockchain has already proven successful in the finance industry by eliminating intermediaries, such as banks so that people are able to process financial transactions through a peer-to-peer network. This technology is also being examined in a larger scale through uploading an entire country's stock exchange (Australia's ASX) on the blockchain (Perera, et al., 2020). While the full extent and scale of the potential risks remains unknown until it has fully been implemented, it seems like a strategic way forward towards a much more efficient method of storing and access to information and business. Blockchain is also continuing to successfully disrupt other industries such as voting, food and agriculture, identity theft, and foreign aid (Perera, et al., 2020). Through these proven industries, blockchain's potential will quickly be realized by several organizations, governments, and people. In the construction industry, this could lead to projects being managed more effectively as it will continue to challenge traditional project management methods. As blockchain allows projects to be managed and executed more effectively, projects of higher complexity and larger sizes may also soon become more of a reality.

Initially, there might be a lot of hype surrounding blockchain technology. Many will believe that blockchain will solve all the problems that currently exist in the construction industry. It is important to realize that while blockchain can solve several issues, it also cannot do everything. However, features such as allowing the interoperability between several other technologies can make blockchain technology limitless.

Blockchain has proven successful even with a very small number of people currently using it and it continues to grow. The full extent, size and shape of risks and issues that develop from blockchain technology – like several other technologies - will remain unknown until a significant portion of users begin to adopt the technology. The solutions that are required to address these issues will also remain unknown and will evolve

as deemed necessary. However, in a realm full of unknowns, one thing is definitely known - the adoption of e-procurement with the internet is being extended with blockchain, through a procurement revolution (Perera et al., 2020). As more disruption of traditional methods of conducting business occur in various industries through the means of blockchain, trust is continued to be built by all of the parties that are involved. This would eliminate the requirement of more and more intermediaries. The roles of these intermediary parties involved – such as the use of banks to send money between two parties - will continue to evolve, just as technology evolves and the survival of the construction industry will not be in jeopardy as trust would have been built in one another. Similar to how blockchain emerged from the finance industry, there is immense potential for blockchain to successfully be adopted in the construction industry. If blockchain were to be implemented successfully into the construction industry, the use of digital identity cards, smart contracts, and the interoperability features of blockchain with a number of other technologies could revolutionize the construction industry. If blockchain could present itself as a solution despite the complex nature of collaboration that is required in the construction industry, then it would also set an example for many other industries and lead a technological revolution.

CHAPTER 7 - REFERENCES

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