American Journal of Sociological Research 2023, 13(1): 4-11
DOI: 10.5923/j.sociology.20231301.02

The Potential of Adopting Blockchain Technology and Developing Smart Construction Contracts

Zeaid Mohammad Bin Masfar*, Omar Mohammad Bin Masfer, Alanoud Abdullah Alqahtani

AKDAN Professional Consulting Company, AKDAN Co. Ltd, Khobar, 34623, Kingdom of Saudi Arabia
Fully Funded Research by AKDAN Institute, (Research and Development Departments), info@akdan.co

Abstract Technological innovation has resulted in a fast-changing landscape for contracts within the construction industry. Construction has always been a collaborative process that involves large or small groups of participants. Historically, information such as conceptual design, basic design, or tender documentation have been exchanged by participants using paper documents. Nowadays, the age of digital technology, greater specialisation has resulted in greater knowledge, better quality, and higher productivity but has also caused more fragmentation in the construction industry. Management of significant information can be used in case of disputes and litigation between contributors to construction projects. New innovations, such as Building Information Modelling (BIM), which is close to becoming compulsory in application, are still facing some issues that are hindering their success. The aim of this paper is to present, in plain language, the possibility of adopting revolutionary innovation: blockchain technology and smart contracts. This paper will introduce aspects of these technological advancements and their possible application in construction in a manner that a lay person will understand. According to the revised version, the "adoption of plain language is not an exercise of merely replacing turgid words or legalese with simpler and more understandable ones. It includes reviewing the whole document and structure." One of the goals of this paper is to explain those things in a language that everybody understands, with the hope that these concepts will be embraced by the readers and lay people. This paper hypothesises that blockchain technology, in collaboration with the existing digital representations model, (Building Information Modelling (BIM)), will revolutionise the construction industry. Further, it recommends that participants in the construction industry should not stop innovating smart contracts because they do not yet fully address the complex challenges that can arise during a project.

Keywords Block Chain, Technology, Smart Construction Contracts

1. Introduction

Technological innovation has resulted in a fast-changing landscape for contracts within the construction industry (Mason, 2017). Construction has always been a collaborative process that involves large or small groups of participants. Historically, information such as conceptual design, basic design, or tender documentation have been exchanged by participants using paper documents. Nowadays, the age of digital technology, greater specialisation has resulted in greater knowledge, better quality, and higher productivity but has also caused more fragmentation in the construction industry (Turk & Kline, 2017).

According to Turk and Kline (2017), it is important to know that management of significant information can be used in case of disputes and litigation between contributors toconstruction projects. New innovations, such as Building Information Modelling (BIM), which is close to becoming compulsory in application, are still facing some issues that are hindering their success.

The aim of this paper is to present, in plain language, the possibility of adopting revolutionary innovation: blockchain technology and smart contracts. This paper will introduce aspects of these technological advancements and their possible application in construction in a manner that a lay person will understand.

According to the revised version, Ali (2008), in his paper presented at the Pacific Association of Quantity Surveyors International Conference in Auckland New Zealand stated that the "adoption of plain language is not an exercise of merely replacing turgid words or legalese with simpler and more understandable ones. It includes reviewing the whole document and structure." Computer programmers use commands, data, formulae, and language that only their fellow programmers can understand. One of the goals of this paper is to explain those things in a language that everybody understands, with the hope that these concepts will be embraced by the readers and lay people.

This paper hypothesises that blockchain technology, in

* Corresponding author:
zmsx1@hotmail.com (Zeaid Mohammad Bin Masfar)
Received: Jan. 23, 2023; Accepted: Feb. 21, 2023; Published: Mar. 15, 2023
Published online at http://journal.sapub.org/sociology

collaboration with the existing digital representations model, (BIM), will revolutionise the construction industry. Further, it recommends that participants in the construction industry should not stop innovating smart contracts because they do not yet fully address the complex challenges that can arise during a project.

1.1. Definition of Terms Used in Blockchain Technology and Smart Contracts

1. **Asymmetric Cryptography (Public Key Cryptography**): Uses public and private keys to encrypt and decrypt data. The keys are large numbers that have been paired together but are not identical (asymmetric). A public key can be shared with anyone, while the private key in the pair is keptsecret. Protocols such as SSH and S/MIME rely on asymmetric cryptography for encryption and digital signature functions (Hickson, 2018).
2. **Bitcoin**: A well-known cryptocurrency, based on the proof-of-work blockchain (Odinsky 2017).
3. **Blockchain**: A type of distributed ledger, comprised of unchangeable, digitally recorded data in packages called blocks. Each block is chained to the next block, using a cryptographic signature. This allows blockchains to be used like a ledger, which can be shared and accessed by anyone with the appropriate permissions (Odinsky, 2017; Hickson, 2018).
4. **Consensus Algorithm**: Ensures that the next block in a blockchain is the one and only version of the truth, and it keeps powerful adversaries from derailing the system and successfully forking the chain (Hickson, 2018).
5. **Cryptocurrency**: A form of digital currency based on mathematics, where encryption techniques are used to regulate the generation of units of currency and verify the transfer of funds. Furthermore, cryptocurrencies operate independently of a central bank (Odinsky, 2017).
6. **dApp:** A decentralised application that must be completely open-source, must operate autonomously, and have no entity controlling the majority of its tokens (Odinsky, 2017).
7. **Decentralised Autonomous Organisation (DAO):** can be thought of as a corporation run without any human involvement under the control of an incorruptible set of business rules (Odinsky, 2017).
8. **Decentralisation**: Refers to a network that operates on a peer-to-peer basis. A global network of computers uses blockchain technology to jointly manage the database that records transactions instead of one central server (Hickson, 2018).
9. **Distributed ledgers**: Distributed ledgers are a type of database that are spread across multiple sites, countries, or institutions. Distributed ledger data can be either "permissioned" or "un-permissioned" to control who can view it (Hickson, 2018).
10. **Ethereum**: An open software platform based on blockchain technology that enables developers to write smart contracts and build and deploy decentralised applications (Odinsky, 2017).
11. **Ledger**: An append-only record store, where records are immutable and may hold more general information than financial records (Odinsky, 2017).
12. **Merkle Tree**: A cryptographic hash tree structure that can store a very large amount of data, where authenticating each individual piece of data only takes O(log(n)) space and time. In Ethereum, the transaction set of each block, as well as the state, is kept in a Merkle tree, where the roots of the trees are committed to in a block (Hickson, 2018).
13. **Mining**: The process by which transactions are verified and added to a blockchain. This process of solving cryptographic problems using computing hardware also triggers the release of cryptocurrencies (Odinsky, 2017).
14. **Node**: Any computer that connects to the blockchain network (Odinsky, 2017).
15. **Peer-to-peer (P2P):** Refers to the decentralised interactions that happen between at least two parties in a highly interconnected network. P2P participants deal directly with each other through a single mediation point (Hickson, 2018).
16. **Smart contracts**: Contracts whose terms are recorded in a computer language instead of legal language. Smart contracts can be automatically executed by a computing system, such as a suitable distributed ledger system (Odinsky, 2017).

2. Blockchain Technology

Blockchain is an incorruptible digital ledger of economic transactions that can be programmed to record not only financial transactions but virtually everything of value (Tapscott, 2016); it is the underlying technology behind cryptocurrencies like Bitcoin. Unlike physical currency, digital cash and cryptocurrencies come with a very real problem, double-spending; Blockchain technology helps prevent this (Mishra, 2016). According to Hughes (2017), a Blockchain is a decentralised database, which chronologically and securely records transactions. Blockchain transactions represent the transfer of value on systems such as Ethereum and others. Value, according to Hughes, might be a service, a product, or an approval in the form of a smart contract.

Mishra (2016) stated that Blockchain technology applies not just to cryptocurrency but to any asset that can be stored, distributed or transacted such as properties, music, insurance, physical goods, and assets, even our own data. According to Tapscott (2016) in his TED Talk, the biggest use of Blockchain technology is in identity management where, as we go to through our lives, we leave a trail of digital data crumbs behind us. These crumbs are collected and created

into a digital profile for us. According to him, these collected data are not owned by us, however he asserted that if we were to reclaim our virtual data and take control over how much and who we give it out to, it would be a big step towards helping us protect our privacy.

2.1. History of Blockchain Technology

A Blockchain is a growing list of records called blocks, which are linked using cryptography (Narayanan, Bonneau, Felten, Miller, & Goldfeder, 2016). Cryptography comes from the Greek words, *Kryptos* and *grahein*, which mean hidden and writing, respectively (Damico, 2009 citing Pawlan, 1998). According to Damico (2009), the purpose of early cryptography was to convert simple messages into unreadable groups of figures to protect the content of the message during its transport. Today, cryptography has grown from basic message confidentiality to embrace some phrases of message integrity checking, sender/receiver identity authentication, digital signatures, and other forms of security.

Haber and Stornetta (1991) said the prospect of a world in which all text, audio, picture, and video documents are in a digital form, which can be easily modified, raises the issue of how to certify when a document was originally created or last changed. They proposed digital time-stamping such documents to make it impossible for users to back-date or to forward-date its documents. Following this, Haber, Bayer and Stornetta (1992) stated that to establish that a document was created after a given moment in time it would be necessary to report events that could not have been predicted before they happened. According to them, in order to establish that a document was created before a given moment in time, there would be a need to cause an event based on the document, which could be seen and scrutinised by others. They used cryptographic hash functions to report events succinctly and to cause events based on documents, without revealing their contents. They introduced Merkle Trees to show the process of achieving an exponential increase in the publicity obtained for each time-stamping event, while reducing the storage and computation required in order to validate a given certificate. In short, Merkle Trees allow several documents to be collected into one block. Please see Figure 1 below:

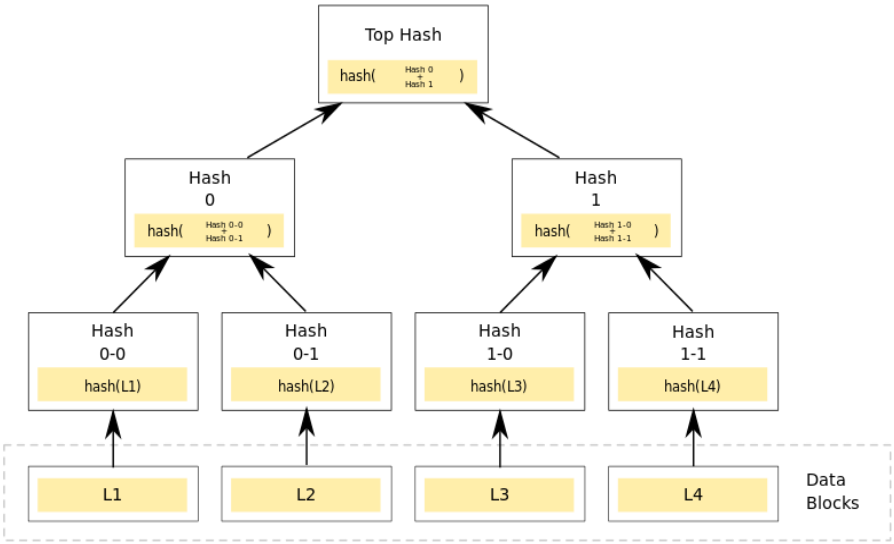

Figure 1. Merkle Tree (Merkle, 1979)

Satoshi Nakamoto is the pseudonym adopted by the creator of Bitcoin. Satoshi started coding Bitcoin around May 2007 and registered the domain Bitcoin.org in August 2008, sending emails to people who might be interestedin the proposal. In October of the same year, the creator publicly released a white paper that described the protocol; later he released the initial code for Bitcoin as well. For two years he maintained it by posting emails and responding to concerns, submitting patches to the code while maintaining the source code in conjunction with other developers, and fixing issues as they arose. In December 2010, others slowly took over the maintenance of the project and Satoshi stopped communicating with them (Narayanan et al., 2016).

Narayanan et al. (2016) concluded that the success of Bitcoin is quite remarkable and includes several notable innovations, including block chain and a decentralised model that supports user to user transactions. According to them, it provides a practically useful but less-than-perfect level of anonymity for users.

2.2. Blockchain Technology Explained in Relation to Cryptocurrency (Bitcoin)

According to Thompson (2016), Blockchain is a trending topic in today's world, yet for the majority, the technology remains a mysterious concept. When undertaking transactions of any value, monetary or otherwise, individuals and businesses tend to rely on middlemen, such as banks and governments, to ensure trust and certainty. Said middlemen help build trust because of their authentication and record keeping functions (Tapscott, 2016).

Thompson (2016), citing Tapscott (2016), stated that the need for intermediaries is important when makinga digital transaction. Digital assets, such as money, stocks, or intellectual property, are essentially files that can be reproduced easily. As a consequence, issues such as double spending prevent peer to peer transfer of digital assets.

The appearance of Bitcoin in 2008, enabling online payments to be transferred directly, without an intermediary, created an innovative peer to peer electronic cash system. However, it is the mechanics behind it that were truly revolutionary; that is, what is known today as Blockchain (Thompson, 2016). According to Pierce (2016), in his INK talks in Singapore, Blockchain is commonly associated with Bitcoin but there are about seven hundred other applications that use the blockchain operating system.

Blockchain is as a type of distributed ledger (Odinsky, 2017; Hickson, 2018) or decentralised database that keeps continuously updated digital records of people and their ownership (Thompson, 2016). Instead of having a centralised administrator, such as a bank, distributed ledgers have networks of replicated databases, coordinated via the internet, which can be seen by anyone that has access to the network (Thompson, 2016).

All digital transactions that occur within ten minutes in a blockchain are grouped together in a cryptographically protected block and then sent out to the entire network. Within the network are miners, with high levels ofcomputing power, competing among themselves to validate the transactions by computing complex coded problems. The first one to solve and validate the recently created block receives a reward e.g., bitcoins if the problem is solved and validation occurs in the Bitcoin Blockchain network (Rijmenam, 2016).

Once a validation is completed, the block will receive a timestamp and a so-called hash. The hash will be used to create the next block in the chain (Rijmenam, 2016). New blocks of validated transactions are linked to older blocks, thereby making a chain of blocks that show every transaction made in the blockchain (Tapscott, 2016). The entire chain is continually updated so that every ledger in the network will be the same, enabling individual members to prove what they own at any given time (Thompson, 2016).

Rijmenam (2016) stated that it is impossible to change (immutable) the content of a block because it would affect the hash, resulting in a change in subsequent blocks. Not only that, revalidation of the changed block would require tremendous amounts of computing power, be very expensive, and is without reward. Hence, there is no benefit to changing any data.

Blockchain's decentralised, open, and cryptographic nature allows people to trust each other without knowing them personally and undertake peer to peer transactions without the help of intermediaries (Thompson, 2016). Blockchain is an important paradigm shift from using third parties who take commissions, for example to take three days to transfer money (Tapscott, 2016) to digital business transactions that can be done instantly, peer to peer (Rijmenam, 2016).

In 2015, Buterin categorised blockchains into public, consortium, and fully private blocks. Anyone can read or send valid transactions in public blockchains, as well as participate in the consensual process of determining what blocks are to be added to the chain to define its current state. This category of blockchain is not secured by a third party but by reward or incentives and by cryptographic verification using mechanisms such as proof of work or proof of stake. This category of blockchain is fully decentralised. Consortium Blockchains have a consensus process that is controlled by a pre-selected set of nodes. The right to read the blockchain in this category might be public, or restricted only to the participants, hence it can be considered as partially decentralised (Buteren, 2015). The third category is fully private blockchains, which, according to Buteren (2016), is where write permissions are kept centralised to one organisation.

Blockchain can be applied to a variety of industries, ranging from shopping, voting, or any other transactions. There are also different kinds of blockchains, such as Bitcoin Blockchains, Ethereum, Hypeledger and many more (Rijmenam 2016).

3. Ethereum in Relation to Smart Contracts

Ethereum is a blockchain system developed by Vitalik Buterin, in 2013, as the next generation Blockchain (2.0) technology, with the capability to program and perform arbitrary and complex computations. It is considered second generation blockchain technology because it was designed to let any person with computer skills develop and deploy their own decentralised application on the blockchain (Thompson, 2016). In the Ethereum blockchain, programmers can write "smart contracts" that are automatically executed according to their code; it generates a cryptocurrency token known as Ether. Like people who run Bitcoin nodes that provide hashing power and are paid in bitcoin, people who run Ether nodes that provide computing power are paid in Ether (Hoffman, 2018).

According to Modi (2018), the main objective ofEthereum is to accept transactions from accounts, update their status, and then maintain their current state until a new transaction updates it again. While the Bitcoin blockchain stores a history of bitcoin transactions only, the Ethereum blockchain stores the Ether tokens in people's wallets, but also stores the most recent state of each smart contract, as well as each smart contract's code (Hoffman, 2018).

Hoffman (2018) explained one advantage of Ethereum Blockchain in the following manner:

> *"If you were using an app built on top of Ethereum, both the code that makes up the app (the smart contract code) and personal data (the state of the smart contract) would be stored on the blockchain. Whenever you used an app and changed your data, all the Ethereum nodes*

would update the state of the smart contract. This means that there's no central "point of failure" that could take away your access to the data or shut down the app you use. Your data and the app's code itself would be backed up all over the world, and no one could take all those notes offline. Of course, your data would be encrypted by the blockchain so no one else could read it."

3.1. Smart Contracts

Masson and Escott (2018) reported that the term smart contract was coined in 1994 by Nick Szabo. A smart contract is a computerised transaction protocol that executes the terms of a contract. Its objectives are designed to satisfy common contractual conditions (payment terms, liens, confidentiality, and enforcement), minimise expectations, and minimise the need for intermediaries (Szabo, 1994).

A smart contract is a contract implemented, deployed, and executed within the Ethereum Virtual Machine (EVM) and by Ether. The EVM is the engine that keeps all smart contracts running on time and coordinates them with the rest of the network (Thompson, 2016). Smart contracts can store data that can be used to record information, facts, associations, balances, and any other information needed to implement logic for real world contracts. In short, they are the digitisation of legal contracts (Modi, 2018).

Kulkarni (2018) stated that Ethereum graced the crypto space with its presence in mid-2015 and its success is mainly attributed to its implementation of smart contracts. He said that in the EVM, gas is a unit of measurement used to assigna fee to each transaction for a smart contract and that the more complex or tedious the computation, the more gas is needed to execute the smart contract. Bitcoin has a network of nodes that validate bitcoin transactions; smart contracts also use a network of nodes to validate whether aspects of anagreement have been completed. There is no need for an intermediary to verify transactions because the nodes and the code within the smart contracts provide the validation itself. Since smart contracts are placed within a decentralised blockchain, nobody is in control of the money unless the contract's terms are completed (Gutierrez, 2018).

According to Modi (2018), there are multiple smart contract authoring tools. King (2018) said smart contracts can be built on multiple blockchain platforms, including Ethereum and NEO. Ethereum is, however, the most popular platform, and develops smart contracts using its original coding language, Solidity. According to Gutierrez (2018) smart contracts can be used on voting, supply chain, automobile, real estate, healthcare, finance, and legal issues.

4. Potential of Adopting Blockchain Technology on Construction Industry

The construction industry is being criticised for beingslow in embracing the changes it apparently so desperately needs (Hughes, 2017). Construction brings together large teams to design and shape the environment and, with technology like the Building Information Modeling (BIM) becoming popular, openness to partnership and new concepts is increasing across the industry. Wang, Wu, Wang and Shou (2017), citing Lau and Rowlinson (2010), said within the construction industry there is concern around trust between people such as clients, contractors, sub-contractors, and suppliers. Wong and Cheung (2005) believed that the establishment of trust was the most critical factor to facilitate partnering success. In order to do this, management teams within the construction industry should direct their efforts to enhancing a systematic and effective trust system between various partners.

Current contractual relationships are mainly based on challenging situations that reveal the level of reliance or doubt in the contract documents that might result in increases in the cost of the project (Zaghloul & Hartman, 2003). At this time, international contracting is common and the complexity of construction projects is increasing (Lau & Rowlinson, 2010). As a result, projects require transfer of advanced construction technology as well as project information and fair data exchange (Wang et al., 2017).

Blockchain is continuously attracting more and more attention due to its incredible versatility (Koutsogiannis & Berntsen, 2017). One way Blockchain may assist construction is by providing transparency to every type of agreement and transaction within the industry. Wang et al. (2017) said that one key feature of Blockchain technology is trust; if construction business or activities are executedon a blockchain system, parties do not need to establish a trusted relationship because the technology takes care of the information exchange by making every participant a custodian of all the information flowing to the project lifecycle. In short, the same information is passed across the whole system, therefore no person has more information than the others.

The potential application of Blockchain in construction management has been classified into three categories by Wang et al. (2017). They are as follows:

1. Notarisation-related applications to eliminate the verification of time documents authenticity. By implementing Blockchain, every document stored ina distributed ledger will have perfect notarisation for each creation, deletion, and update across the system. Everyone in the system will see the source of the information and the technology also enables authentication;
2. Transaction-related applications to facilitate digital procurement and payments. Through the use of Blockchain, the transfer of title for any properties, whether tangible or intangible, will be easy. Since the processes are automated and neutral, disputes that occur in relation to payment, technology transfer, equipment leasing, or house selling will be prevented, saving time and money.
3. Provenance-related applications to improve

transparency and traceability of construction supply chains. The decentralised nature of Blockchain will make it easier to trace the supplier and its authenticity.

5. Developing Smart Construction Contracts and Future Collaboration

The increased use of Building Information Modelling is close to becoming compulsory. BIM, at its most basic, is software that enables the generation and management of digital 3D models of a construction project and has the potential to encourage collaboration between project participants. Aside from generation and management of 3D models, it is intended to integrate a lot of data from multiple sources within the model. The use of BIM will likely progress to a level where all project participants are theoretically capable of making changes to a single and unified project model (Thomson, 2008).

Blockchain is needed for project participants to effectively collaborate within the BIM because it can address issues surrounding secure access to the model and allows reliable audit of who, when, and what changes are made. Collaboration will lead to increased confidence in the reliability of the information it contains, better tracking of copyright and intellectual property, and increased accountability for contributors in the event something goes wrong (Thomson, 2018).

As of this moment, it may be possible for a Blockchain smart contract to cover an entire construction contract, in terms of payment, and supported by BIM. At the signing of the contract, the owner can pre-deposit funds (from the project account) into a cluster of smaller sub-smart contracts that are transparent and visible to anyone working on the project who has the right credentials. The smart contract can program in the release and transfer of pre-deposited funds when certain stage requirements are completed or materials are delivered, upon the validation of the Blockchain miners (engineer, contractor, subcontractor, and others).

The following is an example of using smart contracts, supported by BIM, to make payment through the use of automated payment processes. A supplier would log into the BIM software and signify that he is ready to deliver a particular material. The smart contract, connected to the project account of the client and BIM, will provide verification of the availability of funds to pay for the materials, and will be confirmed by the supplier. Upon delivery of the materials, the project manager will confirm receipt within the BIM. After confirmation, funds will be automatically transferred to the project account of the supplier (wallet). In this scenario, the distributive ledgerwill be updated (time stamped) with the amount transferred to the supplier's wallet and will also be considered an advance of the contract price between the client and the contractor. It will be shown in the ledger that a specified amount was transferred to the supplier's account and by virtue of such transfer, the main contractor's account will also show that an expense has been made and the total amount owed by the client will be updated. By virtue of smart contracts, the client, the manager, the contractor, and the supplier will have the same copy of the updated ledger that cannot be altered by anyone.

If, for example, the materials were delivered (already paid and time stamped) by the supplier and received by the manager in the above scenario, the manager will transfer the physical materials to the sub-contractor, whom we assume has a contract with the main contractor to finish the foundation of a particular building. The sub-contractor then commences construction of the building's foundation and, once complete, updates the BIM software to show the foundation is done. Upon review of the materials used, time of construction, or ensuring any specifications provided by the engineer, architect, or client are strictly followed, the BIM, through the smart contract, will automatically transfer the amount specified from the client's project fund to the sub-contractor's project account. At the same time, by virtue of this transfer, the ledger will again calculate and be updated. It will show the amount that was transferred from the client's account to the sub-contractor's account. Concurrently, the contract price owed by the client to the main contractor will be reduced due to the transfer of amount to the sub-contractor. All the information and updates will be time stamped in a way that no particular project participant can change or control.

The above example is possible because it is based on the same idea as that of Bitcoin. The transaction made on the smart contract between the supplier and subcontractor can be multiplied as much as the project needs. It must be noted that in a construction project there can be many suppliers or many sub-contractors working together as required by the project. By virtue of Blockchain and smart contracts, the transfer of funds can be made automatically.

As long as all the commands, terms, specifications, guidelines, or any other useful commands are programmed into the Blockchain contract, the cryptocurrency aspect of this intelligent contract will work in construction project. However, there might be a slight problem regarding payment in this digital payment procedure. For example, the sub-contractor finishes the foundation and communicates this to the BIM, who verifies that according to its program, the work is complete. There is no way that the software can determine if the materials used were the appropriate standard, or the mixture of concrete was made correctly. All the BIM does is transfer the payment through the smart contract as programmed. The smart contract cannot decide who is liable or responsible for any construction quality issues. There is a need to study this situation further in the future.

Another possible defect of the smart contract is that it may be difficult to combine a smart contract for payments and a smart contract for design, modification rights, copyrights, and intellectual property rights. Although smart contracts can address payment problems without delay, it is widely known that construction projects are complex, involving many participants who each have their own issues or

interests, aside from financial concerns. Perhaps the best solution is to continue innovating by looking at every risk and allocating a way to solve them in a digital manner following a formula that is easy to understand.

6. Conclusions and Recommendations

6.1. Conclusions

Currently a smart contract can be used within the construction industry in terms of payments because it has the same idea or application as the already successful cryptocurrency (Bitcoin). Blockchain and the construction industry is a natural pairing since there is clear monetary movement within a construction project. By spreading the data out to several companies and computers, it makes all payments clear and helps hold different parties accountable. It can also create saved identifications that might help many subcontractors win more work. Capitalist suppliers can also participate in supplying materials because the requirements are available to the public. Blockchain, within the construction industry, has a distinct possibility of success in terms of payment because it requires less energy and is less intensive while keeping the same level of safety. It may also have better results if the Blockchain construction contract works in collaboration with BIM. However, there is a need for further innovation to address some minor risks affecting payments, particularly on the procedure and requirements of transfer of funds.

The researcher believes that smart contracts can help the construction industry in a number of ways, and will soon be used for copyright of design and modification rights, as well as construction payments. However, there are still many steps that need to be taken before it can be claimed that a Blockchain smart contract is a vital part of the building process.

6.2. Recommendations

It is recommended that there be one smart contract addressing payment only. This smart contract blockchain can be public so that suppliers and contractors locally or internationally can participate. With respect to design, copyright, or intellectual property rights, the smart blockchain will be a consortium blockchain or even a private blockchain, so that the consensus process is controlled by a pre-selected set of nodes; for example, only the architect, the engineer, or the client who paid for the design can have access, thereby limiting the chance of reproduction of such a design or violation of rights.

It is recommended that future innovators should study all the risks or possible problems that may arise when adopting Blockchain in construction in order to provide specific programs, commands, or set of rules. They may separateor create as many smart contracts in construction as needed, each having their own specific function, such as a payment-only smart contract, design-only smart contract, or intellectual property rights-only smart contract, as long as it will work effeciently. The primary goal of adopting Blockchain is to limit time, conflicts, and cost in the construction industry. Future innovations might be able to create a single smart contract to cover all the complex situations, with the proper solutions, for the events that occur in the construction industry. If programmers have designed Merkle trees, Blockchains, Ethereum and smart contracts in the past then it is possible that in the future all question as to the application of Blockchain in construction will be addressed.

REFERENCES

[1] Ameer Ali, N. A. N. (2008). Modern plain English drafting and construction: The Malaysian subcontract model terms.

[2] Bayer, D., Haber, S., and Stornetta, W. S. (1992). Improving the efficiency and reliability of digital time-stamping. Retrieved from: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.71.4891&rep=rep1&type=pdf.

[3] Buterin, V. (2015). On public and private Blockchains. Retrieved from: https://blog.ethereum.org/2015/08/07/on-public-and-private-blockchains/.

[4] Damico, T. M. (2009). A brief history of Cryptography. Retrieved from: http://www.inquiriesjournal.com/articles/1698/a-brief-history-of-cryptography.

[5] Gutierrez, J.R. (2018). What are smart contracts and how do they work? (Example & Challenges). Retrieved from: https://cryptovest.com/education/what-are-smart-contracts-and-how-do-they-work-examples--challenges/.

[6] Haber, S. & Stornetta, W. S. (1991). How to time-stamp digital documents. Retrieved from: https://www.anf.es/pdf/Haber_Stornetta.pdf.

[7] Hichson, K. (2018). 101: Blockchain terminology. https://medium.com/my-blockchain-bible/101-blockchain-terminology-874f007c0270.

[8] Hoffman, C. (2018). What is Ethereum, and what are smart contracts. Retrieved from: https://www.howtogeek.com/350322/what-is-ethereum-and-what-are-smart-contracts/.

[9] Hughes, D. (2017). The impact of Blockchain technology on the construction industry. Retrieved from: https://medium.com/the-basics-of-blockchain/the-impact-of-blockchain-technology-on-the-construction-industry-85ab78c4aba6.

[10] Koutsogiannis, A. & Berntsen, N. (2017). Blockchain and construction: The how, why, and when. Retrieved from: http://www.bimplus.co.uk.

[11] Kulkarni, T. (2018). IBM's take on Blockchain technology beyond Bitcoin. Retrieved from: https://bankinnovation.net/2018/02.

[12] Lau, E, & Rowlinson, S. (2010). Trust relations in the construction industry. *International Journal of Managing Projects in Business.*

[13] Mason, J. (2017). Intelligent contracts and the construction

industry. Retrieved from: http://eprints.uwe.ac.uk/30522/3/intelligentcontractsfinal.pdf.

[14] Mason, J. & Escott, H. (2018). Smart contracts in construction: Views and perception of stakeholders.Retrieved from: http://eprints.uwe.ac.uk.

[15] Merkle, R. C. (1979). Merkle Tree.

[16] Mishra, R. (2016). Blockchain technology cxplained- An executive summary. Retrieved from: https://www.whitehatsec.com/blog/blockchain-technology/.

[17] Modi, R. (2018). Introduction to Blockchain, Ethereum and smart contracts- Chapter 1. Retrieved from: https://medium.com/coinmonks/https-medium-com-ritesh-modi-solidity-chapter1-63dfaff08a11.

[18] Narayanan, Bonneau, Felten, Miller, and Goldfeder, (2016). Bitcoin and Cryptocurrency Technologies. Retrieved from: https://lopp.net/pdf/princeton_bitcoin_book.pdf.

[19] Odinsky, J. (2017). Blockchain dictionary. Retrieved from: https://hackernoon.com/blockchain-dictionary-f4d098c9ef89.

[20] Pawlan, M. (1998, February). Cryptography: the ancient art of secret messages.

[21] Rijmenam, V. M. (2016). What is Blockchain and Why is it so Important. Retrieved from: https://www.linkedin.com/pulse/what-blockchain-why-so-important-mark-van-rijmenam/.

[22] Tapscott, D. (2016) How the Blockchain is Changing Money and Business. TED Talks. Retrieved From: https://www.ted.com/talks/don_tapscott_how_the_blockchain_is_changing_money_and_business.

[23] Thompson, C. (2016) How does Blockchain Works. Part 1. Retrieved from: https://medium.com/blockchain-review/what-blockchain.

[24] Thomson, M. (2018). BIM, Blockchain and the Smart Construction Contract. Retrieved from: https://www.millerthomson.com.

[25] Turk, Z., & Kline, R. (2017) Potentials of Blockchain Technology for Construction Management. Retrieved from: https://reader.elsevier.com.

[26] Wang, J., Wu, P., Wang, X., & Shou, W. (2017). The Outlook of Blockchain Technology for Construction Engineering Management. Retrieved from: http://www.blockchainresearchnetwork.org.

[27] Wong, P. S. P., Cheung, S. O. (2005). Structural equation model of trust and partnering success. Journal of Management Engineering.

[28] Zaghloul R, Hartman F (2003). Construction contracts: the cost of mistrust. International Journal of Project Management.