The Potentials and Impacts of Blockchain Technology in Construction Industry: A Literature Review

Kiu Mee San¹, Chia Fah Choy², Wong Phui Fung³

Department of Surveying, Lee Kong Chian Faculty of Engineering and Science, Universiti Tunku Abdul Rahman (UTAR), Sungai Long Campus, 43000 Kajang Malaysia.

Email: kiums@utar.edu.my, chiafc@utar.edu.my, pfwong@utar.edu.my

Abstract. Today, the Blockchain Technology has been widely explored and continuously revolutionising many sectors around the world, including construction industry. Construction industry need blockchain technology to improve the current limitation of centralised technology in its various project life-cycle. In this paper, we presented literature review, aimed to identify the potentials of Blockchain applications in construction industry. This paper also reviewed the unique features behind the blockchain technology which trigger its capabilities in construction industry. Paper further discussed the implications of the blockchain application if it were adopted in construction industry. In short, Blockchain technology is still relatively new in construction industry and further deep research is needed to develop real life on-hand application for construction industry in near future.

1. Introduction
Blockchain technology has been a popularly discussed in recent years. It has been widely discussed as the second wave to change the world after the Internet. The blockchain technology is originated from the Bitcoin founder, Satoshi Nakamoto who has created Bitcoin cryptocurrency[1]. But what the world is seeing now is not only the power of cryptocurrencies in changing the global’s businesses and finances, many other sectors’ expertise are trying to explore and develop the large potentials behind the fundamental technology behind the Bitcoin’s technology – so called the blockchain technology. As Alcazar (2017) perceived, “Blockchain as a technology continues to evolve, yielding new types and potential uses” [2], and blockchain technology is making headway in the construction industry [3].

2. Overview of Blockchain Technology
A blockchain is a type of electronic ledger of digital information (such as records, events, or transactions) that required a hash for digital security purpose and is authenticated and maintained by the participants using a group of consensus protocol through a decentralised network [4]. Blockchain got its naming for the reason where at scheduled intervals, each information on transaction will be recorded as a ‘block’ adding to the ‘chain’ [3] forming incorruptible ledger of ‘blockchain’. Blockchain was first a decentralised transaction and data management technology for Bitcoin cryptocurrency [5] and now where a vital platform for many cryptocurrencies are based on [3]. However, the applications of the Blockchain Technology are not limited to cryptocoins [5]
anymore and it can become somewhat a solution for a problem when we move Blockchain out of its natural home of cryptocurrency [6] to various environments where some forms of transactions are done [5]. Blockchain technology has a few important features that make it to be the current most potential technology to revolutionize many industries and use cases [7], including construction industry:-

2.1. Decentralised
Decentralised is the main feature of blockchain technology which make it different with the current centralised traditional database system or server that we are using now. Decentralised simply mean that there is no middleman or central authority is needed, such as a bank transferring money or a lawyer to confirm the conditions of a contract [8]. Each participant or selected participant on a blockchain has access to verify the records of its transaction partners, and access to the entire database and its complete history directly, without the help of intermediary [9]. Basically, Blockchain removes the requirements for centralized authority by removing the need for the trust management middleman role [2], in another meaning, there is no single database or company or party on which it hinges to controls the data or the information solely [9] [8].

2.2. Autonomous
Another feature of blockchain technology is autonomous. Autonomous means that after the blockchain application is launched and run, a contract and its initiating agent need not be in further contact [10]. Automation includes the deployment of algorithms and rules that can automatically trigger the self-execution, self-enforcement, self-verification, and self-constraint of the performance of the smart contracts [11]. Therefore, the digital nature of blockchain’s ledger is that the information or monetary transactions are tied to computational logic and in essence programmed rules to automatically trigger transactions between nodes [9] without the need for human interaction or trust providers.

2.3. Peer-to-peer relationship
Blockchain’s another main feature is its concept of peer-to-peer systems, which encourage the operation of information or monetary transaction from one wallet to another wallet without the intermediary of trusted third party or central authorities. It was highlighted that “Both the private and public sectors have great expectations for blockchain technology because it provides the bedrock for developing peer-to-peer platforms for exchanging information, assets, and digitized goods without intermediaries” [11].

2.4. Immutable record
As the blockchain technology is a decentralised network, every participants or node across the blockchain entity share and own the same information or transaction record. This is somewhat different from the traditional network or centralised parties, which only the central server or trusted third authorities solely own the information. And when the central location is being hacked and hijacked, resulting in the lost of important information and monetary transaction record. Blockchain however maintains an immutable record of transactions on the ledger system, making it incapable of being falsified after the event [12] as the information are not kept in one place, but are encrypted and split across everyone in the network [3].

2.5. Time-stamping
The information or transaction record inside the necklace chain of Blockchain network are time-stamped. This shall provide historical and chronological fulfilment, especially in the blockchain technology 2.0, smart contract, which are currently wide developing across multiple sectors. Blockchain can be used to time-stamp anything and provide a digital or digitalized asset’s proof-of-existence at a given moment [11].
3. Potentials of Blockchain Application in Construction Industry
Blockchain technology is believed will change how the business, commerce and finance world functions along with the blockchain technology 2.0, the smart contract. As blockchain technology continuously improving and evolving, its potentials will be undeniably impactful to any sectors in the country, not to exclude construction industry. Below are the literature findings on the potentials of blockchain application in construction industry.

3.1. Contract Management
With the development of Blockchain Technology 2.0 - Smart Contract application, the blockchain can do more than ordinary monetary transaction. A smart contract can be applied across contract agreement between client and construction players. The smart contract can also be applied between client and his project consultants (designers, cost engineer or project management). Besides that, it can be applied between private client with general contractor for a simple project or client can engage a few work-package subcontractors for a large project. Furthermore, smart contract will allow more construction projects using labour basis, which the construction activities will be further split into smaller work packages at an individual level with an aligned Smart Contract, whereby the materials and goods can be purchased directly from the factory [13]. This might raise question whether the client still need the main contractor’s service in future as blockchain application encourage project client to direct subcontract. However, main contractor is not to worry as he is still needed for the scheduling, monitoring, safety and health, and supervision works on the construction activities.

Blockchain application brings automated law into the construction contract through deployment of algorithms and rules in a smart contract application. As the current construction contract often facing problem of non-payment or late-payment, it will be possible that blockchain technology can remedy the payment disputes through trust-in-machine concept in Smart Contract. As such, the nature of making legal contracts will likely change dramatically and litigation might take a back seat to prevention [20].

3.2. Electronic Document Management
Before the blockchain technology even born, Electronic document management (EDM) system already existed and are improved from time to time. The use of EDM system in construction projects are increasing due to the increased complex nature of construction projects and procurement, encouraging the consultants and contractor urged to pay a cost to third party for providing the central platform to organize electronic document for distributed work teams.

Blockchain can offer better and cheaper technology solution for current EDM system. Blockchain can provide a trustworthy infrastructure for information management during all building life-cycle stages [14]. With the implementation of the blockchain application, every document can be stored in a decentralised ledger, allowing perfect notarization of each creation, deletion, and updating across the system [15]. The record of important construction information including Drawings (i.e construction, as-built), Instructions (i.e. architect instruction and engineer instruction), Certificates (i.e. payment, extension of time, practical completion, making good defect), Variation order, and Construction work programme can be done in decentralised environment whereby these documents will need validation from the participants across the blockchain system. So every participant (client, project manager, consultants, contractor) are getting same and non-discrepancy information. This is particularly important so that no one get different information. In essence, Blockchain technology is a novel way to manage data and it competes with the data management systems we already have [16].

3.3. Building Information Modelling (BIM)
Building information modelling (BIM), using a centralised platform, often facing information being constantly added, revised, modified, and validated through the project stage and the stakeholders need to find a way so that no merging of wrong files (i.e drawings/model) happened. As such, Blockchain technology provide solution to remedy the limitation faced in BIM system by providing a
decentralised platform for BIM. The managing and recording modification to the BIM model throughout the design and construction phases can be done by using smart contracts to negotiate editing privileges and storing an immutable record of all modifications to the model [17]. In another words, Blockchain application is able to record information on who did what and when and thus provide a basis for any legal arguments that might occur. [14]

There are lots of benefits behind using blockchain application in BIM Model. “Blockchain has the potential to address some issues that discourage the industry to use BIM such as confidentiality, provenance tracking, disintermediation, non-repudiation, multiparty aggregation, traceability inter-organizational recordkeeping, change tracing, data ownership, etc” [14]. By combining blockchain decentralised properties in BIM Model, a vital, visible and permanent chain of “evidence of trust” can be provided and further lead to a new value proposition for the construction industry and the client [6].

3.4. Property management
Blockchain technology can be used to facilitate the ownership of property. Blockchain technology is able to manage and record the registry, purchase and transfer of the property in a more transparent and efficient way. When the asset is registered in the blockchain, the ownership can be controlled by whoever has the private key and the owner can sell the asset by transferring the private key to another party [10].

Here are some affirmation from the other researchers on the huge potentials of blockchain in property management:
1. “A blockchain is an enormously powerful shared global infrastructure that can move value around and represent the ownership of property.” [3]
2. “Blockchain encoded property becomes smart property that is transactable via smart contracts.” [10]
3. “It can be seen as an information and communications technology (ICT) to record the ownership of on-platform and off-platform assets and the rights and obligations arising from agreements.” [11]
4. “It is easy to perform title transfer for any properties including tangible and intangible whose ownerships are controlled by the blockchain.” [15]
5. “Blockchains can be used to trace physical assets which allowing a record of ownership to be maintained for each asset.” [18]

3.5. Supply chain management
Construction industry is a complex network of supplying materials, participants, services and products. This is basically referring to the supply chain management in the construction projects. Many studies have focus on improving the IT applications for supply chain management, which is currently using centralised platform to record, manage, trace and analyse the data. Blockchain-enabled application is believed can improve the current processes of supply chain management [15] by improving the transparency and traceability of products [18]. Input of accurate data is important in supply chain management which increase precise analysis and blockchain allow this to happen by requiring the participants to validate the information across the system. For instance, on construction site, the record of materials delivery and labours. Accurate data thus can provide important information to contractor to analysis and monitor their productivity, profitability, and performance in supply chain management. Therefore, there is a need for a decentralised system in managing supply chain data, which can help improve supply chain management performance without building a trust system between participants [15]. Ultimately, the blockchain application in supply chain management is hope to lower the cost of both contractor and client.

3.6. Funding Management
Most construction projects require huge funding from investors, especially iconic projects that usually become important landmark for a country. Blockchain based crowdfunding therefore offer a great
opportunity for project client to initiate a safe platform to raise fund for his project. The blockchain crowdfunding platforms is peer-to-peer fundraising which can supplant the need for traditional capital funding for initiating project [10]. This can be possible with the creation of own digital currencies and selling “cryptographic shares” to early backers [10]. The blockchain crowdfunding platforms also offer confidence of both investors and client as the use of funds are totally transparent with the blockchain application. The spending of the project budgets can be tracked by the subsequent outflow from the blockchain ledger. Furthermore, all the funding (outflow and inflow) transaction records are immutable due to decentralised feature of blockchain technology.

4. Implication of Blockchain Application to Construction Industry
Blockchain application in construction industry bring huge advantages to the construction industry by improving time and cost performance and increased quality of data (accurate design and work documents). Figure 1 shown the conceptual framework of potential and implication of blockchain application to construction industry.

4.1. Workflow and Time Efficiency
By implementing Blockchain application in construction industry by using smart contract in construction contract (i.e. subcontractor and supplier), it will improve construction productivity. The motivation behind the efficiency of the subcontractor or supplier will be due to that the trust on machine as the smart contract make automatous payment to the subcontractor and supplier when their job is done.

As for the blockchain application in BIM, it will mitigate delay caused by discrepancy of BIM models and conflicts between design consultants during the tender and construction stage. Blockchain application in BIM is suggested to be a private blockchain whereby only relevant project stakeholders such as architect, engineers, consultant quantity surveyor, project manager, and client representatives are allowed to access and validate “blocks” to the blockchain environment. During pre-contract stage, the design consultants will create and from time to time modify the BIM models in the blockchain platform for tender purpose. All participants (the project stakeholders) in the private blockchain are visible to the BIM models and have to validate the changes made prior the updated information to the drawings (so called “block”) is added to the “chain”. This means that all participants in the private blockchain are keep apprised of the new and updated information. These changes on the BIM models are also being time-stamped, whereby this shall ease the stakeholders to trace where and when are the drawings being amended. This shall ease the design process as all changes to BIM models are traceable due to the timestamping feature of the blockchain application and subsequently reduce the conflicts between design consultants caused by provision of wrong version of drawings. This shall also ease quantity surveyor during the preparation of cost plan, bills of quantities and tender addendums (if any) as changes are detectable and transparent. Furthermore, the decentralized structure (flatter organizations) and less centralized logic (less top-down) will decrease latency [2] in preparation of drawings.

During post-contract stage, the blockchain application in BIM allow the quantity surveyor to trace the changes to BIM models for preparation of variation order. This is due to blockchain technology will provide continuously growing necklace of information records, giving historical transaction transparency and chronological fulfilment [3]. As such, client is also apprised of the potential cost implication of the design changes during construction stage. Indirectly, the workflow and time efficiency is achieved with the blockchain application in BIM.

Nonetheless, there will be reduction of administrative load on reporting, governance, monitoring responsibilities and risk transfer [13] by using blockchain application and platform in project funding management, real estate management, supply chain management, and electronic document management.
4.2. Cost efficiency
In current construction industry, most project client make transactions using centralised intermediaries—the bank, financial institution or selling property using property agent or broker. In return, these intermediaries charge the client certain fees for providing facilities and services. However, with Blockchain application in construction industry, it provides opportunity for client to cut out the intermediaries and their associated transaction costs [19] [13]. This can be through the direct contract between project client with design consultants, suppliers and direct contractor with the use of Smart Contract. The use of the Smart Contract in construction contract also will help to reduce cost for administration contract documents [3]. Besides, it will also be possible that the client can sell their property using the blockchain platform eliminating the fee charges by property agents.

One of the issue in construction industry is payment disputes and are often costly settled in the court. By using blockchain application in construction contract, the cost of settling construction dispute can be saved as no issue of late payment or non-payment will occur with Smart Contract. In overall, the time and cost are saved with the blockchain application as all the processes are automated and neutral [15].

Furthermore, the blockchain application in BIM will produce more accurate and correct drawings, and thus allowing for Bills of Quantities to be created much more cheaply than without [13]. This will save the hassle of wrong quantities and drawings for tendering, and thus reduce the variation cost during construction.

4.3. Transparency and trust
Blockchain application in construction industry allowing each participants to see the chronology of monetary and non-monetary transactions (i.e. drawings, land or property transfer). As perceived by [3] “The blockchain is visible to everyone who is participating in a transaction, whether that be financial or a data exchange.” Furthermore, the decentralised feature of blockchain technology allowing the participants to have the same information across the application, and this information cannot be deleted. Both sender and receiver shall have more information than others [15]. Therefore, the traceable and immutable record in the system created transparency for the users. When the transparency is there, this encourage the participants to enter into the binding Smart Contract as a result of trust towards machine. Therefore, with the execution of blockchain application in construction business or activities, the participants does not need to have an established trust relationship as they trust the automated system itself [15].

4.4. Data Security
Current construction industry is practising storing the construction data in centralised database and platform. The main problem here is the security of the data. The important construction data are having risks of being hacked by any hacker who somehow has bad intention to claim monetary ransom in order for the owner to retrieve their data back which had happened in real life scenario. Therefore, the data security is somewhat that we should not ignore as large construction project is handling with huge funded project.

The uniqueness of blockchain technology lies with it ensures data security, where every piece of information in this database is chained to the rest through a digital signature or private key [8]. With the blockchain application in construction business and activities, the decentralised feature of the blockchain ensure all the participants to own same information across the system. The information stored in blockchain are very difficult to corrupt or extinguish as they are replicated across a peer-to-peer network [16] [2]. The validated and immutable record in the system also secure the construction data from being modified or deleted by any participants or hacker. Therefore, this shall create data security and safety to all participants.
4.5. International construction
Geographical issue somehow become the obstacles to encourage international construction in current construction industry. However, as the blockchain is a shared database across a global network of multiple site, geographies or institutions, this will encourage and improve the collaboration between the client, consultants and contractor firms from different countries, if it were adopted in construction industry. As such, the party (i.e client) does not need to have established trust relationship with another party (consultants or contractor or supplier) as the blockchain application provide transparent and trustworthy infrastructure system. The parties entered into the Smart Contract shall be bound with the provenance of rules and conditions, and subject to automated payment when the consultancy and construction services are done. Therefore, the blockchain application in construction industry shall broaden the geographical horizon, ease and increase the construction business and supply chain across different countries.

Figure 1. Conceptual Framework of Potential and Implication of Blockchain Application in Construction Industry

5. Conclusion
Blockchain technology has been applied in some sectors. For example, electric sector which use blockchain’s smart contract to trade electricity [20]. Besides that, research on the potentials of blockchain technology in higher learning, in which the blockchain technology is used to create global network to record education transcripts, student loans and anything that can be expressed in code are also on going [21]. Other than that, many current research also focus on blockchain application in food supply chain, medical records, land transfer, and bank sectors. Moreover, blockchain technology will benefit governmental administration (such as passport and identification) creating smarter cities and is believed to benefit more sectors and industries, including construction industry in the near future.

In conclusion, Blockchain technology is still relatively new to construction industry and are still under exploratory stage. However, the roles and potentials of blockchain application in construction industry should not be ignored. The potentials of blockchain application in construction industry has
been identified and are relate to contract management, Building Information Modelling (BIM) system, Electronic Document Management (EDM), property management, supply chain management and funding management. The unique features of the blockchain application (decentralised, autonomous, peer-to-peer, immutable record, and timestamping) also thereby increase the work productivity, save time and cost, ensure data security, cut off error in transfer and usage of information, and encourage international collaboration in construction industry. Despite the above, there are still many steps that need to be taken before we can claim the Blockchain is a vital part of the building process [8].

One of the main challenge of blockchain application in construction industry is the government approach in regulating the blockchain technology in the countries itself, i.e regulating of the initial coin offering (ICO) which are mainly used for project funding purpose. Some countries are actually banning the use of blockchain technology in their country considering the drawback from blockchain activities (such as criminal activities and uncontrolled currency and financial outflow); while some countries have applied and developing more of the potentials of blockchain technology in their countries. Nevertheless, another challenge in blockchain application in construction industry is the slow adoption of technology in construction industry as compared to other sectors.

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