

The Potentials Of Using Smart Contracts In The Construction Industry

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Abstract: This research aims to evaluate the potentials of using the Smart Contracts in construction through the experience of the professionals in the industry. An extensive literature review was developed to understand the research and the novel technologies linked to it. A questionnaire was developed to assess the different views of the professionals of how and when to use such technology in the construction field. The results were analyzed by different methods as the answered were studied totally and then the respondents were divided into several categories. The answers were leaning towards using the Smart Contracts in the future after more extensive research. The Comparative analysis lead to that the different disciplines of the companies does not make a difference in the responses as the major factor was the years of experience. This research reviews papers as well as the opinions of the professionals in the field to assess the Smart Contracts usage.

Index Terms : BIM, Blockchain Technology, Construction Management, Construction Contracts, Cryptocurrencies, Smart Contracts, Supply Chain Management

1.INTRODUCTION

The Construction industry is one of the most significant industries in the world. The amount produced by the global construction industry was worth an assessed \$10.8 trillion in 2017, and in 2018 was predicted to rise to \$12.9 trillion by 2022. As an industry, construction accounts for more than 10% of global GDP, and employs around 7% of the total employed workforce around the globe. [1] In the United States in February 2020, around \$1.4 trillion worth of construction work was in progress, according to the Census Bureau, of which just over \$1.0 trillion was for the private sector (split roughly 55:45% between residential and nonresidential); the remainder was public sector, predominantly for state and local government.[2] Doubts in payments causing cash flow problems have been stated as a reason of business catastrophes and growing disputes. Some construction activities generate value for one or more of the construction delivery schemes for the customers. Some do not. Some of those that do not; are presently essential to allow the delivery of the value that customers need. Construction is a cooperative process. Collaboration around any economic activity necessitates trust. Most people do not trust thoughtlessly, they need verification and guarantee that the other party is earnest of their trust. Intermediaries take time to undergo the process and they charge a fee for the deal. Typically, intermediaries gather information about you in order to secure the deal; they need to influence the other party. All of these activities take a while; energy and money however, produce no value for customers, nevertheless, they may now be crucial for value to be produced. What if it as no longer essential to use some or all these intermediaries? One plan is by using Blockchain and Smart Contracts.

“Blockchain is a distributed database (ledger) that maintains a list of records (of transactions, information, Internet Protocol (IP), etc.). These records are called blocks. Every block contains a timestamp, which links it to the previous block and has the history of every transaction that came before it which chains the blocks together. The

system is end-to-end encrypted as a whole. Every transaction is linked to a hash function, which is a unique cryptographic signature, which is easily verified and almost impossible to falsify as a large network of personal computers, every computer act as a node host the Blockchain, in the system and every node monitors the other node on a continuous basis. The system can become global as it grows with each transaction.” [12] Blockchain areas of coverage in the construction industry allows each participants to see chronological order of monetary and non-monetary transactions (i.e. drawings). As perceived by “The Blockchain is visible to everyone who is participating in a transaction, whether that be financial or a data exchange.” [26]

A number of different industries such as health care, information sharing, information management, insurance, automated dispute resolution, real estate, crowdfunding, big data analytics, and education is testing the Blockchain. Researches shows that on a typical project with subcontractors, savings in the range of 1% - 2.5% could accumulate from using a web payments platform. These savings could rise over time if the supply chain were to be used with Blockchain technology were able to decrease overheads linking to debt chasing and management. Moreover, greater productivity and a decrease in construction disputes, as well as supply chain failures, although challenging to quantify, are likely to be considerable. The following is a list of direct benefits

- Relative small costs to process, as mentioned before smart contracts are self-executable. Once payments are made, there are no admin costs to redistribute the funds down the supply chain.
- Compliance with the current legislation , it is statutory obligation for a head contractor to pay their subcontractors and suppliers on time. A web payments platform would leave an audit trail and promote transparency.
- Effective mitigation of risks associated to payment delay and associated costs - a web payments platform would protect head contractors, subcontractors, and suppliers from withheld or late payments; but most importantly
- Reduction of the risk of supply chain failure, as payments would carry instructions to follow through between contracts,

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safeguarding subcontractors and suppliers from the insolvency of the head contractor. [9]

Nick Szabo defined Smart Contracts as “A computerized transaction protocol that executes the terms of a contract, coined the term “smart contract” in 1994. “The general objectives of smart contract design are to satisfy common contractual conditions (such as payment terms, liens, confidentiality, and even enforcement), minimize exceptions both malicious and accidental” (Szabo 1994). The Blockchain technology is the basis of the Smart Contracts. With the development of Blockchain Technology 2.0 - Smart Contract application, the Blockchain can do additional than normal financial transaction. A smart contract can be valuable across contract agreement between client and construction companies. The Blockchain and smart contracts together could deliver a dependable payment environment by taking benefit of their features. In the construction industry, there are frequent contracts between parties. The drafted contracts can arise in various forms such as between employer and contractor, contractor and subcontractors, contractors and suppliers, etc. Henceforth, this industry is a heavily contractual oriented industry that is in high need of smart contract technology to face the contractual disputes and payment problems in the business. Traditional contracts, which likewise acknowledged as paper contract resulted in negotiation between parties, drafting phases, the contribution of lawyers, etc. that are established to presents parties responsibilities that are needed to deliver a certain work (Naughter, 2018). Smart Contracts are caused by coding the traditional contract in a computer setting that alike traditional contracts regulate the responsibilities of the parties. However, benefits of smart contracts make it better than the traditional paper contracts in terms of contract payment clauses application. As smart contracts are an electronic and code-based system, the necessity for physical existence is eliminated for drafting the clauses concerning payments and virtual occurrence of parties is appropriate. In addition, a digital signature replaces the wet signature to confirm and sign the contract clauses. The overhead costs and transaction cost are expressively

- Conclude how to make the Smart Contracts more effective and suitable

2. LITERATURE REVIEW

2.1 Blockchain Technology

Dakhli (2019) defined the Blockchain Technology as “Blockchain is a distributed database (ledger) that maintains a list of records (of transactions, information, Internet Protocol (IP), etc.). These records are called blocks. Every block contains a timestamp, which links it to the previous block and has the history of every transaction that came before it (down to the second it was created.) which chains the blocks together. The system is end-to-end encrypted as a whole. Every transaction is linked to a hash function, which is a unique cryptographic signature, which is easily verified and almost impossible to falsify as a large network of personal computers, every computer act as a node host the Blockchain, in the system and every node monitors the other node on a continuous basis. The system can become global as it grows with each transaction. The desktop or a laptop could be a node in the system; it is like a google document but with major differences:

- You can see it;

decreased because in smart contract system there is no need of intermediary participation. In addition, the notary and administration cost concerning the process of chasing payment are reduced. Payment disputes in the construction industry could be expressively reduced by acquiring the benefits of the smart contract. It is a compulsory system by which cost and time are saved in schematizing certain aspects of construction project performance. Cost and times overruns are usually experienced in the payment procedure of the procurement phase of the project. Additionally, late progress payment is likewise an additional payment problem challenged by parties throughout the project. The idea of this research was to measure the potentials of using such technologies in the construction and industry as well as to measure the trust of the professionals who work in this field to view their willingness to use the technologies in their work. So a questionnaire was designed to find these results and the findings were that the usage of the Smart Contracts is possible but currently will be somehow difficult due to certain limitations such as the control of banks, limited knowledge of the effect of Smart Contracts, the irreversible behavior and the need to build the trust in such technology. With hope in the future, that these problems would be tackled and will gain more trust and generate benefits to the industry in the future. This research aims to investigate the viability of using the Smart Contracts in the construction industry as of its novelty it needs to be deeply investigated and tested within the professionals of the construction contracts. As well as investigating, its potential if integrated with other technologies such as BIM and to reach all of the pros and cons of using such technologies in the industry. Here are some points to better visualize the aims:

- Investigate the viability of using Smart Contracts in the construction industry
- Visualize all the advantages and cons of using the Smart Contracts
- Reach the most suitable environment of a project to be used with the Smart Contracts

- You can add information to it, but
- You cannot edit the information that is already there.” [12].

Every node reviews its block with each block in the chain. If it finds a discrepancy, it tries to find consensus as well as if necessary, alters itself with the consensus. This means that to alter the record it is a must to change >50% simultaneously of the nodes in the system, this is not impossible; however it is extremely difficult and becomes more difficult as the length of this chain increases. Blockchain is composed of these five elements:

- Cryptography: the use of different cryptographic techniques, which includes cryptographic one-way hash functions, Merkle trees, and public key infrastructure (private-public key pairs).
- Peer to peer network: A network for peer discovery and data sharing in a peer-to-peer fashion.

- Consensus mechanism: An algorithm which implicates the order of transactions in an environment assuming that not every participant is honest
- Ledger: A list of transactions chained together in blocks which are cryptographically linked
- Validity rules: A common set of rules of the network (i.e., what transactions are considered valid, how the ledger gets updated, etc.) [12].

Safa (2019) described the Blockchain technology as the serving foundation for cryptocurrency Bitcoin. This kind of technology has an enormous effect on a lot of different industries such as banking, construction, infrastructure, healthcare, energy, and law enforcement. "Blockchain technology uses a decentralized peer to peer network to validate transactions and then, once verified, it updates each block with the information from that transaction." This updated block has the hash of the predecessor block so as the viewer can return back and see the edits that have been made. This technique is known as the provenance and has the same working technique of lineage tree as the original block can act as the parent with the successor changes can be considered as the offspring of the parent block. Each block can then be traced back to its original block (the parent) with the whole record of the modifications. There are three different categories of Blockchains for the involved companies to choose from which are: private, public and consortium [35]. In a public blockchain, every user, which can connect to the internet, can become a node in the system. There is a great deal of transparency in a public Blockchain and all the information is available for the public. However, this can expand the chain, and with a

2.2 Smart Contracts

"Smart contracts allow for a set of instructions to be incorporated into a contract, and although smart contracts can probably be forgotten too, payments will be denied unless the contract agreed conditions are satisfied. In that sense, clauses in smart contracts are self-executing, self-enforcing, or both." The idea, by using a smart contract, the digital currencies must be embedded into the contract together with a number of conditions that must be fulfilled for the contractor to be paid. The payment is already embedded in the contract. The contractor needs to deliver their scope of Works to receive the payment. [9]. Moreover, the benefits of Smart Contracts to the construction industry do not end here. Smart contracts can also be chained together. This means that a payment to the contractor could have instructions for a part of such payment to follow through to another contract. That it is to say, contracts connected to the same project, but between different parties, could be linked together to create a web of payments. Payments can be self-executable and self-enforceable, only depending on the execution of the works as per the contract Conditions. [9]. Using smart contracts in the construction industry would have the same effect as the creation of a Construction Trust. "Overall, smart contracts can: (1) guarantee that the required funds to carry out the construction works would be available to finance the project; (2) protect head contractors, subcontractors, and suppliers from withheld or late payments; and (3) safeguard the various parties involved in the project from the insolvency of one party." [9]. Nick Szabo, a cryptographer

huge possibility of slowing down the speed of transactions because of the huge amount of computational capability needed to maintain such a chain. In these conditions, the involved organizations may not prefer private or sensitive information to be public; hence, private and consortium Blockchains could resolve this issue. In private Blockchains, a single company has full control over who can have access to the information in the system. That company will issue and approve all transactions to be uploaded in all blocks. Participants are highly controlled as only those allowed by the controlling company and can have access to the ledger of shared information. This information is accessed through the invitation of the controlling company or verification through a common set of rules. [35].

"The true middle ground between public and private Blockchains is a consortium chain in which there is neither an unlimited amount of nodes nor a single entity with full control." A set of pre-verified nodes control consortium Blockchains, which means that the involved companies can each have a contribution in writing, approving, updating, and adding new blocks of information to the system. In addition, these Blockchains still have the security of a public blockchain and decentralizing while at the same time allowing the companies privacy for their sensitive documents. Blockchain technology has the possibility to enhance most industries, involving construction. Construction industry collaborates between builders, construction experts, vendors, sub-contractors, and several other teams with different expertise. This industry has often been recognized as an industry that needs to enhance its efficiency. [35].

who defined it as "A computerized transaction protocol that executes the terms of a contract, coined the term "smart contract" in 1994. "The general objectives of smart contract design are to satisfy common contractual conditions (such as payment terms, liens, confidentiality, and even enforcement), minimize exceptions both malicious and accidental" (Szabo 1994). The effect of such contracts on contract law and economics and their opportunities were said by their originator to be, "vast but little explored." The key characteristics of smart contracts have been described as being (Norton Rose Fulbright 2016): "it is in digital form and is embedded as code in hardware and software." The execution of the contract and the release of payments and all other actions are enforced by technology and rules-based operations. At the end, the smart contract is irrevocable, as, once initiated, the outcomes for which a smart contract is encoded to perform cannot typically be altered. Execution is automatic. The term intelligent contract is preferred in Mason's paper. As Smart contracts in the United Kingdom stands for a process where a contract is made with the help of a computer program to select suitable terms. Intelligent contracts is the term used where the contract seeks to execute themselves. Szabo drew an analogy with a vending machine where the payment has to be received before the fizzy drink is dispensed. This "money first, goods second" approach can be ignored if the technology allows for the, real time exchanging of goods/services for money. The use of big data and sensors allows payment to be made instantaneously through

cryptocurrency. The first known cryptocurrencies developed in the late 1980s (Griffith 2014). However, the crucial development happened in 2008 when Satoshi Nakamoto published the white paper "Bitcoin: A Peer-to-Peer Electronic Cash System". [28]. Intelligent contracts will release payments and are a probability to protect parties from insolvencies and late payments. An intelligent contract could be composed of not one but thousands of mini contracts, all self-executable and transferring data as they complete, and releasing payment once installed and the relevant online documentation such as performance fulfillment and continuous monitoring have taken place. The adoption of intelligent contracts poses many challenges (Norton Rose Fulbright 2016). A software program can in theory exist for many years. Nevertheless, it is hard to produce a code intended for a long duration where external information sources may not exist. The irreversible behavior

2.3 Cryptocurrencies

"a medium of exchange using cryptography to secure the transactions and to control the creation of new units". Cryptocurrencies are frequently equated to digital currencies; an internet centered medium of exchange. When the contract is signed, the head contractor breaks up the scope of works in trades and signs numerous sub-contracts to execute the works. But what if the principal could embed the contract sum in a construction contract? We believe this would give a sense of safety to all the parties tangled in the project and protection against bankruptcy. [9]. Distributed ledger technology operates alongside cryptocurrency and allows the intelligent contract to operate without the use of traditional payment arrangements and the interface of third Parties such as banks. Blockchain has been described as the fourth industrial revolution (Kemp 2016). A Blockchain is a ledger, or a database of transactions recorded by a network of computers (Peters and Panayi 2015). Often referred to as distributed ledger technology, transactions are grouped in blocks, and the chain forms the history of these transactions. It is widely believed to have been created as a way to distribute cryptocurrency in a way that maintains publicly, and by multiple people a record of the transaction. The cross verification of the process by multiple reference points prevents abuse and builds the participants' confidence in the system. The use of the Blockchain has moved on from simply being the platform for cryptocurrency, to ideas of cheaper transaction processing, crowd funding and smart contracts. Blockchain "holds promise for being the latest disruptive technology".[28].

2.4 BIM

"Blockchain technology allows for instantaneous updates to each user of a BIM by applying Peer-to-peer networks for information sharing. This platform provides superior transparency and superior standards of work being performed constantly. The Blockchain is not seen as a new technology to replace BIM, but as a way to improve on current BIM practices. Presently, the most notable issues using BIM being are:

Establishing who has ownership of documents

Copyright protection

Responsibility for modifications; and

of the arrangement also has problems in the aspect of satisfying both parties that the coding is operating as they intended. Confidentiality and the open behavior of distributed ledger technology impose additional challenges, as does the pseudonymous nature of these procedures. Storage restraints, dependability, and compatibility issues also necessitate workable solutions before wide-scale acceptance of the technology is possible. A semi-automated approach is desirable given the significance of the issues underlined. Contracts usually require judgment and the use of choice, which requires restraint and richness in the language that is extremely different to code. The benefits of intelligent contracts are diluted by this dependency on one or other of the parties. However, value can still be added by the automation of certain processes. [28]

Responsibility for errors."[35].

"The processes of planning and design are today almost entirely digitalized with information being shared and exchanged in a digital format." In current years, an accumulative share of all information is achieved by building information modeling (BIM) technology. BIM is altering the whole AEC industry and unsettling the building processes. What used to be a problem of modeling of buildings is now implicit as a problem of managing building information. It is vital to note that building information management is the administration of legally significant information that can be used in case of disputes and legal process among the frequent and fine-grained contributors to the method. Several authors have recognized these legal issues as obstacles to BIM technology adoption. [41]. There are also other legal and administrative fears such as who possesses the datasets, who pays for the datasets, who is accountable for the accuracy and correctness. They present a challenge for BIM application and identify legal barriers and model possession management as barriers of BIM acceptance by owners and facility managers. [41]. The most prominent variance between the old document-based and recent BIM-based construction process is that in the traditional process information related with legal consequences were normally focused in a bundle of signed, stamped and firmly bound pieces of paper. In that way, copyright over each part of the combined information in physical binder together with resulting responsibilities was barely an issue. On the other hand, information in BIM process is spread among one or more BIM models, model views and experts where a small trait of an insignificant building block can be an entity with its unique history, dependencies, attribution, proprietor and accordingly legal significance [41]. Some are using it to stock sensor data from buildings in a reliable and distributed way. There were also theories that Ethereum could host BIM applications. The usage of Blockchain in co-housing projects has also been recommended as it could "provide a useful tool for managing and recording changes to the BIM model throughout the design and construction phases by using smart contracts to negotiate editing privileges and storing an immutable public record of all modifications to the model"[41]. We can safely adopt that if a Smart Contract could read a BIM file design, then changes could possibly

be recognized and understood by a Smart Contract. However, are BIM files readable by Smart Contracts? Probably not since the BIM file is copyrighted by the software that produced it. Nevertheless, due to software wars, the BIM space still does not have one software package that serves all consultants working in the construction industry. Some software developers like Autodesk might have the lead, but they have not dominated the market yet. In order for BIM files to be transferrable among different software packages an XML protocol has to be written. In computing, Extensible Markup Language (XML) is a markup language that defines a set of rules for encrypting documents in a format that is both human-readable and Machine-readable. Essentially XML allows a BIM file to be exported in a format that can be read by another software package. "A quick Google query about "XML and BIM" will produce the following results; BIM XML, gbBIM and smart BUILD, which essentially are all XML protocols that have been written to transfer data from one BIM software to another. Smart Contracts that can retrieve information from an XML file are reality. Building information contained in a BIM file, or even information published by the Bureau of Meteorology can be generated and transported using XML. We should expect a great deal of constructal integration and communication going forward. As a result the following is a list of the foreseeable benefits that Smart Contracts could deliver to the construction industry as trustworthy data feeds are established." (Cardeira, 2017)

3. Methodology

After carefully examining the literature review, we could find that we have five areas of interest to this thesis, which are:

1. Construction and payment insolvency
2. Blockchain technology
3. Smart Contracts
4. Cryptocurrencies
5. BIM and Smart Contracts

The construction and payment insolvency area discusses the issues facing the construction industry in general and the contractors in particular regarding the insolvency in payment and how the presence of a third party affects the whole project regarding payments and time schedule and on the other hand adding no value to the project. The second area defines the blockchain technology and its characteristics, then it discusses its advantages for the construction industry and how can future projects benefit from this innovative technology. The third area defines the core of this thesis which is the smart contracts and its characteristics and how it can be beneficial to this industry which lacks the dynamic feature regarding accepting new technologies, it also discusses its advantages and disadvantages and its potential to the construction industry and the platform that can operate the Smart Contracts. The fourth area discusses the cryptocurrencies, as it is the tool that can operate the Smart Contracts, as the blockchain technology is the foundation for the cryptocurrencies, integrating the three technologies together (blockchain, Smart Contracts and cryptocurrencies) would produce the optimum tool to help the construction industry (hypothetically) become more efficient. The fifth and last area discusses the potential of integrating the Smart Contracts technology with the BIM, as the latter is the

current breakthrough in the construction industry and probably all of the projects in the near future will embrace the BIM, so as a potential it could be beneficial if the two promising technologies collaborated. This can indicate that the topic is still new and has minimum application until now in the field of construction and is only based on researches. Therefore, there is a deeply need to embrace a methodology to understand the construction company's familiarity with the Smart Contracts and the blockchain technology. Moreover, the research will look over about the experts' opinion about the use of smart contract in the construction field. The methodology to be adopted is a professional questionnaire directed to construction companies in Egypt as well as companies outside Egypt to better understand their familiarity with the technology and how they see its potential to the construction industry. Here is a flow chart to show the chronological order of this thesis. The questionnaire was directed to the professionals who work in the contracts engineering department through online platforms as well as direct contact with the companies. In addition, interviews were held with the professionals to discuss and clarify the idea of the research. The results will be analyzed in a qualitative and quantitative manner as the results will be divided into several sections to better understand the views of the engineers working in different disciplines and to compare the categories with each other. The results will also be validated statistically to ensure the legitimacy of the answers. A pilot survey was conducted to have a trial on the questionnaire and to identify the points that need modification to distribute the most appropriate version of the questionnaire for it to have the best effect and let the users provide the best answers

Questionnaire

4. Data Collection

Regarding what was mentioned in the methodology, the data was collected through several ways. The main way of collecting the data was through the questionnaire that was developed to assess the opinion of the contracts engineer in using the Smart Contracts. Another way for collecting the data was through interviews with professionals from different companies to clarify the purpose of the questionnaire as well as clarifying some of the questions that some users found it difficult to understand. The outcome of this collection methods were around 150 response, which was then downsized to 120 after excluding the non-relative responses and the deviated responses. The final outcome of users was sufficient based on (Mason & Escott, 2019). The users were divided into several categories to better assess the users' mentality based on their years of experience as well as the type of firm that they work for (Contractor, owner, Consultant). The outcome was:

- 40 responses with less than two years of experience
- 39 responses between two and five years of experience
- 27 responses between five and ten years of experience
- 14 responses with more than ten years of experience

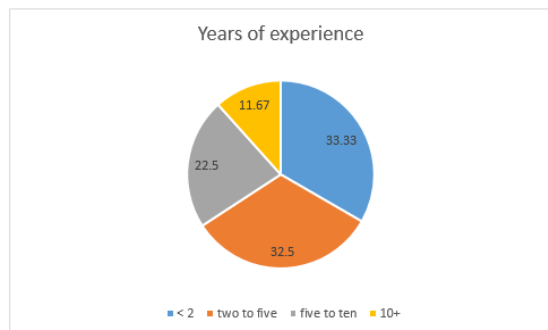


Figure 1 years of experience

The other apportionment was:

- 76 working for contracting firms
- 24 working for consulting firms
- 20 working for Developing firms

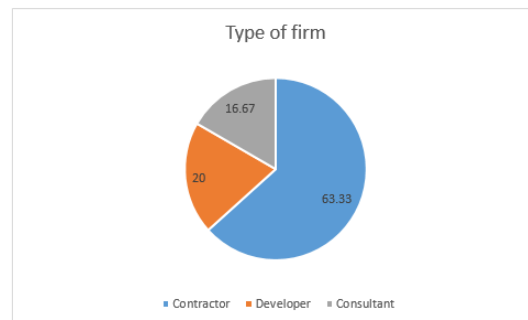


Figure 2 Type of firm

5. Analysis and Results

5.1 List of questions

Question	Point of question	category
1	Familiarity with Blockchain technology	Blockchain Technology
2	Applicability of using Blockchain technology	Blockchain Technology
3	Security of Blockchain technology	Blockchain Technology
4	Need of third party	Blockchain Technology
5	Best type of Blockchain	Blockchain Technology
6	Blockchain 1.0 or 2.0	Blockchain Technology
7	Appropriate type of transactions	Blockchain Technology
8	The process of construction using Blockchain	Blockchain Technology
9	Familiarity with Smart Contracts	Smart Contracts
10	Protection of Smart Contracts	Smart Contracts
11	Automation of Smart Contracts	Smart Contracts
12	Scale of projects	Smart Contracts
13	Type of projects	Smart Contracts
14	Embedding the amount in the Contract	Smart Contracts
15	The irreversible nature of Smart Contracts	Smart Contracts
16	Payment method	Smart Contracts
17	The most suitable organization	Smart Contracts
18	Arbitration of Smart Contracts	Smart Contracts
19	Claims of Smart Contracts	Smart Contracts
20	Breaking down of Smart Contracts	Smart Contracts
21	Disputes Resolution	Smart Contracts
22	The real estate business using Smart Contracts	Smart Contracts
23	The concept of using Smart Contracts	Smart Contracts
24	Smart Contracts or third party	Smart Contracts
25	Familiarity with Crypto Currencies	Crypto Currencies
26	Safety of Crypto Currencies	Crypto Currencies
27	Fluctuation of Crypto Currencies	Crypto Currencies
28	Protection against bankruptcy	Crypto Currencies
29	Improvement of BIM security	BIM
30	Readable BIM files by Smart Contracts	BIM
31	Collaboration of BIM and Blockchain	BIM

32	Collaboration of BIM and Smart Contracts	BIM
33	Usage of Smart Contracts in the current time	Conclusion
34	Usage of Smart Contracts in the future	Conclusion

5.2 Total Analysis

5.2.1 Blockchain Technology

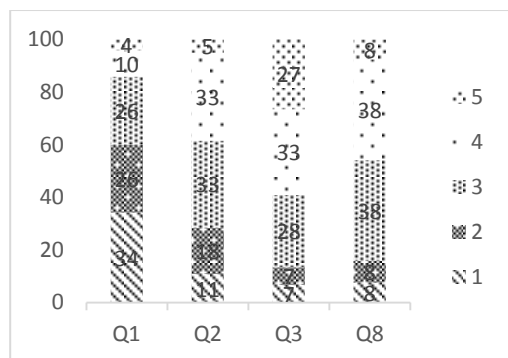


Figure 3 Blockchain questions

In figure 3 we can find that this category of question was intended to measure the opinion of the professionals in using the Blockchain technology in the construction industry. As listed above, the first question was to measure the familiarity of the users regarding the Blockchain technology, which indicated that 60% of the users had minimum knowledge of such technology due to its novelty and limited usage in our industry. The second question was to measure the applicability of using the Blockchain technology in the construction industry, which indicated that the majority of the respondents found that it would be applicable to use technology in our industry. The third question was to measure if the level of security that the Blockchain technology provides is essential to the construction industry, and it was found that most of the users found that the security provided is essential. The eighth question was to measure whether the usage of Blockchain technology will make the whole process of construction trustworthy or not, what was found is that the answers are leaning towards that using such technology will enhance the trustiness of the process.

5.2.2 Smart Contracts

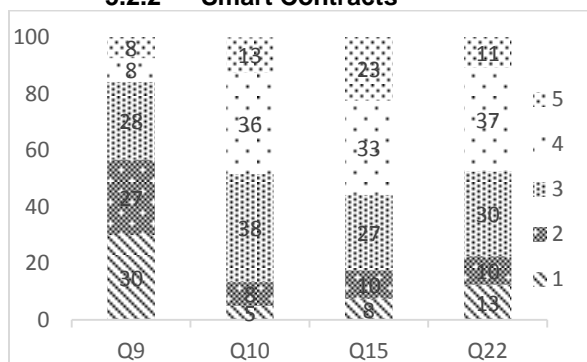


Figure 4 Smart Contracts questions

In figure 4 we can find that this category of questions was intended to measure the opinion of the professionals regarding the Smart Contracts. Question 9 was to measure

the familiarity of the respondents with the Smart Contracts, which was found that similar to the previous category that most of the users did not know about the Smart Contracts. Question 10 was to measure if the Smart Contracts was to protect the parties involved in the contracts, and around 50% of the users found that the Smart Contracts would protect the parties. Question 15 was to assess the opinion of the users if they find that the irreversible behavior of the Smart Contracts is considered an issue and also the majority found that it is an issue and one of the cons of using Smart Contracts.

5.2.3 Cryptocurrencies

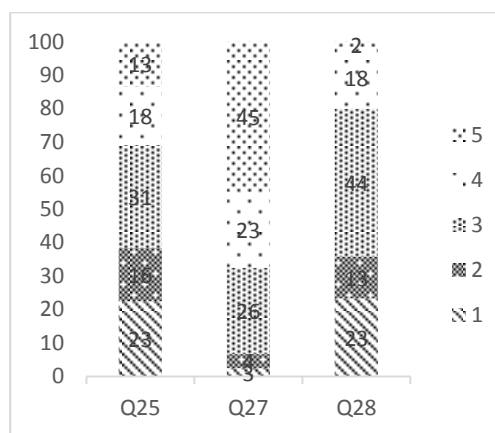


Figure 5 Cryptocurrencies questions

In figure 5 we can find that this category of questions was to measure the opinion of the professionals regarding the Crypto Currencies. Question 25 was to measure the familiarity of the respondents regarding the Crypto Currencies, what was found is that there is a better percentage of users to have good knowledge of such technology due to its spread in the world and in different aspects. Question 27 was to assess the opinion of the respondents regarding the fluctuation of the Crypto Currencies and whether they see it as a problem. What was found is that most of the users found it as a major problem and a huge point of defect in the proposed system. Question 28 was to assess the opinion of the users if they regard the Crypto Currencies as a protection against bankruptcy and the majority of the users were neutral regarding this point and had no assurance towards a strict opinion.

5.2.4 BIM

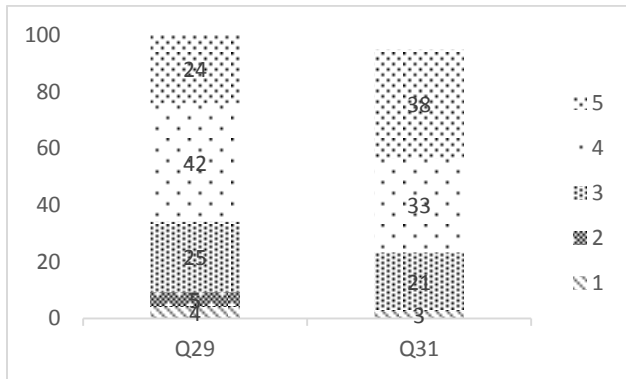


Figure 6 BIM questions

In figure 7 we can find that this category was to measure the opinion of the users regarding collaborating BIM and Smart Contracts. Question 29 was to measure if the Smart Contracts would improve the security of BIM, what was found is that the majority of users found that it would defiantly enhance the security of BIM. Question 31 was to assess if the collaboration between Blockchain and BIM would benefit all of the stakeholders of the project, and what was found is that more than 70% found that it would be huge benefit for all of the stakeholders due to the transparency of both technologies.

5.2.5 Yes & no Questions

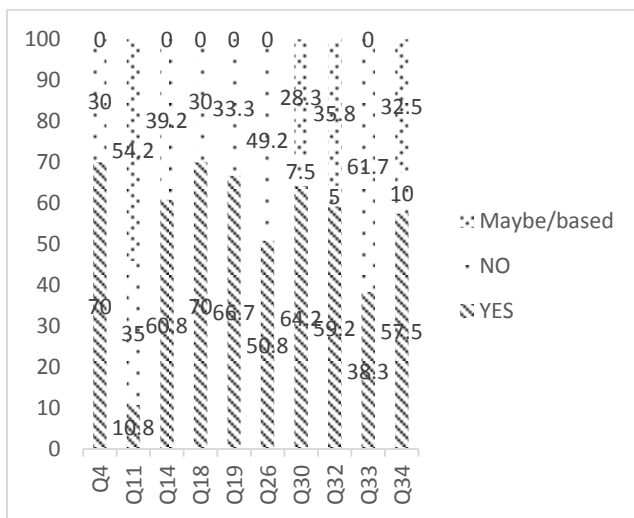


Figure 7 yes&no questions

In figure 8 we can find that These questions are of the same type, as they are answered with yes, no and (maybe in the future/ based on the nature of the project. Question 4 addresses the need to eliminate the third party, which was found with acceptance of 70% of the respondents. Question 11 was to assess the opinion of the users if the Smart Contracts could be fully automated or not, and more than 54% of the users found that this might happen in the future while more than third of the users found that this would never happen. Question 14 addresses if embedding the whole amount of the contract into the Smart Contract itself would be beneficial and more than 60% of the users found that it would be useful. Question 18 measures the possibility

of arbitrating such contracts and 70% of the users found that it could be arbitrated. Question 19 measures if a claim mechanism could be applied in the Smart Contracts and two thirds found that would be possible. Question 26 was to find the opinion of the users regarding if the Crypto Currencies are considered as a safe medium of exchange and the answered were split between the two opinions with a slight leaning towards it being safe. Question 30 was to see if it would be beneficial if the BIM files could be readable by the Smart Contracts and the majority accepted this concept and around 28% of the users found that it would be beneficial based on the nature of the project. Question 32 assess if it is better to incorporate BIM and Smart Contracts and the majority ofound that it would be better and around 36% found that it would be beneficial based on the nature of the project. Question 33 asks the users if it would be applicable to use the Smart Contracts in the current time, which almost 62% of the users found that it is not applicable to use it in the current time. Question 34 asks them same question but in the future which 57.5% of the users found that it would be applicable in the future with around 32.5% found that maybe in the future this could be applicable while 10% were certain that they will never be used.

The other questions of the questionnaire were of special nature as each question measures specific points.

- Question 5 measures if it is preferable to use private, public or consortium Blockchain and what was found is that more than 64% of the users found that the consortium Blockchain is the most suitable
- Question 6 assess if the users find it best to use Blockchain for transactions only or to use with Smart Contracts, and more than 39% found that using both would be beneficial as well as 30% to use it with Smart Contracts
- Question 7 measures if the Blockchain to be used as monetary transactions only or with documents as well, and what was found is that the majority found that using it for both would be beneficial.
- Question 12 assess the most suitable scale of a project and what was found is that ore than 61% found that the short projects are the most suitable type of projects to be used in
- Question 13 assess the most suitable nature of a projhct to use the technologies with and what was found is that the procurement projects are the most suitable nature of a project for the technologies
- Question 16 is to measure which payment method is better (web payment platform or embedding the whole amount) and what was found is that most of the users found that the nature of the project will decide which is better
- Question 17 assess which organization is most suitable for using the Smart Contracts, and what was found that the majority of users chose the private sector
- Question 20 measures the benefit of breaking down the Smart Contract into smaller contracts and what was found is that ore than 61% of the users

thought of using this techniques as milestone checks

- Question 21 measures if the Smart Contracts would reduce the disputes between the parties and around 59% of the users found that it would.
- Question 23 measures if we should use the Smart Contracts with the concept of code is contract or just a payment method, and what was found is that the users found that the nature of the project will decide which will be used
- Question 24 assess which is better to use Smart Contracts only or to use the traditional way of banking or both and the majority of the users found that the nature of the project will decide wile around 23% thought of using the Smart Contracts only.

6. Discussion

Some of the main points of the findings:

- What the users also found was that the most suitable project to use a Smart Contract in is a procurement project.
- the most suitable type of firm is the private firms rather than public or PPP.
- The consortium Blockchain was also chosen as the best way to have a network of blocks.
- Integrating Smart Contracts and BIM is going to be beneficial and will facilitate the whole process of construction.

What was found also as a major impacting factor was the years of experience of the users as the more the years of experience, the more the trust in embracing these technologies in the current time and in the future. While the type of firm did not have a major impacting value of the results as most of the users were contracts engineers so the mind-set is almost the same.

The advantages that was noticed for the Smart Contracts is:

- Eliminating the third party trust
- Encrypted transaction with a control of whom is allowed to participate
- Reducing the transaction cost and time
- Having a contract that is self-executable
- A step towards digitizing the construction industry

7. Conclusion

After examining the findings and the results, we can conclude that the Blockchain technology and the Smart Contracts are novel technologies that need an extensive research and development for a better assessment in the future. The Engineers who were asked to reveal their opinion about the potentials of using such technologies in the construction industry provided insightful reviews. The results were shifting towards using the technologies in the current time is not preferable as there are many challenges facing the technologies currently such as:

- The fluctuation of Crypto currencies.
- The irreversible behavior of the Smart Contract.
- The need to have a bank to execute the

transaction

- The need to develop the trust in using such technologies

So using the technologies in the future was seen as a possibility as if such challenges were eliminated because of the advantages that was found in using such technologies. Smart Contracts have a high potential in the future to be used in the construction industry by eliminating the challenges that are facing such technologies and by developing the trust in using it and it would be considered as a breakthrough for the whole contracting process.

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