Towards Adoption of Smart Contract in Construction Industry in Malaysia

Dewi Noorain Bolhassan[1], Chai Changsaar[1], Ali Raza Khoso[2,3]*, Loo Siawchuing[4], Jibril Adewale Bamgbade[1] and Wong Ngie Hing[1]

[1]Faculty of Engineering, Computing and Science, Swinburne University of Technology Sarawak Campus, 93350 Sarawak, Malaysia
[2]School of Civil Engineering, Faculty of Engineering, Universiti Teknologi Malaysia, Skudai, 81310 Johor Bharu, Malaysia
[3]Department of Civil Engineering, Mehran University of Engineering & Technology, 76062 Jamshoro, Pakistan
[4]Centre of Building, Construction and Tropical Architecture, Faculty of Built Environment, University of Malaya, 50603 Kuala Lumpur, Malaysia

ABSTRACT

The revolution of Malaysian Construction 4.0 through emerging technologies has brought a paradigm shift that has digitalized the construction sector. There is a need to adopt a computerized protocol to assist in automating the performance of a contract to meet future digital challenges. Therefore, this paper aims to serve as a pioneer study to investigate the implementation of the Malaysian construction industry to adopt smart contracts. This study adopted a qualitative scientific methodology, whereby a systematic review was conducted to gather the benefits and challenges of implementing smart contracts in the construction industry. Further, interview sessions were arranged to collect data from the construction contract management experts. The research findings unveil that due to the self-executing attribute of smart contracts, the implementation of smart contracts could provide a better apportionment of risks in a contract. The study also finds that the challenges in implementing smart contracts are severe. For instance, the smart contract is irreversible and immutable and prone to human error. The study concludes that it is more suitable to apply and implement a smart contract to a short-term contract that

Dewi Noorain Bolhassan, Chai Changsaar, Ali Raza Khoso, Loo Siawchuing, Jibril Adewale Bamgbade and Wong Ngie Hing

is not subjected to variation. Furthermore, a smart contract can enhance the efficiency in managing the contracts, such as reducing time and managing the conflicts and disputes that arise during the contract duration. The developed implementation framework is significant for the construction personnel, especially those dealing with the contract administration. The implementation of smart contracts in construction could boost contract administration and management discipline via investment in this new technology.

Keywords: Adoption, construction industry, Malaysia, qualitative research, smart contracts

---

INTRODUCTION

The term *smart contract* was first mentioned by Nick Szabo in 1994, who defined it as "a computerized transaction protocol that executes the terms of a contract" (Li et al., 2020). The general objectives of smart contract design are to satisfy common contractual conditions (such as payments terms), minimize expectations, and the need for trusted intermediaries". There is a consensus that the term "smart" in smart contracts refers to a kind of artificial intelligence replacing a human endeavor for making tasks easier to complete (Mason & Escott, 2018). A smart contract is generally an executable code that runs on the blockchain to facilitate, execute and enforce the terms of an agreement, where the main aim is to automatically execute the terms of an agreement once the specific conditions are met (Alharby & van Moorsel, 2017). Over the years, the development in blockchain technology has strengthened smart contracts, which are considered secure, further, the use of unstoppable computer programs that are executable automatically within a blockchain network (Wang et al., 2019). Smart contracts and blockchain are technologies that have made a significant contribution in various industries such as the healthcare industry, banking industry, and so on (Ekblaw et al., 2016). These digital contracts are digitally created in a paperless condition and executed, completed, and archived digitally.

Smart contracts are exceptionally valuable to manage construction projects, such as effectively minimizing disputes among parties. However, the global construction dispute grew to a value of USD 33 million in 2019, and it takes an average of 17 months to resolve that dispute (ARCADIS, 2019). This report named the top causes of construction disputes as poor contract administration. Like contract management, discretionary clauses allow for discrepancies and contradict other clauses, leading to construction disputes. The three causes for disputes globally are failing to properly administer the contract, poorly drafted or incomplete unsubstantiated claims, and employer/contractor/subcontractor failing to understand or comply with its contractual obligations (ARCADIS, 2019).

The nature of a construction contract where it has always been a collaboration between either a large or small group of participants necessitates risks of these parties to be allocated; hence the development and utilization of standard conditions of a contract is an important

parameter. Smart contracts digitalize the contract and agreement between these parties and reduce the risks of a traditional contract over disputes. It is because of a smart contract's self-executing attribute, where the terms and conditions are coded. Therefore, it can lead to less interpretation of a contract and reduce the risk in a contract structure.

The construction industry is currently observing continuing growth, and it is forecasted that the volume of construction output will grow to USD 10.1 trillion worldwide by 2021 (GlobalData, 2017). The average global growth is expected to increase at a rate of 3.9% per annum. In Malaysia, the construction industry is also expecting an expansion of about 4.7%. However, the construction industry is lagging in productivity which is a crucial aspect of failure, and conversely has the opportunity to boost volume by $1.6 trillion (Barbosa et al., 2017). Digitalization in the construction industry can improve productivity and create value by closing gaps in inefficiencies. However, digitalization has not been genuinely embraced in the industry. According to an index of McKinsey Global Institute, the construction sector is among the least digitized sector in the world (Barbosa et al., 2017). Although there is already an awareness that digitalization influences the industry, there is still so much potential that could be done if the industry pursues more on its digitalization initiatives. Nonetheless, over the recent years, the construction industry has etched its step towards various technological advancements, the prominent ones being the Building Information Model (BIM), Internet of Things (IoT), and Electronic tendering (E-tendering), which are the result of client's expectations, new technological capabilities, and growing legal frameworks and requirement from large infrastructure projects (Kaufmann et al., 2018). Moreover, the Government has pushed for a paradigm shift towards a digital economy in Malaysia, in line with the Industrial Revolution 4.0. Hence, a strategic change is expected with a vision to accelerate economic growth by embracing digitalization.

Considering the above and various other strategic development and paradigm shift pushed by the Malaysian Government towards digitalization, the local construction industry must evaluate the various impacts of smart contracts that could be disruptive technology. However, most construction companies' attitude towards digitalization has no impact on their organization, resulting in not approaching and adopting digital innovation as these organizations find it challenging to embrace and work effectively in the digital revolution (McNamara & Sepasgozar, 2020). Hence, there is a need to evaluate the impacts of smart contract implementation on the construction industry in Malaysia. Therefore, this research aims to enhance the construction contract performance in the Malaysian construction industry via identifying the benefits of smart contracts implementation in the Malaysian construction industry and the challenges of smart contracts implementation compared to traditional contracts in Malaysia. Finally, the study develops an implementation framework of smart contracts for the Malaysian construction industry. However, it should be noted that smart contracts are still considered a state-of-the-art technology, and there are many

gaps in the body of knowledge in the implementation of smart contracts in the construction industry in Malaysia. Therefore, this evaluation can serve as a benchmark and a decision tool in gauging and embracing smart contracts in consideration and preparation of its various benefits and challenges.

LITERATURE REVIEW

Traditional Contracts Vs. Smart contracts

In a construction context, the relatively complex nature of a construction project necessitates using a carefully written contract to prescribe the legal, financial, and technical aspects of the project (Clough, 1986). The construction contract defines the relationship, including responsibilities between the contracting parties, and spells out commercial terms and general project rules. Before the digital age, contracts are traditionally signed on paper and between parties at the same time. The current practice of traditional contracting allows for paper distribution instead of storing electronically in a contract management system. In Malaysia, contracts are governed by the Contracts Act 1950, which covers the rights of the contracting parties. To enforce a contract in Malaysia, the parties must observe the essential elements of the Contracts Act 1950. However, the evolving digital platform and capabilities of the Information and Communications Technology industry and the emergence of e-commerce allows people to have faith in the online environment, including entering into contract digitally and electronically.

In line with this, Malaysia enforced new legislation, the Electronic Commerce Act 2006, where information in electronic form shall not be denied with legal effect, validity, and enforceability. The Act 2006 also enforces the norm of digital signature where a digital signature bears the same effect as a normal wet- signature required in a traditional contract. Table 1 depicts the fundamental differences between traditional contracts and smart contracts. With smart contracts, trust is distributed across a community on a peer two peer network rather than centralized (England & Moreci, 2012). In other words, "no one can unilaterally take actions on behalf of the community" (Lamb, 2018).

Table 1

Differences between smart contract and traditional contract

Aspects	Smart contract	Traditional contract
Governance/Legal Framework in Malaysia	Contracts Act 1950 Electronic Commerce Act 2006	Contracts Act 1950
Signature	Digital Signing	Wet Signature Mandatory

Table 1 *(Continued)*

Aspects	Smart contract	Traditional contract
Platform	Peer to Peer (P2P) Network, Distributed Ledger Technology	Paper-based
Storage	Distributed Ledger	Physical storage
Network	Distributed	Centralized
Administration	Self-Executing	Executed and administered by human

Smart Contracts in Construction

The construction industry, likewise several other industries, is starting to embrace and engage with new technology. It is further assumed that modern technologies are paving their deeper path in the construction industry with the recent technological developments (Khoso et al., 2021). It can be seen with the widespread adoption in Building Information Model (BIM), 3D Modelling, Internet of Things, and many more. However, it can be viewed that smart contracts can be among the technology adopted to enhance the construction industry.

In the execution of a construction project, procurement is among the time-consuming phases of a construction project, and multiple contracts occur within a supply chain. In a construction context, this flows down from supplier, sub-contractor to the main contractor. The trust among the different contracting parties, such as in financial transactions, project management, and others, are usually validities by a contract and amenities such as a Letter of Credit (LC) document where third parties such as banks create trust between the parties (Ahmadisheykhsarmast & Sonmez, 2018). The financial institution's role in this such as banks exist in this financial transaction to ensure trust between both parties and guarantee that the seller will be paid after delivering the predefined conditions. In executing a construction project, payment stability is imperative for avoiding disputes (Mason & Escott, 2018). In a smart contract environment, as the transactions are between parties, there is no need for intermediary involvement other than a traditional contract (Li et al., 2019). Therefore, it is considered advantageous since banks and third-party are involved directly (Crosby et al., 2016). There is also a consensus that overheads in a smart contract can be greatly reduced as it eliminates the need for a 'middle man' for legal costs and administration costs for preparation and supervision of a traditional contract (Giancaspro, 2017).

In the procurement phase of a project, parties can code attributes and clauses such as the amount due to a party. Therefore, it ensures that the transaction between parties is transparent, and both parties cannot access the money up to the due date of payment. It is achieved by taking advantage of the self-executing attribute of smart contracts. However,

it is to be noted that the money and transaction that will be transferred to smart contracts are in a cryptocurrency account as of the present moment. This technology allows the elimination of third-party administration fees and mitigates problems concerning slow processing and verification of payment (Cardeira, 2015). It is important as delayed progress payment has been a significant problem in construction as it contributes to difficulties in cash flow within the construction supply chain (Badroldin et al., 2016). Furthermore, payments are guaranteed and automatically executed with cryptocurrencies, which is considered an enormous contribution to the construction sector (Xue & Lu, 2020).

Apart from the numerous advantages of smart contracts in the modern construction industry, they face setbacks such as collaboration agenda. The construction industry has been regarded as slow in adopting changes, adversarial, and unfair to subcontractors. Therefore, the collaboration agenda has been prominent in the construction industry, where the key to collaboration agenda has always been mutually trusted (Bouchlaghem & Shelbourn, 2011). Moreover, a challenge faced by implementing smart contracts is that once a smart contract is coded, it is immutable and irreversible (Luo et al., 2019). Smart contracts that are coded wrongfully due to human error could result in a disastrous end. Because of the nature of a smart contract, it is self-executing to rely upon the pre-determined conditions and set out all the contracting parties' obligations (Li et al., 2019). Further, a blockchain requires big data, so it is impossible to manage change within the system (Xue & Lu, 2020). Since contracts can run on either public blockchain or private blockchain, but public blockchain consensus of all parties is needed for validation. At present, there is no established blockchain for all project management activities (Yang et al., 2020).

In addition, deviant miners can release malicious blocks at a later stage and attack the blockchain. It can result in acquiring more than 50% of the computational power and resulting in a tampered ledger (Luo et al., 2019). Furthermore, some functions can create malicious notes and libraries in blockchain technology, such as 'self-destruct', which deactivates contracts (Ghosh et al., 2020). In 2016, a malicious user led to a burglary of $50 million in a smart contract transaction implemented in Ethereum, which is a platform for smart contracts (Dorsala et al., 2020). It suggests that the dependability of smart contracts is doubtful as it has been used for criminal purposes. The vulnerability of smart contracts can also inspire cybercriminals to steal and launder money. Therefore, testing smart contract code is necessary as it is vulnerable to attacks, which can be done using security analysis tools (Yang et al., 2020).

Another big challenge to note regarding the implementation of smart contracts in construction is that as smart contracts utilize cryptocurrency, it still has many barriers to overcome. It is not a mainstream application in Malaysia yet. There are still risks in fluctuation due to cryptocurrency usage, suggesting that cryptocurrencies are not stable at the present moment for use in construction projects. In addition, using cryptocurrencies

requires a considerable amount of data and capacity than the typical payment transaction such as a visa (Zhong et al., 2019).

Contract management is an integral part of contract execution. However, it is believed that construction professionals need to know the intricacies of process and involvement in a project. Concerning implementing smart contracts, there is a need for specialist knowledge in the implementation of smart contracts. It requires participation from various disciplines of the contract management team (McNamara & Sepasgozar, 2020). Presently there is a significant lack of expertise to execute and administer smart contracts (Li et al., 2019). Therefore, before designing the blockchain system for a construction project, there is a multitude of information required from multidisciplinary parties (Yang et al., 2020).

A novel smart contract payment security system by Ahmadisheykhsarmast and Sonmez (2020) was adopted in preparation for this research considering the above facts. The purpose of this adaption is because benchmarking is recognized as "an essential tool for continuous improvement of quality" (Dattakumar & Jagadeesh, 2003). However, it has not been assessed regarding the implementation of smart contracts in Malaysia. The framework includes setting up a secured payment system for smart contract implementation. Their framework has eliminated the problem, resolved the payment security system, and done the practical test on a real construction project. Therefore, it is suitable for this study. It exemplifies the success of the implementation of smart contracts in the construction industry. The recommended smart contract payment security system provides guaranteed security of payments of works under construction and a platform for a secure and transparent platform, as shown in Figure 1.
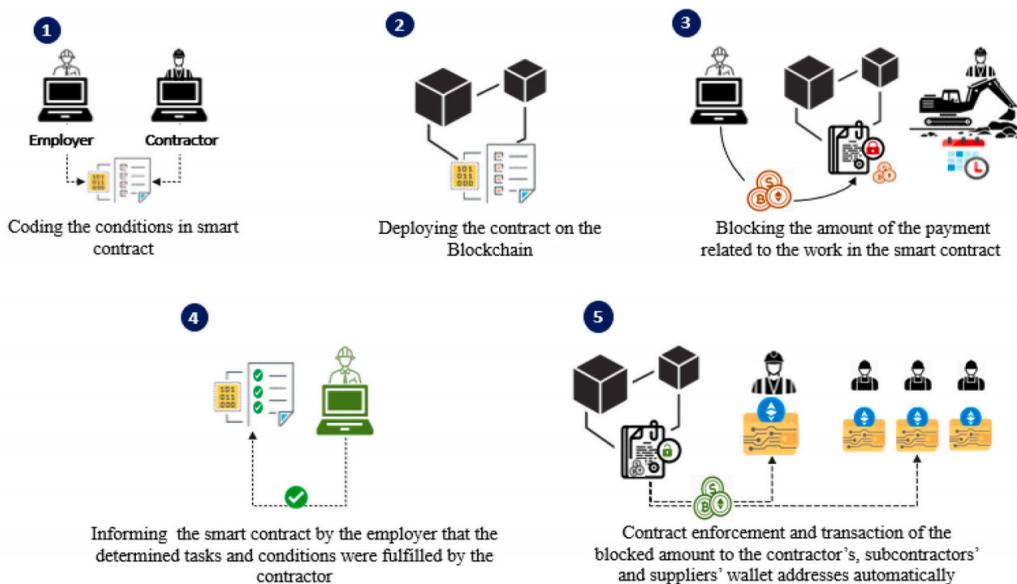

Figure 1. Framework adopted from (Ahmadisheykhsarmast & Sonmez, 2020)

RESEARCH METHODOLOGY

This research adopts a systematic qualitative approach, as depicted in Figure 2. The advantage of applying a qualitative research approach is mainly inductive and explorative; thus is ideally suited in situations where the nature of impacts of smart contracts is to be investigated. Questions like the current challenges and benefits of smart contracts are examined. Qualitative methods such as semi-structured interviews, content analysis, and framework analysis research methods are applied to achieve each research objective.
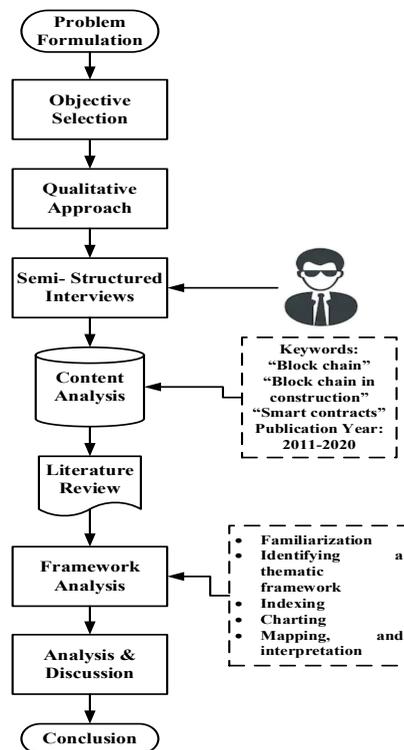

Figure 2. Systematic research methodology

Semi-Structured Interviews

A semi-structured interview technique was applied based on pre-conceived questions. It provided background knowledge to accomplish the objectives, providing relevant outcomes to confirm and validate the data. A personal interview is adopted as there can be much private and confidential data and information in the interview, which would necessitate approval from the interviewee. The interviewees consisted of various backgrounds that included experts were involved from different backgrounds in contracts administration. The interviews were conducted in May 2021, which consumed around two weeks. The information of interviews is illustrated in Table 2.

Table 2

Background of interviewees

Interviewee ID	Profession	Executive Level	Experience
Respondent 1	Contracts Manager	Senior	More than 20 years
Respondent 2	Contracts Manager	Senior	More than 15 years
Respondent 3	Quantity Surveyor	Middle	More than 10 years
Respondent 4	Senior Contracts Administrator	Middle	More than 15 years
Respondent 5	Contracts Administrator	Middle	More than 10 years
Respondent 6	Finance Manager	Senior	More than 15 years

Content Analysis

The focus of content analysis is the characteristics of language, taking into account the content or contextual meaning of the text (Hsieh & Shannon, 2005). The content analysis aims to provide "knowledge and understanding of the phenomenon under study" (Bengtsson, 2016). A more specific type of content analysis considered here is leaning towards a summative approach of content analysis, where it aims to identify certain words or contexts to understand the contextual use of the words and content (Erlingsson & Brysiewicz, 2017). It allows to attempts not to infer meaning but explore usage. It is deemed as a suitable approach in this research context concerned with the research objectives.

The first step of the research involved the academic literature on the topic of smart contracts in construction. The document survey focused only on electronic journals written in English. A set of selection criteria was applied to gather the relevant data to be reviewed, and the first criteria were to restrict the review period to 2010 until 2020. This eleven-year interval shall address maturity and future trends in a smart contract, blockchain, and construction. As smart contracts run on a blockchain, the search also included blockchain in construction. Due to the novel nature of this technology, there is quite a limited number of documents that explicitly address smart contracts in construction; instead, it addresses blockchain in construction and blockchain and smart contracts. Insights were developed to discuss the surrounding theme and context of the literature. From the literature survey, several themes emerged and were discussed surrounding smart contracts.

Framework Analysis

Since the smart contract is still considered a 'state of the art' technology, there are various gaps in knowledge on the implementation of smart contracts, especially in Malaysia, that would be useful for adoption. There is currently no information available for the

construction sector in the implementation of such a disruptive change. A theoretical framework aims to provide an analytical structure and contextualize formal theories into a guide (Adom & Hussain, 2018). It is in line with the aim of the research to identify the impact of smart contract implementation in Malaysia. The theoretical framework outlined from this research would allow future research to identify the practical implications of smart contracts within the local construction industry.

Later, a framework analysis is used to analyze the interview data. The framework creates a new structure for the data to summarize or reduce the data while contemporaneously, capable of answering the research questions (Gale et al., 2013). Following the framework analysis method, data were analyzed in five stages: familiarization, identifying a thematic framework, indexing, charting, mapping, and interpretation, as shown in the following Table 3.

Table 3

Framework analysis stages

Process	Description
Familiarization	Where the collected data from the interview sessions are familiarized and transcribed, and the overview of the collected data is gained.
Identifying a thematic work	Emerging themes of issues and data set are collected. Key issues, concepts, and themes of participants can form the basis of the framework and be used to classify data.
Indexing	Identification of sections of data that responds to a particular theme.
Charting	Specific indexed data is placed in the framework with headings and subheadings.
Mapping and interpretation	Analysis at this stage guides the interpretation of the data set.

RESULTS AND DISCUSSIONS

Benefits of Smart contract Implementation in Malaysian Construction Industry

In a traditional system, the contract is formed between parties which requires a third party (trustee). In contrast, third parties such as banks are not required in a smart contract, as the smart contract attributes are self-executing through the blockchain system. In the interviews, the data revealed that Respondents 1 and 3 were agreed to eliminate the trustee and suggested reducing the processing time for the payment. Thus, there is a necessity to evaluate the benefits of shifting to a smart contract compared to a traditional contract.

Furthermore, it shall provide an overview and basis of migration to a digitalized database. In addition, due to the automation or self-executing attribute, this would also guarantee the payment to the contractor.

In traditional contracts, there is always an emphasis on stakeholder engagement, and construction contracts are usually built on a multi-dimensional party. These stakeholders need to administer the contracts and interpret them based on their disciplines manually. Therefore, it may contribute to inefficient contract procedures and administration. In a smart contract environment, the obligations of the employer and the contractor are coded in the smart contract system that executes automatically in a secure and decentralized platform without third-party involvement. The automation of responsibilities reduces the possibility of disputes between parties, which have been established as a contributing factor in construction disputes. In this current study, Respondents 1, 3, 4, and 6 believe that digitizing the contracts shall improve contract administration. It would decrease the amount to communicate any requirements to the parties as now there is a precise apportionment of responsibility between them. Respondents 4 also believes that the payment part of contract administration benefits greatly from this attribute, where payment automation shall improve payment processing, ensuring that the contractor's cash flow is guaranteed. It is also in line with Respondent 2 views which suggest that a smart contract is an avenue that can replace human intervention in contract execution. Contracts are sometimes entered into without complete knowledge on the potential outcome, and manual contract administration in traditional contracts contributes to tremendous inefficiency, and this can cause disputes with low levels of traceability. Smart contract implementation promotes collaboration between parties with increased transparency than a traditional contract, which will create a stable environment in a project in terms of apportionment of risks.

In addition, as compared to traditional contracts, the smart contract is also indicated as more accessible due to its digital database. Respondent 2 and Respondent 5 commented that a smart contract creates value addition and increases efficiency where parties can easily access the terms and conditions, leaving less room for interpretation. In terms of record-keeping, Respondent 1 believes that a smart contract improves the administration of a contract as terms are now digitized. In addition, the status of a smart contract is automatically updated, and the digital currency will only be deployed after a pre-existing condition is fulfilled. Therefore, it will alleviate concerns on withheld payment and improve efficiency. This efficiency is a product of the smart contract's main attribute, which is self-executing.

Through smart contracts, instant payment is possible as all participants are in the same network to close all payment channels without the involvement of third parties. This problem of late payment can be alleviated as the system could be coded. As soon as the employers verify the work done and the accuracy of the total amount, the payment could be released instantly in a cryptocurrency. Eliminating intermediaries in a smart contract can alleviate the

poor treatment of subcontractors, leading to insolvencies, and payment security will result in a more stable supply chain (McNamara & Sepasgozar, 2020). In summary, the benefits of a smart contract implementation are identified, as demonstrated in Table 4.

Table 4

Benefits of implementation of smart contracts

No	Description	Remarks
1	Better Apportionment of Risks and Responsibilities	Responsibilities are established during the contract formation, and there is better risk apportionment in a multi-dimensional party as obligations are self-executed.
2	Less Room for Disputes	Require less interpretation of parties' obligations.
3	Self-Executing Contract	Automation of contract responsibilities increases efficiency in contract .administration and management due to digitalization.
4	Elimination of Third Party	Reduce the processing time and cost of payment to contractors.
5	Guaranteed Payment	It shall improve the contractor's cash flow due to the automation in payment processing.

Challenges of Smart Contract Implementation Compared to Traditional Contracts in Malaysia

A smart contract is still at the forefront of technology, still has several challenges to overcome, improving accessibility and usage of smart contracts compared to traditional contracts. One of the challenges that should be addressed is cybersecurity. Respondents 1, 3, 4, and 5 voiced concerns about using cybersecurity as often there is confidential information in the contract. Usually, there is much effort to preserve the confidentiality of a construction contract. In addition, as viewed by Respondent 6, which is from a banking background, fault transaction and stolen accounts problems in the banking industry are still unresolved. Therefore, they have posed an issue in the banking industry. Hence, handling the cybersecurity risk would be a challenge in managing this smart contract environment.

Considering that smart contracts utilize a peer-to-peer network where data is only distributed between intended parties, and there is no third party involved, it solely depends on the contracting parties and code to pursue the transaction. There should be malicious code between the blockchain; this affects the other nodes in the blockchain system and

ensures transparency in transactions. However, one could not deny that smart contracts can be susceptible to malicious intentions to the coding system. Data uploaded in the ledger needs to be legitimate, and there is a possibility of fraudulent activity that will run through the supply chain (Li et al., 2019). It is different in a traditional contract environment where transactions are conducted manually, and any alleged malicious intentions can be stopped and possibly would not affect subsequent activities.

The irreversibility and immutability of smart contracts are also a challenge for implementation as contracts coded wrongfully due to human error could result in a disastrous end. Respondent 5 is concerned that if a change in law and taxes calls for any extra deduction from the payment, the smart contract could not accommodate this due to its irreversibility trait. Hence, it has been recommended that projects that are prone to variations do not utilize smart contracts. It could pose a problem for long-term projects many external factors could allow for changes in the contract structure. A more straightforward type of contract would be easier to manage. Respondent 1 emphasized that there should be a strong agreement between client and contractor before executing the smart contract due to it being irreversible. Hence, communication and consensus between the parties are essential in implementation. Should any of the parties decide on changes in the contract structure or terms, this shall not be easy to manage in the future. The immutable nature of smart contracts would give rise to its inefficiency as to 'reasonableness' inherent in contract management, usually found in discretionary clauses (Giancaspro, 2017). It gives rise to professionals versed in programming collaborating with lawyers or legal teams to monitor or enforce the contracts.

The utilization of a cryptocurrency is a prominent feature in implementing a smart contract, as the automation of execution shall subsequently release the payment in a cryptocurrency form. However, all respondents agree that they do not know much about cryptocurrency, as it has not been practiced as a form of payment in the construction industry yet. Respondents 1, 2, and 4 were concerned about the flexibility in using cryptocurrency in the construction industry. However, Respondent 2 believes that it may be possible to exchange the goods if other services and works also use cryptocurrency. Respondent 5 also could not provide opinions on cryptocurrency usage due to the lack of knowledge of cryptocurrency usage in the construction world. Respondent 6, from a finance and banking background, thinks that cryptocurrency is a fast and secure form of transaction; it is still an unrecognized method in the worldwide banking industry. In addition, cryptocurrency is an unstable currency and has a high fluctuation range. The unpredictability of price fluctuation in cryptocurrency constitutes a high risk in the transaction. Therefore, it exhibits a gap that needs to be closed in implementing smart contracts. There should be more training construction professionals need to educate practitioners should cryptocurrency is used in the construction industry.

In addition, the usage of cryptocurrencies requires a considerable amount of data. From the data obtained, most respondents agree that the novelty in implementing smart contracts such as the infrastructure and acceptability of the industry players is the main concern. It was unanimously agreed that the proper training of construction professionals is a major issue. Respondent 1 commented that there should be multiple test cases before the comprehensive implementation of the smart contract first. Hence, a smart contract environment must be implemented in a project, and the contract management team needs to be equipped with technology-based knowledge.

Another challenge from the implementation of smart contracts is the lack of legal precedence. The interviewees (Respondent 4 and Respondent 5) believed finding legal precedence and cover the legal jurisdictions would be challenging. As informed by Respondent 6, a cryptocurrency that has yet to be formally recognized by any government as an authorized transaction might pose a legal risk, and there is no legal entity to enforce and authenticate these transactions. It is important as contracts are heavily reliant upon terms and conditions to administer and enforce the regulation. Hence, contracts written in a more understandable language by the vast majority of the construction practitioners are preferred compared to contracts written in a traditional 'legalese' language (Boon et al., 2019). Respondent 6 believes that there is a gap in the industry's competent personnel and IT infrastructure to execute the smart contract. Smart contracts are developed in a different environment, and their terms must be read, understood, and soon coded into a computer. Therefore, it supports the notion of novelty in smart contract implementation, where there are many gaps in training and execution before implementation in the construction industry. There is also a requirement for a certain level of technological advancement in the construction industry to implement a smart contract successfully. The construction industry's digitalization level is not sufficient to implement new technology such as a smart contract. In summary, the challenges of smart contract implementation are summarized in Table 5.

Table 5

Challenges of implementation of smart contracts

No	Description	Remarks
1	Novelty	Lack of legal precedence and infrastructure.
2	Human Error in Coding	Prone to human error in coding that might provide a disastrous end to the system.
3	Irreversible and Immutable	It is not suitable for long-term projects, where it will be prone to changes or variables as smart contracts are irreversible.

Table 5 *(Continued)*

No	Description	Remarks
4	Cybersecurity Issues	Risk of cybersecurity issues in the contract administration, as information in the contract, are confidential.
5	Uncertainty in Cryptocurrency	Have not been practiced in construction payment, and there is not much knowledge on the stability of the cryptocurrency.

Smart Contract Framework for the Malaysian Construction Industry

The Employer (E) and Main Contractor (MC) need to agree on payment terms in the proposed framework. The agreed terms are presented as a computerized protocol through a smart contract deployed on a blockchain system. A monthly progress payment is assumed to be made. In the smart contract, a projected payment is pre-determined in relation to the planned progress of the project. Then, after payment approval, the smart contract automatically transfers the amount to the contractor's subcontractors and suppliers' wallets according to the agreed terms. It is to be noted that this transaction utilizes cryptocurrency. It is unique for each project, and this has to include a contingency amount to cover the potential fluctuations in cryptocurrency. There is a consensus that integrating hardware and software, including scalability, security, and privacy, is essential in selecting a blockchain. The suggested platforms to execute these smart contracts on blockchain include; Ethereum, Hyperledger Fabric, Corda, Stellar, and Rootstock as major smart contract developer platforms based on popularity. It is to be noted that among those companies, Ethereum is the only one that has a base in Kuala Lumpur, Malaysia. It also has the largest market influence among others. The smart contract procedure enables releasing a blocked amount.

In this system, data is provided and coded into the smart contract. The data required are schedule payment data, actual completion dates, budgeted and actual payment, and parties' information such as contractor, sub-contractor, and suppliers. During the cut-off period, the contractor can update the planned and actual schedule and the payment data for the employer's approval and payment. Employers can click on an authorization button ('approve,' 'pay'). The payment amount will simultaneously be transferred to the main contractor's, subcontractors', and any specified suppliers' wallets through a smart contract. If the Contractor/supplier/subcontractor receives the payment notification, they will convert the currency into any local cryptocurrency amount. The primary framework of the proposed framework is depicted in Figure 3.
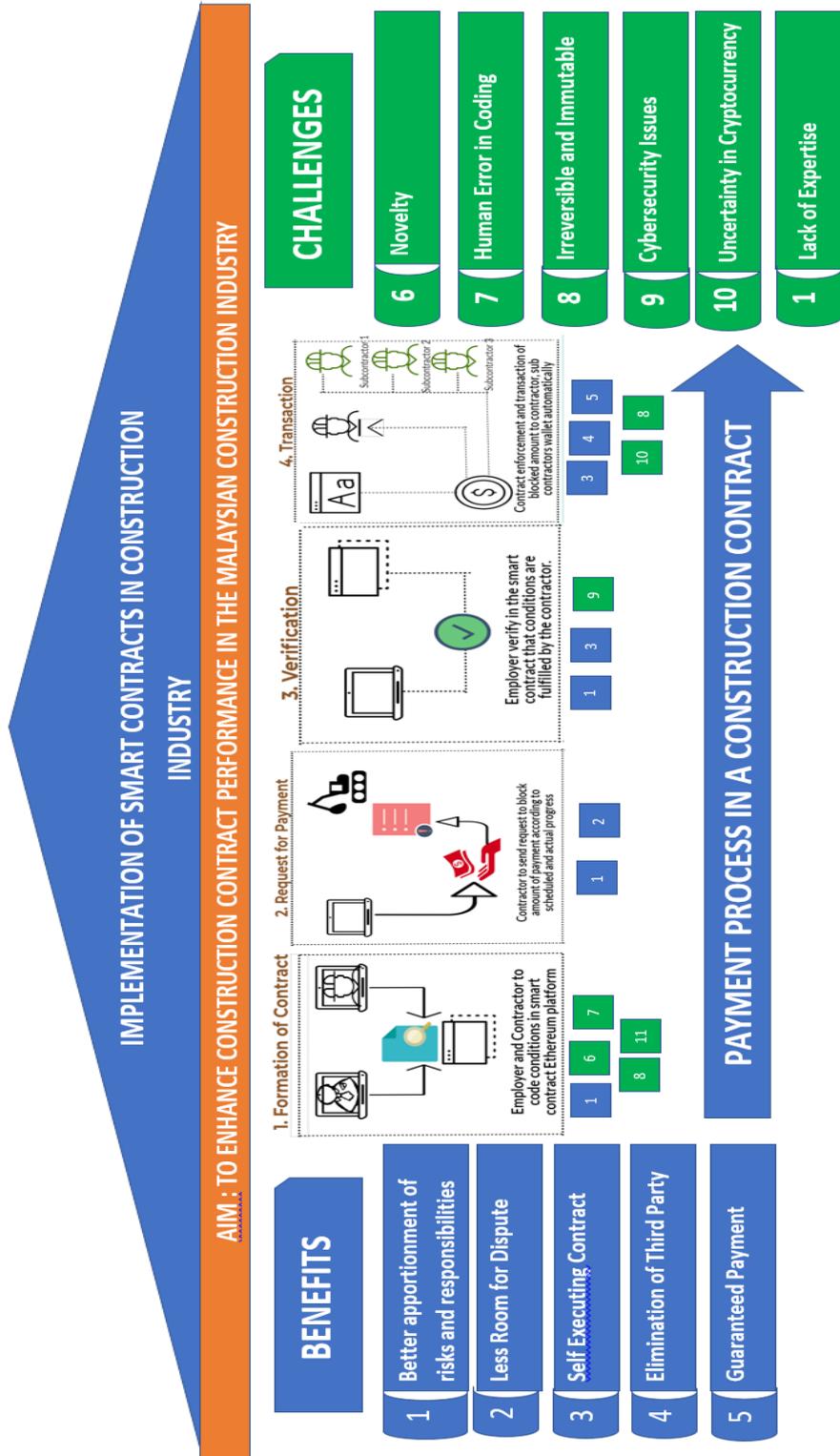
Figure 3. Smart contracts implementation framework

CONCLUSION AND RECOMMENDATION

The construction sector is embracing and pushing the Industry Revolution 4.0, and digitization of contracts fits in rightly in this agenda. Digitization of contracts fits perfectly as a follow-up to introducing modern technologies in the industry, where this generation of practitioners and future generations are more susceptible to technological adventures. The findings and discussion suggest several benefits of smart contracts that could potentially provide efficiency in contract management. It is by several avenues, one of them and the more important one is by greatly reducing disputes in payment processing and improve contractor's cash flow all through the supply chain by automation of payment. The findings on the benefits of the implementation of smart contracts point to possible improvement in the contract management part of a construction project. However, evaluating the implementation of the smart contract includes various challenges. Considering that this technology is still embryonic, it is prudent that the identified challenges be evaluated thoroughly to ensure that it is not detrimental to the successful implementation. For example, overcoming concerns and challenges regarding the irreversible and immutable coding in smart contracts needs to be identified before implementing a construction project.

Hence, referring to the framework developed, it is prudent that all scenarios are taken into consideration, and as respondents have pointed out, there should be a strong and mutual agreement. The mapping of benefits and challenges in the framework suggests that at the moment, it is more suitable to apply and implement a Smart contract to a short-term contract that is not subjected to variation. There are inevitably systemic problems in contract management in the construction industry as it yields a huge number of disputes which also takes a long time to manage. The time spent by the contract management team managing disputes could be reduced or eliminated by introducing a smart contract, where obligations are coded in the system, leaving less room for interpretation. This technology's clarity may add efficiencies in the contract management process and allow for a paradigm shift to proactive and efficient project delivery rather than a defensive approach when disputes arise. This new approach of smart contract implementation could enhance the contractor's contract performance, and more focus can be provided on the quality of the works.

REFERENCES

Adom, D., & Hussain, E. K. (2018). Theoretical and conceptual framework: Mandatory ingredients engineering. *International Journal of Scientific Research*, *7*(1), 438-441.

Ahmadisheykhsarmast, S., & Sonmez, R. (2018). Smart contracts in construction industry. In *5th International Project and Construction Management Conference (IPCMC2018)* (pp. 767-774). ACADEMIA.

Ahmadisheykhsarmast, S., & Sonmez, R. (2020). A smart contract system for security of payment of construction contracts. *Automation in Construction*, *120*(October 2019), Article 103401. https://doi.org/10.1016/j.autcon.2020.103401

Alharby, M., & van Moorsel, A. (2017). A systematic mapping study on current research topics in smart contracts. *International Journal of Computer Science and Information Technology*, *9*(5), 151-164. https://doi.org/10.5121/ijcsit.2017.9511

ARCADIS. (2019). Laying the Foundation for success. In *Global Construction Disputes Report 2019* (pp. 1-31). ARCADIS

Badroldin, M. K. A. M., Hamid, A. R. A., Raman, S. A., Zakaria, R., & Mohandes, S. R. (2016). Late payment practices in the Malaysian construction industry. *Malaysian Journal of Civil Engineering, 28*(3), 149-162. https://doi.org/10.11113/mjce.v28.16005

Barbosa, F., Woetzel, J., Mischke, J., Ribeirinho, M. J., Sridhar, M., Parsons, M., Bertram, N., & Brown, S. (2017). *Reinventing construction: A route of higher productivity*. McKinsey Global Institute.

Bengtsson, M. (2016). How to plan and perform a qualitative study using content analysis. *NursingPlus Open*, *2*, 8-14. https://doi.org/10.1016/j.npls.2016.01.001

Boon, K. S., Sector, I., Firms, C., & Contracting, C. (2019). *Transforming the Singapore built construction project budget*. PAQS Congress Kuching Malaysia.

Bouchlaghem, D., & Shelbourn, M. (2011). Introduction. In *Collaborative Working in Construction* (p. 5). Routledge.

Cardeira, H. (2015). Smart contracts and possible application to the construction industry. *New Perspectives in Construction Law Conference*, *1*, 19-21.

Clough, R. H. (1986). *Construction contracting*. John Wiley & Sons Ltd.

Crosby, M., Nachaippan, Pattanayak, P., Verma, S., & Kalyanaraman, V. (2016). Blockchain technology: Beyond bitcoin. *Applied Innovation Review*, *2*(6), 6-19.

Dattakumar, R., & Jagadeesh, R. (2003). A review of literature on benchmarking. *Benchmarking: An International Journal*, *10*(3), 176-209. https://doi.org/10.1108/14635770310477744

Dorsala, M. R., Sastry, V. N., & Chapram, S. (2020). Fair payments for verifiable cloud services using smart contracts. *Computers and Security*, *90*, Article 101712. https://doi.org/10.1016/j.cose.2019.101712

Ekblaw, A., Azaria, A., Halamka, J. D., & Lippman, J. D. H. A. (2016). A case study for blockchain in healthcare: "MedRec" prototype for electronic health records and medical research data. In *Proceedings of IEEE open & big data conference* (Vol. 13, p. 13). IEEE Publishing.

England, K., & Moreci, J. (2012). *Contingency - Are you Covered?* Project Management Institute.

Erlingsson, C., & Brysiewicz, P. (2017). A hands-on guide to doing content analysis. *African Journal of Emergency Medicine*, *7*(3), 93-99. https://doi.org/10.1016/j.afjem.2017.08.001

Gale, N. K., Heath, G., Cameron, E., Rashid, S., & Redwood, S. (2013). Using the framework method for the analysis of qualitative data in multi-disciplinary health research. *BMC Medical Research Methodology*, *13*(1), 1-8. https://doi.org/https://doi.org/10.1186/1471-2288-13-117

Ghosh, A., Gupta, S., Dua, A., & Kumar, N. (2020). Security of cryptocurrencies in blockchain technology: State-of-art, challenges and future prospects. *Journal of Network and Computer Applications*, *163*(April), Article 102635. https://doi.org/10.1016/j.jnca.2020.102635

Giancaspro, M. (2017). Is a 'smart contract' really a smart idea? Insights from a legal perspective. *Computer Law and Security Review*, *33*(6), 825-835. https://doi.org/10.1016/j.clsr.2017.05.007

GlobalData. (2017). *Global construction outlook 2021*. GlobalData UK Ltd.

Hsieh, H. F., & Shannon, S. E. (2005). Three approaches to qualitative content analysis. *Qualitative Health Research*, *15*(9), 1277-1288. https://doi.org/10.1177/1049732305276687

Kaufmann, D., Ruaux, X., & Jacob, M. (2018). *Digitalization of the construction industry: The revolution is underway.* OliverWyman.

Khoso, A. R., Yusof, A. M., Chai, C., & Laghari, M. A. (2021). Robust contractor evaluation criteria classification for modern technology public construction projects. *Journal of Public Procurement*, *21*(1), 53-74. https://doi.org/https://doi.org/10.1108/JOPP-06-2020-0053

Lamb, K. (2018). *Blockchain and smart contracts: What the AEC sector needs to know* (Issue July).Centre for Digital Built Britain Publication. https://doi.org/10.17863/CAM.26272

Li, J., Greenwood, D., & Kassem, M. (2019). Blockchain in the built environment and construction industry: A systematic review, conceptual models and practical use cases. *Automation in Construction*, *102*(February), 288-307. https://doi.org/10.1016/j.autcon.2019.02.005

Li, T., Chen, Y., Wang, Y., Wang, Y., Zhao, M., Zhu, H., Tian, Y., Yu, X., & Yang, Y. (2020). Rational protocols and attacks in blockchain system. *Security and Communication Networks, 2020*, Article 8839047. https://doi.org/10.1155/2020/8839047

Luo, H., Das, M., Wang, J., & Cheng, J. C. P. (2019). Construction payment automation through smart contract-based blockchain framework. In *Proceedings of the 36th International Symposium on Automation and Robotics in Construction, ISARC 2019* (Vol. 36, pp. 1254-1260). IAARC Publications. https://doi.org/10.22260/isarc2019/0168

Mason, J., & Escott, H. (2018, May 06-11). Smart contracts in construction: Views and perceptions of stakeholders. *In* Proceedings of FIG Conference. Istanbul, Turkey.

McNamara, A. J., & Sepasgozar, S. M. E. (2020). Developing a theoretical framework for intelligent contract acceptance. *Construction Innovation, 20*(3), 421-445. https://doi.org/10.1108/CI-07-2019-0061

Wang, S., Huang, C., Li, J., Yuan, Y., & Wang, F. Y. (2019). Decentralized construction of knowledge graphs for deep recommender systems based on blockchain-powered smart contracts. *IEEE Access*, *7*, 136951-136961. https://doi.org/10.1109/access.2019.2942338

Xue, F., & Lu, W. (2020). A semantic differential transaction approach to minimizing information redundancy for BIM and blockchain integration. *Automation in Construction*, *118*(May), Article 103270. https://doi.org/10.1016/j.autcon.2020.103270

Yang, R., Wakefield, R., Lyu, S., Jayasuriya, S., Han, F., Yi, X., Yang, X., Amarasinghe, G., & Chen, S. (2020). Public and private blockchain in construction business process and information integration. *Automation in Construction*, *118*(May), Article 103276. https://doi.org/10.1016/j.autcon.2020.103276

Zhong, L., Wu, Q., Xie, J., Guan, Z., & Qin, B. (2019). A secure large-scale instant payment system based on blockchain. *Computers and Security*, *84*, 349-364. https://doi.org/10.1016/j.cose.2019.04.007