

# AN INVESTIGATION ON THE APPLICABILITY OF SMART CONTRACTS IN THE CONSTRUCTION INDUSTRY

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**ABSTRACT:** Smart contracts and blockchain technology are becoming key parts in advancing the Digital Construction discipline. Although blockchain technology has just started to be used in construction industry, the applicability of smart contracts is being debated. The adaptation of this technology is relatively limited and slow compared to other industries such as finance due to the special characteristics of the construction industry which make it more complicated and fragile. For this purpose, this research investigates the applicability of smart contracts in construction industry, its limitations and possible benefits. First, smart contracts are compared to traditional contracts. Then, the relationship between smart contracts and blockchain technology is discussed, and finally the impact of blockchain technology on the construction process is investigated. In this research, which has utilised a literature review, the following results have been found. In spite of the fact that smart contracts have some limitations for this industry, such as the difficulty of changing transactions and being legally binding, they have potential benefits in many fields, primarily the solution of payment problems and high security. The use of this technology in for example, simple and small-type projects or semi-automation of activities could facilitate their adoption. Furthermore, it is considered that using these technologies together with Building Information Modelling (BIM) in construction projects will contribute more benefit to the project.

**Keywords:** Smart Contracts, Blockchain, Building Information Modelling (BIM), Digital Construction, Construction Industry

## 1 Introduction

The use of technology and its applications continue to increase rapidly in the construction industry, across the world. However, due to the nature of the construction industry, its adaptation to technological advances is slower compared to other industries such as finance, automotive [1]. Blockchain technology, and accordingly smart contracts, are seen as the technology of the future, and are envisaged to be used in this industry [2-3]. Using this technology more efficiently requires a smart contract [4]. This contributes to acceleration and automation of the process through the ability of smart contracts to execute themselves.

Smart contracts are a program code that allows transactions to be performed without the need for intermediaries such as banks, lawyers, and notaries [5]. They are based on reducing or eliminating the need for third parties in contracts and automating transactions [6]. The code in the program automates the contract in the blockchain system after the realisation of the variables and principles determined in the project [7]. In this way, it is aimed to prevent loss of time in the projects and to solve the issue of payments, which is one of the major problems in the construction industry, as well as to protect the parties from bankruptcy.

Construction projects are a type of project where multiple professional groups work together. Various problems are encountered due to the lack of coordination and collaboration among these groups. This situation, which is rather extensive in the projects, causes undesirable results in

the project [8]. Digital construction aims to increase collaboration among project stakeholders in a project. It gathers projects in an environment and contributes to teamwork. In addition, coordination deficiencies are reduced with the simulation feature. The fact that the transaction approvals in the blockchain system require joint action automatically requires collaboration among the parties. Thus, possible disputes that may occur among the stakeholders in the project can also be reduced.

This study investigates the applicability, possible benefits, limitations of smart contracts in the construction industry. Smart contracts are first compared to traditional contracts. Next, the relationship between smart contracts and blockchain is revealed. Finally, the impact of blockchain technology on the construction process is investigated.

## 2 The Relationship between Smart Contracts and Blockchain Technology

Smart contracts are defined as computer codes that execute a contract partially or fully automatically and stored on the blockchain platform. Programming languages are used in the formation of smart contracts. The codes contribute to the execution of agreement among stakeholders and the realisation of payments. They are replicated and archived at nodes in the blockchain system and these codes cannot be changed. Each node added to the blockchain network means that the activity determined in the project has taken place. This is accomplished by initiating a transaction on the blockchain network by project stakeholders and requires

consensus among them. If the activity determined in the project has not taken place, the code will not progress [9].

Bitcoin and Ethereum are two common samples of the blockchain system known as distributed ledgers. While Bitcoin has distributed ledgers and cryptography capability, Ethereum may also include codes capable of executing transactions. The Bitcoin blockchain system uses Bitcoin as its digital currency, while the Ethereum blockchain system uses Ether [4]. A transaction fee is required for a smart contract to be executed in blockchain system. In these transaction fees, digital currencies Bitcoin and Ether are used. The payment made in the Ethereum blockchain system is called 'gas'. As the figure of nodes in a blockchain network increases, the amount of gas spent increases accordingly [9]. The size and complexity of a project affect the amount of gas needed. Therefore, the amount of gas to be spent on a large and complex project will be much higher than for a small and simple project.

Today, smart contracts generally carry out the transfer of money among stakeholders through cryptocurrencies in the blockchain system once the set criteria are complete. Figure 1 demonstrates the general working principle of smart contracts in the blockchain system.

Figure 1. Working Principle of Smart Contracts in Blockchain System [14]



First, an account is created in the blockchain system, the smart contract depending on the events determined in the project is written as a code to the blockchain system and all project parties are included in this account. In the second step, in consequence of the realisation of an event determined, the conditions coded in smart contracts are triggered. In the third step, the payments are transferred to the related parties in the blockchain system. Finally, the project parties have an immutable example of all the activities that have taken place and they can be accessed at any time. Their functions are expected to increase with their use and adoption over time. In addition, it may take much longer to add criteria such as performance evaluations of the parties and compensation [9]. These limitations would delay the adoption of smart contracts in the construction industry.

### 3 Applicability of Smart Contracts in the Construction Industry

Smart contracts and blockchain technology have become key parts in the advancement of the finance discipline nowadays [1]. Therefore, this technology is closely related to all sectors based on finance. This situation is reasonable considering the payment method and security for industries

with minor transaction complexity such as banking, real estate, insurance, healthcare and retail. Some countries, including Ghana, Georgia and Honduras, have switched to smart contracts to avoid land disputes and problems in the land transfer [10]. The adoption of smart contracts, which are also considered to be used in the construction industry, is debated due to the nature of this industry.

By its nature, the construction industry is exposed to many variables and unknowns. Transaction load and complexity are higher compared to the industries mentioned above. For this reason, while some of the industry members favour the adoption of smart contracts, some oppose it. For example, in the study conducted by Mason, some of the participants argued that the potential benefits of smart contracts, mainly in eliminating payment problems, outweigh the limitations. On the other hand, some participants specified that adoption is much more difficult than it seems, particularly because of the complexity in the construction works, each identified event cannot be reduced to "yes" or "no" in smart contract transactions [6].

Smart contracts currently make payments automatically based on sensors or devices. However, there is no flexibility in any changes or mistakes during the project. Due to the immutability of the blockchain, a change in the smart contract is fairly complicated [9]. For this reason, it is more reasonable to use and develop these contracts primarily in simple and small-type projects. Thus, while solutions to existing limitations are being developed, both possible losses can be reduced, and their adoption can be facilitated.

Although the main factor in contracts is money, contracts do not consist of just payments. It also includes many key factors such as time, quality and responsibilities. These critical factors are not involved in enabling of smart contracts. This restricts the use of smart contracts in the construction industry. On the other hand, digital construction supports the collaborative approach to tackle the problems encountered [11]. The inclusion of the smart contracts and blockchain technology in the Building Information Modelling (BIM) process increases collaboration in the project and enables more precise data to be obtained [2]. According to Perera et al. BIM has made various contributions to construction projects, but it has been ineffective on supply of goods and services [12]. The potential of blockchain and smart contracts on supply encourages the combined use of these technologies and enables more contribution to the project. In addition, this process contributes to the automation of the contract [6]. Liu et al. investigated the potential benefits of using blockchain and BIM technologies together in sustainable building design information management [13]. As a result of this research, they have demonstrated that smart contracts could be used effectively in this process, the possibility of sustainable design being realised, and proposed a framework for this.

Blockchain and BIM can be used together in many fields such as pre-construction, procurement, and construction process, similar to the design process in construction projects. As can be seen from these mentioned studies, the combination of these technologies has the potential to reduce the main problems in the construction industry as well as facilitate their adoption.

## 4 Comparison of Smart Contracts and Traditional Contracts

This comparison was made to determine the potential advantages and limitations of smart contracts for the construction industry over traditional contracts, and it uses a number of measures such as payments, collaboration and trust, cost and time, possibility of mistake, archiving-backup and safety, prevention of bankruptcy; difficulty changing transactions, long-term trade relations, execution options, hacking and fund security, and legally binding and responsibilities.

### 4.1 Possible Benefits of Smart Contracts to the Construction Industry

It is anticipated that smart contracts will be able to solve or reduce some important problems and make a significant contribution to the project if their adaptation to the construction industry is provided. These possible main benefits are outlined below:

\* **Payments:** Payments are one of the main problems in the construction industry. It is thought that the most significant advantage of smart contracts will be in solving payment problems. The activities and milestones in the project compose smart contracts in the form of codes. Completion of these determined activities and milestones allows smart contracts activated by sensors to make payments instantly in the blockchain system [15]. This provides construction projects the opportunity to minimise payment-related disputes, one of the main problems encountered in traditional contracts.

\* **Collaboration and Trust:** On the basis of blockchain, transactions on the network require consensus. Therefore, project funds are not allowed to be managed by a single person or organisation as in traditional contracts [16]. This increases collaboration and trust among stakeholders while at the same time ensuring the protection of the rights of the parties.

\* **Cost and Time:** Since the execution of transactions is automatic in smart contracts, monitoring and execution process does not require human intervention. Thus, the need for monitoring and execution costs in the contract is eliminated [9]. In addition, the amount paid for transaction fees in smart contracts is much less than the transaction fee paid to the bank in traditional contracts [16]. They also prevent any friction that may arise between the parties accordingly. As a result, they contribute to shortening the project duration while reducing the project cost.

\* **Possibility of Mistake:** The formation of smart contracts from codes and automating the process of these codes eliminates possible errors during the preparation of contracts in traditional contracts. They also prevent a contract from being perceived differently by different people [1]. Thus, they provide the potential to reduce human errors as well as not requiring human intervention.

\* **Archiving, Backup and Safety:** While the parties archive and backup the data themselves in traditional contracts, smart contracts utilise features such as digital archiving, backup and cryptography which are at the core of blockchain. Whole stakeholders in the blockchain network can instantly access the project data and keep it in their archive. Also, the data is encrypted on each block through cryptography [17]. Thus, the project is rather protected against possible attacks.

\* **Prevention of Bankruptcy:** In traditional contracts, one of the main reasons for the bankruptcies of the construction companies is the lack of timely payments to the project parties, and the consequent deterioration of the cash flows of the companies. It is expected from smart contracts to guarantee the project funds, to ensure that the payments of project stakeholders and suppliers other than the client are made on time, and to protect the project stakeholders from bankruptcy. In addition, the instant realisation of payments will reduce companies' cash flow problems [18].

### 4.2 Limitations of Smart Contracts in the Construction Industry

The adoption of a new technology will induce with it some risks and limitations. These main risks and limitations are summarised below:

\* **Difficulty Changing Transactions:** Smart contracts do not offer the opportunity to change transactions in their current form. Considering that the blockchain is immutable, a change in contract is much more complex than standard contracts. The change in the contract will increase the transaction cost of the smart contracts which are normally more economical, and the margin of error resulting from the change [9]. Despite this disadvantage, as the use of smart contracts becomes widespread, such deficiencies could be expected to be resolved or reduced over time.

\* **Long-term Trade Relations:** The ability to conduct transactions automatically, seen as a key feature of smart contracts, restricts the flexibility in traditional contracts. For example, in a traditional contract, a short-term delay of payment can be tolerated when long-term trade relations among stakeholders are considered. The absence of such options available in a project that uses a smart contract is one of the main obstacles to their adoption [9].

\* **Execution Options:** Another limitation of smart contracts is execution options. Transactions in smart contracts are conducted on the consensus in the blockchain network. The fact that the command system is based on the "yes" or "no"

principle ("maybe" as a third option can be added in the future) restricts their use [1-7]. For example, "yes" or "no" options are offered to the parties as a payment option by smart contracts in the blockchain system for an identified expired job. If 95% of this job was completed within this time period, the option "no" is selected and no payment is made to the parties.

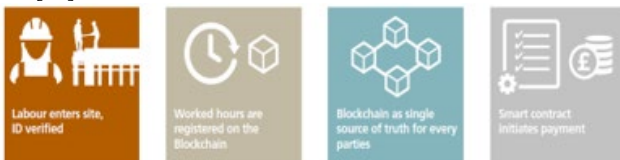
**\* Hacking and Fund Security:** Smart Contracts are much more resistant to tampering and hacking than other applications thanks to the cryptography feature of the blockchain. However, there are still gaps in the system and accordingly some cases of hacking have been encountered in some industries [10]. The fact that the entire project fund is in the system makes the issue even more critical.

**\* Legally Binding and Responsibility:** There is currently no legal binding available for smart contracts. In this case, in a project where smart contract is used, if the parties cannot agree on the contract, it causes the problem of which path to follow. It is an issue to be considered who will be responsible for the mistake that may occur in the project. It also includes legal and operational constraints such as what can be done in case of possible problems of sensors that will activate smart contracts and how this affects project stakeholders [19].

## 5 The Impact of Blockchain Technology on the Construction Process

The construction industry allows many professions to work together. Therefore, the performance data, identity and reliability of the contractors involved in the project must be verified [20]. This is very important for the project to continue as planned, especially in a special and complex project. Stakeholders involved in a project must verify their identity in order to access the blockchain system, otherwise they cannot access the project data. All transactions made in the blockchain system are recorded on the network in the form of chains. The tracking and performance analysis of the project can be done more easily by this feature. In addition, data such as working hours, breaks and wages of labourers can be calculated, and payments can be made automatically accordingly (Figure 2).

Figure 2. An example for the Use of Blockchain in Construction Site [21]



Working hours, breaks and wages of labourers can be kept under legal control and used as evidence in possible labourer-employer disputes. Furthermore, the transactions completed in the project require majority approval of the stakeholders in the system [7]. This allows for increased

collaborative work among the stakeholders while contributing to the reduction of possible disputes.

One of the most important features of the blockchain system is that it features cryptography. It is one-way encryption which adds to the security and privacy of the system. The blockchain system encrypts all transactions made in the system [4]. Thus, it is almost impossible to change or manipulate the data contained in the chain [22]. Each transaction performed is added linearly to this network in real-time and this network continuously expands depending on project progress.

Cost, duration and quality are the basic elements in the construction industry. The aim is to achieve maximum quality with minimum cost and duration. The fact that blockchain makes the project traceable and transparent contributes to the increase in quality. It also provides for more efficient material procurement [20]. Blockchain technology offers the opportunity to eliminate intermediaries by smart contracts while eliminating paperwork such as paper, invoices, documents [23]. As a result, it has a positive impact on project cost and duration [19].

## 6 Conclusion and Recommendation

Smart contracts are expected to offer benefits to construction projects on key issues such as timely payments; increasing collaboration and trust among stakeholders; optimizing project cost and duration; reducing error rates; archiving, backing up and security of data; and preventing bankruptcy of stakeholders involved in the project. On the other hand, since this technology is quite novel, it needs improvements to overcome the difficulty of changing transactions, to be adoptable to all payment conditions of traditional contracts (e.g. timing of payment, deduction of payment), to improve the security of the system, to formalise legal binding and responsibility in the project.

Smart contracts and blockchain have complementary features. Generally, blockchain facilitates collaboration and trust among the stakeholders while smart contracts execute the blockchain system. With the principle of working together, payments are made instantaneously and automatically.

The fact that Blockchain makes the project traceable, enables collaborative work and contributes to project security makes a significant contribution to the project in terms of cost, quality and duration.

Finally, the use of semi-automatic contracts in the beginning will contribute to the adoption of these systems, as it is quite difficult to change to smart contracts and the blockchain system in one stage. Furthermore, the implementation of these technologies primarily in small and simple-scale projects can ensure that possible limitations are seen more clearly and that the losses that can be experienced in the project remain at a low level. The fact that smart contracts

are based on sensors and blockchain consensus can make these technologies easier to use with BIM. Thus, this process will contribute more to the project efficiency in the construction industry.

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