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Smart Contracts in Construction from Management to Materials: Acting as a Bridge between the Two

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Abstract. The goal of this article is to demonstrate how smart contracts can be leveraged via blockchain technologies. This will enable us to create a bridge between management and the materials used in the construction industry. It is all too common for construction projects to encounter a number of problems along the way, including a lack of communication between builders, laborers, and vendors. As a result of these issues, the proposed timelines and quality of construction end up being compromised. Oftentimes, stakeholders involved in the project are not quite aware of the quality and quantity of materials that will be used to complete the project. It is precisely this problem that we aim to solve through the use of blockchain technology. As a result of the use of blockchain technology, smart contracts offer transparency and trust to their stakeholders. In order to achieve our primary objective, we intend to leverage the advantages of blockchain. This will enable us to ensure clear visibility of construction materials, deadlines, subcontractors and any other elements that are part of a construction project.

Introduction

The key to success is understanding the details and small pieces of a project and this is not different in large-scale construction projects either. These projects tend to take a lot of time. They bring together a lot of people in different forms such as employees or subcontractors. Communication is often not the most effective among them since the project is not always clearly defined and the requirements are not visible to all stakeholders. The smallest pieces in a construction project are the materials, which basically ensure the overall quality of the construction. If we want to harness trust and transparency in a construction project, we need to ensure that the materials used meet the necessary quality requirements. Our objective is to build a model that will leverage smart contracts supported by blockchain technology in order to create transparency and trust among its stakeholders.

In order to obtain a deeper understanding of the struggles that the construction industry faces, we conducted in-depth interviews as part of this research. The goal of the research is to propose, as a possible solution, a model that can serve as a basis for addressing each of these challenges.

Literature Review

Throughout the life cycle of a construction project, "information exchange across disciplines" needs to be supported by appropriate techniques, Celeck and colleagues argue in their article. New possibilities for data and process integration have emerged as a result of recent advances in Building Information Modelling (BIM), which uses open data formats, process mapping, and terminology. BIM data must be used consistently and traceably across multiple disciplines in construction projects. An example of this would be data objects or collections of attributes that are associated with a discipline or organization. Moreover, the information would be accompanied by a description of the transaction. Blockchain technology can be used to describe the discipline of issuance, the version, and the responsibility and liability of BIM objects. Blockchains provide stakeholders with enhanced security and can increase trust in BIM objects. To support the provenance of BIM data in construction projects, this paper proposes using Blockchain-based model information exchange. Stakeholders can

share BIM data more confidently, reduce costs, and mitigate risk with their proposed approach. This solution has been proven to identify competence levels in a real-world bridge construction scenario and to improve the implementation of BIM by testing the solution in a real-world bridge construction scenario [1].

Using BIM as an integrated smart contract progress payment administration system, Sonmez and collaborators present a novel system for the administration of progress payments based on the integration of smart contracts and building information models, where they use the real world and the blockchain to link both. During a survey of construction professionals, it was determined that the proposed system would significantly improve traditional payment procedures by speeding up the process. In addition, it would decrease the risk of disputes over progress payments, especially for lump sum projects. Researchers in the future can also investigate semi-autonomous BIM integrated smart contract systems to increase the adoption of BIM and smart contract technologies for construction progress payments [2].

[3] explores issues regarding BIM and design change management in the context of analyzing, managing, and visualizing design change. This paper discusses design change management using BIM in a concise manner. In addition, the authors briefly discuss the current developments in native BIM tools, as well as the functionality dedicated to design change management. This is tracking and analyzing design changes based on BIM models. A number of recent developments in design visualization are illustrated by a number of examples. Using BIM to maximize its potential can be achieved by automating or semi-automating analyses.

Blockchain Technology Overview. Blockchains have been described as distributed ledgers or append-only logs [4]. Its key feature is that it is distributed, meaning a single entity cannot add data to it from a centralized database. A chain of blocks is created using a cryptographic method. A consensus protocol is used when additional information needs to be added, which all peers need to agree on. Once an information block has been created, the so-called Merkle tree cannot be changed by cryptographic hashing. Essentially, the hash table is tamper-proof and transparent, since it contains a hash of the previous block for every block.

Consensus protocols will allow all nodes to agree on what information needs to be changed. For our model, we will focus on just a few essential protocols [5-7]. To begin with, there is proof of authority. To remain trustworthy, nodes must reveal their identities and register with a public notary database. Another aspect of a blockchain system is proof of work [8], which is the basis of most of them, including Bitcoin. An "zero-knowledge-proof" cryptographic puzzle must be solved to link two blocks collectively [9]. Every time the puzzle is solved, the difficulty increases, requiring more and more computational power to solve the puzzle. There are two additional protocols to be considered: proof of time elapsed and proof of activity [7, 10]. Our model will depend on these protocols to prove the time spent on a particular task, although they are not as essential as the previous ones.

Blockchains and Smart Contracts. Due to their inherent security and tamper-proof capabilities, smart contracts are used in various sectors around the world. Within the logistics industry, especially supply chain management, blockchain-centric solutions are used to communicate with distributed databases. Cybersecurity is today's biggest challenge for any industry. There is a great deal of concern about data theft and leaks. A smart contract may contain sensitive data, which could provide an advantage to anyone with access to it. Cybercriminals may also access large sums of money through these smart contracts, making them even more vulnerable. In comparison to other IT systems, blockchain technology is more resilient to cyberattacks because it is based on append-only permissions and has a distributed and resilient nature [11].

A smart contract can handle financial transactions between two parties (such as a currency exchange) based on the cryptographic features of blockchains [12].

Smart Contracts Models based on Blockchains. A similar model to the one we are proposing can be found in many other areas as well. This is, for example, the software industry [13], the electricity

bill business [14] and the utility business as a whole [15]. The construction industry faces similar challenges to these other industries, so we will propose a comparable solution.

Model Implementation

Problems that Smart Contract would solve in the Construction Industry. The following are the primary advantages of leveraging a smart contract:

1. It is all too common for information to be lost in construction projects. As a result, blockchain's distributed ledger can preserve life cycle information, which means warranties, certifications, and materials won't be lost. Regular evaluations of construction materials would ensure that maintenance is carried out correctly and on time.
2. Due to blockchain's decentralization, contracts are visible and searchable. In case of a problem, the contract can easily be traced back to its origin, preventing extra oversight.
3. We can easily verify that the quality of materials and work used by subcontractors meets government regulations, due to the open nature of smart contracts.
4. Using milestones in small contracts ensures that we only pay for what has been completed.
5. Due to the transparency of smart contracts, all parties are able to monitor the pieces and make suggestions and improvements where needed. All changes must also be approved by all stakeholders before the smart contract can be modified.
6. In complex construction projects, smart contracts can ensure that materials are efficiently and correctly used at all steps of the process.

Methodology

We conducted in-depth interviews with 16 individuals from different positions within the Hungarian construction industry, in order to achieve a better understanding of the struggles and needs of the industry. During these interviews, our primary objective was to determine whether or not our proposed model was something they would require in their daily processes. This was in order to accomplish their goals. We also sought to ensure that our proposed models would appear to fit into their daily activities, as a secondary objective. In order to meet the above-mentioned objectives, each interview was conducted online and focused on the above-mentioned goals. After the interviews were conducted, we transcribed the conversations and analyzed the data to identify patterns, themes, and insights based on the data that was collected. As a result of these interviews, the following topics arose: budget overruns, schedule delays, quality issues, changes in the scope of work, and disputes with various parties. A high level of transparency within the project roadmap was viewed favorably by all participants, as they considered it to be beneficial for the project as a whole. In addition, they consider trust to be one of the main pillars of a successful project, since it is the essence of all communication.

The proposed model acts as a bridge between multiple stakeholders within the construction industry rather than replacing existing workflows. Trust and transparency will be ensured. This model shouldn't negatively affect the team's daily process; it should actually improve performance and visibility. It is possible to ensure the success of a construction project by using the right materials in the right places. Additionally, maintenance costs can be reduced. Our proposed model consists of the following steps:

1. Smart contracts will connect the two parties. Sources and requirements for construction project funds will be loaded by the customer.
2. Together with subcontractors or its own employees, the contracted party will further define the construction project and divide it into smaller pieces. This involves specifying the quality and quantity of materials used.

3. Each element of the construction project will require cryptographic credentials. The project timeline, materials used, subcontractors, and known limitations would be included.
4. The parties involved must set joint milestones and ensure that the materials used meet the requirements of the law and the customer.
5. Each milestone will need to have acceptance criteria as this will ensure payments are made to the contractors and subcontractors.
6. In a smart contract, a milestone represents a payment transaction. It can only be initiated when both hashes extracted from the defined tasks are a match and the stakeholders accept the milestone.

All the above mentioned steps are presented in the below diagram (Fig. 1):

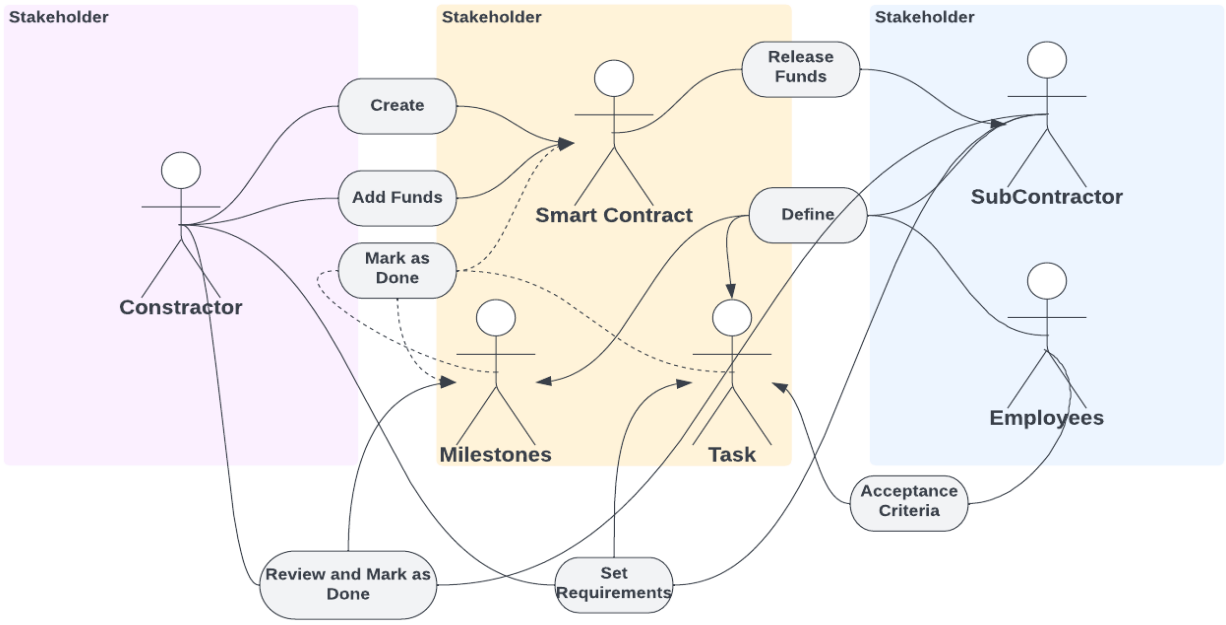

Fig. 1 The steps in our proposed model

Algorithm

Using the model above, the following pseudocode shows how our smart contract with blockchain would work in a real-world application. This pseudocode shows the major functionality of a smart contract that triggers a transaction and explains the key elements that should be included in a smart contract

create constructionIndustryPaymentContract {

define contractor(name, fundSource)

define theContracted(name, fundSource)

define workers(names, roles)

define subContractors(contractors, roles)

define task(ID, requirement, materials, acceptanceCriteria, employee)

function initiateFundTransfer(contractor, subContractors, task) {

```
        If contractor.acceptanceCriteria.meet and taks.acceptanceCriteria.pass
                amount = taks.acceptanceCriteria.pass.totalTimeSpent
            startFundTransfer(contractor.fundSource, theContracted.fundSource, amount)
        end
    }
    function startFundTransfer(contractorFund, theContractedFund, amount) {
        subtract(amount, contractorFund)
        pay(amount, theContractedFund)
    }
    }
```

Conclusions

A smart contract's quintessential part is to create trust between its stakeholders. Due to its transparency, blockchain creates an environment of trust, which is beneficial to any project, not just construction projects. In large-scale construction not all stakeholders have the necessary overview of the project to ensure that all used materials meet the requirements and demands of the contract and local laws. By leveraging smart contracts we solve exactly this issue and due to the contract's transparent nature we can always check and be sure that the used materials meet the necessary requirements. In addition to that, the in-depth interviews confirm the need for a similar model to be implemented within the construction sector as well.

Since a construction project is complicated enough on its own we do not wish to change the existing processes, only to support them. With our developed model and pseudocode, we just provide an additional layer of oversight for the project. It is imperative that our proposed model can be seamlessly integrated into the current workflow of the project.

We are planning to investigate different aspects of the construction industry in the future. We will tailor our model to each key aspect and not be too general as it is now. We acknowledge that human decision making plays a key role in establishing trust within a group, so our model does not aim to eliminate this aspect. We will simply strive to maximize trust levels.

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