How Can Blockchain Benefit Payment Systems in Smart Construction Contracts: A Brief Review

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Abstract. Construction industry professionals suffer regularly from poor cash-flow which reflects non-payment or payment delays down the hierarchical chain. This issue is important as the construction industry has the highest rates of insolvency in Australia, the UK and many other countries. Payment conditions under current construction contracts have proven to be inefficient in delivering timely payments as human interference has control over processing claims. This paper investigated the status of contracts and contract law in Australia and the potential of smart contract technology in improving payment issues in the industry. Qualitative data was collected from secondary literature sources which included observations from industry professionals, real case studies, secondary research and government surveys. It was found that smart contracts feature self-executing digital contracts, immutable data, require no intermediaries and provide transparency on all levels. Although these features are fit for purpose in resolving current contractual issues, smart contracts are not yet available in the construction industry. It was also found that smart contracts do have the potential to provide a trusted and reliable payment system in the construction industry, although there are some aspects it is unlikely to replace such as human performance. Research limitations and future research directions are also provided.

1. Introduction

There are issues with how organisations currently manage and distribute financial transactions for cashflow purposes. Ramachandra & BamideleRotimi [1] recognise payment delays to be caused by contractual disputes, unfeasible financial backing, unresolved disputes and the delay of payments from the initial stages of the supply chain causing a domino effect [1]. The current method for ensuring that payments are made on time and in full is for two or more parties to agree on terms and conditions which are bound by a contract. However, traditional building contracts have proven to be inefficient as clients or contractors often undermine claimants' rights by neglecting their obligations and exploiting their dominance by taking a more flexible approach to the contract [2]. Construction contracts in Australia are backed by the Building and Construction Industry Security of Payment Act [3] which ensures that any person who conducts work under a construction contract is entitled to receive and recover progress payments; moreover, regardless of progress payment provisions under a contract, a person is still entitled to statutory progress payments set by the Act.

The construction industry has a culture of aggressive and confrontational relationships as a result of inappropriate risk allocation due to the competitive nature of securing contracts [4]. This study aimed to investigate how blockchain technology can improve the current payment systems in smart contracts

in the construction industry. This paper first started with literature review on construction contracts including smart contracts, construction law on payment, performance irregularities on payment, and blockchain application in the construction industry. Then we explain how qualitative data was collected from secondary literature sources which included observations from industry professionals, real case studies, secondary research and government surveys. Results were analysed in the following section with findings presented in the same section. Last but not least, research limitations and future research suggestions are presented in the Conclusion section.

2. Literature Review

The construction industry has been described as having a culture of payment abuse that negatively impacts on quality, productivity and safety [5]. This leads to a litigious nature in the industry which can have destructive consequences depending on how disputes are handled. Poor cash flow in correlation with high-cash outgoings is considered to be partly responsible for the magnitude of construction insolvencies in Australia which indicates that claim-driven disputes are frequent. Claim-driven disputes occur when a claim is rejected by the other party and the rejection is not accepted by the claimant [2]. The uncertainty of timely claims makes the industry extremely vulnerable to delays in money owed. The following literature investigates the current payment system by looking into contracts, laws and performance. This leads to discussion on the potential of blockchain technology to improve the current payment system.

2.1. Construction Contracts

A construction contract is generally a safety mechanism to achieving profitability and reducing the chances of losses during a project if executed properly [6]. It is a consensual activity that involves an offer and acceptance type protocol which creates a legally enforceable agreement between two or more parties [7]. A construction project is a temporary mission to construct a product typically under the influence of three constraints which are usually scope, quality and budget [8]. If one of these constraints is amended, changes to at least one other will occur which could potentially go against one party and benefit the other.

2.1.1. Smart Contract. A smart contract is an application that uses blockchain technology to store a digital agreement between the parties involved without the need of an intermediary. A smart contract will ensure that currency, shares and property are exchanged according to the contract [9]. The terms of a contract are written into lines of cryptography which are stored on a distributed ledger or blockchain ready to automatically execute the contract by a consensus protocol [10]. The concept of smart contracts dates back to the early 90's where it was described as having the potential to minimise malicious and accidental behaviour but also to remove the need for a trusted third party. Smart contracts were proposed to provide automated services such as performing payment terms under the contract, ownership, confidentiality and prosecution measures which would see a drop in rates of fraud, arbitration and costs subject to enforcement [11]. A simple example of a smart contract is a vending machine where an amount of money is inserted, an option is chosen and in return the machine automatically performs its duty (i.e. agreement) and dispenses the item [12]. The automation of a smart contract is executed through a computer adding a code to a blockchain which is then verified by participating nodes on the network. These codes translate legal prose into the executable program which controls the physical or digital items that are rewarded at execution. If the conditions of the smart contract are not met, then the enforcement can be executed such as fines for late payments. Overall, a smart contract does not rely on a centralised entity to enforce legal penalties but instead a decentralised network that operates a consensus protocol [12].

2.2. Construction Law

It was found that retention monies owing was frequently delayed, along with final and progress payments. A recommendation from contractors and subcontractors to solve this issue was the use of

payment bonds, direct payments or the use of trust accounts. The method to this research was conducted using a survey style approach where contractors, sub-contractors and consultants participated [1]. This study provides understanding that even with the updated Security of Payments Act in place, it still does not solve the issue of payment delays. In some cases, payment delays are caused by intermediaries such as financial lenders who come under the "pay when paid" provisions which undermines the claimant's rights to progress payments.

2.2.1. Cash-flow and Intermediaries – Clause: Effect of "pay when paid" provisions. A 'Pay when paid' provision of a construction contract means that the liability of the first party (client) to pay the money owing to the second party is reliant on a third party (bank) to make the whole or any part of the payment. This essentially means that a client or contractor has no control over receiving remittances until the bank or financial institution (third party) is satisfied with the progress of the project as they hold the money borrowed making them liable. These terms would be contingent or dependent under the operation of a separate contract [3]. An issue recognised from the 'pay when paid' clause is that the third person or intermediary has control over of the remittances which could possibly lead to a delay in payments owed to the builder and furthermore have a knock-on effect on cash-flow throughout the supply chain.

2.3. Performance Irregularities on Payment

The performance of each party in a contract is a critical element to its success. Despite laws and regulations reinforcing obligations of a contract, there remains the risk of payments being delayed. There are many contributing factors to payment delays with most being related to the performance of the parties involved.

2.3.1. Intermediaries. A trusted intermediary such as a superintendent is meant to perform obligations to achieve successful completion of a contract, however, the contractual parties are at risk due to the superintendent's ability to exercise discretion. The risk of deviation from the superintendent may lead to unethical and underperforming contractual obligations [4].

2.3.2. Client. It has been recognised by researchers that disputes often occur due to default by the client and in turn contractors suffer from poor cash flow. Contractors can also be at fault which may lead to payment delays or non-payment with reasons such as incorrect valuation of work completed, or errors in submitted claims [13]. The supply chain of a construction project is entirely disrupted by a client's failure to pay the principal contractor on time which can cause delayed payments, project delays, reduced profitability and negative cash flow, which can lead to insolvency [13].

2.3.3. Contract literacy. It is believed that the most common causes of delay are a lack of understanding of contractual responsibilities and also the manner by which contracts are owner-dominated. Most claims relate to an owner not understanding contractual responsibilities of changes in site conditions, variations and delays which are usually resolved by negotiation, arbitration and adjudication [14].

2.3.4. Ambiguity. Ambiguous requirements in contractual documentation have been found to promote conflict, disputes and claims with ambiguity factoring around changes to bills of quantities, poorly written clauses, amendments to the scope of works and unrealistic demands in performance [15].

2.3.5. Unethical behaviour. Cashflow issues from payments withheld or refused are one of the leading causes of insolvency in the construction sector where even profitable companies can become insolvent if they do not receive timely payment of claims [16]. From a contractor's standpoint they have the burden of relying on slow paying clients or stakeholders but also, at the other

end of the supply chain, they have pressure from suppliers and sub-contractors who have submitted claims [17].

2.3.6. Communication. The construction industry is known to be the slowest in evolving digitized workplaces due to a lack of adoption in digital technology possibly stemming from workers facing physical and cognitive demands during everyday activities which affects the well-being and performance of those involved [18]. Physical demands such as manual labour in construction have always been part of the job, however, in recent years there has been a higher demand on the intellectual capacity of workers which is an issue that closely relates to the potential adoption of smart contract technology and how it may increase or reduce cognitive demands.

2.3.7. Complex technology. Smart contracts offer simplicity which is what most clients prefer given the choice, especially construction clients. An example of modern technology which has seen slow adoption because of its complex nature is Building Information Modelling (BIM); a virtual fully operational set of plans in a 3-Dimensional form. Although BIM has received praise for its abilities, it is considered a long-term investment which requires committed BIM professionals to operate the system [19].

2.3.8. Fraud. Contractors conduct fraudulent activities for many reasons such as an opportunity to gain personal wealth or because of poor financial management. A red flag in detecting fraud may be from: loss of owner's deposits or using deposits to fund other projects, delayed release of contractor's retention, other invoice abnormalities potentially from funding outside projects, or abusive change orders in terms of pricing and practices [20].

2.3.9. Contract incompleteness. Contract incompleteness refers to a contract that contains claims for multiple contingencies which limits a contractor to providing accurate costs, therefore opening themselves up to complex decisions, alternatives and consequences [21].

2.3.10. Compliance. Subcontractors and suppliers can cause significant payment inefficiencies from delaying a project by not meeting their quality and professional competence obligations. These two parties in the supply chain are known to be complex low transparent links that weaken the level of trust and the security of deliverables [22].

2.4. Blockchain Technology

The first real use case of blockchain technology (BCT) was in 2009 where an anonymous person or people (sometimes referred to as Satoshi Nakamoto) released a digital currency called Bitcoin which was described as being "a purely peer-to-peer version of electronic cash" allowing online payments to be sent from one party to another without the need for a financial institution [23, 24]. Double-spending is where the same digital cash can be spent more than once or at different locations simultaneously; this is made possible as the coding that banking institutions use can be duplicated or falsified unlike physical cash where a face-to-face exchange means that the payment is uncorrupted [25].

Blockchain technology is a new and promising technology that is recognised as being one of the most transparent, efficient and secure ways of transacting and storing digital assets. An extension of this technology is the early development of 'smart contracts' which are digital contracts. The principles of blockchain technology in conjunction with smart contracts are helpful in alleviating the uncertainty of payment claims received, provide transparency in context and ensure obligations are met. Given the current research of blockchain technology, it is suggested that integrated project delivery through smart contracts (blockchain) will allow multiple stakeholders (clients, contractors and subcontractors) to share and receive data (or payment transactions) without there being a dominant power to withhold transactions [26].

There are many studies on blockchain technology and smart contracts, many of which are related to its potential use to secure payments in the construction industry. However, little attention has been given

to the current payment systems and the weaknesses surrounding it. Moreover, the current contractual system has not been thoroughly investigated in conjunction with human intervention factors. These form the fundamentals for a discussion on the potential of current technologies to conduct automated and efficient payments, requiring no third-party such as banks or lawyers [16].

3. Research Method

Qualitative data were collected from secondary literature sources which included observations from industry professionals, real case studies, secondary research and government surveys. The below keywords have been used in a systematic literature review, researching resources provided by Scopus, Google Scholar, and government reports. The selection of appropriate resources was by applying key words to the online search engines mentioned above. To further refine the search, most publication dates ranged from the year 2017 and onwards with only selective literature dating back further due to relevance of the topic and information.

Relevant keywords used in literature search were: Construction contracts, Contract law, Smart contracts, Blockchain technology, Disputes, Ambiguity, Immutability, Trust, and Delayed payments. Around 80 journal papers were listed as the initial findings. After manually screening these papers, 31 were selected as the most relevant for this research and were reviewed in this paper.

4. Findings and Discussion

4.1. Issues with construction contracts

ASIC [27] reported in 2013 that the leading cause of failure was poor cash flow and high cash use which made up 43% of all cases. This strengthens the argument that there are deficiencies in the current payment system. Podvezko et al. [6] described a construction contract as being a safety mechanism for achieving profitability and mitigating losses. However the laws that regulate the current contractual system give no indication of reducing insolvencies in the construction sector, even with the latest amendments to the Security of Payments Act. The construction industry operates under a hierarchical chain of parties in which money is exchanged, with the financial lenders acting as intermediaries in the process. It is clear that owners or intermediaries dominate in withholding/delaying payments in the hierarchy. This is a leading cause of payment issues. There are many motives for owners to withold or delay payments, some of which are due to contractual misconceptions or unethical behaviours. Overall, human intervention is the leading cause of payment issues.

4.2. Blockchain solution in smart contracts

Blockchain's attributes of immutability, security and capability to efficiently share data are some of the features that solve the various issues facing the healthcare industry such as; medical device and drug tracing, interoperability and data interchange [28]. For these reasons, similar aspects of a contract could be used in the construction industry.

The potential advantages of smart contracts compared to conventional contracts are:

- They are not vulnerable to unlawful alteration or manipulation as the data stored in a blockchain is immutable, traceable and auditable which highly reduces the risk of fraud.
- Cost savings in administration and service fees by a protocol consensus that automatically distributes data or money through a peer-to-peer network, bypassing any intermediary.
- Business efficiency can be improved especially in the supply chain where financial authorization is automatically complete after peer-to-peer transactions, which removes the need for auditing, reducing the turnaround time for products or services to be delivered.

There are three main types of blockchain networks - private, public or consortium networks. These are all digital distributed ledgers with different levels of accessibility. A public blockchain is also known as a permission-less blockchain which allows anyone to participate in the network or access data [29]. For example, cryptocurrencies like Bitcoin use this digital ledger to promote transparency among its users allowing them to see its transaction history. A private blockchain is for participants who are authorized to join the network [30]. An example of this category is a smart contract which only allows those who form an agreement or those authorized under the digital contract to access the data stored on

the blockchain. A consortium blockchain is part private and part public with no single owner. The architecture of blockchain technology is made up of three main elements including the ledger (a distributed network of computers for storing data in chronological order), cryptographic keys and a network servicing protocol [31].

4.3. Comparison of traditional contracts and smart contracts in construction

The theoretical application of smart contracts indicates great potential in resolving issues surrounding the current payment system. A key fundamental of a smart contract is the decentralisation of the application which is contrary to traditional governance. A comparison of traditional contracts and smart contracts is presented in Table 1. This was conducted in relation to aspects of Governance, Payment claims, Fraud, Transparency, and Efficiency. It is apparent that smart contracts theoretically resolve most of the issues current contracts face. However, this comparison only identifies the possibilities as there are no case studies relevant to the construction sector. Notwithstanding this, the technology is in its early stages of development. Concerns over the maturity of blockchain technology have remained since the community backlash against Bitcoin in 2008. However, the potential of smart contracts and their ability to provide trust seems to outweigh public criticism.

Table 1. Comparison between Traditional and Smart Contracts in Construction

Issue	Contract Type	Comparison
Governance	Traditional contract	Requires an adjudicator or tribunal court system in dispute resolution. Intermediaries such as lawyers are an added expense. Time consuming.
	Smart contract	Permission-less consensus (anonymous run nodes automatically run the protocol). Time saving capabilities.
Payment claims	Traditional contract	Claims are reliant on the proprietor or a bank institution. Human intervention such as fraud, error or strategic management may cause delays in payments.
	Smart contract	The terms of a contract are automated and transactions are performed instantly. Peer-to-peer remittances means that intermediaries are not required.
Fraud	Traditional contract	Handwritten documents can be lost or open to fraud (e.g. forged signatures) and evidence can be difficult to gain access to. Duplicating invoices, unfairly back-charging subcontractors or abusive pricing in variations.
	Smart contract	Built on a private blockchain where the parties involved in the contract are able to access information efficiently. Immutable agreements are stored safely. Information on a distributed ledger can be accessed globally though computers without the need for a centralized data storage system or centralized administrator.
Transparency	Traditional contract	Ambiguity is caused by complex jargon. Misconception on the scope of works often leads to variations.
	Smart contract	Has the potential to redefine ambiguous content to reduce risk.

Efficiency	Traditional contract	Intermediaries interfere with authorization and audit processes. Procurement process in time consuming.
	Smart contract	Enhanced audit speed and process payments quicker via peer-to-peer transactions. Procurement time can be reduced. Dispute resolution time can be reduced.

5. Conclusions and Further Research

This investigation has found that the construction industry is extremely vulnerable to payment delays and non-payments. When comparing a current construction contract to a smart contract it is easy to recognise the potential of blockchain technology. However, the complex nature of human performance and their many variables complicate construction smart contracts. Their implementation is not as simple as the example of vending machine type contracts. Intermediaries play a major part in the payment system and could be responsible for some of the insolvencies in the industry. It is clear that the "pay when paid" clause has an effect on contractors and impacts on those further down the supply chain with the possibility of delayed remittances due to processing time. Analysis of the literature reviewed for this paper indicates that the construction industry's current contractual system is flawed, allowing acts of unethical or accidental behaviour which increases financial risk. Furthermore, in identifying the characteristics of blockchain technology and the abilities of smart contracts, it has been concluded that there is a need for such a system to be implemented in the construction industry as it promises great potential for payment security.

The limitation of the research is that it has focussed on exploring impacts of blockchain technology on the payment system in smart contracts. It leads to suggestions for future research directions. Future research could exam how blockchain benefits other aspects in smart construction contracts. Also, future research could be conducted on applications of blockchain in the construction lifecycle.

6. References

[1] Ramachandra T and BamideleRotimi J 2015 Causes of Payment Problems in the New Zealand Construction Industry *Construction Economics & Building* **15** 43-55

[2] Zhang L, Fu Y and Lu W 2021 Contract Enforcement for Claimants' Satisfaction with Construction Dispute Resolution: Moderating Role of Shadow of the Future, Fairness Perception, and Trust *Journal of Construction Engineering and Management* **147** 04020168

[3] Legislation N 1999 Building and Construction Industry Security of Payment Act 1999 No 46. NSW Legislation 46

[4] Wang B and Burdon M 2021 Augmenting Superintendent Discretion: Trustworthiness and the Automation of Construction Contracts *ANU Journal of Law and Technology* **2** 119-149

[5] Hurley J 2021 Builders pay a high price for payment delays: construction after grenfell The construction sector is mired in a damaging culture of withholding cash from suppliers, reports James Hurley [Scot Region] Times (London, England: 1788). London (UK), News International Trading Limited

[6] Podvezko V, Mitkus S and Trinkuniene E 2010 Complex evaluation of contracts for construction *Journal of Civil Engineering and Management* **16** 287-297

[7] Shash A and Habash S 2020 Construction Contract Conversion: An Approach to Resolve Disputes *Journal of Engineering, Project & Production Management* **10** 162-169

[8] Komurlu R and Arditi D 2017 The role of general conditions relative to claims and disputes in building construction contracts *New Arch-International Journal of Contemporary Architecture* **4** 27-36

[9] Fauziah Z, Latifah H, Omar X, Khoirunisa A and Millah S 2020 Application of Blockchain Technology in Smart Contracts: A Systematic Literature Review *Aptisi Transactions on Technopreneurship (ATT)* **2** 160-166

[10] Luu L, Chu D, Olickel H, Saxena P and Hobor A 2016 Making smart contracts smarter

Proceedings of the 2016 ACM SIGSAC Conference on Computer and Communications Security DOI: http://dx.doi.org/10.1145/2976749.2978309
[11] Szabo N 1994 Smart Contracts Available online at: http://www.fon.hum.5uva.nl/rob/Courses/InformationInSpeech/CDROM/Literature/LOTwinterschool2006/szabo.best.vwh.net/smart.contracts.html (accessed December 9, 2021)
[12] Raskin M 2016 The law and legality of smart contracts Available online at: https://georgetownlawtechreview.org/wp-content/uploads/2017/05/Raskin-1-GEO.-L.-TECH.-REV.-305-.pdf (accessed December 9, 2021)
[13] Mohamad N, Suman A, Harun H and Hashim H 2018 Mitigating delay and non-payment in the Malaysian construction industry. IOP conference series *Earth and environmental science* **117** 12037
[14] Kisi K, Lee N, Kayastha R and Kovel J 2020 Alternative dispute resolution practices in international road construction contracts *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction* **12** 04520001
[15] Koc K and Gurgun A 2021 Ambiguity factors in construction contracts entailing conflicts *Engineering, Construction and Architectural Management*, DOI: 10.1108/ECAM-04-2020-0254
[16] Ahmadisheykhsarmast S and Sonmez R 2020 A smart contract system for security of payment of construction contracts *Automation in Construction* **120** 103401
[17] Lowe J and Moroke E 2010 Insolvency in the UK construction sector Proceedings 26th Annual ARCOM Conference
[18] Rodriguez F, Spilski J, Hekele F, Beese NO and Lachmann T 2020 Physical and cognitive demands of work in building construction. *Engineering, Construction, and Architectural Management* **27** 745-764
[19] Mason J 2019 BIM Fork: Are Smart Contracts in Construction More Likely to Prosper with or without BIM? *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction* **11** 02519002
[20] DeFlaminis W, Bryant S, Cook J and Krischbaum D 2014 An ounce of prevention: A guide for combating fraud in construction *Construction Lawyer* **34** 1-12
[21] Cheung S and Pang K 2013 Anatomy of Construction Disputes *Journal of Construction Engineering and Management* **139** 15-23
[22] Wong A 1999 Total quality management in the construction industry in Hong Kong: A supply chain management perspective *Total Quality Management* **10** 199-208
[23] Nakamoto S 2008 Bitcoin: A peer-to-peer electronic cash system *Decentralized Business Review*, 21260
[24] Yaga D, Mell P, Roby N and Scarfone K 2019 Blockchain technology overview arXiv preprint arXiv:1906.11078
[25] Chohan U 2017 The double spending problem and cryptocurrencies Available at http://dx.doi.org/10.2139/ssrn.3090174
[26] Elghaish F, Abrishami S and Hosseini M 2020 Integrated project delivery with blockchain: An automated financial system *Automation in Construction* **114** 103182
[27] ASIC 2014 Insolvency statistics: External administrators' reports (July 2013 to June 2014) Available at: https://asic.gov.au/regulatory-resources/find-a-document/statistics/insolvency-statistics/insolvency-statistics-series-3-external-administrator-reports/
[28] Bell L, Buchanan W, Cameron J and Lo O 2018 Applications of blockchain within healthcare *Blockchain in Healthcare Today* DOI: https://doi.org/10.30953/bhty.v1.8
[29] Li X, Jiang P, Chen T, Luo X and Wen Q 2020 A survey on the security of blockchain systems *Future Generation Computer Systems* **107** 841-853
[30] Nanayakkara S, Perera S and Senaratne S 2019 Stakeholders' perspective on blockchain and smart contracts solutions for construction supply chains The CIB World Building Congress 2019, DOI:10.6084/m9.figshare.8868386
[31] Eenmaa-Dimitrieva H and Schmidt-Kessen M 2019 Creating markets in no-trust environments: The law and economics of smart contracts *Computer law & security review* **35** 69-88