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POTENTIAL IMPACTS OF BLOCKCHAIN TECHNOLOGY IMPLEMENTATION ON CONSTRUCTION CONTRACT MANAGEMENT IN SRI LANKA

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ABSTRACT

The construction contract is the mainstay for the ascendancy of the construction project requiring proper contract management. The Sri Lankan construction industry has many complications associated with contract management. Blockchain, as a decentralised transaction and data management technology, can potentially address the issues related to contract management amidst the impediments to effective implementation. However, blockchain technology adaptation in the Sri Lankan construction industry lacks evidence, even though other sectors, for example, banking and agriculture, are with the initial implementation. Hence, this research aimed to identify the potential impacts of implementing blockchain technology in construction contract management in Sri Lanka. A literature review was conducted to identify the concept of blockchain technology, its applications and its benefits. A qualitative survey strategy was adopted, and data were collected via semi-structured interviews in two phases; Phase I with ICT and finance industry experts and Phase II with construction contract experts. Samples were selected purposively through snowball sampling. The data analysis revealed that the awareness and use of blockchain technology in Sri Lanka are relatively low. However, Sri Lanka has the potential to adopt Blockchain in different fields, depending on their capabilities. Furthermore, the study found associated positive impacts of Blockchain, e.g., avoiding complex procedures, providing transparency, no ambiguities, no human errors and reducing political influence to mitigate contract management issues. Besides, Blockchain may negatively impact due to, e.g., high initial and maintenance costs, lack of knowledge and expertise, unavailability of rules and regulations, and reluctance to change those need mitigations.

Keywords: *Blockchain Technology; Construction Contract Management; Smart Contracts; Sri Lanka.*

1. INTRODUCTION

Construction is a dynamic industry with complicated and distinctive nature having many constraints and stakeholders. One of the specific requirements of the construction industry is to adjust quickly to new circumstances within the fast-changing environment (Hanisch et al., 2009, as cited in Mesaroš et al., 2018). Innovative tools and applications

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such as the Internet of Things (IoT), Building Information Modelling (BIM), and general digitalisation help achieve construction project goals more effectively (Mesaroš et al., 2018). Even though there is a significant opportunity and possibility for enhancing the process of construction projects through digitalisation, it is one of the last industries to go digital (Mesaroš et al., 2018). Recently, the construction industry tried improving its procedures while mitigating their challenges, e.g. lean construction and BIM. However, still, there are issues in supply chain management in the construction industry due to a lack of trust and transparency (Hamma-Adama et al., 2020). Hence, the construction industry faces several challenges regarding information sharing, trust and process automation (Wang et al., 2017).

Blockchain is one of the most significant technological breakthroughs in recent years, influencing the productivity of construction projects and possessing a key feature of enabling trust (Sarmah, 2018). Hence, participants do not need pre-existing trust relationships if the construction business or activities are carried out on a blockchain system. In addition, Blockchain can be used in various ways due to its unrivalled security and ability to provide a comprehensive solution to digital identity issues (Sarmah, 2018). There are several domains where blockchain-based applications are emerging, including reputation systems, financial services, the IoT (Zheng et al., 2017), smart property, cybersecurity, cloud storage and provenance, blockchain healthcare, intellectual property and smart contracts (Rawat et al., 2020). Blockchain-enabled applications can also assist contract administration by using smart contracts, financial management without the involvement of third parties, subcontractor management by linking payment schemes, asset management by tracking movements of materials and purchase control by linking key stakeholders in supply chains (Hewavitharana et al., 2019). Furthermore, due to the immutable data record, Blockchain can reduce the risk of disputes and litigation compared to conventional methods (Wang et al., 2017).

Some Sri Lankan organisations are currently at the testing, initial implementation, or use stage of blockchain technology only for a few products/services. For instance, the Central Bank of Sri Lanka has completed the Proof-of-Concept project enabling efficient and secure sharing of Know-Your-Customer (KYC) information between banks (Central Bank of Sri Lanka [CBSL], 2021). Although foreign banks currently use blockchain-based cryptocurrencies for transactions, Sri Lankan banks have little trust in the technology's ability to execute payments (Gunasekara & Sridarran, 2021). However, no organisation has completely adopted Blockchain due to several reasons, e.g. the lack of understanding, unavailability of technological facilities, organisational and environmental barriers, a lack of isomorphic pressures, and a lack of trust among stakeholders, etc. (Gunasekara & Sridarran, 2021). Moreover, due to potential issues and a lack of proven models, blockchain adoption in the supply chain and logistics in Sri Lanka is also slow (Madhunamali & Jayasena, 2020).

On the other hand, with a young workforce and an expanding population, Sri Lanka, as a developing country, has much to gain from the Blockchain (Madhunamali & Jayasena, 2020). Even though other sectors in Sri Lanka, e.g. banking and agriculture, have begun adopting blockchain technology, the construction industry lacks evidence. Hence, the Sri Lankan construction industry is identified as an industry with less adaptation to new technologies (Weerakoon & Chandanie, 2021). According to Nitharsan and Francis (2022), the urge to adopt blockchain applications outweighs their readiness in the Sri Lankan construction industry. However, as discussed, blockchain-based contract

management is a disruptive innovation that can transform how the construction sector does business. Hence, this research aims to identify the potential impacts of implementing blockchain technology in construction contract management in Sri Lanka.

2. LITERATURE REVIEW

2.1 BLOCKCHAIN TECHNOLOGY AND ITS APPLICATIONS

Blockchain can be defined as a distributed database of transaction records that are checked and updated by a worldwide network of computers (Sarmah, 2018). It also refers to a distributed data storing method for synchronising, sharing, and replicating data dispersed over numerous places, nations, or organisations (Perera et al., 2020).

There are many common advantages of blockchain technology. E.g. hacking threats will be reduced to a greater extent (Geroni, 2021), audibility is high (Makadia, 2022), supports the creation of new classes of applications and business models (Kriptomat, 2022), and democratising (Bertagnoli, 2022). Further, there are disadvantages such as. high implementation costs (Budhi, 2022), high energy consumption (Song et al., 2016), slower than centralised databases (Song et al., 2016), and speculative markets (Fauvel, 2017).

Blockchain has several applications for a transparent, verifiable register of transaction data, mainly on a decentralised platform with no need for centralised control and is, therefore, resistant to fraud (Martin, 2018). Blockchain-based solutions are being developed and commercialised by numerous organisations from various industries to upend current business procedures or practices (Martin, 2018). Table 1 summarises how the researchers discussed the application of blockchain technology in different fields and related areas.

Table 1: Fields and areas of blockchain technology application

Reference	Construction	Finance	Supply Chain	Health Care	Legal Applications	Manufacturing	Transportation	Food & Agriculture	Insurance	Real estate	Advertising, media and entertainment
Nofer et al. (2017)		✓			✓				✓		
Balint (2018)		✓		✓			✓		✓		
Makridakis & Christodoulou (2019)			✓	✓							✓
George et al. (2019)		✓	✓		✓						
San et al. (2019)	✓										
Bodkhe et al. (2020)		✓	✓	✓		✓		✓			
Rawat et al. (2020)		✓	✓	✓				✓		✓	✓
Perera et al. (2020)		✓		✓			✓	✓			
Baiod et al. (2021)		✓	✓	✓	✓				✓	✓	✓
Javaid et al. (2021)				✓		✓		✓			
Kosala et al. (2021)	✓										
Nitharsan & Francis (2022)	✓										

2.2 BLOCKCHAIN IN THE CONSTRUCTION INDUSTRY

The construction sector has constantly been challenged to increase productivity and efficiency while embracing opportunities brought by disruptive technologies. Blockchain

is the most recent technology that has started the construction industry's digital transformation (Hewavitharana et al., 2019). Blockchain application is projected to enhance the accuracy of the construction project data and their management through the concepts such as 'peer-to-peer networks, public-key cryptography, consensus algorithm, and hashing algorithm, establishing a transparent and high-security data storage platform throughout the lifecycle of construction projects (Gamage et al., 2020).

Perera et al. (2020) identified that many possible blockchain applications exist for the construction industry in supply chain management, building information modelling, payment management, document management, stakeholder management, waste management, and contract management.

2.3 CHALLENGES IN CONSTRUCTION CONTRACT MANAGEMENT

Contracts are extremely vital in construction projects with big targets, extended implementation times, and complex coordination relations (Zheng, 2018). Construction contracts are agreements, either oral or written, between owners and contractors for construction and/or maintenance work performed for remuneration, consisting of five stages: proposal, design, award, construction, and completion (Phillips, 2009). Further, construction contracts are required to control and manage the project design, bid package preparation, contract award, compliance, progress, spending, timetables, inspection, completion, and acceptance in a standard, orderly, and effective manner (Phillips, 2009). Therefore, managing construction contracts has a high standing in construction projects with high technical requirements, complex construction, enormous investments, a significant social impact, and a long life cycle (Wang, 2020). Further, construction contract management should also consider being implemented in compliance with the appropriate laws and rules in the contract. However, construction contract management also involves several challenges identified in the literature as shown in Table 2.

Table 2: Challenges in construction contract management

Challenges	Ref.
Lack of supporting laws and policies and lack of legal awareness of parties to the contract	[1] [5]
Inadequate supervision	[2] [5]
Poor planning	[2] [4]
Delay in approvals	[2] [4]
Delayed payments	[2] [3]
Lack of skilled and trained professionals	[3] [6]
Insufficient use of technology	[3]
Poor communication across parties	[5]
Misunderstanding of roles and responsibilities by professionals	[6]

Sources: [1] Zheng (2018), [2] Memon and Rahman (2013), [3] Ahmed (2015), [4] Alzara et al. (2016), [5] Surajbali (2016), [6] Gunduz and Elsherbeny (2020)

2.4 THE NECESSITY OF BLOCKCHAIN FOR CONSTRUCTION MANAGEMENT

Technology has advanced to help construction projects lessen their associated problems through applications like Blockchain. According to Kosala et al. (2021), traceability, accountability, transparency, fast transactions, and trust are the main benefits of implementing blockchain technology in the Sri Lankan construction industry. Blockchain technology can help contract execution by optimising and ensuring a transparent

information flow during the various stages of the construction process (Pattini et al., 2020).

Blockchain technology introduced the 'smart contract', a digital contract that can be automatically carried out when certain circumstances are satisfied (Balint, 2018). Smart contracts refer to transactions beyond the basic buy/sell currency transactions and may have more detailed instructions (Swan, 2015).

Table 3: Benefits of using smart contracts

Benefits	Szabo (1994)	Swan (2015)	Pattini et al. (2020)	Alzara et al. (2016)	Hughes (2017)	Hewavithar ana et al. (2019)	J. Wang et al. (2017)
Reduces the need for trusted intermediaries	✓	✓					
Minimises malicious and unintentional exceptions	✓			✓			
Forms automatically and without human intervention		✓					✓
Funds can be embedded into the contract, and payments can be automatically released at the end of each project verification cycle			✓	✓			
Ensuring participants' maximum fairness in the tender stage			✓			✓	
Transform contractual clauses into computational language expressions		✓	✓				
Tenders can process immutably and transparently			✓				
Save significant time for contract registration, monitoring, and updating				✓			
Reduce the inherent risks under contract administration planning and data hoarding					✓		
Avoid unnecessary costs for written text, legal consultation, and contract document drafting						✓	

Table 3 summarises the benefits of blockchain technology applications, e.g. smart contracts for construction contract management. Accordingly, a smart contract is an automated transaction mechanism that carries out a contract's provisions in a way that satisfies standard contractual requirements (Szabo, 1994), abandoning opportunistic behaviour due to the free interpretation of clauses in a traditional contract (Pattini et al., 2020). It saves contract registration, monitoring, and updating time as a tamper-proof system (Wang et al., 2017). With smart contracts, various contractual terms can be rendered entirely or partially self-executing and self-enforcing (Nitharsan & Francis, 2022).

Accordingly, the inherent properties of blockchain-based smart contracts, such as traceability, immutability, and security, create greater cooperation and transparency between project stakeholders (Ernst & Young Global Limited, 2018). Hence, blockchain technology provides several benefits and helps mitigate issues in construction contract management if adequately implemented. Therefore, this study aims to identify the potential impacts of implementing blockchain technology in construction contract management in Sri Lanka.

3. RESEARCH METHODOLOGY

A literature review investigated current knowledge of Blockchain and its implementation in the construction industry. Since Blockchain is a new concept and its inside is lacking among Sri Lankan construction industry experts, finding a reliable large sample was difficult for quantitative data collection. Hence qualitative data were collected using semi-structured interviews with experts. Due to the nonuse of Blockchain in the Sri Lankan construction industry, finding two or more independent sources for data collection was difficult. Hence, a mono-method qualitative choice was adopted. Figure 1 shows the research process of the study.

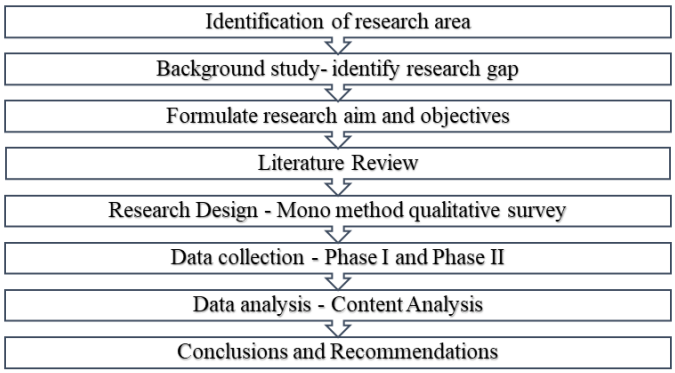

Figure 1: Research Process of the Study

Data were collected in two phases; Phase I focused on other industries those already initiated blockchain technology to find the awareness, features and use of Blockchain in Sri Lanka and to get opinions on blockchain adoption in the Sri Lankan construction industry. Phase II interviews were with construction industry experts to investigate the issues in construction contract management and to identify the potential impacts of Blockchain in construction contract management in Sri Lanka.

The non-probability purposive sampling method is used to select the interviewees for Phases I and II interviews and further used snowball sampling. Pre-defined criteria were also used when selecting samples of both phases, as shown in Table 4.

Table 4: Selection Criteria for Interviewees

	Phase I	**Phase II**
Education qualification	A bachelor's degree	A bachelor's degree
Industry Experience	5 years or more	10 years or more
Knowledge on	ICT (Blockchain)	Construction administration and ICT
Socioeconomic status	Professional	Professional

Table 5 presents the coding and profile of Phase I and Phase II interviewees used for data analysis.

Table 5: Codings and Profile of Interviewees

	Interviewee ID	**Organisation**	**Designation**	**Area of expertise**
Phase I	BE1	Consultancy	Managing director	Software development and digital marketing
	BE2	Consultancy	Director	Technology and resource planning

	Interviewee ID	Organisation	Designation	Area of expertise
	BE3	Banking	Senior assistant director	Software engineering and finance
	BE4	Trading	Software quality engineer	Software development
Phase II	CE1	Contractor	Deputy general manager	Project management
	CE2	Contractor	Quantity surveyor	Quantity Surveying
	CE3	Consultancy	Senior quantity surveyor	Construction Administration
	CE4	Consultancy	Director	Civil engineering
	CE5	Consultancy	Assistant director	Project management

All the interviews were audio recorded with the interviewees' permission and transcribed for data analysis. This study has employed a manual content analysis method to analyse qualitative data collected from interviews, as per Krippendorff (2004).

4. DATA ANALYSIS AND DISCUSSION

4.1 AWARENESS AND THE CURRENT USE OF BLOCKCHAIN IN SRI LANKA

The awareness of Blockchain in Sri Lanka is low. Interviewees disclosed the lack of awareness. For instance, BE1 stated*, "in Sri Lanka, there are professionals who have never heard of the word blockchain*". The awareness is not up to the required level to effectively apply Blockchain in Sri Lanka, as highlighted by BE2 saying, *"there should be great awareness of blockchain to apply in Sri Lanka"*. According to BE4, *"Sri Lanka is prevented from taking full advantage of the new technology due to not keeping pace with digital advancements and continuing to require paper-based documentation*". Therefore, *"it will be good to have some plans from the government to initiate the technology first"* [BE4].

Although the awareness of blockchain technology in Sri Lanka is minimal, according to BE4, *"the awareness is yet to gain momentum, and few organisations have considered adopting initial-level implementations*". BE4 pointed out, *"some banks are doing proof of concept to understand how they can leverage blockchain"*. For instance, *"blockchain technology has been introduced to payments and banking through 'Know Your Customer' projects"* [BE3].

It was also suggested that Sri Lanka has the potential to adopt Blockchain in construction. For example, "*Blockchain can be applied to the construction industry due to the benefits to contract management and supply chain*" [BE3]. BE1, BE3, and BE4 identified "Smart Contracts" as one of the blockchain-based applications that can create a boom in the construction industry. BE4 stated that blockchain technology is good for the construction industry because the transactions of construction projects are massive amounts.

There are requirements to fulfil when properly implementing Blockchain in any industry in Sri Lanka. For instance, BE3 warned about government initiation and support conditions since specific organisations cannot easily implement them independently. Further, BE 1 stated, *"Sri Lanka will benefit from blockchain if there is a proper governance model"*. Sri Lanka can benefit from Blockchain in several ways. E.g. *"Blockchain is great because records and transactions cannot be changed, only updated so that it can reduce corruption and fraud*" [BE1].

Figure 2 summarises the findings from Phase I.

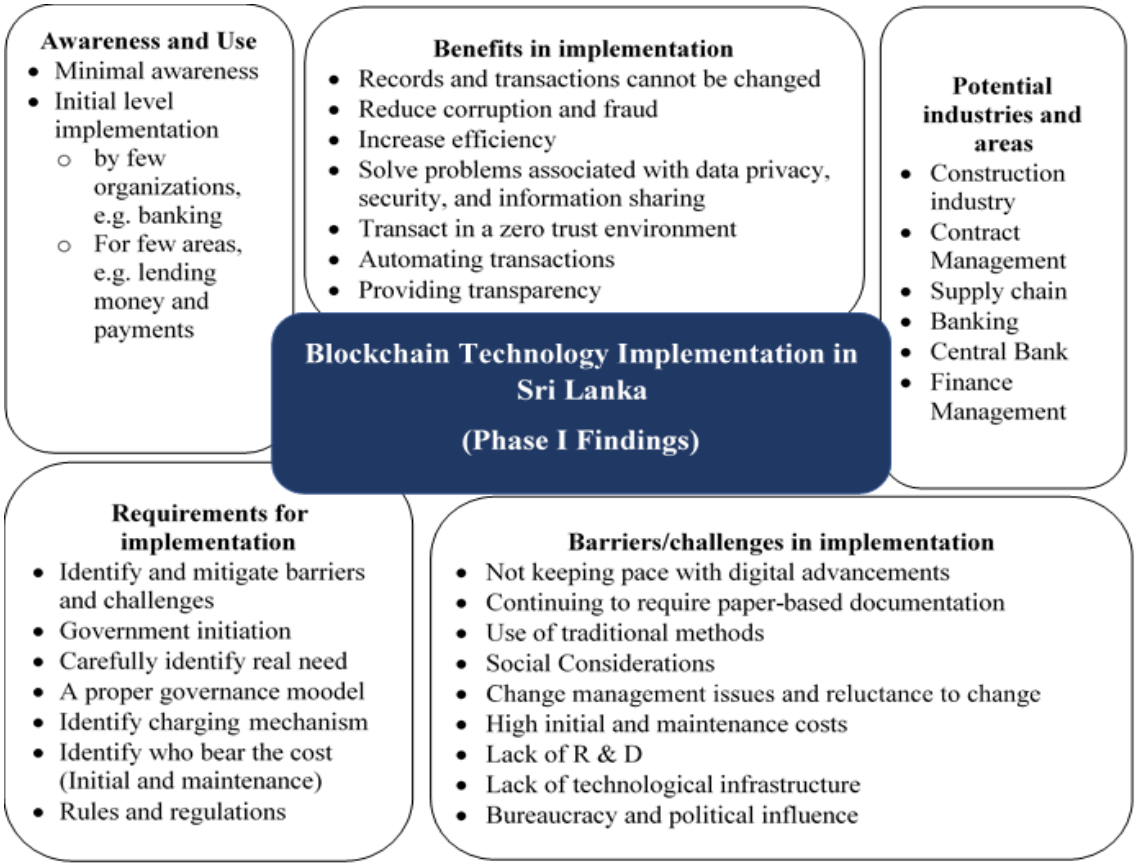

Figure 2: Summary of Phase I findings

As per Figure 2, there are barriers to implementing Blockchain in Sri Lanka. E.g. lack of research and proper investigations [BE1, BE2] and lack of technological infrastructure [all Phase I interviewees], social barriers [BE4], Bureaucracy and political influence [BE1, BE3], use of traditional methods and lack of technological knowledge [all Phase I interviewees], and reluctance to change [BE3, BE4].

All Phase I interviewees suggested that the construction industry has the potential to use blockchain technology for managing financial activities and contracts since it is currently suffering from numerous issues. Moreover, Phase I findings provided different aspects to be considered when implementing Blockchain in any industry (Figure 2). E.g. the requirements to be fulfilled to successfully implement Blockchain and challenges to implementing Blockchain.

4.2 CONSTRUCTION CONTRACT MANAGEMENT IN SRI LANKA

As per findings, contract management is one of the most important areas of a construction project. CE2 stated, *"Contract gives the basis for all the phases of a construction project, preconstruction, construction and post-construction stages"*. The contract ensures legal enforceability, providing vital protection for all stakeholders in a construction project. *"The most important part of contract management is the legal relationship between the parties to the contract"* [CE2, CE3, CE5].

Contract management handles parties' obligations to the contract as per all Phase II interviewees. According to CE1, *"Contract management prevents conflicts and resolves many more disputes"*. CE4 expressed, *"Contract management provides a clear line of*

accountability, decisions and its impact". Subsequently, as per Phase II interviewees, contract management ensures value for money and maintains a project's time, cost and quality. As per the findings, some issues related to construction contract management in Sri Lanka are listed in Table 6.

Table 6: Issues related to construction contract management in Sri Lanka

Construction contract management issue	CE1	CE2	CE3	CE4	CE5
Complex procedures	✓	✓			✓
Lack of structure	✓	✓			✓
Excessive documentation	✓	✓	✓	✓	✓
Poor Communication	✓	✓		✓	✓
Unethical acts like fraud and bribery	✓	✓		✓	✓
Defining and tracking contract costs					✓
Maintaining unwritten contracts	✓				✓
Outdated boilerplate language and ambiguities in the contract	✓			✓	✓
Poor handling of contract stakeholders		✓		✓	✓
Errors in decision-making ability				✓	
Requirement of legal assistance		✓	✓		
Issues in payment (e.g. payment delays)			✓	✓	

4.3 POTENTIAL POSITIVE IMPACTS OF BLOCKCHAIN ON CONSTRUCTION CONTRACT MANAGEMENT IN SRI LANKA

As per Phase II findings, blockchain-based smart contracts ensure the time-saving of a project in many ways. E.g. CE2 stated that the traditional use of documents could be reduced via blockchain technology. In addition, CE4 mentioned, *"Through smart contract physical presence can be minimised which saves time and money"*.

According to CE1, CE2 and CE5, smart contracts can contain functions that trigger conditional actions. CE5 gave an example, *"if one party clears their payments, the contract can self-close or inform all the parties involved in the smart contract"*. In addition, CE3 stated, *"Blockchain will prevent overpayments and repetitions, and thus avoid financial issues"*. All Phase II interviewees accepted that Blockchain restricts unethical acts and corruption. CE3 confirmed, *"corruptions and frauds in the construction can be minimised with the adoption of blockchain"*.

Finally, the solutions from blockchain technology for the identified issues of construction contract management were analysed from Phases I and II and presented in Table 7.

Table 7: Solutions to construction contract management issues in Sri Lanka

Construction contract management issue	Solutions from blockchain technology As per Phase I and Phase II findings
Complex procedures	The use of smart contracts will avoid complex procedures
Lack of structure	Use of smart contracts which automate procedures
Excessive documentation	Use of smart contracts which does not comprise complicated documentation
Poor Communication	Use of Blockchain, which shares data in a distributed and transparent way
Unethical acts like fraud and bribery	Solve problems associated with data privacy and security Provide transparency

Construction contract management issue	Solutions from blockchain technology As per Phase I and Phase II findings
Defining and tracking contract costs	Use of Blockchain, which keeps track of all transactions among network participants
Maintaining unwritten contracts	Use of smart contracts which only allow digitalised data
Outdated boilerplate language and ambiguities in the contract	Use of smart contracts which does not comprise ambiguities
Poor handling of contract stakeholders	Use of smart contracts which automate procedures and build trust among stakeholders
Errors in decision-making ability	Use of smart contracts which does not comprise human errors
Requirement of legal assistance	Use of smart contracts which does not comprise third-party involvement (e.g. political influence)
Issues in Payment	Use of Blockchain, which allows peer to Peer transactions and does not comprise third-party finance institutes Reduce corruption and fraud Increase efficiency and transparency

Accordingly, blockchain technology implementation impacts construction contract management positively in several ways by providing solutions for the issues and problems in construction contract management in Sri Lanka (Table 7). Further, it offers benefits like time-savings, reduced physical presence and avoiding corruption.

On the other hand, Phase II findings explored some negative impacts of implementing blockchain technology in construction contract management in Sri Lanka due to several barriers. All Phase II interviewees stated that the lack of technological infrastructure is one of the barriers. For example, CE1 stated, *"Practising blockchain in construction contract management in Sri Lanka is questionable due to lack of required facilities."* Further, it was emphasised that a lack of expertise also would be a barrier to implementing Blockchain. CE4 expressed, *"It will be difficult for construction companies to handle blockchain-based applications due to skill and education gap"*. CE4 highlighted their experience *"when implementing Enterprise Resource Planning; we were struggling to find experts in IT and related field*s".

Difficulties in integrating the Blockchain into the existing systems, being expensive, time-consuming [all interviewees], lack of awareness among stakeholders [CE2, CE4, CE5] and unavailability of rules and regulations [CE1, CE3, CE5] were also identified as barriers. CE3 pointed out, *"Although blockchain can be used for financial transactions, digital currencies are still legally unregulated in Sri Lanka"*. CE1 stressed, *"lack of awareness and experience to handle these technologies may create even more disputes"*. However, CE5 stated*, "conducting awareness programs will be an additional cost"*.

Therefore, CE2 mentioned, "*We have to think separately about how this technology will affect our time and cost management"*. According to all the interviewees, the Sri Lankan construction industry still has to become competent to adopt blockchain technology. Thus, CE4 suggested the need for comprehensive research studies on blockchain implementation in the Sri Lankan construction industry. CE2 emphasised the requirement of including blockchain technology in the higher education system.

5. CONCLUSIONS

This study aimed to identify the potential impacts of implementing blockchain technology in construction contract management in Sri Lanka by collecting qualitative data via interviews in two phases.

Accordingly, blockchain technology is an emerging technology possessing prominent characteristics such as immutability, transparency, improved security and privacy, and traceability. Hence it provides several benefits and allows many applications. Literature review and empirical findings identified that blockchain technology use and awareness are minimal in Sri Lanka, with few initial implementations in, e.g. banking, finance and ICT industries. Moreover, Phase I data analysis provided details on current awareness and use, barriers/challenges, benefits and requirements for implementing blockchain technology in Sri Lanka (Figure 1). These aspects of Blockchain can be used by academia to gain further knowledge of Blockchain concerning different industries.

Phase II identified the current issues related to construction contract management in Sri Lanka, e.g., complex procedures, excessive documentation, unethical acts and maintaining unwritten contracts. Implementing blockchain technology would positively affect construction contract management by mitigating its issues through, e.g. maximised transparency, eliminated ambiguities, no human errors, minimised corruption and increased efficiency. On the other hand, barriers such as lack of technological infrastructure, lack of awareness and absence of rules and regulations will negatively affect the implementation of blockchain technology in construction contract management in Sri Lanka. Accordingly, construction industry practitioners can identify benefits and barriers when implementing Blockchain. This study suggested enhancing blockchain technology awareness in Sri Lanka by including it in Sri Lanka's higher education system. The qualitative findings of this study require validation through quantitative results in future. Further research is necessary to find strategies to mitigate the negative impacts of implementing Blockchain in the Sri Lankan construction industry.

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