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ADAPTABILITY OF BLOCKCHAIN-BASED E-PROCUREMENT SYSTEM IN SRI LANKAN CONSTRUCTION PROJECTS

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ABSTRACT

E-procurement and Blockchain are relatively new technologies that have the potential to provide a variety of benefits due to their unique features such as transparency, decentralized approach, immutability, and consensus. The Sri Lankan construction industry is corrupted and that drives up construction costs, which are then passed on to the general public. Procurement plays a major role in construction projects as it is the basis of any transaction. E-Procurement is one of the recent technologies used by modern businesses to save time, money, and effort. Therefore, the current research aims to investigate the adaptability of e-procurement using Blockchain technology in the Sri Lankan construction industry. A mixed research approach was adopted including a questionnaire survey and semi-structured interview. A total of 55 questionnaires were distributed among experienced professionals, and 37 responses were received. The data collected from the questionnaire survey were analysed using Relative Important Index (RII) and Gap analysis. For the interview, total of 5 professionals who have experience in procurement and tender management were drawn through the snowball sampling technique to identify the strategies for the adoption of Blockchain based E-procurement. The survey found that there is a gap between the desirability and readiness for Blockchain adoption. In addition, the eight important drivers and barriers to the adoption have been identified. As a result, from an organizational and governmental perspective, measures must be designed and implemented to overcome barriers and enhance readiness levels, so closing the gap between desirability and readiness. Finally, based on the findings, strategies for improving the readiness of Blockchain-based E-Procurement practices in the Sri Lankan construction industry were identified.

Keywords: *Blockchain; E-Procurement; Payment Management; Smart Contracts; Supply Chain Management.*

1. INTRODUCTION

As a result of the rapid uptake of ICT in Sri Lanka which is fuelled by the COVID-19 pandemic, its impact on the construction industry also cannot be neglected. The research problem arises from the fact, people in the construction business are of the opinion that the Sri Lankan construction industry is complexed and that drives up construction costs, which are then passed on to the public (Hadiwattege, et al., 2010). The works of Eadie, et al. (2011) revealed that the involvement of different parties and less defined specifications with unknowns makes construction procurement more complex and unique than the general types of goods and services procurement. The digitization of public

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procurement is gaining traction around the world, and the reason has been attributed to how procurement is handled by various public institutions, which has led to corrupt practices in which funds set aside for development initiatives end up in the pockets of public officers (Ogunlela Oyebanjo, et al., 2021). Algama (2017) quoted that "Some of the contracts appear to have been awarded without observing the fundamental principles of governance in procurement such as transparency and accountability.

Nicoletti (2020) noted that it is critical to improving the procurement sector's effectiveness, efficiency, and economics to satisfy the rising need for adding value and delighting consumers by using all an industry's operations. A blockchain is a digital record of transactions that are replicated and disseminated throughout the whole network of computer systems on the blockchain, making it difficult or impossible to modify, hack, or defraud the system (Christidis and Devetsikiotis, 2016). Blockchain technology is very reliable because of its six major components such as decentralized, transparent, open-source, autonomous, immutable, and anonymous. Because of blockchain's immense potential, every agreement, process, task, and payment in the world would have a digital record and signature that could be recognized, validated, stored, and shared, eliminating the need for intermediaries like lawyers, brokers, and bankers and allowing individuals, organizations, machines, and algorithms to easily transact and interact with one another (Marco and Lakhani, 2017). As a result, the introduction of blockchain technology has a beneficial influence on how businesses conduct procurement, resulting in greater opportunities for worldwide development and expansion (Akaba, et al., 2020).

Management of government money and budget clearances used to be a nightmare in traditional public institutions, making it a time-consuming endeavour to secure the necessary approvals from the many government departments (Ogunlela Oyebanjo, et al., 2021). Further, they argued that these issues, however, can be overcome by creating a blockchain system, in which funds can be allocated practically instantaneously following approval by the appropriate authorization levels. The businesses are adaptive, dynamic, and will collaboratively operate in an open and free environment globally soon and the question is whether the participation of the Sri Lankan construction industry is guaranteed? Change in procurement must become faster in responding to organizational needs, more networked, more agile because of the effort stemming from the fourth industrial revolution (Nicoletti, 2017). There were few studies conducted in terms of EP in Sri Lanka. Therefore, to improve the transparency, traceability, and security of electronic procurement using blockchain technology, the current study aims to investigate the adaptability of EP using Blockchain technology in the Sri Lankan construction industry.

2. LITERATURE REVIEW

2.1 INTRODUCTION TO BLOCKCHAIN

The blockchain is a safe and efficient distributed ledger system for sharing data across multiple geographical locations without a single point of control, eliminating intermediaries, and ensuring trust in an untrustworthy environment (Guegan, 2017). Blockchain is a technology that allows you to copy, distribute, synchronize, and analyse data that is scattered over various sites, countries, or companies (Nanayakkara, et al., 2019). In his research, Gaikwad (2020) identified six properties of Blockchain, which are described below:

- Immutability - The block that is created in blockchain cannot be updated or altered at any time. Every block has a different hash value. To change a single block on the blockchain, a person would have to change every single block after it.
- Anonymity - One of the most critical aspects of blockchain security is anonymity. The identity of the user conducting the transaction is unknown. Although the user will be linked to a public address, no one will know the user's real identity or address.
- Decentralization - Decentralization allows transactions to be done directly between users without the involvement of a third party. This increases financial efficiency and reduces people's reliance on banks and other financial institutions.
- Transparency - The transparency of blockchain technology is one of its major advantages. The foundation of blockchain transparency is having the same records dispersed across a broad network for everybody to see.
- Persistence - As agreed by consensus, blockchain will not produce or maintain incorrect transactions. The blocks created are cryptographically locked in the chain, making it difficult to delete, change, or copy previously created blocks and place them on the network. This results in the creation of digital assets, as well as a high level of reliability and trust.
- Auditability - Blockchain can be used as a distributed ledger to record and verify transactions between two parties. Auditors can immediately verify transactions on publicly accessible blockchain ledgers instead of requesting bank statements from clients or submitting requests to third parties.

According to Niranjanamurthy, et al. (2019), blockchain technologies can be divided into three types namely; public, private and consortium as described in Figure 1.

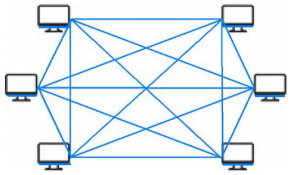
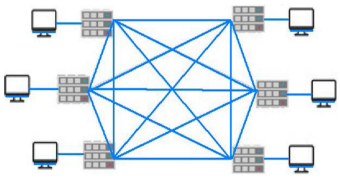
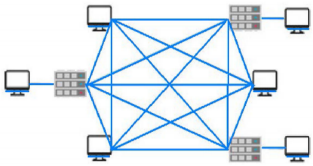
Public Blockchain	**Private Blockchain**	**Consortium Blockchain**
		
Anyone can go through the transaction and verify it, as well as participate in the consensus process. Bitcoin and Ethereum, for example, are both Public Blockchains	Node participation will be restricted; not every node will be able to join in this Blockchain, which will have rigorous authority management over data access.	This indicates that the node with authority can be chosen ahead of time, usually has business-to-business connections, and the data in Blockchain can be open or private, making it partially decentralized.

Figure 1: Different types of blockchain

Source: Niranjanamurthy, et al. (2019)

At its inception, blockchain was conceived as a public ledger that allowed everyone access to the ledger network's history and the ability to check the history of transactions (Kwak, et al., 2019). It is more dependable and preserves a modest level of privacy when compared to the private blockchain (Venkateswara, et al., 2018). Private Blockchain technology can be used to transcend these constraints and set up a distributed network only for authorized members (Kwak, et al., 2019). Through a simple application program

interface (API), any private blockchain may be connected to a block bench and benchmarked against workloads based on real and synthetic smart contracts (Dinh, et al., 2017). A consortium blockchain is a type of blockchain that includes features from both public and private blockchains. Rather than an open system in which everyone can access the ledger or a closed system in which only authorized parties are allowed, the consortium blockchain relies on a small number of equally strong parties serving as validators (Zhong, et al., 2020).

2.2 OVERVIEW OF BLOCKCHAIN-BASED E-PROCUREMENT

Many countries throughout the world have profited from government EP (Electronic Procurement) because it allows the government to provide more convenient and widely available government services in a more efficient, cost-effective, and sustained way (Premathilaka and Fernando, 2018). Batenburg, (2007) elaborated that EP is one of the most recent technologies used by modern businesses to save time, money, and effort. The blockchain is a safe and efficient distributed ledger system for sharing data across multiple geographical locations without a single point of control, eliminating intermediaries, and ensuring trust in an untrustworthy environment (Guegan, 2017). There are various applications and services linked with blockchains and distributed ledgers that contribute to their use, such as applications that operate over blockchain networks and allow users to interact with them easily (Lemieux, 2017).

2.2.1 Smart Contracts

Smart contracts, which are self-executing contracts written into a blockchain network, enable confidence in a trustless internet environment without the need for an intermediary (Alharbyet al., 2018). Lemieux (2017) stated that smart contract code governs which transactions and what information is stored in the blockchain. Furthermore, many types of contractual conditions can be made partially or entirely self-executing and self-enforcing with smart contracts. Smart contracts are programmed to commence payments based on the number of hours worked and the timely delivery of deliverables, resolving late payment and cash flow difficulties (Penzes, 2018).

2.2.2 Payment Management

Incorporating a blockchain-based platform into the project execution process, which can begin payments based on digitally approved work, contractual terms, and smart contract activities, is one of the most appropriate uses of blockchain in the construction industry (Penzes, 2018). Implementation of smart contract-enabled blockchain payment applications can provide greater trust in transactions with automation and effective operation to mitigate payment-related issues in the procurement process (Samudaya, et al., 2019). As there is no involvement of a third party in the transactions, the procedure is considerably easier and faster than the traditional method, which will increase the construction organization's productivity in terms of cash flow management (Hewavitharana, et al., 2019).

2.2.3 Supply Chain Management

With many internal and external suppliers connected through dynamic and lengthy supply chains, the construction industry produces one of the most complex and largest objects (Perera, et al., 2017). A supply chain is a network of numerous organizations' activities

that are linked as upstream (suppliers) and downstream (customers) to deliver items or services to the ultimate consumer (Mentzer, et al., 2001).

3. RESEARCH METHODOLOGY

A mixed-method was adopted to the current research as it requires to collect qualitative data and quantitative data from the professionals who have knowledge in blockchain and its application. However, the professionals with such profile are limited in Sri Lankan construction industry. Initially, a questionnaire survey was carried out to identify significant drivers and barriers for the adoption and to identify the readiness and desirability of the Sri Lankan construction industry. Survey provides a relatively quick and efficient method of assessing information about the population (Kelley, et al., 2003). Surveys allow the collection of a large amount of data from a significant population in a highly economical way. Often obtained by using a questionnaire administered to respondents. Further semi-structured interviews were carried out to investigate the strategies to overcome the barriers to adoption and to reduce the gap between desirability and readiness. Semi-structured interviews helped to collect in depth views of professionals regarding the implementation of Blockchain application in Sri Lankan construction industry. Table 2 provides the relevant work experience of the respondents and the response rate of the respondents to the questionnaire survey results.

Table 2: Experience and response rate of respondents for the questionnaire

Relevant Experience in years	Distributed	Received	Response rate
0-5 years	25	17	68%
6-10 years	25	17	68%
Over 10 years	5	3	60%
Total	**55**	**37**	**67.27%**

For the questionnaire survey, a total of 37 responses were received out of 55. Survey results of barriers and drivers were analysed using RII and gap analysis between readiness and desirability of the adoption. Subsequently, five experienced professionals were interviews and their profile is given in Table 3.

Table 3: Profile of the interview respondents

Respondent Code	Designation	Years of Experience	Scope of work
A	Tendering Section Head	7	Estimation; Tender management; Procurement management
B	Assistant General Manager	10	Estimation; Contract management; Procurement management; Tendering
C	DGM of Contract Management	15	Precontract management and overall scope of contract organizing
D	Project Manager	10	Project Management; Contract Management
E	Senior Quantity Surveyor	8	Tendering; Cost estimating; Claim management

In terms of years of experience, all the interviewees were possessed with adequate industrial experience in pre and post contract phases to contribute to the study

with their technical and professional know-how. Moreover, all the interviewees are chartered quantity surveyors and had exposure to the fields of project management, procurement management, and contract administration, so they were able to enlighten the study with their peculiar expertise. Thus, this profile of information of research participants indicates that the collected data are reliable.

4. RESEARCH FINDINGS

4.1 SIGNIFICANT DRIVERS AND BARRIERS FOR ADOPTING BLOCKCHAIN-BASED E-PROCUREMENT

A questionnaire was created to discover the most important drivers and barriers for the Sri Lankan construction sector to adopt Blockchain-based EP. Respondents were given a Likert scale ranging from 1 to 3, denoting great importance for each driver and barrier. Table 4 presents the significant drivers to adopting Blockchain-based EP.

Table 4: Significant drivers to adopting Blockchain-based E-procurement

No.	Drivers	RII
1	Administration cost savings	0.838
2	Enhanced (automated) decision making and market intelligence	0.829
3	Improved inventory management and contract management	0.829
4	More transparency throughout the process	0.820
5	Competitive edge in procurement	0.811
6	Cost and time savings in the entire procurement process	0.811
7	Better utilization of all parties	0.802
8	Increased efficiency and enhanced quality of outputs	0.802
9	Errorless process flow	0.802
10	Improved management and control of procurement system	0.784
11	Improved dispute resolution	0.784
12	Communication and collaboration effectiveness and enhancement	0.775
13	Simplified and streamlined process flow	0.766

All the drivers in Table 4 have a level of significance of RII value of 0.75 or above. According to the questionnaire survey, administration cost savings is the biggest driver for adoption. Because in construction organizations, administration cost is attached to every procurement which increases the bid price and creates ineffective expenses. Contractors unnecessarily suffer different types of administration costs during a construction project which include a huge part in the procurement. According to (Golosova and Romanovs, 2018), Blockchain technology minimizes costs as well as legal and bureaucratic barriers, which require a long time to process and begin transactions in a banking company. The second most selected driver is Enhanced(automated) decision making and market intelligence. The enhanced and automated decision-making will improve the efficiency and accuracy of the construction procurement process in a greater sense. And it is essential to create a feedback loop that constantly analyses the rules against the results they create to build a self-learning, self-correcting system. Each action is recorded on the Blockchain, and the data of records are accessible to all Blockchain

participants and cannot be modified or deleted, providing transparency, immutability, and trustworthiness to the Blockchain (Bahga and Madisetti, 2016). Transparency is another important driver which will greatly contribute the Blockchain adoption. With Blockchain decentralization, the transparency of the transactions can be heavily improved without any fraud activities in the procurement process. Along with that, cost and time savings in the procurement process will be another major driver in adapting Blockchain-based EP.

Along with that, cost and time savings in the procurement process will be another major driver in adapting Blockchain-based EP. The time taken by a construction project is far higher than the general industrial procurement. Therefore, many different professionals involved in the procurement process will make the procurement process very time-consuming. If the procurement process time increase, it is natural that the cost of the procurement process also will increase. In most construction procurements, the client and consultants suffer more time and cost in the procurement process even before the construction projects start. And during the bidding process, different contractors who bid on the project also will go through the time extensions and other costs related to procurement. By simplifying the procurement process by adopting Blockchain technology the actual time and cost can reduce to the minimum level which is beneficial to all main parties of procurement such as the client, consultant, and contractor.

Improved management and control of the procurement system, improved dispute resolution, communication, and collaboration effectiveness and enhancement, and simplified and streamlined process flow does not have much significance as drivers in adopting Blockchain-based EP. Since construction procurement is complicated and can't be simplified into a single streamlined process due to the involvement of various factors. Respondents have stated that the effectiveness of communication and collaboration won't be a significant driver due to the reason that, Blockchain technology does not directly improve the communication and collaboration in the procurement process. When considering the dispute resolution in the construction process, even though the Blockchain process can help to reduce disputes it is not enough significant driver to adopt Blockchain technology. In adopting any new technology, the drivers must surpass the barriers of the adoption. In adopting Blockchain technology, the advantages of Blockchain will be the main drivers and according to the survey, it is clear there are the most significant drivers of adopting Blockchain-based EP in the Sri Lankan construction industry.

Table 5 shows the barriers in adopting Blockchain based EP in Sri Lanka.

Table 5: Significant barriers to adopt Blockchain-based E-procurement

No.	Barriers	RII
1	IT infrastructure	0.757
2	Software capabilities of integrating internal and external issues related to Blockchain and EP	0.748
3	Absence of an accepted standard	0.748
4	Lack technical expertise	0.730
5	Issues in collaboration, communication, and coordination in the supply	0.721
6	Security of transactions	0.694

No.	Barriers	RII
7	Lack of training of the staff	0.685
8	No absolute business benefit	0.685
9	Unreliability and lack of confidence on new technologies	0.676
10	Cost concerns are associated with the system implementation, internet services, and initial cost	0.667
11	The legal position of Blockchain and EP	0.667
12	Lack of support from the upper management or authorities	0.658
13	Resistance to change	0.631
14	Interoperability concerns	0.514

Although the Sri Lankan construction industry is knowledgeable about Blockchain and EP, the numerous benefits it can provide, the adoption and use of Blockchain-based EP are hampered by several obstacles. It is necessary to research the importance of these stumbling blocks. Table 5 shows the RII values for the key impediments found through the questionnaire survey.

According to the survey, the most significant barrier is the IT infrastructure necessary for Blockchain-based EP. To use Blockchain technology, an IT infrastructure is required. Although Blockchain offers considerable cost and time advantages, the high initial capital cost may be a deterrent (Niranjanamurthy, et al. 2019). The country's present information technology infrastructure does not satisfy the standards for implementing new information technology-based technologies. The government urgently must establish a strong information technology infrastructure in general, and it must achieve a particular degree of maturity before implementing a complicated and sophisticated technology like Blockchain. Because Blockchain code is publicly available and they become autonomous entities once they are created, smart contracts can be vulnerable to hackers (Gatteschi, et al. 2018). Sri Lanka's IT industry is now through new stages of development, most notably in the construction sector. Governments and other private entities have also initiated the move to electronic procurement and the implementation of new electronic procurement capabilities. Even if there is a barrier, it can be overcome rather quickly. Sri Lanka's government must provide standard IT knowledge and embrace and practice more technological features to increase IT infrastructure standards. Another important significant hurdle is software capabilities for merging internal and external issues related to Blockchain and EP. Even while certain industrial procurements have been converted to EP using basic software, Blockchain requires sophisticated cryptography software to implement any Blockchain-based procurement application. The lack of an acknowledged standard is the next big stumbling block. The Sri Lankan construction sector has developed some fundamental norms for electronic procurement for government projects, but none for Blockchain technology. If the construction industry is to accept new technologies, it is critical to have well-defined standards in place, at the very least for government construction projects. Another stumbling block for Blockchain-based applications is a lack of technical expertise. Due to the absence of technical understanding of construction professionals and technical practice in Sri Lanka, the construction sector lacks technical experience in Blockchain. The other five barriers, such as cost concerns related to system implementation, internet services and initial cost, the legal position of Blockchain and EP, lack of support from upper management or authorities, resistance to

change, and interoperability concerns, are considered minor barriers due to their lower RII value survey score. Nonetheless, these considerations must be considered for the adoption of Blockchain technology.

4.2 GAP ANALYSIS BETWEEN THE LEVEL OF READINESS AND DESIRABILITY OF BLOCKCHAIN-BASED E-PROCUREMENT APPLICATIONS IN THE SRI LANKAN CONSTRUCTION INDUSTRY

To enhance Blockchain-based EP procedures in the Sri Lankan construction sector, it is critical to assess if the construction industry is willing to use Blockchain-based EP. Even though generally construction business is desirable to adopt new technologies, there is a need to explore the readiness in terms of financial, legal, organizational, and technological competence for improved acceptance and usage of Blockchain-based EP applications by these Sri Lankan construction organizations.

As a result, the respondents were asked to indicate their preparedness by considering their technological, legal, organizational, and financial capabilities, as well as their desirability by considering their willingness to use Blockchain applications that relate to procurement. A Likert scale was created, with values ranging from 1 to 3, with 1 denoting low level, 2 denoting medium level, and 3 denoting high level. The arithmetic average was used to calculate the spread of respondents' readiness and desirability scores for each application of Blockchain-based EP. For a better understanding of the gap between readiness and desirability, the quantitative data acquired for readiness and desirability were evaluated separately. The desirability and readiness of Blockchain-based EP applications are depicted in Figure 2.

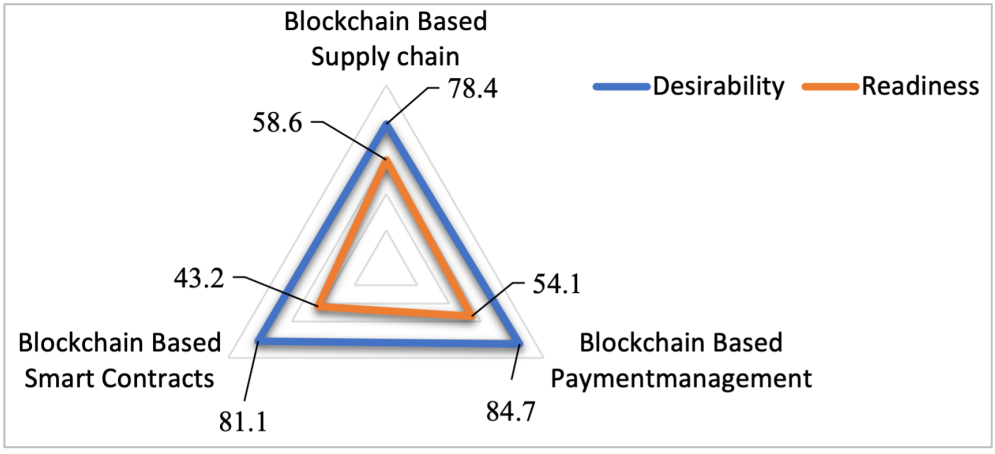


Figure 2: Gap analysis between the level of readiness and desirability of Blockchain-based E-procurement applications in the Sri Lankan construction industry

According to the survey results, respondents believe that the desire to use Blockchain applications is greater than their readiness to do so. Blockchain-based payment management is more desirable than the other two applications in terms of desirability. The increased awareness of payment management systems, which was also highlighted in the last data collection, is the cause of this desirability. According to the survey, the Blockchain-based supply chain system is the least popular of the three applications. In terms of construction sector readiness, the survey shows that the supply chain is the readiest for adoption. The payment management application is the next application with the readiest. Blockchain-based smart contracts have the lowest adoption readiness.

A deeper understanding of Figures 2 reveals that the gap between desirability and readiness of the Sri Lankan industry is lesser across all tools of Blockchain. The supply chain management application has the smallest gap between readiness and desirability among these three applications, but it is also the least desired. As a result, it is hard to conclude that supply chain management has a higher likelihood of adoption than the other two applications. As a result of study findings, payment management appears to have the next smallest gap, making it a preferable alternative for initial adoption when comparing other applications. Smart contracts based on blockchain have the largest gap in all three applications, indicating the least likelihood of adoption in the Sri Lankan construction industry.

4.3 SUGGESTIONS FOR THE SRI LANKAN CONSTRUCTION INDUSTRY TO OVERCOME THE SIGNIFICANT BARRIERS ASSOCIATED WITH THE ADOPTION OF BLOCKCHAIN-BASED EP

The list of barriers impeding the adoption of Blockchain-based EP in the Sri Lankan construction industry was determined using the survey. Interviewees were asked to summarize their reactions to the findings on key hurdles and to provide suggestions on how to decrease such barriers. All significant challenges and ideas raised by interviewees are compiled and presented in a tabular manner below for simple comprehension.

Table 6: Summary of strategies to weaken the barriers to adoption

Barriers	Strategies to overcome the barriers
IT infrastructure and Software capabilities for integrating internal and external issues related to Blockchain and EP	• EP to all government projects • More research and education on new technology developments • Backend-as-a-Service (BaaS) • Awareness programs regarding new technologies
Absence of an accepted standard	• Borrow from other countries and customize • Creating and testing new standards for government projects • Collaborating with international construction organizations
Lack of training of staff, lack of technical expertise, and lack of knowledge	• Top management accountability and support • Recruitment of skilled and technically sound people • Training and knowledge sharing from system providers • Continuous professional development • Incorporation to curriculum
Absence of a nationwide framework and policies for collaboration, communication, and coordination	• Policies to ensure continuous project flow • Centralized EP portal or framework for all Government projects • An effort from Private construction organizations
Security of transactions and system	• Complex passwords and usernames • System suppliers' built-in security system • Security features embedded into the system must be made aware of and updated regularly. • Regulation by the Central bank in the transaction history

Barriers	Strategies to overcome the barriers
No Absolute business benefit and lack of confidence in new technologies	• Creating awareness programs through CIDA • Actual project implementation and use as a model to attract more private businesses

5. CONCLUSIONS AND RECOMMENDATION

As detailed in the introduction, the underutilization of Blockchain technology and EP by the construction industry has been identified, as the need for initiatives to improve Blockchain-based EP practices in Sri Lanka's construction industry. As a result, the goal of this research study was to improve the construction sector of Sri Lanka's Blockchain-based EP practices. The literature review has highlighted Blockchain-based EP applications which include smart contracts, payment management, and supply chain. The survey was used to identify nine important drivers and barriers to adoption. The survey was also employed to determine the readiness and desirability of three applications in the Sri Lankan construction industry. The results showed that the Sri Lankan construction industry has higher overall desirability and low readiness to adopt Blockchain-based EP. Further, it demonstrated the gap between desirability and readiness was comparatively high across all three Blockchain applications. Due to this reason semi-structured interviews were conducted with construction industry experts to identify the strategies for weakening the barriers for adopting Blockchain-based EP. Experts believe that bridging the gap between the desire for Blockchain-based EP and the preparedness of the Sri Lankan construction sector is necessary for its effective implementation. Expert views were used to develop ways to decrease important hurdles and close the gap between readiness and desire, and it was discovered that they must be complemented by government-led and organizational actions. Furthermore, it has been stated that gap closing is linked to the decrease of obstacles to adoption. The strategies shown in Table 6 were developed using the results of expert interviews. The Sri Lankan construction industry will need to do more research and development, and the government will need to raise awareness of Blockchain applications. Further, the industry needs to try standardized and regulated common platforms from the government which provide an easy way to use and costs much lesser than customized systems for each different organization. Government Authorities and Regulatory Bodies need to set future goals and support the Sri Lankan construction industry to enhance Blockchain and EP.

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