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EVALUATING BLOCKCHAIN IN CONSTRUCTION SUPPLY CHAIN MANAGEMENT

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ABSTRACT

The supply chain in the Architecture, Engineering, and Construction industry is often perceived as inefficient due to a lack of data and traceability links. This study investigates the practitioners' understanding and acceptance of blockchain to address this inefficiency. A survey is conducted to glean expert opinions concerning implementing blockchain technology in the Construction Supply Chain Management (CSCM) domain. The research hypothesizes that professionals are open to blockchain technology adoption and that this adoption positively impacts four variables that represent the primary factors that can be implemented using blockchain technology. The One-Sample Test of Means is then used to evaluate the four identified variables against the hypotheses. Survey findings reveal that CSCM experts are knowledgeable about innovative technologies such as blockchain and believe that all characteristics of blockchain should be considered during implementation. Findings also show that most experts acknowledge that their current CSCM systems disregard blockchain entirely.

KEYWORDS

Blockchain, Supply chain, Smart contract, Lean construction, Trust.

INTRODUCTION

The Architecture, Engineering, and Construction (AEC) industry confronts various difficulties, including supply chain fragmentation, insufficient information and manufacturing traceability integration, and lack of innovation (Koskela, 2000; Hamzeh, 2021). Construction Supply Chain Management (CSCM) regulates managing the movement of information, money, and materials throughout the lifecycle of a project (Vaidyanathan & Howell, 2007). Modern Supply Chain Management (SCM) practices advocate executing the supply chain as a continuous value creation stream rather than a collection of discrete processes (Vrijhoef et al., 2001). SCM suffers from insufficient standardization and process integration, resulting in an inability to meet industry requirements (Atiq et al., 2021). Papadopoulos et al. (2016) highlighted further shortcomings in existing CSCM practices, including lengthy design processes, document modifications, and frequent misunderstandings. Finally, a lack of trust and transparency,

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combined with the current payment methods, contributes to the current CSCM's inadequate performance, which blockchain technology (BCT) might assist in addressing (Shemov et al., 2020).

With the dawn of Lean construction 4.0, the urge to integrate smart technologies and digitalization to boost performance and production while eliminating waste is more crucial than ever. While there are multiple ways to increase the "Leanness" of CSCM, one of the most promising means is the use of blockchain technology to decrease waste and increase value (Tezel et al., 2020). Although blockchain is a relatively novel technology that has not been widely embraced in the construction sector, it can help improve the business considerably, particularly in the CSCM domain (Tezel et al., 2020). A blockchain is a decentralized system that stores and manages information and transactions (Dakhli et al., 2019). Blockchain technology saves data in blocks that build a chain of blocks that records each piece of data (Mason, 2017). Once added, records can only be modified by impacting all the primary data, which exceptionally can be used for corporate processes or developing decentralized currencies (Baumers & Holweg, 2019). Nawari and Ravindran (2019) provided an overview of blockchain technology and its uses in the AEC industry and possible inclusion in the Building Information Modeling (BIM) procedure. Their research examines how blockchain technology may benefit the BIM process by focusing on network security, offering more reliable data storage and traceability, using Smart Contract technology, and verifying data ownership (Nawari & Ravindran, 2019).

According to the emerging literature, the most common application of blockchain that is increasingly being used in supply chain processes is digitalization, transparency, visibility, and smart contracts (Nabipour & Ülkü, 2021). Perera et al. (2021) investigated the principles of blockchain technology and its advantages. They regarded Decentralisation, Immutability, Transparency, Security, Auditability, and Trust are features of blockchain-based procurement procedures in the AEC sector. Wang et al. (2019) indicated that blockchain applications in construction management might be used to authenticate documents, automate payment and processes, and increase transparency and traceability. CSCM involves many documents, such as design documents, blueprints, terms and conditions, contracts, and agreements. Blockchain technology may help reduce the time and effort necessary to verify them and increase transparency. This may be performed by adding a unique identifier to the blockchain (Cresitello-dittmar, 2016).

Trust among participants and stakeholders is essential for a free flow of information and resources throughout a project, which is difficult to achieve amidst the current methodologies. As a result, third parties are virtually always involved to ensure that transactions run smoothly (Dakhli et al., 2019). Professionals such as lawyers and financial organizations serve as intermediaries, and these transactions take a substantial amount of non-value-added time and effort to complete. Smart contracts are one solution that satisfies traditional contractual limitations while simultaneously lowering expectations and eliminating the requirement for trustworthy intermediates. One type of smart contract is an automated contract to purchase and pay for goods and services. Smart contracts may begin the payment after all prerequisites have been met and completed (Hughes, 2017).

Data about the supply chain is not necessarily visible, accessible, or trustworthy. Quality control is simplified by quality traceability and an open information flow that enhances transparency in the supply chain. Traceability may act as reliable quality control by highlighting any possible defects. As a result, the requirement for traceability across the supply chain is critical (Zhang et al., 2020). However, the most critical aspect of traceability is identifying and collecting relevant information that may be used in the future (Olsen & Borit, 2013). Although some promising new technologies, such as the blockchain, have been established, the AEC industry has usually been one of the slowest industries to accept new technologies (Foroozanfar et al., 2017). The unwillingness of stakeholders to provide information due to potential conflicts of interest is another factor slowing blockchain adoption in the AEC industry (Longo et al., 2019).

Implementing new and smart technologies requires all aspects and components of the industry to accept the improvement culture. A Lean culture that seeks continuous improvement within the industry requires transparency, the value offered to customers, and proactive input may all be improved (Hamzeh et al., 2021).

Also, as blockchain provides a high level of openness, companies may be less likely to use it. Zhang et al. (2020) developed a framework to help with traceability and quality control. Their study used three smart contacts to accomplish a set degree of traceability via blockchain. The study found that conservatives' adoption resistance and stakeholders' reluctance to reveal private information were among blockchain's challenges (Zhang et al., 2020). Also, because of the blockchain's novelty, organizations claim to have limited information about smart technologies (Longo et al., 2019).

Additionally, the AEC industry is likely to lack innovative technology and digitization facilitated by blockchain. This is due to the AEC industry's ineffective organizational transformation management (Maali et al., 2020). The question that is thus raised is regarding CSCM's expertise in blockchain technology and its adoption as a novel and smart technology. Therefore, this study wants to determine how blockchain is understood and accepted in CSCM by analyzing responses from industry professionals. This will aid in the development of future blockchain concepts and applications within CSCM.

METHODOLOGY

The AEC industry is concerned about the effectiveness of the operations in the projects since there is a lack of expertise and perspective in the industry (Hamzeh et al., 2021). One of the obstacles facing blockchain implementation is a lack of knowledge and acceptability. Therefore, this research evaluates the industry professionals' opinions on new and smart technologies and their knowledge of blockchain technology and its execution in the construction supply chain. The study hypothesizes that professionals are willing to adopt blockchain technology and that this adoption has a beneficial impact on four variables that represent the primary factors that can be implemented using blockchain technology. In this regard, following a literature review, data collection was conducted. The covid-19 outbreak and its related limitations restricted the methodological approach. Due to the difficulty of visiting construction projects and companies, the most secure data collection method was via a web-based questionnaire. The survey was made available by contacting several companies and emailing them a link to the survey.

The survey is developed based on blockchain characteristics and distributed among respondents. The questionnaire includes 17 questions divided into two sets. The first set contains two questions and analyzes respondents' frequency distribution according to their socioeconomic characteristics. The second section includes 15 questions categorized into the four variables addressed through the survey. The variables for the research are chosen through the literature review. According to the reviewed literature, the factors that can be implemented using blockchain technology in the construction sector include visibility, smart contracts, transparency, and digitalization. The methodology diagram is shown in Figure 1.

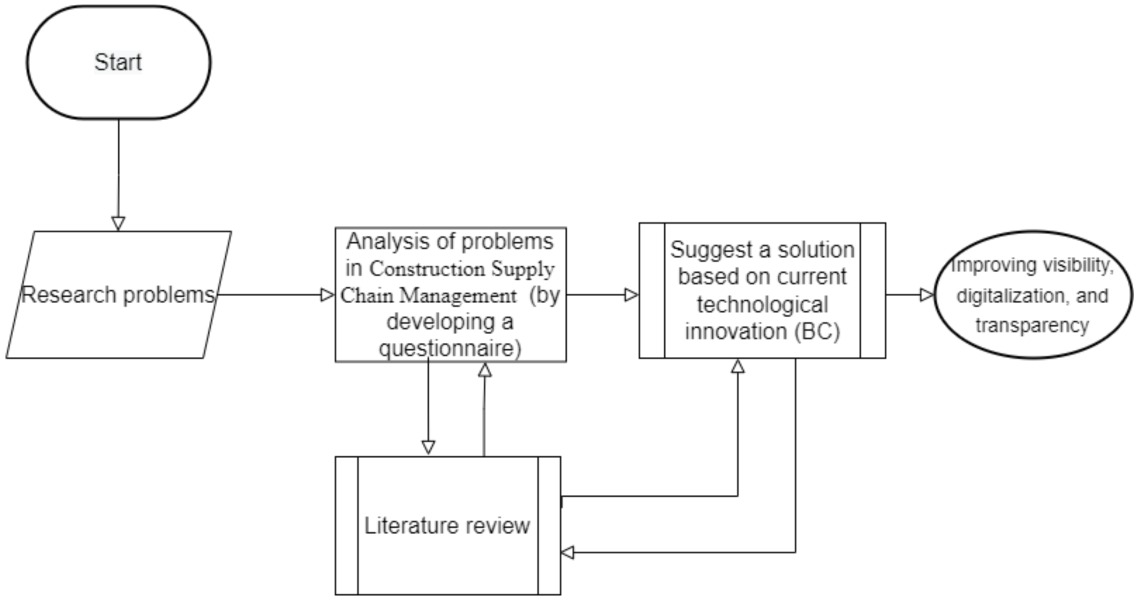

Figure1: Methodology diagram

Each answer is rated on a five-point scale derived from the Likert model. The participants use this scale to determine their agreement with the variables based on predetermined levels. These levels are sequential and indicate the degree of understanding from lowest to highest. The five-point Likert scale, in this case, is one as “totally disagree,” three as “disagree,” five as “neutral,” seven as “agree,” and nine as “totally agree.” As a result, the mean result of comparing the respondents’ opinions is five.

In statistics, the One-Sample Test of Means can compare two sets of data containing a single value. This test is available in two parametric and non-parametric modes: the One-Sample T-test is used in the parametric model, while the non-parametric model employs the One-Sample Wilcoxon Signed Rank Test.

To choose the appropriate mode of analysis for the questionnaire, two conditions must be considered: questionnaire reliability and data normality (Gotama & Simamora, 2022). Reliability is one of the measurement tools’ technical characteristics. This concept refers to how a measurement tool produces identical results under conditions. The accuracy of its results primarily determines a measurement tool’s reliability. In general, reliability is a term that can be used interchangeably with accuracy. A reliable tool is capable of reproducibility and obtaining consistent results.

The next thing to consider is the normality of the data as an assumption of parametric testing (Mishra et al., 2019). The Kolmogorov–Smirnov (K–S) test is done to evaluate the normality of data. The null hypothesis is that the variables are normal in a normality test. A null hypothesis asserts no statistical significance difference between the two possibilities.

RESULTS

In order to carry out the survey, a web-based survey was used. The email was sent out to around one hundred fifty employees working for CSC. One hundred twelve responses were received, and the following section provides the results. The survey commenced with the question about the respondent's job experience. Work experience is one of the respondents' characteristics. The participants in this study are classified into four broad categories based on their work experience. Not having worked for more than ten years, this group accounts for 75% of the total sample. The work experience groups of 10 to 20 years and over 30 years, which accounted for approximately 7% of the total sample, had the lowest frequency. Finally, 20 to 30-year-olds accounted for 13% of the total sample. Finally, 20 to 30-year-olds represented 13% of the whole piece. Figure 2 presents the frequency of this characteristic among respondents.

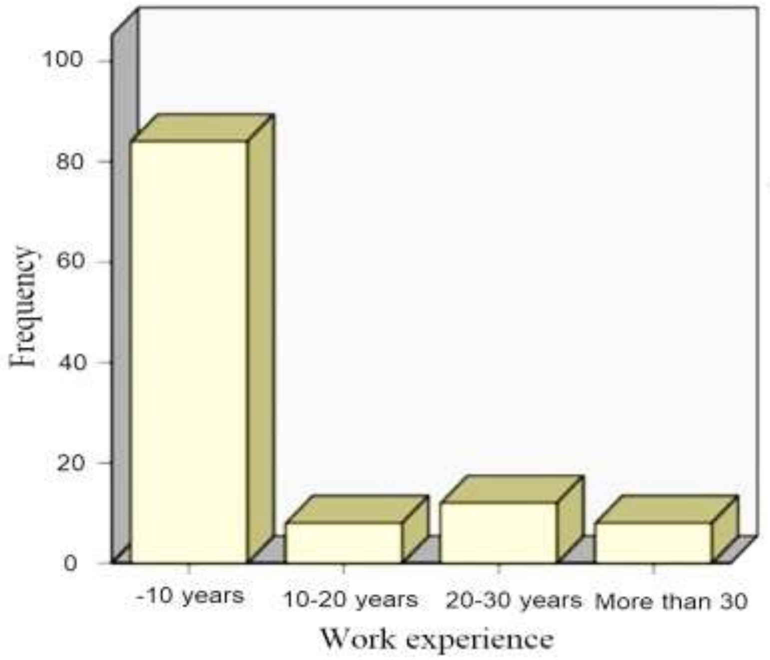

Figure 2: Three-dimensional bar chart of respondents' work experience

Moreover, the participants were asked about four majors of experience as the procurement specialist, construction engineer, project manager, and other disciplines for the experience. The result shows that the highest frequency is related to the procurement specialist group, with more than 38% of the sample volume. Moreover, the circular diagram of the respondents' field of experience is in Figure 3.

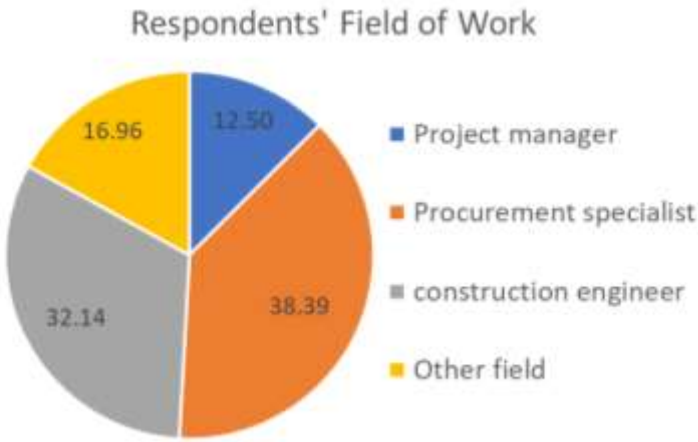

Figure 3: Circular diagram of the respondents' field of work

As previously stated, this research applies the 5-point Likert scale. The average score for the research variables is greater than the median, indicating that the variables have an above-average success rate. Table 1 summarizes the findings for the research variables, and Table 2 shows the variable's average for different work experiences.

Table 1: Descriptive Statistics

Variables	Median	Average	Standard deviation
Visibility	5	5.539	1.5241
Transparency	5	7.310	1.9066
Smart contract	5	6.457	1.6302
Digitalization	5	7.32	1.992

Table 2: Variable's average for different work experiences

Work experience	Frequency	Average			
		Visibility	Transparency	Smart contract	Digitalization
-10 years	84	5.66	7.12	6.43	7.14
10-20 Years	8	5.75	7.92	6.20	8.00
20-30 Years	12	4.96	7.89	7.00	7.67
+ 30 Years	8	4.90	7.83	6.20	8.00

Figure 4 shows the histogram charts for the research variables, including the average and standard deviation.

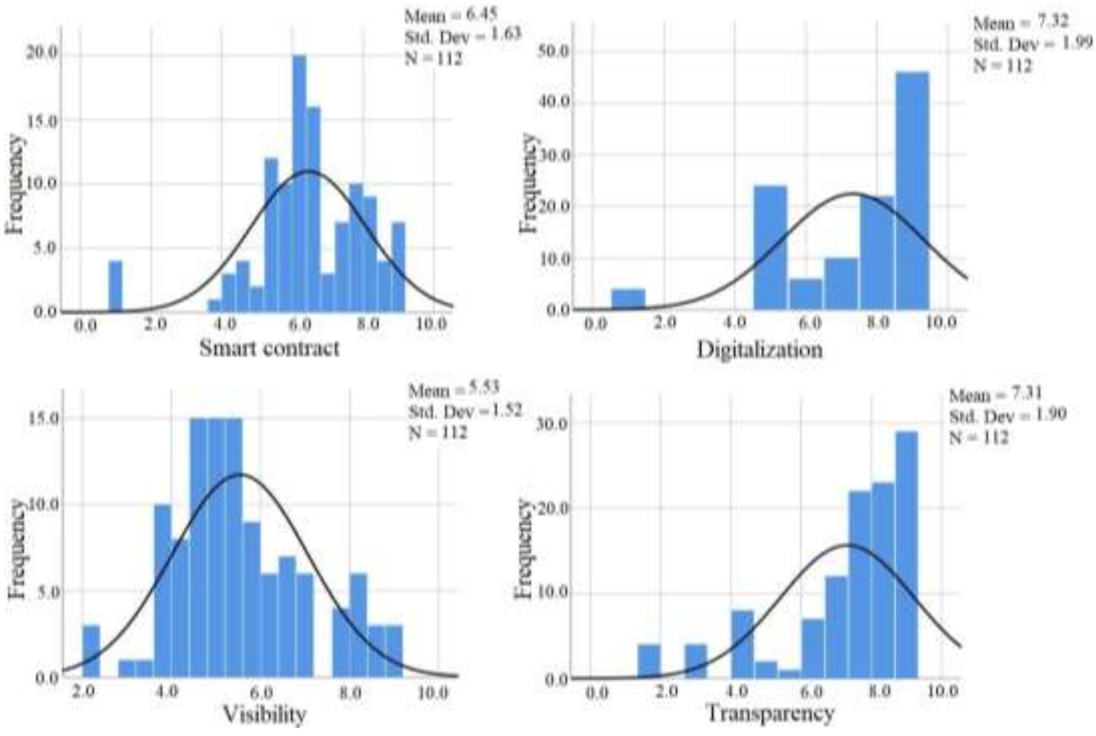

Figure 4: Histogram charts for the research variables

The reliability of a questionnaire could be evaluated using Cronbach's alpha coefficient. Values above 0.7 for this coefficient indicate high reliability, while values between 0.5 and 0.7 indicate acceptable reliability. Table 3 examines the reliability of the questions.

Table 3: Cronbach's Alpha Coefficient for Variables

Variables	Questions	Cronbach's Alpha Coefficient
Visibility	5	0.707
Transparency	3	0.778
Smart contract	5	0.785
Digitalization	2	0.882

According to Table 3, it can be concluded that the reliability assumption of the questionnaire is confirmed. The Kolmogorov–Smirnov (K–S) test for normalcy is reported in Table 4.

Table 4: K-S Test Coefficient for Variables

Variables	Static	Sig. (2-tailed)
Visibility	0.144	0.001
Transparency	0.235	0.001
Smart contract	0.133	0.001
Digitalization	2.109	0.001

If the null hypothesis is not banned at the level of 0.05 (when the significant rate is greater than 0.05), it would be concluded that the data related to the tested variable follow the normal distribution, and they do not reject the normality hypothesis. However, if the null hypothesis is rejected at the level of 0.05 (a significant value is less than 0.05), the data relating to the tested variable would not have a normal distribution. As shown in Table 4, the assumption that the data is normal for all research variables is rejected. Therefore, the non-parametric method, One-Sample Wilcoxon Signed Rank Test, should test the research hypotheses. The following is the result for testing each hypothesis.

The first one is about the effect of increasing visibility in implementing blockchain in the construction supply chain. The null hypothesis for this test is that there is no statistically considerable difference between the mean of the respondents' answers and the score's mean value, which is five.

According to Table 5, this assumption is rejected (the significance level is less than 0.05). Therefore, there are significant differences between the mean of the answers given to all variables, and the mean value and differences are in a positive direction. This means that increasing all aspects effectively implements blockchain and new technology systems in CSCM. Therefore, the hypothesis of the study is confirmed.

Table 5: One-Sample Wilcoxon Signed Rank Test

Variables	Static	Sig. (2-tailed)
Visibility	3.213	0.001
Transparency	7.925	0.001
Smart contract	7.440	0.001
Digitalization	7.272	0.001

DISCUSSION

The average score for all factors is greater than the median, and the differences are positive. Therefore, increasing transparency, visibility, digitalization, and implementing the smart contract effectively facilitate implementing blockchain and new technology systems in the construction supply chain. As our hypothesis, we hypothesized that adding blockchain technology will lead factors to have positive effects on enhancing AEC. As a result, the study hypothesis has been validated.

Each variable had a mean score greater than the median, indicating that each variable was significant in the opinion of experts. According to Table 1, digitalization and transparency scored higher than the other two variables, indicating that these two variables have a more significant impact.

Moreover, the average visibility score is 5.5, while the average smart contract score is 6.4. This demonstrates that these two have not been well-introduced compared to other variables. It could also imply that they did not demonstrate an urging need in the industry. Smart contracts and visibility contribute to the CSCM with the assistance of a third party, like a bank or a lawyer. This may explain why experts in the CSCM place a premium on matters directly related to them.

Comparing each variable's average across different work experience classes in Table 2 shows that digitalization scored the highest in -10 years, 10-20 years, and more than 30 years of work experience. Consequently, this variable has a more significant effect than the other factors. However, transparency has the highest average in 20-30 years of work experience class. Figure 5 shows the Hypothetical Median and the Observed Median of each variable.

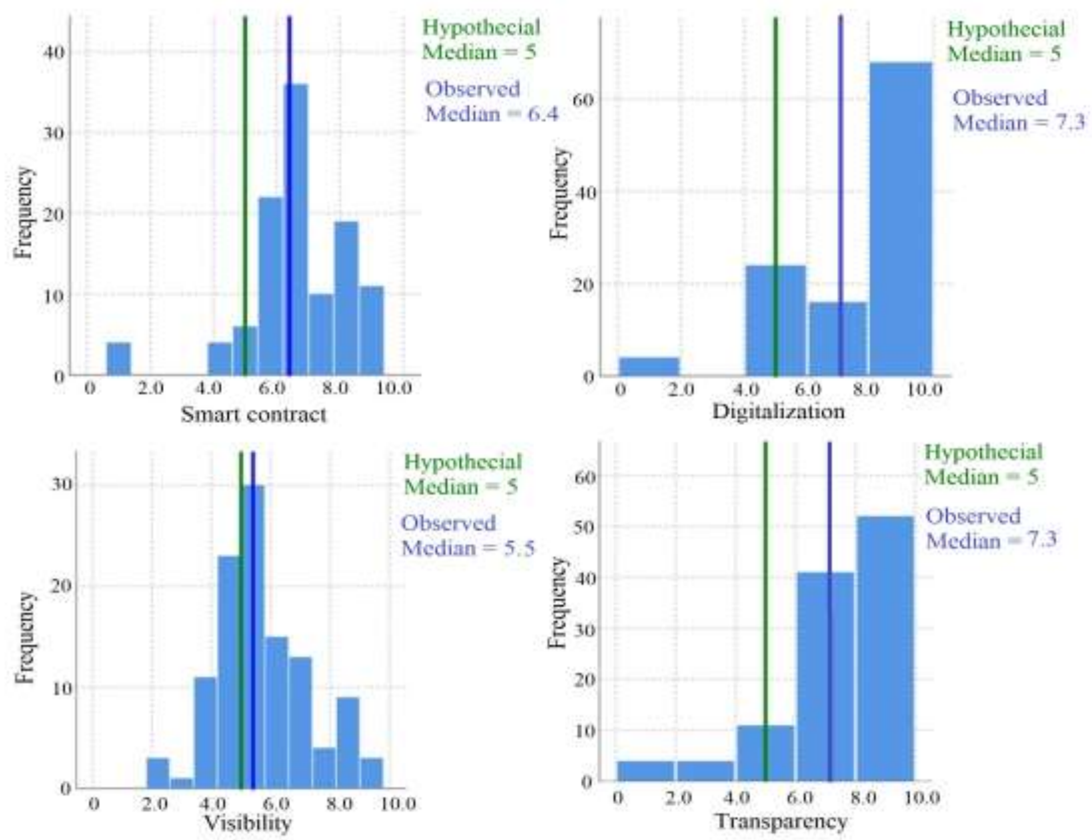

Figure 5: the Hypothetical Median and the Observed Median of each variable

Transparency may increase mutual trust and risk sharing, as all parties have access to the data preserved in CSCM. According to participants' responses, it is clear that all experts understand the critical nature of trust and transparency in completing a project, as traceability, which comes with digitalization, contributes more to quality control during the CSCM. RFID, sensors, software, and other tools or artificial intelligence techniques that enable tracking and tracing a product throughout CSC may help improve quality.

CONCLUSIONS

This study examines the adoption of blockchain technology in CSCM and the significant differences among the respondents' assessments of blockchain benefits on visibility, transparency, smart contracts, and digitalization in implementing blockchain systems.

As a result of this research, it is concluded that implementing blockchain technology in the construction industry would benefit industry professionals. However, due to the recorded survey questions' average scores ranging from 5.4 to 7.3, there is still a long road to adopting this technology. To further address the limitations of the research and the obtained results, future research can investigate additional hypotheses and variables to evaluate their effect on implementing blockchain in the construction industry generally and construction supply chain specifically.

Integrating blockchain into CSCM allows for the following benefits:

- Redesigning the process to achieve a high value-added and continuous flow. This may be achieved by eliminating idle or waiting for a third party to perform on a project. Blockchain allows for automating this procedure and thus facilitates the flow.
- Eliminating unnecessary burden on people and equipment as avoiding inconsistency in the supply chain schedule is just as critical as avoiding waste.
- Utilizing blockchain as a reliable and thoroughly tested technology to assist people.
- Creating operations that need very little inventory. This will make a waste of time and resources readily apparent to everybody. Once the waste is identified, staff could be encouraged to reduce it through a continuous improvement approach (Kaizen).

Other researchers could conduct future research on examining the result of blockchain technology deployment in enhancing productivity in the CSCM. Data collection methodologies were constrained due to the covid-19 epidemic. However, we encourage other researchers to employ different methodological methods (e.g. interviews) for comparable studies.

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