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Exploring Implementation of Blockchain for the Supply Chain Resilience and Sustainability of the Construction Industry in Saudi Arabia

Naif Al Azmi [1], Ghaleb Sweis [1], Rateb Sweis [2] and Farouq Sammour [1,*]

[1] Civil Engineering Department, The University of Jordan, Amman P.O. Box 11942, Jordan; abo.noof-2008@hotmail.com (N.A.A.); gsweis@ju.edu.jo (G.S.)
[2] Business Management Department, The University of Jordan, Amman P.O. Box 11942, Jordan; r.sweis@ju.edu.jo
* Correspondence: farouq.nahi@gmail.com

Abstract: The construction industry plays an essential role in economic development since it is one of the largest industries all over the world. Blockchain has the potential to reshape the structure of all accessible networks in the future. Construction businesses are increasingly interested in embracing blockchain technology to improve supply chain sustainability performance and supply chain resilience in times of globally increasing risks and volatility. This study evaluates the readiness of actors involved in the producing of concrete goods to emphasize the necessity to bring blockchain into the construction industry, as it may be a solution for supply chain resilience and long-term sustainable growth. Qualitative and quantitative research methods were used in collecting and analyzing the data and testing the hypotheses. Data were collected using an online questionnaire distributed to 300 employees who work within the biggest concrete producing companies in Saudi Arabia. 120 respondents completed the questionnaires. Additionally, confirmatory semi-structured interviews with experts in supply chain financing, IT departments, and procurement departments have been conducted; the study's findings revealed a low level of blockchain knowledge within Saudi Arabia's construction industry, since (90%) of respondents have not worked with Blockchain technology. Several technologists barely understand it, and the level of readiness is very low. However, there is a lot of potential, and it is worth investing in it combined with other technologies such as BIM technology. In this study, the authors have sought to provide a measure of Saudi professionals' attitudes and understanding of blockchain technology solutions within the construction industry in Saudi Arabia. Furthermore, the study's novelty aimed to provide a grasp of the conceptual, theoretical, and fundamental features of blockchain technology in the construction industry, as blockchain solutions could benefit the global economy by increasing levels of monitoring, tracing, and confidence in international supply chain resilience.

Keywords: blockchain technology; sustainability; concrete producing; supply chain management; supply chain financing; construction industry

Citation: Azmi, N.A.; Sweis, G.; Sweis, R.; Sammour, F. Exploring Implementation of Blockchain for the Supply Chain Resilience and Sustainability of the Construction Industry in Saudi Arabia. *Sustainability* **2022**, *14*, 6427. https://doi.org/10.3390/su14116427

Academic Editors: Iftikhar Azim and Yasmin Zuhair Murad

Received: 11 March 2022
Accepted: 18 May 2022
Published: 24 May 2022

1. Introduction

The global construction industry will be facing a boom in challenges in the coming digital era. Saudi Arabia's infrastructure and construction sectors are still being driven by technology adoption, dynamic methods of construction delivery, and the application of new operational standards, all of which are fueling the country's infrastructure and construction expansion. The construction industry in Saudi Arabia plays a vital role in economic growth; Saudi Arabia presently has US $1.15 trillion in future projects, with construction and infrastructure, as well as transportation, being the most important. The value of contracts awarded increased from US $11.2 billion in 2016 to US $14.6 billion in 2018 [1].

Generally, several factors affect this industry, causing frequent and lengthy delays [2–5], most notably change orders and re-designing, as 70% of projects face time overrun, with 45 out of 76 projects in Saudi Arabia experiencing delays. Lack of expert contractors, ineffective planning and scheduling of projects, poor site management, poor communication among ministries and other companies, and slow decision-making by the owners, are all factors that contribute to frequent and prolonged delays.

There is a noticeable weakness in the technical and financial aspects of construction projects so far in Saudi Arabia [6]. According to Deloitte [1], the construction industry ranked as the lowest industry in terms of the percentage of budget spent on IT among all industries they researched. The lack of investment in IT has had consequences for the construction industry worldwide, especially in Saudi Arabia. Research conducted by Algahtany [7] pointed out that construction projects in Saudi Arabia experienced poor performance for the past three decades and need more effective risk-management strategies for helping contractors deliver projects on time and within budget while meeting quality expectations.

Multiple internal and external hazards have increased supply chain vulnerability, necessitating the development of risk management approaches and strategies to foster organizational resilience and preparedness [8]. Blockchain has the potential to be a significant technology in a new technological revolution characterized by increased automation and the merging of the digital and physical worlds. It has an influence that extends beyond the economy, as it has the potential to change social interaction, governmental institutions, and our relationship to the environment, as well as countries' possibilities for achieving sustainable development. Policymakers should enhance their digital capabilities to strategically position themselves to gain from this new technology wave. Several developing countries will need to improve their digital infrastructure, skills, and regulatory frameworks in order to achieve this [9].

Technological innovation and advancements within the construction industry can create smarter and more sustainable processes in Saudi Arabia. Many improvements can be gained by using Blockchain technology; for example, it may allow for enhanced good tracking with real-time planning, less administration, increased efficiency throughout the supply chain, and improved financial flows. The introduction of blockchain technology in the Saudi Arabian construction industry will offer many solutions for a more robust and resilient supply chain.

This article presents the possible benefits and improvements obtained by implementing blockchain technology in the construction industry in Saudi Arabia. Specifically, the study assesses the readiness of actors involved in the production of concrete goods to highlight the need to introduce the Blockchain in the construction industry, considering that it can be a solution for supply chain resilience and sustainable development. The difference between the approach used and those in the literature is that this study utilizes a mixed research design that gathered qualitative data from experts in supply chain financing, IT departments, and procurement departments in addition to the quantitative data.

The present study aims at answering the following main question:

- What is the status of knowledge surrounding blockchain technology within the construction supply chain in Saudi Arabia?
- How can blockchain technology help improve the efficiency in supply chain management and supply chain financing in the construction industry in Saudi Arabia?
- What is the perceived preparedness and willingness for implementation of blockchain technology among related parties?

2. Literature Review

A broadly acknowledged definition of a supply chain is given by Christopher [10] as "the network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate customer". According to Liu et al. [11], it is a

chain that links raw material, suppliers, and contractors as well as its operational decisions regarding inventory stock, prefabrication, procurement, and construction.

Supply chain integration is considered a well-researched area by both practitioners and researchers. Prajogo and Olhager [12] inspected the integrations of both interrelated information and material flows between different supply chain actors and their leverage on operational performance; their results showed a significant effect of information technology capabilities and information sharing on logistics integration. As well as this, logistics integration also has a significant effect on operations performance.

Environmental, economic, and social burdens from local and global governments, communities, and consumers pressure managers to achieve sustainability goals. The function of blockchain solutions in terms of sustainability is very crucial. Saberi et al. [13] listed four major blockchain features that can support sustainable supply chains: (1) Significantly lower product recall and rework due to its tracking capabilities; (2) making it simpler to trace the actual carbon footprint of products and determine the exact amount of carbon tax that each company should be charged; (3) encouragement of recycling actions by rewarding individuals who take part in deposit-based recycling programs; and (4) increased efficiency of emission reduction programs.

Parung [14] investigated how blockchain technology may help with the development of long-term supply chain management from an environmental, economic, and social standpoint. The findings showed that blockchain technology has the potential to improve cost and time efficiency and has the ability to bring social advantages to the enterprises engaged with it due to those organizations' growing excellent reputation. Pollution decrease is one of the main environmental advantages of the more efficient shipping strategies. Blockchain also benefits all users financially because it lowers expenses by using more efficient manufacturing and delivery techniques. Social benefits are that customers feel secure and comfortable using the goods since they can track the product movement transparently and enhance the reputation of all supply chain partners.

Resilient supply chains are less prone to disturbances and speed up the recovery period. The use of blockchain technology facilitates several current initiatives to increase supply chain resilience using smart contracts to provide a transparent, safe, and fast data exchange and automation via blockchain. Lohmer et al. conducted simulation research for smart contracts employment for risk-related cooperation. The results showed that if the underlying cooperation is built on time-efficient procedures, resilience is increased by the reduction of network recovery time and the overall costs [15].

The supply chain is an essential part of any business and may have an impact on a variety of factors. The disturbance in the supply chain, in particular, has tremendous ramifications and repercussions that are difficult to manage. To address the challenge of supplier assessment and selection, Sawik [16] investigated several criterion decision-making methodologies and provided an overview of some of the most common multiple criterion difficulties in supply chain optimization. The techniques for prevention, reaction, protection, and recovery are discussed. The practical aspect focuses on risk-averse models that leverage single sourcing to reduce the worst-case situation. The CPLEX solver was used to solve computational experiments for practical instances.

The potential impact of blockchain technology on supply chain resilience (SCR) to cybercrime was highlighted in a study conducted by Bayramova et al. [17]. The most productive countries, sources, publications, and writers at the forefront of blockchain research and acceptance were identified through a scientometric study. Following that, a grounded theory analysis found six major research clusters: "case study", "challenges and opportunities", "traceability", "smart contract", "blockchain and IoT", and "data security".

Kim et al. [18] investigated the use of Blockchain technology in carbon trading in order to achieve the United Nations' sustainable development goals. The study used blockchain technology to assess carbon emission rights to make transactions more credible. The study employs blockchain to verify carbon emissions rights. In mobile cloud settings, users may use big data and artificial intelligence to defend against carbon emissions oddities.

The study developed a blockchain-based carbon emission rights verification system that uses governance system analysis and the blockchain main-net engine to overcome carbon emission rights issues.

It is more difficult to identify goals and objectives when many stakeholders exist within a project; undoubtedly, there is a correlation between time, cost, quality, and project complexity. Lundesjö [19] clarified the divergence between both the traditional and modern contractual structures within any construction supply chain. As shown in Figures 1 and 2, there are obvious differences between them. The modern structure is more complex and has a higher risky relationship among all related parties in projects; the arrows show contractual relationships, while the broken lines are non-contractual.

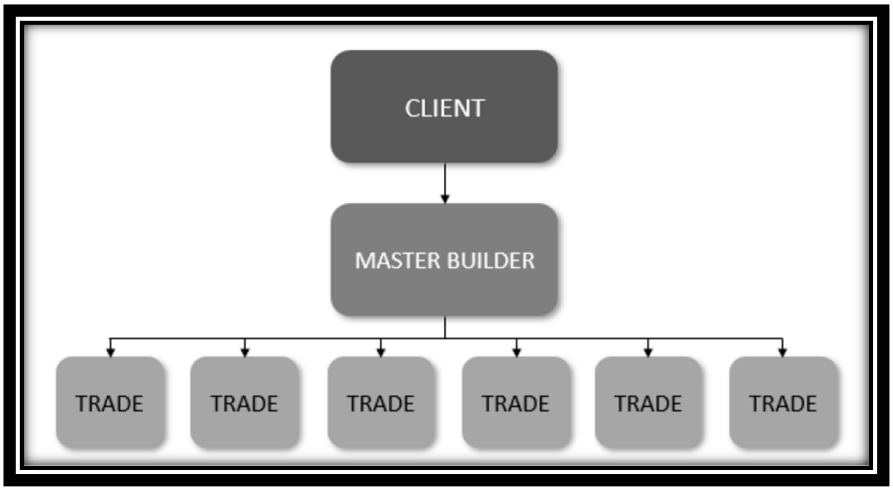

Figure 1. Traditional Contractual Structure [19].

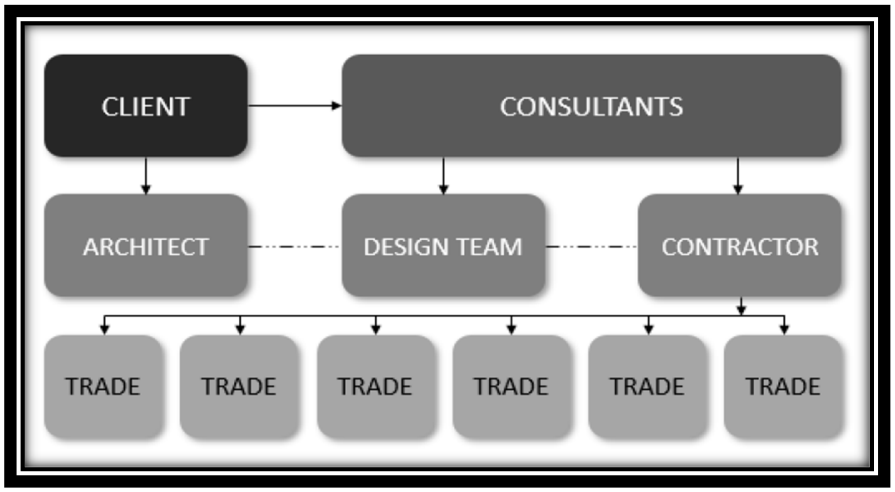

Figure 2. Modern Contractual Structure [19].

Segerstedt and Olofsson [20] and Clough et al. [21] agree that CSC is complex because of its underlying processes and structure in a way that differs from the manufacturing supply chain, due to its complicity, Lundesjo [19] emphasized the importance of information sharing within construction projects and avoiding any re-creation or re-entering of information during the project life cycle.

Bjorklund and Vincze [18] defined supply chain financing as "a financial instrument method, usually an application that uses technology to optimize working capital effectively and manage the liquidity embedded in the supply chain via collaboration between buyers and suppliers and financial institutions". They pointed out that the construction industry

does not just need to improve digitization aspects but that there is also a growing need for another key area of essential improvement that focuses on increasing the efficiency of the financial flows in companies and the SCF within the whole industry.

The main objective of SCF is to reduce capital costs, and that is clearly done by improving financial performance and cash flow, or through interlinking the relationships between many actors in the supply chain [22,23]. To provide an effective way to solve the financing problem in any industry, Liu et al. [11] used a method to analyze the financing model of supply chain finance and the relationship between the members of the supply chain financial ecosystem. The resulting financing model of supply chain finance allows new ideas for solving a problem. However, any SCF solution is only efficient and applicable if all the supply chain actors agree on the solution.

The forces of globalization and digitalization are impelling the construction industry to make the industry more effective, productive, and efficient. Recently, there has been great attention paid to introducing an advanced technology that contributes mainly to disruptive innovation, called Building Information Modeling (BIM). Essentially, BIM makes a change in the design paradigm [24]; however, it has not yet created corresponding impacts on procurement, while blockchain has addressed more construction procurement aspects, fulfilling the unattended gap of BIM and also exploring further applications for both construction and the built environment.

According to Pal et al. [25], blockchain technology, or a decentralized secure ledger, is one of the most popular technologies that can eliminate and mitigate a third party's requirement to validate any possible transactions over a Peer-to-Peer network. It generally enhances decentralization, transparency, equality, and accountability on the internet, as highlighted by Al-Saqaf and Seidler [26]. Moreover, members of the network within blockchain technology usually keep the transactions' data in the form of a ledger. This ledger is updated by adding a new extra block of transactions to maintain the integrity and righteousness of the available data. Figure 3 shows a simplified structure of how a transaction is reached, and a block is chained as a final step, which is illustrated by Laurence [27].

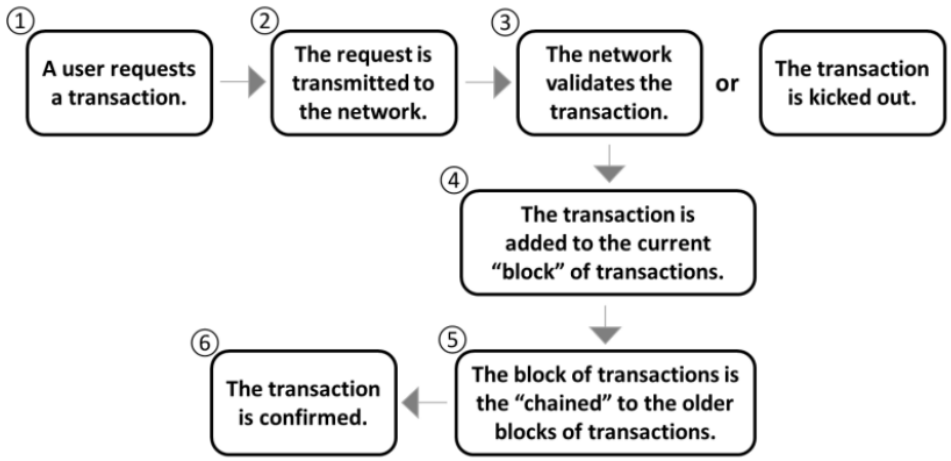

Figure 3. How Blockchain Works [27].

Some essential principles should be met either on a high or low level when using blockchain technology as a foundation. Public, hybrid, and private blockchain are considered the three main types of Blockchain technology in various projects. This is shown by Suichies [28], as can be seen in Figure 4. The ideal use of the application of blockchain technology is in the nature of transactions in collaborative building projects in addition to legal consequences in case of any project failure.

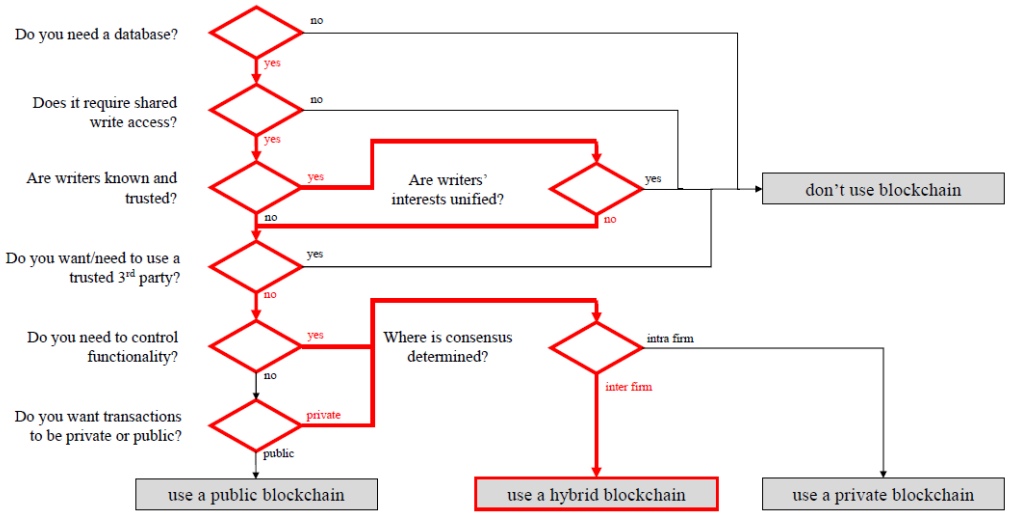

Figure 4. The Decision Taken on What Kind of Blockchain to Use [28].

Andoni et al. [29] pointed out that when there are no limitations or restrictions regarding the interactions with blockchain, when all information is visible for all actors in the network, and when they are encouraged to interact and contribute easily with the network, this is called a public blockchain.

Blocks in a blockchain are linked together, and the structure of a blockchain often comprises numerous blocks. The first block is called the 'genesis' block; each block comprises multiple transactions [30]. Apart from the transactions, each block includes a respective hash derived from the data stored on the block and the hash of any previously accepted block in the blockchain. In the same year, a study conducted by Nofer et al. [31] stated that the hash values are usually unique and matchless, so any change to a block in the chain will directly change the respective hash value.

To store larger and longer transactions in an unproblematic way, Figure 5 observes a Secure Hash Algorithm-256 (SHA-256), which is the most frequently cryptographic used in blockchain platforms. As shown below, the output always contains a combination of 64 fixed digits and letters. The hash is an essential key element in any blockchain, providing security to prevent tampering with all data stored in blocks.

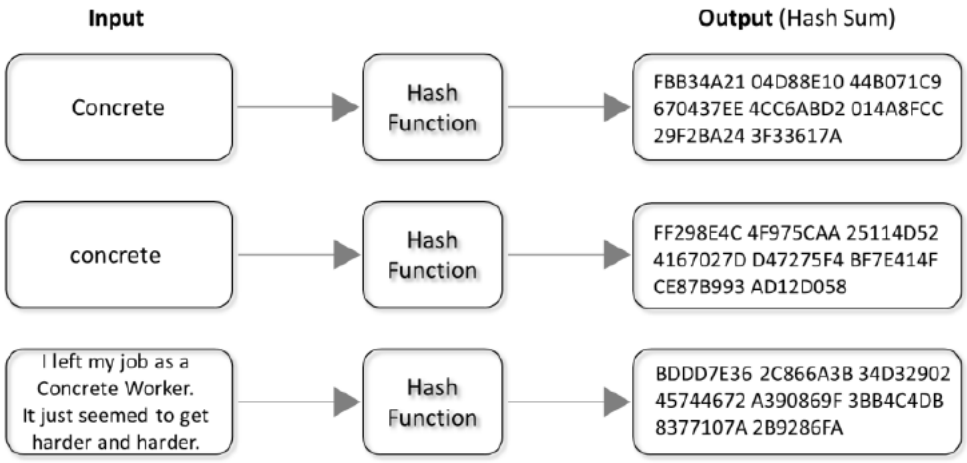

Figure 5. Secure Hash Algorithm-256, hashes generated in Python [29].

3. Studies Related to Blockchain in Construction Supply Chains

In recent decades, the industrial revolution in automation and artificial intelligence (AI) is the new and innovative trend known as the fourth industrial revolution (IR 4.0). Implementing the fourth industrial revolution within the construction sector would certainly drive the industry's performance to match with their industry counterparts. Technologies such as BIM, Modularization, and Cloud Computing have developed significantly and widely compared to other technologies such as Augmented, Virtual, and Mixed Reality and are still being enhanced to influence sustainability and development in the industry [32].

Blockchain technology has significant potential in improving how supply chains are managed through companies in an extremely efficient way. In other words, as pointed out by Saberi et al. [13], blockchain technology could provide traceability, reliability, corrected information, and could facilitate the flow of material and data throughout the supply chain when it is combined with IoT devices, for example.

According to Agarwal et al. [33], the construction industry is considered the second-lowest industry to have applied information technology, and that is the main reason the global construction industry is ranked as the least productive among all sectors. Conversely, Betts and Robinson [34] highlighted that by 2030, the rate of investment in the construction industry will considerably be increased with around USD 8 trillion as a predicted growth in the global construction market.

Many construction projects involve large amounts of money transfers carried out through intermediaries such as banks to guarantee a constant trustworthy platform. However, blockchain, which provides a fraud-resistant platform, can reduce the intermediaries and facilitate direct payments between stakeholders without any possible delays, non-payment, or cash flow issues, as reported in a study by Lu and Xu [35]. Unsurprisingly, Mason and Escott [36] showed in their study that the level of knowledge surrounding technology in the construction industry is very low.

Precast construction has many advantages that lead to innovative methods with clean, secure, and highly efficient systems in the construction industry. Due to poor traceability, fragmentation, and lots of challenges that current precast supply chain management faces, a study has been carried out recently by Wang et al. [37] that builds a blockchain-based information management framework for an effective precast supply chain to use such technology in the domain of construction supply chains. The developed framework facilitates the real-time scheduling of precast components, and the on-time delivery also tracks the causes for any disputes centered on precast components within the precast supply chain.

Moreover, a recent study accomplished by Wang et al. [38] indicated that Blockchain was used to enhance supply chain management in terms of many prospective such as traceability, fragmentation of the system, plus the capability to deal with real-time information even sharing or control. Additionally, for better security, Blockchain should be integrated with Internet of Things (IoT) technology to guarantee that every product, item, or service is distributed within the maximum permissible and acceptable storage time, also improving privacy preservation.

Lu et al. [39] parallel the same idea of the previous study in which blockchain in combination with advanced information and communication technologies (ICT) such as Internet of Things (IoT), Building Information Modeling (BIM), or Cyber-Physical Systems (CPS) can enable sustainability innovation and also ignite new modes of smart construction specifically in prefabricated housing construction (PHC) in which data are transferred safely with broad quality supervision through the development of a well-defined, platform-based smart product-service system.

Blockchain should be understood strictly from a technical perspective because there is room for improvement that the industrial revolution has recently produced, so in the current situation for the construction industry it is necessary to look for better management and effective outcomes. Considering the current limited studies and lack of knowledge and understanding of blockchain technology in Saudi Arabia, this study is, to the best of the author's knowledge, the first study that investigates the possibility of implementing

blockchain technology within the construction industry in Saudi Arabia. Additionally, this study attempts to increase the role and the efficiency of supply chain management, supply chain financing, and chain financing resilience in construction projects in the country and to fill the other studies' gaps.

4. Research Methodology

This study adopted a mixed research approach, which is a combination of quantitative and qualitative methods. Although qualitative methods can offer a diversity of opinions and problems, they will not tell you the extent of that diversity. This method is considered more appropriate and provides more flexibility since there is a lack of real-world applications and academic research articles and journals. Bryman and Bell [40] concluded that the quantitative method can bridge any gaps that exist in the qualitative method.

4.1. Research Hypothesis

Hypothesis 1 (H1). *The respondents with different experiences have no differences in their responses towards the study factors.*

Hypothesis 2 (H2). *There are no significant differences among respondents' responses to study factors regarding different company sizes.*

4.2. The Study's Population and Sample

The study population consisted of employees who work in construction companies in Saudi Arabia including concrete producing companies specifically, in Finance, Sales, Procurement, IT, and Production. There are about 902 concrete-producing companies in Saudi Arabia. A random sampling technique was used in the study to collect the data; this was done by a random assignment to a list of concrete producing companies in Saudi Arabia through random number generators.

The required sample size was calculated depending on the study accomplished by Hair et al. [41]. To collect the primary data for 21 factors and a 6-point Likert scale, a minimum sample size of 105 was required. Accordingly, after distributing about 300 questionnaires online and via emails to a group of employees in different departments within the biggest concrete producing companies in Saudi Arabia, 120 questionnaires were received and were appropriate for the study.

4.3. The Design of the Questionnaire

The questionnaire consisted of 21 items. The assessment factors of this study are based on six Likert scales to show the degree of agreement and avoid any neutrality in answers. An "Insufficient Knowledge" option was also available for most of the questions and statements to avoid the skew of respondents in case they were not familiar with the required knowledge and were not able to answer the questions in the questionnaire.

4.4. Interview Guide

The primary data for the qualitative section used a semi-structured interviews approach to gain the interviewees' perspectives, thoughts, and high level of understanding. Experts from various concerned parties in the construction who also possessed knowledge about blockchain and supply chain financing were selected and interviewed to assess the potential of the implementation of blockchain technology within the construction supply chain in Saudi Arabia and judge the level of readiness of actors for blockchain. Undoubtedly, barriers caused by COVID-19 led the interviews to be conducted via email, Skype, and Zoom to share the required knowledge.

In total, four different interview guides were chosen to gain new knowledge of this unexplored field in Saudi Arabia: one for the procurement department, one for the IT department, one for the blockchain expert, and lastly one for the supply chain financing.

5. Results and Discussion

Based on the study methodology, this research is quantitative and qualitative and depends on data that were obtained from a survey to answer study questions, a case study comparison, and confirmatory interviews that built appropriate conclusions and recommendations. The data were gathered through a questionnaire, and Statistical Package for Social Sciences (SPSS) version 26 was utilized to analyze the data.

5.1. Validity and Reliability

Exploratory Factor Analysis (EFA) is a statistical mechanism conducted to reduce factors to a smaller set of factors. Based on EFA results, we can decide which factors are appropriate and can be used in further analysis and which caused cross-loading and should be eliminated. To ensure that the data are suited to factor analysis, a Kaiser-Meyer-Olkin (KMO) test was conducted.

The sampling was considered adequate if the KMO values ranged between 0.5 and 1. The value of KMO was 0.701, which meant that the factor analysis was relevant for these factors. Six main groups were extracted and named according to the loading items that were greater than (0.35) for all factors, namely (1) time of administrating transaction and fraud within contracts, (2) transaction and contract sufficiency, (3) administration costs and contract process, (4) understanding of blockchain technology, (5) contract alterations and trust, and (6) contract obligations and the tracking process.

To guarantee the high quality of this study and accurately measure what this study intends to investigate, Cronbachs' Alpha Coefficient was used to estimate the reliability. Cronbachs' Alpha Coefficient value ranges between 0 and 1. If there is no variance among study instruments (i.e., internally independent), then $\alpha = 0$, but if all study items have a high covariance, then α will be close to 1. However, there is a consistency among researchers that the instrument considers an item reliable and stable if the α value is more than 0.7.

For this study, Cronbachs' Alpha Coefficient is 0.840, which is more than 0.7, and then the instruments of the questionnaire are reliable and consistent.

5.2. Socio-Demographic Statistics

The results show that out of 120 respondents, 40% of them have experience of less than 5 years, 18.3% have experience of between 5 and 9 years, and 16.7% have experience of between 15 and 20 years. In addition, the results show that more than half (53.3%) of respondents are working in large companies (number of workers more than 51), followed by (22.5%) who are working in small companies (number of workers between 5 and 19). On the other hand, 90% of respondents do not have experience related to blockchain technology.

5.3. Descriptive Analysis

This section aims to describe the attitude of respondents toward study factors through the ranking of factors regarding their importance from respondents' perspectives. To achieve this objective, a Relative Importance Index (RII) was calculated for overall respondents. The Relative importance index analysis allows the identification of most of the important criteria based on participants' replies, and it is also an appropriate tool to prioritize indicators rated on Likert-type scales. Key interpretations of the results of the RII are presented in Table 1. The interpretations, ranging from "not important" to "very important", are to represent the RII percentages classes. To calculate RII, the following equation was used [42]:

$$\mathrm{RII} = \frac{\sum \mathrm{w}}{\mathrm{AN}} \times 100\% \quad (1)$$

where W: the weighting given to each factor by the respondent, A: the highest weight, and N: the total number of samples. RII was classified to reflect the respondent's rating as illustrated in Table 1.

Table 1. Key Interpretations of the Results of Relative Importance Index (RII).

RII	**0 < RII ≤ 20%**	**20 < RII ≤ 40%**	**40 < RII ≤ 60%**	**60 < RII ≤ 80%**	**80 < RII ≤ 100%**
Interpretation	Not important	Very little important	Somewhat important	Important	Very important

The coefficient of variation (COV) represents the standard deviation as a percentage of the mean; it measures the predictability of evaluating bias. The COV is a standardized measure of the dispersion of a probability distribution or a frequency distribution. It displays the degree of variation in reference to the population mean. The COV was computed by using the following equation [42]:

$$\text{COV} = \frac{s}{\mu} \times 100\% \quad (2)$$

where S is the standard deviation and μ is the mean.

As shown in Table 2, the coefficient of variation (COV) of factors ranged between 27% and 58%. This indicates that there is low to moderate variation in respondents' attitudes about these factors. This is a positive indicator that indicates a high level of agreement among the responders.

Table 2. Descriptive analysis.

Factor	**Mean**	**SD**	**COV**	**RII**	**Rank**	**Interpretation (RII)**
The current contracts process works well	5.28	1.43	27%	75%	1	Important
The ability to enforce contracts works adequately	5.01	1.55	31%	72%	2	Important
Disputes between two parties (buyer-supplier) often result in additional costs (That is in form of administrative costs, legal costs, or other additional costs)	5.01	2.04	41%	72%	3	Important
Current contracts are sufficiently secure (The contracts are secure enough that you can trust them to secure the interests of both parties involved)	4.83	1.75	36%	69%	4	Important
The current process has the capability of tracking and tracing products	4.82	1.84	38%	69%	5	Important
Administration costs related to transactions are justified (The amount of cost in form of time, effort, and fees are at an acceptable level)	4.81	1.86	39%	69%	6	Important
Companies in the construction supply chain fail to meet their contractual responsibilities	4.77	1.61	34%	68%	7	Important
The transaction process needs intermediaries (for example, banks)	4.73	2.20	47%	68%	8	Important
The current transaction speed is sufficient (This includes the time between delivery and payment. Ex. delivering the concrete and getting paid or delivery of the raw material and paying the supplier).	4.65	1.75	38%	66%	9	Important
Disputes between the two parties (buyer-supplier) to a contract are common	4.57	1.79	39%	65%	10	Important
The construction sector should aim toward using a Blockchain smart contract solution.	4.54	2.61	58%	65%	11	Important
Contracts work as intended	4.54	1.42	31%	65%	12	Important
The time spent on administrating transactions is too much	4.53	1.60	35%	65%	13	Important

Table 2. *Cont.*

Factor	Mean	SD	COV	RII	Rank	Interpretation (RII)
Forgery/fraud is common within the contracts process (before and after agreement) (Meaning that parties to the contracts commit fraud after agreeing to the contract or before. An example of this could be lying about their financial situation)	3.98	1.74	44%	57%	14	Somewhat important
The contracts are often altered after being agreed upon (This is where one of the parties attempt to alter the contract after they have agreed upon and signed the contract)	3.93	2.05	52%	56%	15	Somewhat important
There is a lack of trust between your company and suppliers	3.73	1.60	43%	53%	16	Somewhat important
There is a lack of trust between your company and buyers	3.73	1.62	43%	53%	17	Somewhat important
Having a shared and open ledger (database) between suppliers/buyers and your company is bad.	3.48	1.88	54%	50%	18	Somewhat important
My understanding of smart contracts is	2.94	1.52	52%	49%	19	Somewhat important
My understanding of Blockchain technology is	2.78	1.00	36%	46%	20	Somewhat important
Contracts are in no need for improvement	2.62	1.24	47%	37%	21	Very little important

In addition, Table 2 reveals that the RII values ranged between 37% and 75%. From the respondent's perspective, these values indicate that the majority of these variables are regarded as important. "The current contracts process works well" was ranked as the most important factor, while "Contracts are in no need for improvement" was ranked as the least important factor.

5.4. Hypotheses Testing

ANOVA and post hoc tests were used to test the hypotheses.

5.4.1. First Hypothesis

ANOVA at a 95% confidence interval was conducted for all factors to test this hypothesis. The p-values for all factors are less than 0.05 (the level of significance). The level of significance is the fixed probability of wrong elimination of the null hypothesis when in fact it is true. The null hypothesis is accepted at $p > 0.05$ and is rejected at $p < 0.05$. Hence, there is a statically significant difference in the respondents' responses towards these factors regarding the different respondents' experiences.

A post hoc test was conducted for the hypotheses that have significant differences to find out these differences. The results showed that the most differences appeared between respondents who had experience of fewer than 5 years.

5.4.2. Second Hypothesis

ANOVA at a 95% confidence interval was conducted for all factors to test this hypothesis. The *p*-values for the following factors are less than 0.05 (the level of significance):

- The current contracts process works well
- Companies in the construction supply chain fail to meet their contractual responsibilities
- Disputes between the two parties (buyer-supplier) to a contract are common
- Disputes between two parties (buyer-supplier) often result in additional costs
- The transaction process needs intermediaries
- The current transaction speed is sufficient
- Administration costs related to transactions are justified
- There is a lack of trust between your company and suppliers

- There is a lack of trust between your company and buyers
- The current process has the capability of tracking and tracing products
- Forgery/fraud is common within the contracts process (before and after agreement)
- The contracts are often altered after being agreed upon
- Current contracts are sufficiently secure
- Having a shared and open ledger (database) between suppliers/buyers and your company is bad.
- The construction sector should aim toward using a Blockchain smart contract solution.

The null hypothesis is accepted at $p > 0.05$ and is rejected at $p < 0.05$. Hence, there is a statically significant difference in the respondents' responses towards these factors regarding the different company sizes.

A post hoc test was conducted for the hypotheses that have significant differences to find out these differences. The results showed that the most differences appeared between respondents who belong to companies that have more than 51 employees.

5.5. Saudi Arabia's Construction Industry toward Blockchain Technology

5.5.1. Current State of Knowledge in Blockchain and Readiness

This questionnaire aimed to gain insight into the respondents' understanding of Blockchain technology within the construction industry in Saudi Arabia. Surprisingly, the results of this study showed that (76%) of respondents answered that they had either no, poor, or very poor understanding of Blockchain technology. Only (23.3%) had either good or acceptable knowledge of Blockchain technology in the Saudi Arabian construction industry.

5.5.2. Current Traceability Capabilities and Trust

The results show that actors in the construction industry primarily keep track of transactions not only for the financial transaction but also to evaluate the quality of processes and keep manual documentation for historical references. The majority (76.5%) of respondents believe that there is effective and adequately good tracking to assure that construction projects meet certain guidelines within Saudi Arabia's construction industry. Different ISO certifications are unquestionably required for concrete producer companies, and companies must also carry out extensive checks and audits on their suppliers in future construction projects, as stated by Bjorklund and Vincze's [18] study.

The degree of trust is measured between companies and actors in the supply chain in both studies, where about (61.7%) of respondents indicated that they did not suffer from a lack of trust between companies and suppliers. Similarly for the trust between companies and buyers, (55%) did not think there was a lack of trust, keeping in mind that quality and other concerns related to the construction industries should be evaluated frequently, alongside historical events, which play a major role in the level of trust in the relationships between the actors in the construction industry, which have been built up carefully over time.

5.5.3. Information Sharing

The question about having a shared and open ledger (database) between suppliers/buyers and the company indicated that (50.8%) of respondents in Saudi Arabia's construction industry considered this to be something beneficial, but only without too much information sharing, because sometimes it becomes negative and leads to uncontrollable situations. Select information is shared with those who have access to the open ledger. For example, everyone can see how much raw material was purchased from someone but not the price.

5.5.4. Intermediaries and Payment

Importantly, many studies indicated that there is a significant delay in the additional cost within the supply chain. There is a sturdy agreement surrounding the excessive time spent on administrating transactions; the majority (54.2%) of respondents within Saudi

Arabia's construction industry face additional time spent administrating. Frankly speaking, the results also indicated that the amount of cost in form of time, effort, and fees are considered at an acceptable level for both studies.

Moreover, (70%) of respondents pointed out that the current transaction speed is sufficient, including the time between delivery and payment; specifically, delivering the concrete and getting paid or delivery of the raw material and paying the supplier are significantly accepted and controlled.

Nevertheless, to have a more secured transaction process, banks as intermediaries in Saudi Arabia require specific improvements, as the transactions process takes a great deal time to register in any system, although without it, transactions would not be viable.

Finally, due to the low digitalization surrounding the construction industry, there is still a low level of readiness according to the study, unless the actors in the construction industry focus more on IT development and merge many technologies.

5.6. Confirmatory Interviews

Four major companies in Saudi Arabia were interviewed. Semi-structured interviews within the following areas of expertise have been carried out: blockchain, supply chain financing, and different departments such as the IT department and procurement departments. Qualitative studies tend to be more unstructured because the aim is to achieve an enrichment level of understanding of a certain subject and be capable of realizing the interviewee's individual perspectives and opinions. What is more, it is very helpful to let insights and new information come to light at some stage in the interviews, as blockchain technology is basically an unexplored focus area within the construction industry in Saudi Arabia. Table 3 shows four different interview guides that were answered by different experts.

Table 3. List of Interviews.

Interview Guide	Firm	Role/Position	Referred to as	Date/Duration	Interview
Smart Contract Technology	Saudi Business Machines	Blockchain Developer	CC-1	7 April 2021 40 min	Zoom
Supply Chain Financing	Al Sharq Ready Mix	Area Manager/Ready Mix Concrete	RMC-1	3 April 2021 30 min	Zoom
IT Department	Saudi Business Machines	Senior Solutions Architect (ICT—Blockchain—Cloud)	CC-2	6 April 2021 40 min	Skype
Procurement Department	Jubail Concrete Products	General Manager/Ready Mix Concrete	RMC-2	8 April 2021 40 min	Zoom

5.6.1. Blockchain Technology

According to CC-1, a "Blockchain developer", there are different types of blockchain that apply to nearly all the industries. For this reason, we have plenty of opportunities. CC-1 has leveraged blockchain for many businesses and makes huge impacts on them. By working in the electricity industry, as an example, blockchain is being used to underpin a platform to help balance the electricity grid in Saudi Arabia by storing and releasing electricity to and from batteries stored in people's homes.

Limitations of blockchain are scalability, immutability, lack of awareness, limited availability of technical talent, and consensus mechanism. Additionally, CC-1 stated that blockchain can disrupt several business domains, ranging from supply chain and healthcare to finance and accounting. There is also some anxiety surrounding those technologies' legal and regulatory aspects, since poor regulation can strangle innovation. However, strong regulation can boost the adoption of disruptive technology. CC-1 is not familiar with supply chain financing.

5.6.2. Supply Chain Financing

By looking into the use of SCF strategies in Saudi Arabia's construction industry, and to the best of the interviewee's knowledge, there were no concerned parties who used the techniques or mechanisms examined by Tate et al. [43]. However, RMC-1 thinks that SCF is an attractive method to implement within the construction industry; additionally, it could also lead to more prospective benefits and could be a complement to the current manual financial process in construction companies since it is weakly digitized. It is worth mentioning that RMC-1 stated that in 2020, the Ministry of Finance in Saudi Arabia has recently signed supply chain finance agreements that include three commercial banks in Saudi Arabia to ease and improve different government payments to many sectors, particularly the private sector suppliers such as contractors, with the aim of accelerating the various payment process within a specific period and allowing contractors to protect the money owed to them more rapidly.

5.6.3. IT Department

The interviewee claims that blockchain has some application in the supply chain world to introduce some business values. The construction industry depends heavily on the supply chain, and ensuring provenance is mandatory for costing and regulation purposes. Using material from unknown sources and with low quality is considered a risky aspect that will cause severe damages such as collapsing. Hence, provenance must be tracked. Simultaneously, such companies pay limited attention to IT capabilities and do not understand the values that IT can bring. As a result, CC-2 thinks that from a readiness point of view, the level is very low. However, the potential is good.

5.6.4. Procurement Department

According to RMC-2, a general manager at Ready Mixed Concrete Co., the procurement process goes through many phases: an examination of suppliers, an approved list, negotiation and contract, budget, and payment approval. Generally, clients pay for goods/services within 30 days or 180 days; automating the payment, in this case, might be difficult due to payment delays or unavailable cash. There are many risks involved in the procurement process, such as insufficient need analysis, poor supply chain management, fraud, and delivery. So far, there is trust between the company and the raw material suppliers after qualifying them and making sure that suppliers have registered companies. The company currently does not use any supply chain financing solution. Several outcomes are experienced in the contract process, namely: payment delay, trust issues, disputes, transaction security, contract tampering, transparency issues, high transaction costs, and power imbalance. The company currently does not involve any blockchain solutions since no one is very familiar with these technologies. Additionally, RMC-2 is not aware of any ongoing projects in the construction industry involving Blockchain.

RMC-2 showed moderate agreement that Blockchain technology uses an open ledger that provides visibility and traceability for everyone's supply chains since the cost structure in construction projects is considered an important factor, especially for private sectors, as shared information is not recommended. However, by this year, an Enterprise Resource Management (ERP) system will connect all companies with the General Authority of Zakat and Tax (GAZT), with new E-invoicing requirements. Saudi Arabia is considered one of the countries that seeks to facilitate transactions and encourages any IT advancements and digitalization. For that reason, RMC-2 asserted that blockchain technology has the potential of removing intermediaries (banks, etc.) from the transaction process. Recently, many companies used an electronic signature in the delivery note, but it became unrecognizable after a certain time due to legal considerations.

Moreover, a lack of legal a framework, a low level of knowledge and understanding, a ridged system (inability to alter), an open ledger/database, the inability to code and foresee most scenarios, cancellation, and changes are considered risks that smart contracts might pose after being implemented. However, RMC-2 believes that there is a place for

this technology or any technology within the construction business in Saudi Arabia since this sector, compared to other sectors, still requires many improvements.

6. Conclusions

This study sought to present the possible benefits and improvements gained from implementing blockchain technology within the construction industry in Saudi Arabia. For this purpose, the study collected data from 120 employees who work in ready mixed concrete in the Saudi Arabia construction industry using the pre-designed questionnaire to gain insight into the level of understanding of the mentioned technologies within Saudi Arabia's construction sectors. Specifically, the study appraises actors' readiness for introducing blockchain in the construction industry as a solution to supply chain resilience and sustainable development.

The findings revealed that combining both technological ideas leads to valuable opportunities. Additionally, some technical and environmental challenges need to be conquered. Furthermore, as concluded by Bjorklund and Vincze [18], other technology solutions such as a concrete mixer truck system and new apps will be required.

Unsurprisingly, the analysis results showed that the knowledge surrounding blockchain technology in Saudi Arabia's construction industry is very low, where (76.6%) of the respondents have no, poor, or very poor knowledge of blockchain technology. However, there is a positive sentiment among the respondents about the potential of implementing blockchain technology in Saudi Arabia's construction industry.

In the current state of knowledge surrounding the construction industry in Saudi Arabia, the results revealed that blockchain technology cannot be used principally to increase efficiency in supply chain management or supply chain financing due to the low-level maturity of digitalization within the industry; (90%) of respondents have not yet worked with blockchain technology. However, half of the respondents (50.8%) agreed that ''Having a shared and open ledger (database) between suppliers/buyers and your company is not bad" and had a strong willingness to share information between all the actors within construction projects, which means there is still a place for the implementation of blockchain solutions in the future, especially if they are integrated and combined with BIM technology or any similar technology. In addition, the respondents in the industry showed an interest in using these technologies for transaction automation, since about (54%) of them agreed that the time spent on administrating transactions is relatively long.

The Relative Important Index (RII) was used to describe the attitude of the respondents toward study factors. "The current contract process works well" (RII = 75%) and "The ability to enforce contracts works adequately" (RII = 72%) were ranked as the most important factors, while "Contracts are in no need for improvement" (RII = 37%) and "My understanding of Blockchain technology" (RII = 46%), were ranked as the least important factors.

There is a statistically significant difference in the respondents' responses towards the factors regarding the different respondents' experiences based on the first hypothesis testing results. Particularly, it is found that the most differences appeared between respondents who had experience of less than 5 years and the others. Furthermore, there is a statically significant difference in the respondents' responses towards these factors regarding the different company sizes according to the second hypothesis testing results; the most differences appeared between respondents who belong to companies with more than 51 employees and the others.

The confirmatory interview also added precious information related to the topic; the level of readiness from an IT point of view is very low due to the low level of understanding of these technologies even among several technologists; in addition, blockchain projects are generally expensive and the cost of building a blockchain app, as mentioned, depends on various factors, including app features, complexity, type of blockchain, and blockchain platform. Additionally, based on the results, the limitations of blockchain are scalability, immutability, lack of awareness, limited availability of technical talent, and consensus

mechanism. Furthermore, there is some anxiety surrounding the legal and regulatory aspects.

To summarize, the findings showed that the combination of both technological solutions leads to valuable opportunities, which have some limitations due to some technical and environmental challenges that need to be overcome, as well as the improvement of existing technological solutions. This article is of definite local interest, but less so in global terms, as this study's approach may be used to assess the digital transformation of fundamental company activities utilizing blockchain technology in other developing nations. Furthermore, business services and communications services will benefit from blockchain, while wholesalers, retailers, manufacturers, and construction services will benefit from adopting blockchain to engage customers and fulfill the demand for authenticity and traceability on international supply chains.

The study findings recommend increasing the knowledge of blockchain technology within Saudi Arabia's construction industry by providing extensive training to the employees and all actors in the industry. Due to the amount of improbability surrounding blockchain technology, an organized framework must be studied carefully.

For future research in this area, the authors recommend investigating the potential of blockchain Technology for Construction Management in Saudi Arabia while considering the challenges and opportunities for stakeholders.

Author Contributions: Conceptualization, N.A.A. and G.S.; methodology, R.S.; software, N.A.A.; validation, G.S., R.S. and F.S.; formal analysis, N.A.A.; investigation, G.S. and R.S.; resources, F.S.; data curation, N.A.A. and F.S.; writing—original draft preparation, N.A.A. and G.S.; writing—review and editing, R.S. and F.S.; visualization, N.A.A.; supervision, G.S. and R.S.; project administration, G.S. and R.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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