UK Government

FAIR BIZ

UNDP

Blockchain Technology for the Construction Industry of the Philippines

May 2020

FAIR BIZ

UNDP, in cooperation with the UK government, aims to promote fair, transparent and predictable business environments in dynamic ASEAN countries by working with governments, civil society and the business sector.

Author:

ADRIAN ROY L. VALDEZ, Ph.D.

University of the Philippines Diliman
Department of Computer Science
CENTER OF BLOCKCHAIN RESEARCH AND APPLICATIONS

UNDP in the Philippines
15th Floor North Tower, Rockwell Business Center Sheridan, Sheridan Street corner United Street, Highway Hills, Mandaluyong City 1550 Philippines
P.O. Box 7285 DAPO, 1300 Domestic Road, Pasay City, Philippines
www.ph.undp.org | www.facebook.com/undp.ph

Cover Photo by Terry on Unsplash

Following photos by: Stanislaw Zarychta, Clint Adair, Chuttersnap, André François McKenzie, EJ Yao, Dmitry Demidko

Table of Contents

Table of Contents

1. Introduction

Construction has always been a key driver of economic growth for our country, the Philippines. Last 2018, the industry was considered to be one of the biggest industries in the country, making a contribution of 6.8% to the Philippines's Gross Domestic Product [12]. Furthermore, the government increased the spending on infrastructure by 49.7% in the first 11 months of the same year as compared to same period in 2017 [7]. This is largely because of the government's recent plan to upgrade the country's transport infrastructure complemented by positive developments in the regional economic condition from residential and energy infrastructures.

Funding the right projects and completing them efficiently and safely determines the value in the construction industry. Infrastructure projects that are completed at a lower cost and on a faster time deliver higher returns. However, the effectiveness and productivity of the industry has often been subject to question. Based from a McKinsey research, the productivity of the construction industry has been stagnant for decades, whereas in other areas such as manufacturing, productivity has been doubled over the same period [11]. This means that the construction industry needs to be more effective in order to keep up the phase of the global economy.

Technological innovations have completely transformed the way people work and live. Robotics, cloud technology, and artificial intelligence are just a few examples that have greatly increased the potential of other industries. In more recent times, blockchain technology is becoming one of these revolutionary technologies. Numerous people have already recognized its potential to change industries, operating processes, and business models. It has been applied into various industries such as healthcare, finance, energy and utilities, government, retail, and many more [5].

In order to facilitate a robust and cost-efficient adoption of the blockchain technology in the Philippine engineering and construction industry, it is imperative that its benefits are assessed against its costs. There are intangible and indirect impacts to be mapped aside from the invested resources. Similarly, there are applications that may have not been explored by the other countries which are functionally relevant to the stakeholders in the Philippine context. The following are the specific objectives of this study with the purpose of establishing these characteristic consequences. The study aims to present how blockchain technology is being applied in the engineering and construction sectors of other countries. It also plans to identify enablers and challenges in adopting blockchain technology in the Philippines. Additionally the study presents the sustainability and scalability of use of blockchain in the local engineering and construction industry. This study also identifies the positive and negative impacts (e.g. economic, social, environmental, and legal), of blockchain adoption, and present ways to manage identified risks. Lastly, the paper offers recommendations to UNDP and partners on how to facilitate SME blockchain adoption in the Philippines.

The paper is organized as follows. Section 2 provides a literature review that defines blockchain fundamentals, identifies the current blockchain applications, describes on the current situation of the construction industry of the Philippines and relays the possible applications of blockchain technology in the Philippine setting. Section 3 presents the survey methodology and experimental design used as well as the results gathered. Finally, Section 4 summarizes and concludes the results of this study.

Photo of physical coins to represent cryptocurrency

2. Literature Review

2.1 Blockchain Overview

In 2008, a white paper was released by a group of developers under the pseudonym of Satoshi Nakamoto. In this paper, they have presented a model of the Bitcoin and described how blockchain technology, a distributed peer-to-peer structure, could be the an answer to solve the problem of maintaining a large registry of transactions. This model was implemented in 2009 and eventually created a spike in the interest of people in Bitcoin and the development of other cryptocurrencies. Bitcoin eventually became successful by reaching 10 Billion dollars with its capital market in 2016.This led to even greater heights in 2017 when one token of the crypotcurrency reached $ 17,900.

Fundamentally speaking, blockchain can be described as a digital ledger made up of a chronological chain of “blocks”, where each block is a record of network activity that is added to the end of the existing chain [5]. The basic unit in this technology is a single transaction that involves one or more bodies. This can be a transfer of information but is usually a payment process [6]. Several transactions like this can be combined into a single block, and each block can be defined as an encrypted piece of information that is stored, time stamped and distributed to multiple servers. These are then validated and verified by a network of participants, often called as “miners” who compete with each other to create the next block. If a block is successfully validated, it is appended to the chain of previous blocks, hence the term blockchain [7].

There are three generations of blockchain technology so far namely, blockchain 1.0 for cryp- tocurrencies, blockchain 2.0 for digital processes and finance, and blockchain 3.0 for digital society [8]. The first generation focuses on the decentralization of transactions of money and payments. The second generation, on the other hand, functions in a more general way and focuses on trans- actions related to any kind of asset. While, the third generation of blockchain goes beyond the concept of transactions and covers areas such as health, science, culture and government. Although the applications of blockchain as non-currency assets is relatively new, it has been accepted and applied by future-oriented institutions. An example of this can be the Dubai government wherein, they issued digital health records for citizens that will enable digital title transfers supported by blockchain technology [9].

Photo of network to visualize blockchain concept

2.2 Blockchain Characteristics

According to a study by Zheng [10], blockchain has four key characteristics namely; decentralization, persistency, anonymity, and auditability.

- **Decentralization**

In the conventional transaction systems, all transactions conducted must be validated by a either a trusted agency or an established institution. This results in the inevitable cost and bottlenecks at the central servers. In blockchain, a third party is no longer needed. Consensus algorithms are used to maintain data consistency in this distributed network.

- **Immutability**

In blockchain, the transactions can be validated at a faster rate and all invalid transactions would not be admitted by miners. Deletion and modification of transactions that are already included in the blockchain is restricted and considered impossible to be done.

- **Anonymity**

The identity of the users in blockchain is safe because each user in the system can interact with a generated address that does not reveal their identities.

- **Auditability**

Bitcoin blockchain stores data about the balances of the user based on the Unspent Transaction Output model [11]. Any transaction in the system has to be linked to a previous unspent transactions. Once the current transaction is recorded into the blockchain, the state of those referred unspent transaction become unspent to spent. Thus, transactions could be easily verified and tracked.

Another important feature of blockchain technology is data distribution. This means the database can be scattered around multiple locations in a shared manner. It share similarities with a cloud system, but instead of having only one source where the information is stored, there are multiple ledgers that are scattered around which are simultaneously being updated [12]. This direct exchange of information between users is enabled by a consensus mechanism or a highly resilient network protocol without the need of any intermediaries.

2.3 Blockchain Limitations

Despite the evident benefits and features of blockchain, it still faces a number of challenges and limitations. One of the most prominent challenges of blockchain is scalability. Validating and reaching consensus requires the presence of the entire blockchain, i.e. all the transactions that ever happened, thus demanding a lot of data storage space [13]. In addition, a proof-of-work consensus algorithm is theoretically vulnerable to the so called “51 percent attack”. This happens whenever on network node would have 51% of total network computational power, thus gaining the power to single-handedly create blocks and confirm transactions [14]. Another challenge can be that immutability is not always desired. This feature might be useful for irreversible proof ensuring, but not in the case of important transactions. Considering the maturity of the technology, blockchain is still relatively young. The lack of academic research and standardization in the industry might post great security risks. As Halpin and Pierkarska [15] pointed out in their study, blockchain development is done by practitioners without involvement of cryptography specialists. Thus, resistance and security solutions are done in a case-to-case basis due to the individual choices of the developers, which are based from their practical experience.

2.4 Current Blockchain Applications

The adoption of blockchain technology was first pioneered in the Financial Technology industry through cryptocurrencies such as Bitcoin and Ethereum, but has now expanded into other sectors such as health, real estate, entertainment, supply chains and many more. Below are just some of the examples of the application of the technology.

- **Smart Contracts**

A smart contract is one of key innovations brought by blockchain technology. It is basically a digital contract, which can execute its terms automatically upon the fulfillment of the predefined conditions [12]. Smart contracts are transactions that take place between verified parties, done by a computer code and vary widely in scale and complexity [16]. Through this functionality, a wide of processes can be improved, automatized and eventually become more effective.

- **Healthcare**

Majority of problems in healthcare stem from the lack of traceability of transactions and the complex network intermediaries [17]. Due to the potential of blockchain, it has gathered significant interest in the medical industry. Identified use cases for blockchain industry are: patient data management, pharmaceutical research, prescription management, supply chain management of medical goods, billing claims, and many more. One example is the company called Medicalchain has developed a blockchain platform that enables secure, fast and transparent exchange of medical data. This platform then records the interactions of the patients to create a user-focused electronic health record that is auditable, transparent and secure [18].

- **Retail**

In this industry, some high value items that rely on certificates that can be lost or easily tampered with. The authenticity of certain products such as diamonds can sometimes be difficult to determine. The start-up Everledger takes an alternative approach by utilizing 40 data points that uniquely identify a diamond. Using these records, the buyer can determine whether the seller is the actual owner of the diamond and the can they also be sure that they are not buying a diamond from a conflict region [19].

- **Real estate**

The real estate sector tends to be highly segmented and localized, with privately negotiated transactions at high costs because of the involvement of a number of trusted third parties [20]. The high transaction costs, lack of transparency and need for digitalization in real estate companies give blockchain its game-changing potential [21]. A company like Ubiquity was formed with its platform that records and tracks the ownership and property information using blockchain technology. The decentralized system of record keeping and information they created helps increase the confidence in the information being recorded and the overall real estate ecosystem [22].

- **Entertainment**

In the music industry, the handling of copyrights, licenses, and royalties still follow the outdated methods, resulting in the increasing complex revenue streams, lack of trans- parency, and lack of compensation for majority of the artists involved [23]. Applying blockchain technology across this industry would simplify the management of rights and royalties into a single version of truth, regardless of rights ownership specifics, ensuring all stakeholders the right amount in a timely fashion. This type of blockchain use case is currently applied by Spotify wherein they acquired Mediachain labs to develop a decentralized database that will facilitate the connection of artists and their licensing agreements with the tracks on the streaming platform [24].

- **Supply chain**

The supply chain industry has been one of the biggest benefactors of the blockchain technology. The problem of document tracking and automated paperwork processing in the con- text of international container transportation is an example of one key issues being addressed by blockchain. Companies such as IBM and Maersk worked together to form “TradeLens” as a means to connect the vast global network of shippers, ports, carriers and customs and tackle the inefficiencies and digitize paper records [25]. Furthermore, Walmart also partnered with IBM to augment the existing IT system of their supply chain using a blockchain ledger that tracks the movements of their food items. This new traceability in their system tracks data such as farm origin, batch number, factory data, and shipping details that were written on the blockchain and is available to all network participants [26].

- **Construction**

In the construction industry, young startup companies are developing software that address the management aspect of a construction project. These usually range from documentation and supply chain management. SiteSense is a material management software that maintains an activity feed for every construction resource and record document. Blockchain is used in conjunction with this program to store these transactions privately and securely, allowing the stakeholders to connect and sync the transactions [27]. Brickschain or Briq, on the other hand, is company that digitizes buildings in the blockchain and chronicles the entire process. Their process integrates into systems, workflows and the building’s supply chain to chronicle the entire building process and create a data repository. This in return provides risk management and risk mitigation tools [28].

2.5 Blockchain in South East Asia

The decentralized and versatile nature of blockchain is attracting a number of businesses and governments across the South East Asia (SEA) region. Majority of the current applications of the technology in the region revolves around payments, cryptofinancing and supplychain management. In Thailand, Omise is a startup that offers an online payment gateway through blockchain to facilitate seamless digital transactions. The company also focuses on processing solutions that are tailored to business needs such as automated checkout, social assistance, automated workflow and flexible payment options [29]. In Singapore the startup, Yojee, is gaining ground for using artificial intelligence (AI) and blockchain technology to help logistics companies coordinate their fleets and optimize and manage tracking, pickup and delivery operations in real time. Moreover, Dacsee, which was launched in Malaysia, is the world’s first fully decentralized and autonomous social ride-sharing service. This application uses the tokenized blockchain technology to create a special cryptocurrency market for the ride-hailing industry [30].

In the construction industry, the use of blockchain in SEA is considered to be in its early stages. Majority of the studies still revolve around the review, feasibility and evaluation of

possible blockchain applications in their respective countries [31] [32]. However, the use of blockchain in BIM or building information modeling is considered to be on the rise in the region. BIM enables the stakeholders to create a virtual model of a building or a prototype before the actual construction. This in return is beneficial in optimizing the construction process by reduction of possible on-site revisions and errors. Blockchain improves BIM by its information sharing feature. Blockchain application in building information modeling are vast, including integration of IoT, asset management, artificial intelligence, virtual reality, augmented reality, and many more. It is important to point out, however, that the adoption of BIM is limited in Asia with the exception of Japan and South Korea with 85% and 58% adoption rate respectively [33]. Furthermore, only 17% of global adopters use BIM on very high-level engagement, which is to utilize the tool from the planning to analysis and execution. The other 22% are using BIM mainly as analysis tool in terms of building performance and energy efficiency tool. And more than half are still in a low to moderate level engagement, only using it as model creation tool. This is due to the lack of experience as new adopters [34].

2.6 The Philippine Construction Industry

In the context of the construction industry, optimization of the construction project management is essential to the contractors, because it translates to the utilization of less resources such as time, cost, and manpower to achieve maximum profit. However, this is difficult to achieve, since it involves smooth coordination between members of the working group, i.e. contractor, architect, structural engineer, client, and supplier. According to a study by Salic, conflicts between consultant and design engineer, obsolete technology, insufficient data collection, slow mobilization of labor and equipment, delay in progress payments and short original contract duration are the main reasons why construction projects are delayed [35].

An important hindrance in achieving efficiency in the construction industry is the lack of trust between the project stakeholders. Projects in this industry tend to be expensive and bigger that projects from other industries. This carry a lot of risk and fear among those involved. Mistakes are costly and stakeholders can end up losing enormous amounts and closing their businesses. The people involved therefore try to mitigate that risk to an unusual degree, through the use of contracts and data hoarding [36].

The issue of corruption according to the think tank REID foundation, is also present and evident in the industry. Based from their confidential interviews conducted from October 2018 to March 2019, construction companies allot up to 35% of their budgets for infrastructure projects to pay off government officials and employees in order to prevent them from causing any further delays. In order to accommodate the additional costs and keep the project moving, companies had to compromise the other parts of construction such as the quality of raw materials and number of laborers. [37]

The increase in the number of stakeholders such as clients and contractors has increased throughout the years. According to Philippine Statistics Authority, the total number of constructions from approved building permits issued by Local Building Officials (LBOs) for the year 2018 reached 173,193. This number is higher by 3.9 percent from the 152,012 constructions recorded in 2017 [38]. 73 percent of the total constructions or 126,429 were classified to be residential projects, having a growth rate of 14.0 percent from the 110,942 projects reported in 2017. This translates to the increasing in value of construction which was estimated to be at PHP476.0 billion, 42.9 percent higher compared

to the PHP333.2 billion reported value from the previous year. Furthermore, the number of registered contractors is increasing since 2008. In 2018, it was reported that 10,909 contractors were successfully licensed, that is 12.2 percent higher than the previous year [39].

The Philippine Contractors Accreditation Board (PCAB) is the primary government agency tasked with the licensing of contractors for both private and public projects. They were able to categorize the contractors into three main classifications namely: General Engineering, General Building, and Specialty. These main classifications are then further sub classified based from their area of specialization. Each contractor is then put into a category based on their financial capacity, technological capacity and experience, and overall accumulation of points. This range from AAAA to D for General Engineering, General Building, and Specialty, while Specialty-Trade classification is automatically categorized as E. The contractors that are categorized as AAAA, AAA, and AA are considered to be large corporations, while those that are categorized as A and B are medium sized companies, and the rest are deemed to be small businesses. The classification table of PCAB can be seen in Figure 2.1

2.7 The Construction Industry Supply Chain

In order to obtain a concrete picture of the vulnerabilities of the construction industry to aspects of graft and corruption that this study aims to explore, the supply chain of procedures, documents, and protocols followed by the entire ecosystem of the construction and engineering industry should be defined formally. The identified structure is illustrated in Figure 2.2.

The necessity for the transactions within this sector stems from companies, entities, and agencies demand for development, expansion, and investment into structures. They will be referred to as Clients and are shown as the orange enclosure in the diagram. The client will provide the necessary requirements in the form of specifications or target metrics. Most importantly, the client will provide the financial funding during the period of the project.

Answering the call for these projects are to be referred to as Primary Contractors. These are usually firms, companies, and corporations with knowledge and capabilities in realizing the various developments that are called for by the client. They are shown as the blue enclosure in the diagram. They are made of two entities, the consulting collective for the project's design and the main contractor for the construction execution and management.

The designs put forward are subject to the client's approval through the requirements defined by the client themselves and the standards established by the client's consulting quality inspectors. This will also be applicable to every deliverable and progress made by the main contractor in the execution (construction per se) of the project. Most standards validation in the project is concerned with the quality and safety assurance throughout the development. These includes the materials and work quality, structural strength and resilience, and common hazard safeties like fire and earthquake considerations.

Depending on the needs of the client, the primary contractors may acquire materials, equipment, manpower, etc. from third-party companies to supplement or accomplish various subcomponents of the project. They are procured in the project secondarily by the main contractors. They will be referred to as Subcontractors and are shown as the red enclosure in the diagram.

PCAB CATEGORIZATION - CLASSIFICATION TABLE
(BOARD RESOLUTION NO. 201, SERIES OF 2017

Classification	Category	Minimum Qualification Requirements					
		(1) Financial Capacity*		(2) Sustaining Technical Employee (STE) Construction Experience**			(3) Overall Credit Points***
		Minimum Networth / Equity (PhP)	Credit Points	Individual (Years)	Aggregate (man-years)	Minimum Credit Points	
A. General Engineering	AAAA	1,000,000,000.00	10,000.00	10	60	300	10,300.00
GE-1 (Road, Highways, Pavement, Railways, Airport Horizontal Structure, and Bridges)	AAA	180,000,000.00	1,800.00	10	60	300	2,850.00
	AA	90,000,000.00	900.00	10	50	250	1,365.15
GE-2 (Irrigation or Flood Control)	A	30,000,000.00	300.00	7	21	105	475.00
GE-3 (Dam, Reservoir, or Tunneling)	B	10,000,000.00	100.00	5	10	50	177.50
GE-4 (Water Supply)	C	6,000,000.00	60.00	3	3	15	105.50
GE-5 (Port Harbor of Offshore Engineering)	D	2,000,000.00	20.00	3	3	15	35.00
B. General Building	AAAA	1,000,000,000.00	10,000.00	10	60	300	10,300.00
GB-1 (Building or Industrial Plant)	AAA	180,000,000.00	1,800.00	10	60	300	2,810.00
GB-2 (Sewerage or Sewage System)	AA	90,000,000.00	900.00	10	50	250	1,345.00
GB-3 (Water Treatment Plant & System)	A	30,000,000.00	300.00	7	21	105	471.00
	B	10,000,000.00	100.00	5	10	50	175.50
GB-4 (Park, Playground or Recreational Work)	C	6,000,000.00	60.00	3	3	15	96.50
	D	2,000,000.00	20.00	3	3	15	35.00
C. Specialty							
SP-FW (Foundation Work)	AAAA	1,000,000,000.00	10,000.00	10	60	300	10,300.00
SP-SS (Structural Steel Work)							
SP-CC (Concrete Pre-casting, Pre-Stressing or Post-tensioning)	AAA	180,000,000.00	1,800.00	10	60	300	2,410.00
SP-PS (Plumbing & Sanitary Work)							
SP-EE (Electrical Work)	AA	90,000,000.00	900.00	10	50	250	1,145.00
SP-ME (Mechanical Work)							
SP-AC (Air-conditioning or Refrigeration)	A	30,000,000.00	300.00	7	21	105	421.00
SP-ES (Elevator or Escalator)							
SP-FP (Fire Protection Work)							
SP-WP (Waterproofing Work)	B	10,000,000.00	100.00	5	10	50	165.50
SP-PN (Painting Work)							
SP-WD (Well-Drilling Work)							
SP-CF (Communication Facilities)	C	6,000,000.00	60.00	3	3	15	90.50
SP-MS (Metal Roofing & Siding Installation)							
SP-SD (Structural Demolition)							
SP-LS (Landscaping)	D	2,000,000.00	20.00	3	3	15	35.00
SP-EM (Electro Mechanical Work)							
SP-NF (Navigational Facilities)							
D. SP-Trade	Trade/E	100,000.00	1.00	none	none	none	1.00

* Minimum Qualification Requirements for Principal Classification

** For Other Classifications/s. Minimum 3 Years Actual Construction Experience

*** Overall credit points inclusive of Equipment Capacity (1 point/P100Th); Experiences of Firm (10 points/years of active existence); and 1 point/P100Th of 3 year Average Annual Volume of Work Accomplished; and COMTCP points if STEs are COMTCP certified

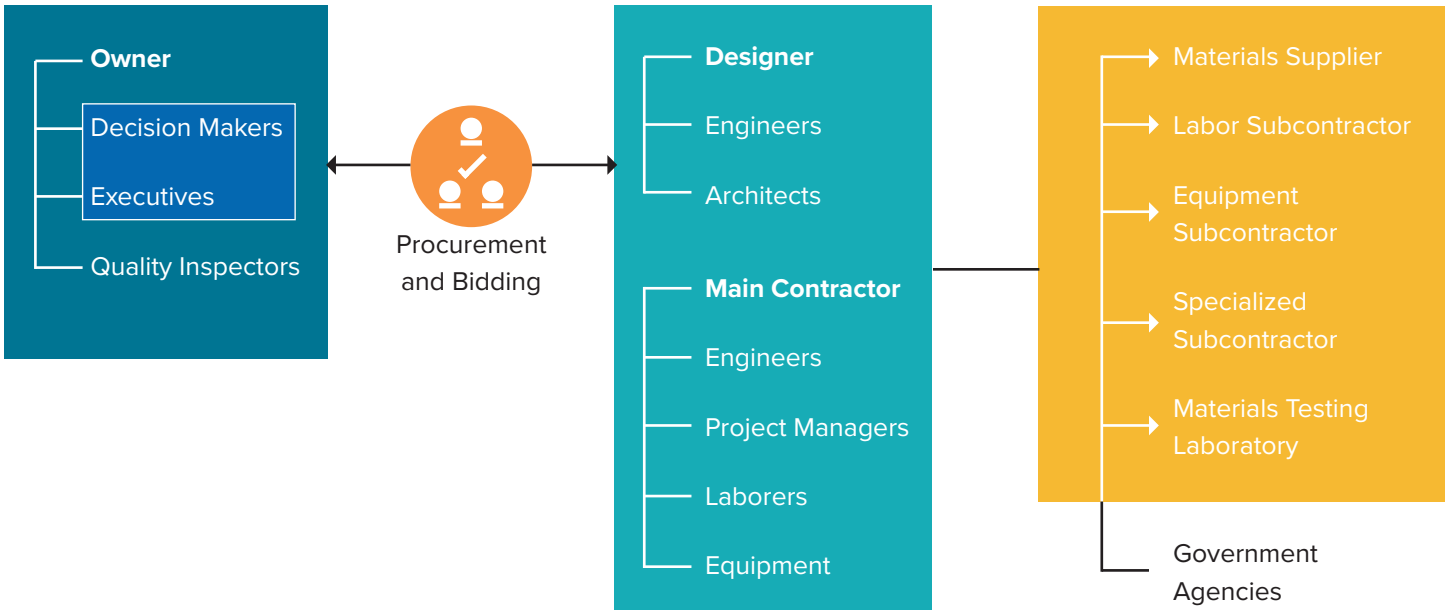

Figure 2.2: A diagram of the key players within construction industry projects.

2.8 Blockchain and Construction

In identifying the enablers and challenges of establishing the blockchain in the construction industry in the Philippines, the specific applications must be conceptualized to have a better mapping of their corresponding enablers and challenges. These applications are presented as follows:

- **Automated payment systems through smart contracts**

A prevalent issue in the construction industry is the inevitable delay of fund turnover from client to contractor. This cascaded payment structure reflects on the progress and performance of the contractor with respect to the agreed project specifications and timeline. The conflict arises when the client third-party QA does not align with the declared report of the contractor.

Smart contracts can be implemented to require the client to provide the recompense of project milestones in advance. The smart contract will only release the payment immediately after the validation of the project progress. QA will remain to be handled by a third-party consultant but the blockchain records the report of all parties involved. The blockchain and smart contract implementation will ensure the timely payment for the contractors, the assurance of quality performance against agreed standard, and the accountability of future dispute in agreement.

- **Tokenized labor payments**

Construction project management is a very fragmented operation. One of its significant undertaking is tracking project workforce for the purposes of compensation and performance monitoring.

A blockchain tracking interface can be deployed to substitute the laborer daily time record under the verification of respective foremen. Compensation for the laborers' work can be provided immediately and the project progress can be audited with a immutable and transparent record at hand.

- **Supply chain and inventory**

Construction supplies undergo a chain of custody following various regulatory standards. This supply chain ranges from

processing of raw materials to manufacturing of fabricated components. These materials, along with others, are stored on-site or in a separate warehouse awaiting for use in a construction project.

A blockchain record can be implemented to track the history and specifications of the materials such as its, source, time of delivery, compliance with quality standards and many more. A blockchain infrastructure would streamline the workflows for all parties involved and would also provide the auditors with great visibility into the activities in the supply chain.

- **Health and Safety using IoT (Internet of Things)**

In a blockchain enabled construction management system, every health and safety incident or record of unsafe conditions (extreme weather, unauthorized actions on site, events logged in the risk register, etc.) can be registered and a risk mitigation can be initiated.

The use of sensors and the internet of things (IoT) are primarily useful as these tools can act as a reliable source of data. Blockchain collates health and safety data from the supply chain and provides important insights to the project team about emerging or potential health and safety issues.

- **Equipment life-cycle tracking using IoT**

Field productivity is greatly affected by the performance of the equipment utilized on-site. IoT sensors can detect multiple indicative metrics of wear and life-cycle of the equipment for tracking. These can be utilized for regular maintenance monitoring to ensure maximized productivity and safe use for the project workforce.

Recording the data produced by the sensors in a blockchain provides a platform to identify accountability in case of missed maintenance and operations failure.

3. Experimental Design

Having identified specific applications of the technology in the local construction industry, its suitability and acceptability are to be examined through consultations with various experts and practitioners. This inquiry was done through person interviews and survey questionnaires.

3.1 Private Entities

In the context of the private sector, it is important to know the insights of the members particularly the contractors and engineers who are in charge of the construction project. The people who work in the field would be the major beneficiaries of this technology upon implementation. As with any disruptive new innovation there is a need to fully understand how it functions and how it could be used within the construction industry. In order to get to know more about this, a questionnaire survey and person interviews were conducted.

- **Survey Questionnaire**

A questionnaire was designed for companies identified as clients and as main contractors. A priming set of questions is asked comprised of optional information regarding the company or the individual's identification and required information that are relevant to the study.

The first part of the questionnaire aims to identify the characteristic of the correspondent. This includes the position of the correspondent in the company,the PCAB classification (AAAA to E) and primary classification (General Engineering, General Building, Specialty, Sp. Trade). These are then followed by questions on familiarity and common knowledge with the concept of Blockchain technology.

The second part of questionnaire aims to know whether or not the respondents are open to adopting the identified blockchain applications for the their industry. A question on the possible challenges of using this type of blockchain application follows. For the benefit of the respondent, a

brief introduction of blockchain technology is provided. The specific applications discussed in Section 5 are also presented individually in this part of the survey.

Lastly, the respondent is provided with an option to suggest areas of the industry in which they think the technology would be applicable and what other applications of the technology do they think would be helpful to the engineering/ construction industry.

- **Interview**

Five key informant interviews were conducted in order to identify the current practices of the industry and the common perception on how blockchain technology can solve them. Each chosen participant was a member of a different sector of the construction industry. The key informant interviewees composed of a supplier, a subcontractor, an engineer and two contractors. The first part of the interview asked about the instances of corruption and other negative practices they have experienced in their respective careers. This was then followed up by their stand on these practices and their willingness to reduce the possibility or instances of corruption in their respective fields. The next part of the interview asked for their personal views of whether blockchain would be effective in minimizing bribery and corruption. Lastly, the respondents were asked for their opinions on what they think about the possible advantages and disadvantages of applying the technology in the construction industry.

3.2 Government Body

In the intention of gaining further insight from the government body with regards to the policy setting, mandates delineation, and general sectoral viewpoint involved in the construction and engineering industry, various government entities were approached with a solicitation for an open- type questionnaires. These agencies could have involvements in the construction and engineering industry ranging from recommending associations of professional and academic expertise to directly governing and regulating the sector itself. For agencies with a broader scope beyond the said industry, specific bureaus or departments were identified to target a refined and representative response from its parent agency.

The questionnaire submitted for answering were not uniform insofar as they were tailored to envelop with the published mission and mandates of each concerned agency. However, it follows a common structure of inviting the respondent to discuss the agencies' efforts; historical, currently implementing, or intended, in curbing corruption, promoting good business practices, or generally improving efficiency of the industry's processes and organization. The respondent is then lead to a succeeding section regarding the technologies, specifically blockchain, utilized in enhancing the procedures, administrative or operational, within the industry.

Photo of bitcoin/cryptocurrency

4. Results

In this section, we present the results as the following: the aggregated answers of different construction companies to the possible adoption of blockchain technologies for their operations, the consultation with our key informants who are directly involved in the construction business, and the responses of two government agencies to our questionnaire and further insights they hope to share in the subject matter.

4.1 Survey Questionnaire

4.1.1 Survey Coverage

Out of all the questionnaires distributed through different channels, 30 samples have returned. The positions indicated by the respondents are identified to be within general capability to answer on behalf of the overall operations of their company. These positions range from project engineers of larger companies to owners themselves of smaller companies. The responses are summarized below as follows.

4.1.2 Demographics

More than 84.0% of the respondents belong to the small (PCAB-C, D, E or not yet accredited) to medium (PCAB-A, B) company category. The dominant company classification were general engineering and general building which each accounting for 42% of all the respondents.

In terms of familiarity with the concept of blockchain Technology, majority of the respondents identify themselves as somewhat familiar (36.0%), not so familiar (36.0%) or not at all familiar (28.0%) with the technology. This goes with the fact that 88.0% of the respondents did not have any previous experience with blockchain technology. The rest that did have experience were only limited to cryptocurrencies (i.e. they own or invest in cryptocurrencies like Bitcoin).

4.1.3 Blockchain Technology Applications

The study has identified five possible applications of the blockchain technology in the engineering and construction industry:

4.1.3.1 Automated Payment Systems through Smart Contracts

For this type of application, 73.0% of the respondents said they would consider using this technology in their engineering/construction business. However, several challenges in adopting this technology were identified by the respondents—the hardest being the corruption in the existing system. On the contractor side, one respondent pointed out that contractors/subcontractors “fake accomplishment reports” and that “the quality of the projects did not follow specifications stated in the contract”.

Most contractors will tend to stick to what has been working for them, to what they are used to—and most of them, especially among the subcontractors, does not even comply with the existing PCAB requirements. The implementation of the smart contracts hinges on the reports submitted in the system and the validation of accomplishment reports involves some form of human interaction which can be manipulated and bribed. Another problem would be the lack of understanding on how the blockchain system operates.

On the client side, respondents pointed out that it may be difficult to secure cash from the client since most of them might prefer the traditional method wherein they are not required to provide the payment in advance. Adding a third party to handle the smart contracts would also mean additional costs to the client, and most small to medium construction projects tend to have limited budget. Additional training or hiring of personnel knowledgeable on blockchain may also be needed.

4.1.3.2 Tokenized Labor Payment

Only 50% of the respondents were willing to adapt this blockchain application in their business. Most of them agree

that companies already have systems in place that provide a structured compensation program for its workforce, so using DLT for tokenized labor payments may not offer that much improvement. Respondents pointed out that the standard daily time record for example, is easier to use and is sufficient in tracking the project workforce.

Another challenge is the technology illiteracy of laborers and foremen. Most laborers and foremen did not even finish high school and do not understand how to use blockchain application and most of them needs to be trained to do so. This process can be very difficult and time consuming and could cause delays in the project. Another problem is that laborers tend to use paper cash more; most of them do not even own a bank account. The availability of internet access in construction sites located in provinces makes the use of blockchain application even more difficult.

The system is not also safe from corruption. Concerns about the laborers conniving with foremen is common among the respondents. Putting a lot of trust on foremen to be fair with the laborers and the company defeats the purpose of establishing a trustless system. The application does not address the problems of the traditional method like assessing the quality of work rendered by the laborers, not just counting the man hours. While it is true that the data captured by using this application can provide insights on the most critical work in the project, it still falls short on providing a just and fair system for labor compensation.

Photo of bitcoin token

PCAB Category	Yes	No
AAAA	2	0
AAA	1	2
AA	0	0
A	0	1
B	3	2
C	2	0
D	3	0
E	2	1
Not yet accredited	9	2
Total	22	8

Table 4.1: Response summary for blockchain application: automated payment systems through smart contracts

PCAB Category	Yes	No
AAAA	1	1
AAA	1	2
AA	0	0
A	1	0
B	3	2
C	1	1
D	0	3
E	0	3
Not yet accredited	8	3
Total	15	15

Table 4.2: Response summary for blockchain application: tokenized labor payments

4.3.3.3 Supply Chain and Inventory

Around 77% of the respondents were willing to try this type of blockchain application in their business, however, concerns were raised regarding the reliability of input data. It was pointed out that "suppliers sometimes cheat the quality or amount of materials", and automated systems that still rely on human input would still be vulnerable to corruption. Again, most of the respondent are concerned about the assurance of reliable record of materials since the application does not necessarily eliminate cheating in the material quality tests for example. They still need to "trust the supplier".

Respondents also pointed out that although it [blockchain application] can reduce redundancy in the records and encourage stakeholders to comply with agreed upon specifications, most contractors already have a system for procurement, purchasing and inventory of materials. Powerful software like SAP are already in use in the industry and shifting from one system to another would mean that they have to spend resources and time to retrain their staff and make major adjustments. Additionally, one should take into consideration that not all areas in the country has internet access, so once the materials have been mobilized to project sites in remote areas, it would be difficult to keep track of.

Finally, only large companies and suppliers would be able to provide the necessary resources to shift into a new system. Small to medium hardware stores, suppliers and contractors in the country would be faced with high entry barriers (i.e. technical know-how needed, suppliers in remote locations without proper and reliable internet access, etc.) and would probably not take part in using the application. The system will only work if enough suppliers become part of the blockchain network, otherwise, there would be a lot of missed opportunities for contractors and suppliers outside the system (i.e. if this becomes a legal requirement for bidding, then projects would only go to contractors who can afford to use the system; or one contractor will be limited to purchase materials from suppliers who are part of the blockchain network).

4.3.3.4 Health and Safety using IoT (Internet of Things)

Although 77% of the respondents said they would consider using this type of application, the primary concern among all of them is how the sensors would be to accurately detect accidents. The use of such technology could be expensive and advanced knowledge (about internet of things) would be required to operate it. It can be a good safety monitoring system but on the other hand, inaccurate assessment of unsafe conditions could cause delays in the project which could mean additional costs to the contractor. When sensors fail or get damaged in project sites located in remote areas, its replacement/repair can also cause delays in the project.

Data safety was also a concern. Transparency is required to provide reliable insights about safety but it can give away too much of the construction techniques used by different contractors (which seems to be a trade secret in the Philippine setting, different contractors handle things differently, and there is not one standard methodology for everything) so it is a concern as to who has access to the data. Individual job safety assessments and plans need to be established pragmatically and every step of the job needs to be laid out in the open and some contractors might be hesitant to provide that information.

The integration with current rules and regulations should also be considered. The Department of Labor and Employment (DOLE) already has existing health and safety rules and monitoring systems, so it is important that the application does not cause any conflict with the existing regulations of the department. Finally, the issues of report validation and access to a reliable internet connection still remains a concern among the respondents.

PCAB Category	Yes	No
AAAA	1	1
AAA	1	2
AA	0	0
A	1	0
B	3	2
C	2	0
D	2	1
E	3	0
Not yet accredited	10	1
Total	23	7

Table 4.3: Response summary for blockchain application: supply chain and inventory

PCAB Category	Yes	No
AAAA	2	0
AAA	1	2
AA	0	0
A	1	0
B	5	0
C	2	0
D	1	2
E	0	3
Not yet accredited	11	0
Total	23	7

Table 4.4: Response summary for blockchain application: health and safety using IoT

4.3.3.5 Equipment life-cycle tracking using IoT

Around 83% of the respondents said that they were willing to test the technology in their respective businesses. The most common concern would be technological implementation and costs. The technology must work with and be calibrated to different types of equipment and creating a sensor that could work for both new and existing (old) equipment can be a challenge. Initial costs for the technology may be high and may be difficult to maintain (i.e. it may be difficult for some companies to access replacement sensors or the blockchain application).

Another concern is that the country has no standards for assessing the conditions of equipment and PPE and accurate assessment could depend on a multitude of things (e.g. condition and manner of usage, incident evaluation, equipment breakage, damage and overuse, etc.) so it may be take a lot of effort and time to have an objective way of evaluating the wear of an equipment. Additionally, it was pointed out that operators and renters of equipment tend to lie about the age and quality of their equipment, so establishing a baseline condition for old and existing equipment could pose some challenge.

Companies in the Philippines also tend to get the most out of the equipment and may be opposed to the idea of retiring old machinery/equipment. These companies believe that the productivity on site still depends on the skill of the workers and not on the wear of the equipment. There were also concerns about the mechanics who would perform the maintenance checks and repairs since there are those that are just out to make money (i.e. mechanics who don't do the job well because that would mean more checkups and repairs so they would earn more, while companies may want the opposite). Finally, the accuracy and reliability of the data reports and access to internet is still seen as a problem to the application the technology in the industry.

PCAB Category	Yes	No
AAAA	2	0
AAA	3	0
AA	0	0
A	1	0
B	5	0
C	2	0
D	1	2
E	3	0
Not yet accredited	8	3
Total	25	5

Table 4.5: Response summary for blockchain application: equipment lifecycle tracking using IoT

4.3.3.6 Other Applications of the technology

Respondents proposed the use of blockchain technology for the following applications:

- Automatically input/track/certify material testing results (e.g. concrete strength tests, leak tests, rebar tests etc.).
- Project documents, permits and changes in the contract may be tracked and incorporated in the smart contracts.
- Standard Compensation database and a fair system for performance evaluation for everyone involved in the project. (i.e. everyone from engineers, administrative staff, foremen and laborers)
- Accomplishment report evaluation, automated payment schedules
- Planning of an effective catch-up plan based on the data collected in the network.

4.2 Interview with Private Entities

The five key informants have different backgrounds with respect to the construction industry. One is a project engineer of government projects, another is a project associate for a construction firm, one is a contractor and proprietor, another is a business development manager, and the last one is an owner of construction supplies.

For the key informant interviews, four main themes were addressed – from their knowledge on the corrupt practices in the construction industry, their willingness in curbing such practices, to their outlook on blockchain technology as a tool to minimize corruption, and their perceived pros and cons on the adoption of blockchain technologies by the construction sector. As there are only five interviewees, a general impression of their collective answers is written below.

4.2.1 On corruption in the construction industry

The interviews confirmed the existence of corruption in the industry.

The most common form mentioned was fixed bidding or the awarding of projects to fixed contractors or suppliers. This can come in many forms. One would be the monopoly of a single supplier where contractors who bid for the project are required to only purchase (usually overpriced) materials or services from suppliers who usually have ties with officials who decide to whom the project will be awarded. Another would be bribery among officials/decision makers for the project. Construction companies do not mind giving huge amounts to top officials and executives to increase, if not ensure, their chances of winning the current project they are bidding for and to receive inside information and favors for future projects. For awarded projects, the contractors are expected to continue giving money to the project administrators and officials for the project to proceed smoothly.

Another type of corruption has something to do with the

quality of the materials used for the project. Materials of lower quality are used instead of the ones declared. This happens when site inspectors do not do their job of checking the quality of materials, and contractors bribe the inspectors and/or suppliers to produce fake progress reports, mill certificates, test results, etc. In the event that concrete or strength tests are required, a different material for testing is submitted by the contractor.

4.2.2 On willingness to reduce/ eliminate corruption

On the issue of the interviewees' willingness to help in reducing corruption, there was a strong desire for change shown in the interviews. All respondents said that they would be cooperative about minimizing corruption. Companies are confident that they could win projects without resorting to bribery and corruption.

However, according to them, it would be a difficult, if not impossible, feat to accomplish. It would greatly depend on the willingness and initiative of the leaders in the industry and the cooperation of all of the other players. Finally, additional costs and time spent for developing and adapting a system that can make that happen will inevitably be passed on to the clients.

4.2.3 On the effectiveness of blockchain technology for minimizing corruption

If the technology can be fully utilized in the industry, then it can be a great tool for tracking and documenting the project. However, it will not be that effective as a way for minimizing corruption.

Primarily, most companies do not have a functional system to store their respective digital records and inventories. Additionally, the technology should be able to penetrate a considerable share in the industry; otherwise, companies may view the technology only as a costly investment for them that might otherwise be utilized in a better prospect if their competitions are not obliged to implement it as well.

If the service will be executed by a third-party company, then there is a great chance that corruption would just take on a different form. This exposes the system to a potential collusion between the service provider and the respective contractors. The corrupt business practices in the industry has been substantially normalized in the system that the blockchain technology may not be the most effective way of eliminating it. For example, smart contracts won't be effective when projects are still awarded without a safeguarded, transparent, and fair bidding. Eliminating bribery through identifying the personas involved does not guarantee eliminating comprehensively the unfair practices itself in the bureaucracy. Consistently, however, the various constituent of this system is still governed by financial and economic regulations. These companies, regardless of their size, will have profitability as their principal interest. Therefore, if honest, accountable, and clean practices are to be hoped for the industry, interventions and measures that touch on financial management, auditing, and fiscal regulations should have considerable focus for rationalization.

4.2.4 On the pros and cons of blockchain in the construction industry

Below are lists of positives and negatives in adopting blockchain technologies in the construction industry as identified by our interviewees.

Pros

1. Blockchain technology can provide the industry with a more efficient and convenient way of handling data related to the project and gain insights about the project through the analysis of those data. The usual code of practices where experience has always been the sole basis can now have quantitative and objective measures.

2. It would allow companies to keep track of everything with ease.

3. It can promote accountability and transparency for all transactions within the project.

4. It can be integrated to the current system with minimal training.

Cons

1. It does not effectively address corruption since the input of data into the system by a third party may be vulnerable to corruption. The corruption in the system would just resurface in another form.

2. It could require a lot of capital. The system needs the right hardware (computers, smart phones, sensors, etc.) for it to work.

3. It needs a lot of users for it to be attractive. At least 40% of the industry probably needs to use the technology in all of their transactions before it can attract other contractors to try it.

4. It could take time for the industry and country to adjust to using such a system. Despite construction being a foundational industry, the rate of research implementation to trickle down to and be used in the field is really slow

5. Legal issues could also be a problem since money is involved. It is hard to put regulations on a decentralized system. Since a lot of money is involved in the industry, the question would be "who decides those regulations?". This could also be the reason why even though blockchain is technically accepted as secure, it still does not prevail over regular banking systems.

4.3 Identified Vulnerabilities

Based on the interviews with the respondents, the following facets of the structure discussed above are found to be the commonplace for corruption. This is illustrated in Figure 4.1.

The interviews confirmed the existence of corruption in the industry.

1. Subcontractors can bribe decision makers and executives from the client's side in order to earn their favor over other subcontractors within their respective categories

2. The client then refers these subcontractor to the winning main contractor, or even strictly require them to hire only these subcontractors, or to purchase materials only from a sole supplier, or to conduct materials testing on a single laboratory. This is as opposed to the just and proper protocol where a winning primary contractor can choose any qualified subcontractor freely

3. The main contractor may bribe the client to bypass the bidding process for a project or to directly win a bid

4. The client then discloses information to the main contractor such as the budget for project which allows the main contractor to adjust their bids accordingly and obtain higher chances of winning the bid for the project. The client may also omit the bidding entirely and immediately hire the main contractor instead.

   NOTE: (3) and (4) are also identified to be commonplace between subcontractors and the main contractor

5. The main contractor can bribe government offices or officials to obtain permits that other- wise would take a lot of time to process. They can also obtain permits which are otherwise impossible for them to acquire, or, in some cases, with questionable legality such as in the case of zoning and environmental permits (e.g. building oil excavation sites or mining sites in an environmentally protected zone, or putting up a structure with different zoning requirement). In other cases, the main contractor may also bribe regulatory agencies to acquire documents and certifications which are primary requirements to bid for certain projects like Environmental Impact Assessments (EIAs), PCAB Qualifications, etc.

6. The main contractor may bribe materials testing centers to fabricate test results within the required standards

7. The main contractor may also bribe the quality inspectors from the client's side to disregard the use of substandard materials that failed the quality tests. The main contractor can just bribe them both. (Worst case example: the main contractor could opt to just give monetary gift to the testing centers and the inspectors than redo a failed subcomponent of the project which might cost considerably more)

8. The main contractor may deliberately choose a subcontractor that does not necessarily adhere to labor and safety protocols, without the client's knowledge, in the purpose of obtaining an even more significant profit.

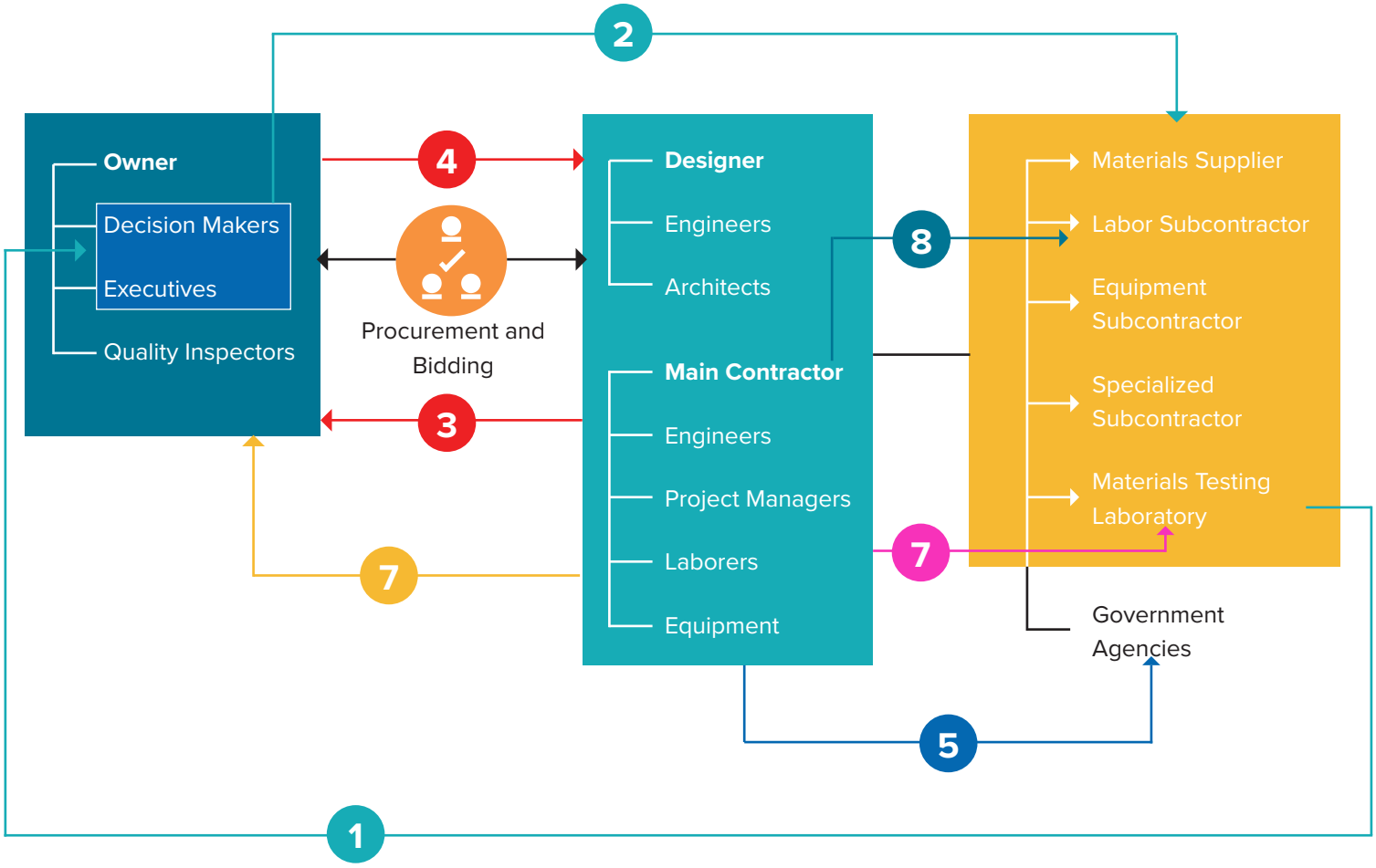

Figure 4.1: The construction industry supply chain with vulnerabilities of corruption highlighted.

4.4 Government Body

Out of the numerous agencies approached only two provided interest in accomplishing the interview: the National Economic and Development Authority (NEDA) and the Public-Private Partnership Center (PPPC).

NEDA was created in 1972 as an independent planning agency of the Philippine govern- ment. It was reorganized in 1987 to enhance its ability to coordinate the development planning and policy formulation process, in order to achieve the objectives of sustainable economic growth coupled with an equitable distribution of income and wealth. It is responsible for the nation-wide regulation, policy-making, and initiation of economic development and planning for projects and ventures of national scope. The NEDA Board is primarily responsible for formulating continuing, coordinating, and fully integrated social and economic policies, plans, and programs. [2]

The NEDA Secretariat, headed by the Socioeconomic Planning Secretary, is regarded as authority in macroeconomic forecasting, and policy analysis and research. It provides high-level advice to the Congress and the Executive Branch. One of its key responsibility is the review, evalu- ation, and monitoring of infrastructure projects identified under the Comprehensive and Integrated Infrastructure Program (CIIP) consistent with the government's thrust of increasing investment spending for the growing demand on quality infrastructure facilities.

In this study, the Infrastructure Staff (IS) and the Infrastructure Committee (InfraCom) will be of interest as they are closely involved in the construction and engineering industry in the country. Their respective functions are listed below.

Infrastructure Staff

- Provide technical staff support in coordinating the formulation of physical plans for the transportation, information and communications technology (ICT), water resources, power and energy; and, social infrastructure sectors;

- Evaluate and conduct studies on policies in the various infrastructure sectors;
- Provide technical staff support in the appraisal of proposed programs and projects in the various infrastructure sectors in coordination with the Regional Development Group and in close consultation with the sectoral agencies concerned;
- Provide technical assistance to the NEDA regional offices and relevant government agencies in program and project identification, development and evaluation as necessary;
- Monitor sectoral performance;
- Act as lead secretariat to the NEDA Board Committee on Infrastructure (INFRACOM), Inter-Agency Technical Committee on Transport Planning (IATCTP), INFRACOM Sub-Committee on Water Resources (SCWR), and NEDA Build-Operate-Transfer (BOT) Group; NEDA Price Escalation/Adjustment Committee (NPEAC); Contract Review Committee (CRC); and the Philippines Development Forum – Infrastructure Working Group (PDF-IWG);
- Process requests for contract price escalation;
- Process request or use of alternative method of procurement and repository of contracts of at least Php 300 million;
- Coordinate the formulation and updating of the Comprehensive and Integrated Infrastructure Program;
- Review, evaluate, and monitor infrastructure projects included in the Comprehensive and Integrated Infrastructure Program (CIIP);
- Act as the focal unit of the NEDA on matters related to Public-Private Partnership (PPP), spearheading the capacity building of other NEDA sector staffs, building on the Staffs expertise on PPP project evaluation, and sharing lessons learned on the evaluation and review of PPP projects.
- Facilitate conduct of Value Engineering/Value Analysis(VE/VA) and Risk Management/Analysis for major infrastructure projects
- Perform such other appropriate tasks as may be assigned by the Director-General, Deputy Director-General and Assistant Director-General.

Infrastructure Committee The InfraCom is composed of the Director-General of the NEDA Secretariat as Chairman; Secretary of DPWH as Co-Chairman; and the Executive Secretary, the Cabinet Secretary, and the Secretaries of DOTr, DBM, DOF, DTI, DOE, Department of Agriculture (DA), Department of Tourism (DOT), and Department of Information and Communications Technology as members. The InfraCom performs the following functions:

- Advises the President and the NEDA Board on matters concerning infrastructure development, including highways, airports, seaports and shore protection; railways; power generation, transmission and distribution; telecommunications; irrigation, flood control and drainage, water supply and sanitation; national buildings for government offices; hospitals and related buildings; state colleges and universities, elementary, and secondary school buildings; and other public works;
- Coordinates the activities of agencies, including government-owned and controlled corporations involved in infrastructure development; and
- Recommends to the President necessary government policies, programs and projects concerning infrastructure development consistent with national development objectives and priorities.

PPPC, on the other hand, was created with the primary functions of coordination and monitoring all PPP programs and projects including all variants and arrangements under the Build-Operate-Transfer Law and Joint-Venture Agreements; conduct project facilitation and assistance to the national implementing agencies including government corporations and Local Government Units (LGUs) in addressing impediments or bottlenecks in the implementation of PPP program and projects provide advisory services, technical assistance, training and capacity development to agencies/ LGUs in PPP project preparation and development; manage and administer a revolving fund known as the Project Development and Monitoring Facility; establish and manage a central database system of PPP programs and projects and prepare reports on the implementation of the PPP program and projects of government for submission to the President at the end of each year.

PPPC assists the government in the realization of various development ventures that are structured to follow a public-private arrangement. One of its core mandates is improving the policy environment for the stakeholders of these said projects. It facilitates the country's inclusive growth and sustainable development for the delivery of public

infrastructure and other development services. [2]

PPPC, on the other hand, was created with the primary functions of coordination and monitoring all PPP programs and projects including all variants and arrangements under the Build-Operate-Transfer Law and Joint-Venture Agreements; conduct project facilitation and assistance to the national implementing agencies including government corporations and Local Government Units (LGUs) in addressing impediments or bottlenecks in the implementation of PPP program and projects provide advisory services, technical assistance, training and capacity development to agencies/ LGUs in PPP project preparation and development; manage and administer a revolving fund known as the Project Development and Monitoring Facility; establish and manage a central database system of PPP programs and projects and prepare reports on the implementation of the PPP program and projects of government for submission to the President at the end of each year.

PPPC assists the government in the realization of various development ventures that are structured to follow a public-private arrangement. One of its core mandates is improving the policy environment for the stakeholders of these said projects. It facilitates the country's inclusive growth and sustainable development for the delivery of public infrastructure and other development services. [2]

4.4.1 NEDA

The questionnaire prepared for NEDA is divided into two parts: the first part relates to its possible role in curbing corruption in the government; the second part relates to its knowledge of blockchain, if it is being considered as a tool to promote good governance, and its take on the possible hindrances in adopting such technology by the different Philippine government agencies.

With respect to its role in addressing corruption in the government, the agency initially declares that it does not have a direct mandate on safeguarding and promoting good governance. More specifically, these are highlighted as the following UN Sustainable Development Goals:

- 16.5 Substantially reduce corruption and bribery in all forms.
- 16.6 Develop effective, accountable and transparent institutions in all levels.
- 16.7 Ensure responsible, inclusive, participatory and representative decision-making at all levels.

Indirectly, however, its formulation of the Philippine Development Plan(PDP) touches on these measures (Results Matrices) as it examines various indicators in the different economic and development sectors of the country. Moreover, NEDA identifies the Office of the Ombudsman (OMB) as the responsible office in quantifying and reporting these indicators as part of the Inter- Agency Committee on Good Governance. A subcommittee on Sustainable Development Goals was created in December 2019 to monitor the country's progress in meeting its SDG commitments. NEDA co-chairs this committee together with the Department of Budget and Management (DBM).

As for the adoption of blockchain technologies, NEDA believes that the technology is still an emerging and evolving one. Citing the lack of evidence-based studies on the potential benefits and impacts, it wants researches that address potential issues like costs, technological complexity, risks, data privacy, security/trust among others be made before it can support its adoption.

Their response concludes with the highlighting of obstacles that the adoption of the blockchain technology might encounter. These are as follows:

1. ICT infrastructure is lacking due to ongoing duopoly.
2. Regulations for telecommunications companies are outdated but still stringent favoring the larger companies (the duopoly) and penalizing smaller ones.
3. Bureaucracy in public institutions hindering the adoption of the technology (procurement, perception) and that the implementation's consequent requirement of institutional reorganizations will not be negligible.

Data privacy. As there are no current laws explicitly governing the use of blockchain while there are existing legal provisions on data privacy, some stakeholders might be hesitant in using the technology. Moreover, the lack of regulations on the use of information generated from these technologies is also of concern.

4.4.2 PPPC

PPPC carefully details the difference of procedures of PPP projects from the traditional one. It underscores particularly the requirements of the procurement process wherein the specifications are identified in terms of the output measures of the development “Key Performance Indicators” rather than input ones such as detailed engineering design and materials to be used. This provides leniency on the construction design and methodology to be implemented. As the development projects progress, PPPC is entailed to oversee the progress and its compliance to the agreed output.

On the issue of hindrances in productivity and development of operations in the construction and engineering projects based on the agency’s experience, PPPC identifies the unavailability of the project site at the contractually agreed time as the main culprit. This is normally due to the following: right-of-way issues involving private property acquisition, utility relocation, and the resettlement of the informal settler families. Another problem encountered by the private sector is the capacity of their subcontractors as this may lead to some liquidation damages that the government can claim.

As for the utilizing various technological implements, in this case blockchain, the defined protocol for PPP project stakeholders specifies that the technology to be implemented is left at the discretion of the winning private sector. This therefore opens up an opportunity in initiating various emerging technologies such as blockchain for the purpose of pilot testing the commencement or further promotion of its potential use cases.

The response also concludes with the recommendations on the considerations that must be looked into should the implementation proceed. These are as follows:

1. The initial formulation, execution, and maintenance would require significant investments. Aside from the infrastructure and equipment procurement, the essential personnel are to be trained for this new enterprise. Being an emerging technology, its sustenance could be prolonged until general public acceptance.

2. The new technology will require new, or at least revisions to, laws and policies having it in their considerations. Moreover, to push further its use, they are to be mandated as necessary.

3. Institutional reorganizations will be an apparent conflict, especially concerning the human resource.

4. Interoperability of various systems especially with those already in existence and wide use. 5. Confidentiality of information throughout the system.

Both NEDA and PPPC further recommend consulting the relevant government agencies in the assessment, development, and implementation of the technology which are the Department of Science and Technology, the Department of Trade and Industry, and the Department of Information and Communications Technology. These agencies were also the primary objective of this part of the study. Unfortunately, no correspondence was established for this purpose.

Photo of construction

5. Summary

In 2018, the United Nations Development Programme (UNDP) and the UK government launched a project called "Promoting a Fair Business Environment in the ASEAN" which aims to create a business environment in the ASEAN region that minimizes corruption risks and shape sustainable business practices in the private sector. In response to this, UNDP Philippines is implementing the Business Integrity PACTS (Partners for Accountable, Clean and Transparent Sustainable Enterprise) project, with the aim of addressing unethical business practices prevalent in the Philippines' private sector.

Anchored on the UN Sustainable Development Goal 16.5-7, this study looked at the feasibility of using blockchain technology as a possible solution to promote transparency and integrity in the public and private sectors with the hope that this will minimize the risk of corruption focusing on the construction industry.

In order to assess its feasibility, the study looked at the different stakeholders from the construction sector namely: the contractors, suppliers, their clients and some government agencies mandated to overlook at their activities.

Questionnaires were distributed to government agencies that might have the power to push for the adoption of blockchain technologies in the private sector. On the other hand, the contractors, suppliers and clients were asked to fill out a survey form while key informants from their ranks were interviewed on a person-to-person basis.

Based on the replies submitted by NEDA and PPPC, adoption of blockchain technologies by the government will require creation and/or revision of laws and policies pertaining to data management and privacy, among others. Infrastructure-wise, the Philippines under a duopoly cannot manage bandwidth requirements blockchain applications may need in the future. Adoption of such technology will also entail some institutional reorganization and redefinition of processes of a lot of government agencies. In addition, NEDA wants evidence-based studies that show potential benefits and impacts before it endorses such technologies for adoption.

From the interviews, the informants were all willing to help curb corruption. But they think it is a losing battle as it needs the commitment of all the stakeholders in the construction industry to push this through. The adoption of blockchain technologies will provide the industry with more efficient and convenient way of handling data that promotes transparency and accountability. However, they also pose problems as most companies are not prepared or are clueless on this technology, aside from the possible additional expenses this may entail. It remains to be seen how blockchain technologies can capture the intricacies of the corruption happening in the industry as they believe that corruption in the system would just reappear in another form.

Survey responses conclusively show that blockchain technology remains uncommon in the local context, at least for the construction sector. However, as possible applications to the industry of this unfamiliar technology are presented, similar respondents expressed their interest optimistically.

Four applications out of five were definitively confirmed (77–84%) to be implementations that the contractors would utilize. These are automated payment systems, supply chain and inventory tracking system, health & safety and equipment tracking system using IoT.

Respondents also identified potential challenges for each of these applications based on their professional expertise. Specific concerns unique to the applications were provided, however, skepticism about the technology and its applications was a common sentiment throughout the results. This was attributed to substantial investment required in fully mobilizing the systems. This venture does not only require financial investment, but also institutional retraining and organization, constitutional and regulatory amendments, and general market acceptance and penetration.

Respondents also shared their concern regarding the persistence of corruption even with these new interventions to curb it. These applications target the eradication of bad business practices but it will be inevitable to introduce new, currently unidentified, vulnerabilities for exploitation and misuse.

Finally, general complacency regarding the system has been identified as respondents claim that the current structure and technology (or lack thereof) function well as intended with proper compliance to the industrial regulations and administration. This further illustrates how these unfair and overall unrighteous business environment has been normalized and blindly accepted as a market culture at least for this sector.

6. Conclusion and Recommendation

Based on the results of the survey, the questionnaire responses and the interviews, the general sentiment is that while blockchain technologies offer a promising solution to minimize and/or eliminate corruption, a lot of groundwork must first be done ranging from ICT infrastructure improvements to the creation and revision of laws and processes concerning data management and data privacy in the context of this newly emerging technology, among others.

Government agencies like the Department of Science and Technology (DOST), the Department of Information and Communications and Technology (DICT), the Department of Trade and Industry (DTI), and the Philippine Congress must be mobilized to help speed up the adoption of blockchain technologies through their influence in the industry, regulatory mandates, promotional programs, etc.

DOST must spearhead studies concerning the benefits and impacts of the adoption of blockchain applications, and fund proof-of-concept blockchain applications that may be used by public and private sectors, in particular those that address minimizing corruption. DICT, on the other hand, has to improve the ICT infrastructure in the country by fast-tracking the giving of franchises to telecommunication companies that can contribute to the improvement of the country's bandwidth. DTI should start reassessing the different standards and processes it requires different businesses incorporating the possibility of blockchain use in their new guidelines and regulations. Congress must be enjoined to review, revise and create laws that adapts to the changes brought about by new and emerging technologies such as blockchain.

However, all these endeavors will take some time.

In the mean while, initiatives coming from the private sector may help jump-start the adoption of blockchain technologies. As was shown, the different stakeholders are open to the idea of using some blockchain applications on their operations. But they are also having some reservations as they do not have enough knowledge of the new technology aside from financial, operational and administrative considerations.

One possible solution is to create an incentive mechanism to attract early adaptors to the new system. Development of the blockchain applications can be funded externally and may be given to the early adaptors free of charge or at a minimal fee. Such action hopes to create a critical mass that will hasten the technology adoption by the whole construction industry.

This should be done hand-in-hand with properly educating the private sector on blockchain technologies, its potential uses, and its impact on doing business and on the environment.

Further consultations with government entities, especially the regulating bodies and agencies with greater influence in the sector should be executed as they possess the relevant control once these technologies are implemented. The public acceptance and utilization of these applications can only be ensured by the necessary mandates and ratification to the systems currently in place.

Finally, with all that is written, majority of currently existing and known use cases of blockchain technology application in the construction industry mainly relate to data management and verification, but not necessarily to curb corruption. Blockchain can hypothetically provide the platform that would link the physical world and the digital one. The decentralization, immutability, anonymity and auditability characteristics of blockchain have the potential to reform the current practices of the construction industry.

Blockchain has the potential to make accounting books and supply inventories of companies more transparent, and its data management more efficient. However, it remains unclear how blockchain can address specific forms of corruption like fixed bidding, under-the-table negotiations, bribery of officials or the "palakasan system" which are the most common forms of corruption in the Philippines.

7. Acknowledgments

The author wishes to thank the following:

Engrs. Mel Francis Eden, Virgilio Ma. Ramos III and Arse John Salison of the *University of the Philippines National Center for Transportation Studies* (UP-NCTS) for lending their talents, time, effort and contacts to make this study a success;

Director Jeffrey I. Manalo from the Policy Formulation, Project Evaluation and Monitoring Service of *Public-Private Partnership Center* (PPPC) for sharing his invaluable insights in answering our questionnaire;

Ms. Esther O. Kinuta, and the unnamed people of the *National Economic and Development Authority* (NEDA), who painstakingly did their research just so they can reply to our queries in the most comprehensive way possible;

Assistant Director Bien A. Ganapin of NEDA for allowing his team to help us in our study;

Ms. Marifel S. Geronimo of NEDA for helping us find the right people to approach for our inquiries;

Ms. Ruby Ruth Jinon of the *Philippine Institute of Civil Engineers Inc.,* (PICE), for facilitating the interview schedule of PICE officers and doing all the follow-ups though in the end none of them materialized;

Mr. Emerson Fonseca of *NEM Philippines* for clarifying some issues concerning Blockchain applications in the construction industry;

The five key informants we interviewed who refused to be named in this report, for their unbridled responses to our questions;

The thirty companies who anonymously participated in our surveys on the different Blockchain applications;

Ms. Roxanne Lu of the *Makati Business Club* (MBC) who helped us connect with some clients to answer our survey, and for all the other efforts she extended in this study;

Mr. Jose Cortez of the *United Nations Development Programme Philippines* for all his encouragements and help to make this study a reality.

Bibliography

[1] Blockchain-as-a-service platform. https://www.ubitquity.io/products.html. Accessed: 2020-03-08.

[2] Department of budget and management: General appropriations act. https://www.dbm.gov. ph/wp-content/uploads/GAA/GAA2015/GAA%202015%20Volume%20I/NEDA/NEDA.pdf. Accessed: 2020-05-15.

[3] Can Blockchain FiX The Construction Industry's Productivity Problem?, 2018.

[4] Construction statistics from approved building permits for the year 2018 (final results). https://psa.gov.ph/content/construction-statistics-approved-building-permits-year-2018-final-results, 2018. Accessed: 2020-03-08.

[5] PwC's Global Blockchain Survey, 2018.

[6] Statistics of pcab licensed contractors by category. http://ciap.dti.gov.ph/content/statistics-pcab-licensed-contractors-category, 2018. Accessed: 2020-03-08.

[7] Construction in the philippines - key trends and oppor- tunities to 2023. https://www.giiresearch.com/report/ time237680-construction-philippines-key-trends-opportunities.html, 2019. Accessed: 2020-03-08.

[8] PwC's First Streaming, Now Blockchain, 2019.

[9] Corruption eats up 15-35% of construction firms' budget, 2020.

[10] Spencer Bogart and Kerry Rice. The blockchain report: Welcome to the internet of value. 2015.

[11] Sriram Changali, Azam Mohammad, and Mark van Nieuwland. The construction productivity imperative. McKinsey Productivity Sciences Center, 2015.

[12] Construction Industry Authority of the Philippines. 2018 Construction Industry Performance Highlights.

[13] Ignacio DeLeon and Ravi Gupta. The impact of digital innovation and blockchain on the music industry, 2017.

[14] Harry Halpin and Marta Pierkarska. Introduction to security and privacy on the blockchain. IEEE EuroS&PW, 2017.

[15] Vincent Hargaden, Nikoalos Papakostas, Anthony Newell, Adam Khavia, and Adam Scanlon. The role of blockchain technologies in construction engineering project management. EEE International Conference on Engineering, Technology and Innovation (ICE/ITMC), 2019.

[16] IBM. Maersk and ibm introduce tradelens blockchain shipping solution. 2018.

[17] Gajendra J. Katuwal, Sandip Pandey, Mark Hennessey, and Bishal Lamichhane. Applications of blockchain in healthcare: Current landscape & challenges. 2018.

[18] Kirsten Lamb. Blockchain and smart contracts: What the aec sector needs to know. Technical report, Centre for Digital Built Britain, 2018.

[19] David C. Ling and Wayne R. Archer. Real Estate Principles. McGraw-Hill, 2004.

[20] Qinghua Lu and Xiwei Xu. Adaptable blockchain-based systems: A case study for product traceability. IEEE Software, 2017.

[21] Medicalchain. Medical chain whitepaper 2.1. 2018.

[22] William Mougayar. *The Business Blockchain.* Wiley, 2016.

[23] Satoshi Nakamoto. Bitcoin: A peer-to-peer electronic cash system. 2008.

[24] Max Nijland and Jan Veuger. Influence of blockchain in the real estate sector. *International Journal of Applied Science*, 2019.

[25] Balit Penzes. *Blockchain Technology in the Construction Industry*, 2018.

[26] Deepak Puthal, Nisha Malik, Saraju P. Mohanty, Elias Kougianos, and Gautam Das. Everything you wanted to know about the blockchain. *IEEE Consumer Electronics*, 2018.

[27] Jawad Salic. Success factors in Lanao del sur construction projects: A study for the development of project performance. *International Journal of Humanities and Social Sciences*, 2017.

[28] Alireza Shojaei. Exploring applications of blockchain technology in the construction industry. ISEC, 2019.

[29] Horst Treiblmaier. The impact of the blockchain on the supply chain: a theory-based research framework and a call for action. *Supply Chain Management*, 2018.

[30] Sarah Underwood. Blockchain beyond bitcoin. *Communications of the ACM*, 2016.

[31] Zibin Zheng, Shaoan Xie, Hongning Dai, Xiangping Chen, and Huaimin Wang. *An overview of blockchain technology:architecture, consensus, and future trends*. IEEE: Big Data, 2017.

[32] Kaspars Zile and Renāte Strazdina. Blockchain use cases and their feasibility. *Applied Computer Systems*, 2018.