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TECHNICAL AND FINANCIAL RISKS CHALLENGING THE ADOPTION OF SMART CONTRACTS IN CONSTRUCTION

Cihan ÖZCANLI

MASTER OF SCIENCE THESIS
Department of Civil Engineering
Program of Civil Engineering

Supervisor
Prof. Dr. Aslı Pelin GÜRGÜN

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A thesis submitted by Cihan ÖZCANLI in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** is approved by the committee on 13.06.2023 in Department of Civil Engineering, Program of Civil Engineering.

Prof. Dr. Aslı Pelin GÜRGÜN
Yildiz Technical University
Supervisor

Approved By the Examining Committee

Prof. Dr. Aslı Pelin GÜRGÜN, Supervisor
Yildiz Technical University _____

Assoc. Prof. Pelin ÖZENER, Member
Yildiz Technical University _____

Prof. Dr. Gül POLAT TATAR, Member
Istanbul Technical University _____

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Cihan ÖZCANLI

Signature

I dedicate this thesis to my newborn nephew, Yusuf Mete AKYÜZ. I wish you a journey filled with success in every aspect of your life. Your presence brings us hope and inspiration. May you grow with love and discover your unlimited potential. I am here for you and will always be by your side.

With love,

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LIST OF SYMBOLS

n	Number of Criteria
w	Eigenvector
w’	Eigenvalue
λmax	Largest Eigenvalue

LIST OF ABBREVIATIONS

AHP	Analytic Hierarchy Process
TE2	Complexity in The Developing Draft
CR	Consistency Ratio
CM	Construction Management
FI4	Cost Of Adequate Human Resource
FI3	Cost Of Too Many Updates
FI2	Cost Of Upskilling
TG3	Cyber attack to the documents (Hacking, Abuse)
TW2	Difficulty in setting deadlines and original time scales
DLT	Distributed Ledger Technology
TG5	Error prone nature of computers
TW1	Excessive time for approval procedures
FI1	Expensive And Clunky Drafting And Registration Process
E-01	Expert-01 Attended To Ahp Questionnaire
E-02	Expert-02 Attended To Ahp Questionnaire
E-03	Expert-03 Attended To Ahp Questionnaire
E-04	Expert-04 Attended To Ahp Questionnaire
E-05	Expert-05 Attended To Ahp Questionnaire
E-06	Expert-06 Attended To Ahp Questionnaire
E-07	Expert-07 Attended To Ahp Questionnaire
E-08	Expert-08 Attended To Ahp Questionnaire
FI	Financial Risks
TE5	Inaccurate Recorded Information

TE6	Incorrect Coding (Risks From Implementing To Completion)
TE3	Irrevocable Control To TM Machine
TE1	Lack Of Experienced Personnel
TG4	Lack of technological advancements
TW5	Long lasting negotiation process
MI	Main Risks
TG1	Mg probability leading to permanent failure
MCDM	Multi-Criteria Decision-Making
TG2	Privacy issues (information security)
RI	Random Index
TE	Technical Risks
TG	Technological Risks
CI	The Consistency Index
TW3	Time constraints (Such as insurance arrangements etc.)
TW4	Time consuming process of developing the contract draft
TW	Timewise Risks
TE4	Updating Issues After Changes (i.e. Design Change)

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ABSTRACT

Technical And Financial Risks Challenging The Adoption Of Smart Contracts In Construction

Cihan ÖZCANLI

Department of Civil Engineering
Master of Science Thesis

Supervisor: Prof. Dr. Aslı Pelin GÜRGÜN

A smart contract is characterized as computerized transaction procedures that meet contractual constraints such as progress payment, claims, and confidentially while minimizing the need for an intermediary. Smart contracts may be thought of as an effective and different answer to the typically lengthy, complex, and difficult-to-comprehend construction contracts. Construction businesses face several technical and financial risks when using smart contracts. Risks discovered through literature research were communicated to specialists, and their comment was obtained following the study. From a financial and technological aspect, it is recognizable that the incorporation of smart contracts into construction management processes will be risky, according to expert opinions.

Keywords: Smart contracts, automated construction processes, technical risks, financial risks, construction contracts

YILDIZ TECHNICAL UNIVERSITY
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ÖZET

İnşaat Sektöründe Akıllı Sözleşmelerin Kabulünü Zorlaştıran Teknik ve Finansal Riskler

Cihan ÖZCANLI

İnşaat Mühendisliği Anabilim Dalı
Yüksek Lisans Tezi

Danışman: Prof. Dr. Aslı Pelin GÜRGÜN

Akıllı sözleşme, bir aracıya olan ihtiyacı en aza indirirken hakediş, talepler ve gizlilik gibi sözleşme kısıtlamalarını karşılayan bilgisayarlı işlem prosedürleri olarak karakterize edilir. Akıllı sözleşmeler, tipik olarak uzun, karmaşık ve anlaşılması zor inşaat sözleşmelerine etkili ve farklı bir yanıt olarak düşünülebilir. İnşaat işletmeleri, akıllı sözleşmeleri kullanırken çeşitli teknik ve finansal risklerle karşı karşıyadır. Literatür araştırması ile tespit edilen riskler uzmanlara iletilmiş ve çalışma sonrasında görüşleri alınmıştır. Uzman görüşlerine göre, finansal ve teknolojik açıdan akıllı sözleşmelerin inşaat yönetimi süreçlerine dahil edilmesinin riskli olacağı kabul edilebilir.

Anahtar Kelimeler: Akıllı sözleşmeler, otomatik inşaat süreçleri, teknik riskler, finansal riskler, inşaat sözleşmeleri

1
INTRODUCTION

1.1 Purpose of Thesis

The purpose of this thesis is to conduct a comprehensive and detailed examination of the technical and financial risks associated with the implementation of smart contracts in the construction industry. The main goal of this research is to determine the level of technical and financial risks involved in the use of smart contracts in construction management processes. The research will provide valuable insights into the current state of the industry, the challenges that need to be overcome, and the benefits that can be achieved through the adoption of smart contracts. This research will be conducted through a systematic approach, which includes a thorough literature review of the current state of research on smart contracts in construction management and the associated risks. Additionally, a survey will be conducted among experts in the field, who will be asked to provide their opinions on the technical and financial risks associated with the use of smart contracts in construction management. The data collected from the survey will be analyzed using multiple decision-making methods, and the results will be discussed in detail in the thesis.

Furthermore, this research will also investigate the current state of the adoption of smart contracts in the construction industry and identify the factors that are hindering their adoption. It will contain the impact of smart contract adoption on the construction industry and the benefits it can bring to the stakeholders involved in the construction process such as cost savings, increased efficiency, and transparency.

In summary, this thesis aims to provide a comprehensive understanding of the technical and financial risks associated with the implementation of smart contracts in construction management. The research will provide valuable insights for industry professionals, policymakers, and researchers interested in the use of smart contracts in construction management, and will contribute to the successful implementation of smart contracts in the construction industry.

1.2 Scope of Thesis

The scope of this thesis is to investigate the use of smart contracts in construction management and to examine the technical and financial risks associated with their implementation. The research will be conducted through a systematic approach, which includes a thorough literature review of the current state of research on smart contracts in construction management and the associated risks. Additionally, a survey will be conducted among experts in the field, who will be asked to provide their opinions on the technical and financial risks associated with the use of smart contracts in construction management. The data collected from the survey will be analyzed using multiple decision-making methods, and the results will be discussed in detail in the thesis. This research will provide insights into the technical and financial risks associated with the use of smart contracts in construction management and will contribute to the understanding of the challenges that need to be overcome to ensure the successful implementation of smart contracts in the construction industry.

It should be noted that the research is limited to the use of smart contracts in construction management, and will not extend to other areas of application for smart contracts. Also, the research will be limited to the analysis of technical and financial risks, and will not consider other potential benefits or drawbacks of using smart contracts in construction management. The research will be based on expert opinions and is not based on an experimental study.

1.3 Studies in Literature

Szabo, a computer scientist, and legal scholar, first came up with the idea of "smart contracts" in 1994. He wrote about them in a paper called "Smart Contracts: Building Blocks for Digital Markets." In this paper, Szabo described smart contracts as computer programs that can automatically carry out the terms of a contract. He suggested that these types of contracts could be useful for digitally verifying and enforcing agreements. Szabo's work was an important step in the development of blockchain technology and the use of smart contracts in this field [1]. Szabo first introduced the idea of smart contracts in a paper he wrote called "Smart Contracts: Building Blocks for Digital Free Markets." In this paper, he described smart contracts as self-executing contracts with the terms of the agreement written directly into lines of code. He also discussed the potential benefits of smart contracts, such as increased efficiency, reduced costs, and improved security [2].In the following years, Szabo continued to refine his ideas about smart contracts, and he wrote several other papers and articles on the topic. He also developed a digital currency called "bit gold," which is considered to be a precursor to Bitcoin [3].

In early 2010, The implementation of smart contracts and blockchain technology in the construction process has been acknowledged as a means to improve collaboration and communication among participants by providing a secure, transparent, and tamper-proof way to manage and exchange legally significant building information. Additionally, it has been posited that the utilization of these technologies can provide a solution to legal challenges by creating a decentralized, autonomous system for managing and tracking building information, ensuring the security and integrity of data, and facilitating the resolution of disputes among parties. Furthermore, the use of smart contracts to automate and streamline various construction-related processes, such as payment, compliance, and quality assurance has been emphasized as a means to reduce costs, increase efficiency and improve the overall performance of building projects. As the construction industry becomes increasingly digitized and data-driven, it has been noted that the use of smart contracts and blockchain technology can provide a robust and secure way to manage, track and share a large amount of information and data generated during the building process.[4]

In 2015, The construction industry has been widely acknowledged for its contribution to economic growth and long-term national development, particularly in developing countries. However, there is a lack of consensus regarding the definition and classification of the construction industry, with some arguments regarding whether it should be considered a standalone industry or a collection of multiple industries. Therefore, in order to improve the construction industry in developing countries, it is crucial to understand its fundamental characteristics and specific requirements and to use this information to develop and implement improvement programs[5]. Purnu et al stated the construction sector is noted to be vulnerable to economic changes, particularly during recession periods, due to high capital outlay, cost flexibility, and high competition. The impact of changes in the business environment, including shortage of funds, exchange rate fluctuation, and political instability, on the financial risks of construction projects, is acknowledged[6]. Agarwal et al stated that the construction industry is in need of innovation and the adoption of new technologies, tools, and approaches. They have highlighted that a change in mindset is crucial for project owners and contractors, as it has been observed that owners tend to hold the belief that their responsibility ends with the awarding of contracts, ignoring the fact that they are also accountable for the financial costs incurred by delays [7].

"Hileman and Rauchs' study highlights the disconnect between the hype surrounding blockchain technology and the general public's understanding of it. The findings of the study indicate that a considerable portion of the general public lacks a clear comprehension of blockchain technology, despite ongoing efforts to educate them about it. The authors stress the significance of effective communication and education

in order to bridge this understanding gap and fully harness the potential of blockchain technology. The authors also aimed to address questions such as: What are the reasons for using blockchain technology? What are the main elements of the technology? and What are its limitations? [8]. According to Hileman and Rauch blockchain can be understood as a specific kind of database that is spread across multiple computers on a peer-to-peer network. A blockchain typically consists of the five components shown in Figure 1.1 below and Figure 1.2 which illustrate the various applications and uses of blockchain technology.

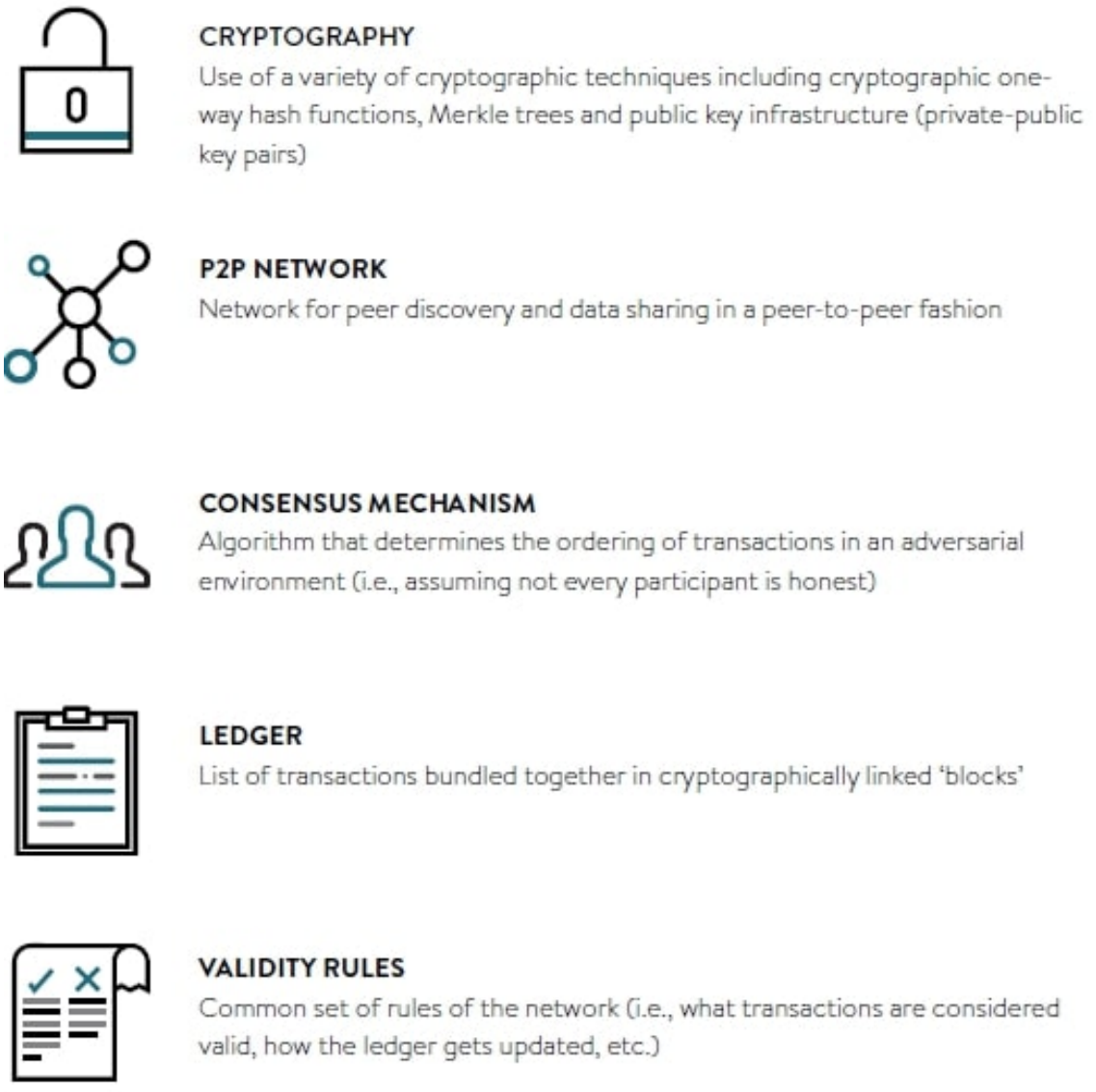


Figure 1.1 The five components of a blockchain [8].

In 2017 Turk et al reported that the potential for blockchain technology to revolutionize computing in areas where centralization is unnatural and privacy is important is acknowledged. It is also mentioned that Turk conducted research on the utilization of blockchain technology in the construction industry, with a focus

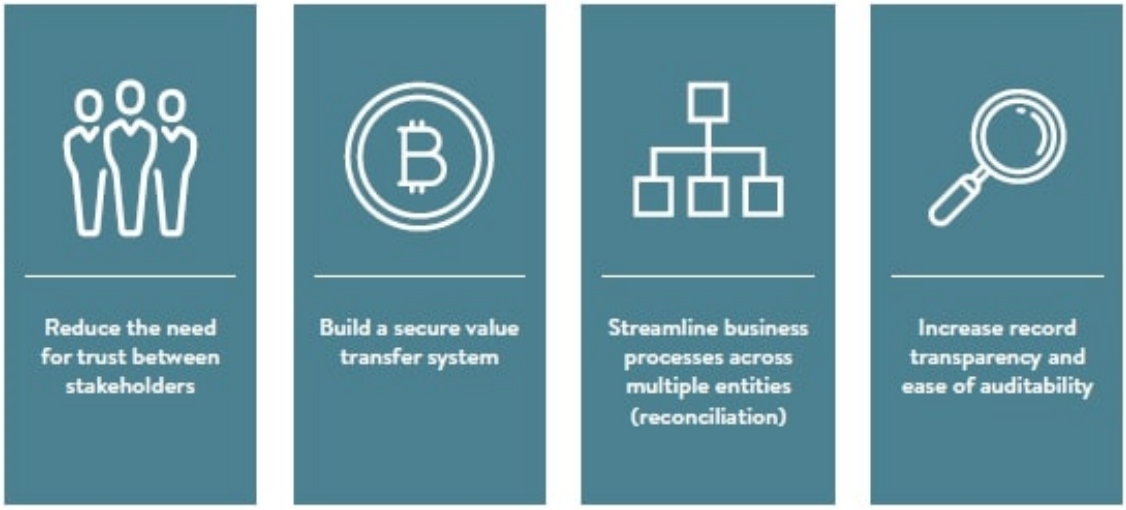


Figure 1.2 The advantages of implementing blockchain [8].

on addressing open issues in construction process management and matching these issues with the capabilities of blockchain technology. It is also noted that construction projects involve a dynamic grouping of several companies and the degree to which the relationships among them are hierarchical or peer-to-peer is studied. It is suggested that blockchain can provide a trustworthy infrastructure for information management during all stages of the building life-cycle, including construction, building information modeling, and facility maintenance. It is also highlighted that blockchain technology has the potential to improve the reliability and trustworthiness of construction logbooks and secure the storage of sensor data during the facility maintenance phase. Additionally, it is proposed that blockchain technology may be integrated into generic IT infrastructure rather than used directly in construction-related software and the need for further research in this direction is suggested. Also Figure 1.3 depicts the logic of the blockchain concept as demonstrated by Turk.[9].

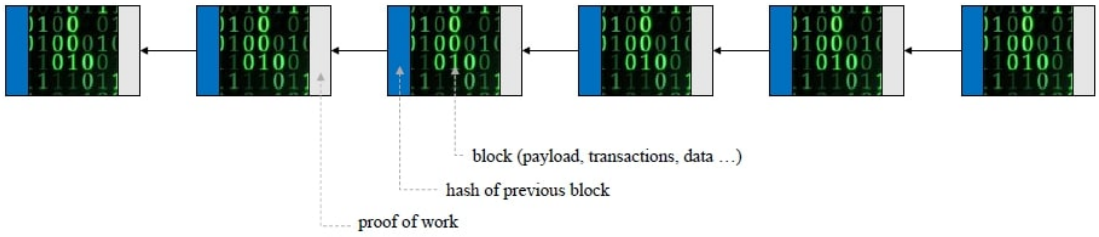


Figure 1.3 The blockchain concept [9].

Hamida et al. in 2017 it was reported that Blockchain technology had received increased interest from both the scientific community and industry professionals. The technology was seen as a major shift in the development, operation, consumption, and marketing of smart city solutions. Despite its potential impact, the article highlighted the need to address open challenges in the field. The focus of the

article was on enterprise Blockchains, and it provided a detailed analysis of its core components, technologies, and applications, as well as discussed research challenges and opportunities. Hamida et al stated that the conclusion was reached that Blockchain technology will have a major impact on how business applications are developed, run, used, and marketed in the near future, as it represents a fundamental change in the industry [10].

According to Kalra et al in 2018, smart contracts can be difficult to fix once they have been deployed, regardless of the amount of money they hold. They cite a recent example of a bug that resulted in losses of approximately 50 million American dollars in cryptocurrency. To address this issue, Kalra et al, presented EUS, a framework for verifying the correctness and validating the fairness of smart contracts. The framework defined correctness as adherence to safe programming practices and fairness as adherence to agreed-upon higher-level business logic [11]. Ahmadisheykhsarmast and Sonmez stated that the conclusion was reached that Blockchain technology will have a major impact on how business applications are developed, run, used, and marketed in the near future, as it represents a fundamental change in the industry. [12]

In 2019, Darko et al mentioned that a literature review of 77 papers published in eight peer-reviewed construction management journals from 2004 to 2014 revealed that risk management and sustainable construction were the most commonly studied application areas for the Analytic Hierarchy Process (AHP) in construction management[13]. According to the study of Dakhli et al, it was discovered using blockchain technology can potentially lead to cost savings of 8.3 % in the total cost of residential construction. This finding was determined with a standard deviation of 1.26 %. Additionally, the study also delved into the potential implications, risks, and application of blockchain in the construction industry as well as identifying opportunities for further research in this field.[14]

According to Nanayakkara et al, the construction industry faces challenges in monitoring compliance and ensuring the quality of final products in its complex and large supply chains. The use of blockchain technology, which extends beyond cryptocurrencies, has the potential to improve these issues by providing increased efficiency, trust, fairness, security, transparency, accountability, compliance, and standardization. The research was conducted by Nanayakkara et al through an industry engagement workshop in the form of round-table discussions, with input from both academics and industry practitioners. they showed The findings of the study can be used to improve the implementation of blockchain solutions in the construction industry in the future. The study highlighted that stakeholders in the

construction industry believe that the use of blockchain and smart contracts can lead to increased efficiency, trust, fairness, security, transparency, accountability, compliance, and standardization in the supply chain. Additionally, the study found that the requirements and drivers of blockchain and smart contracts in the construction industry can be reconciled.[15]

At beginning of 2020, according to a study by Perera et al, the construction industry has been slow to adopt new technologies such as Big Data, the Internet of Things, and blockchain. Blockchain, a type of distributed database, has the potential to be used in the construction industry for replicating, sharing, and synchronizing data across multiple geographical locations. By examining its potential through a use case analysis and literature review, the study determined that the potential of blockchain in the construction industry is credible due to its multiple uses, investments involved, and the number of start-up businesses contributing to Industry 4.0[16]. According to Das et al studies, It is found that interim payment provisions in construction projects are susceptible to unfair practices due to the varying financial capacities of project participants belonging to different organizations. To address this issue, a distributed blockchain-based framework is proposed in which the trust of project participants is not required to automatically enforce the terms and conditions related to interim payments and to share payment records transparently and securely. A logic for automatically initiating, validating, and disbursing interim payments according to general contract conditions is formalized and a blockchain-based data model that enables selective transparency in payment records is proposed. This data model facilitates the sharing of sensitive financial information privately between two contracting parties and non-sensitive payment-related information publicly among all project participants. A key management strategy that facilitates security properties such as confidentiality and authenticity of data and users, is also proposed in the framework [17].

The study conducted in 2021 by Gurgun and Koc aimed to investigate the potential administrative challenges of implementing smart contracts in the construction industry as an alternative to traditional contracts. They used a literature review to identify the risks and a pilot study to ensure the framework was suitable. Through the use of the fuzzy analytical hierarchy process method, the study determined the criteria weights and conducted a sensitivity analysis to verify the robustness of the hierarchy and stability of the results. Additionally, the study included a focus group discussion to discuss strategies for mitigating the top-level risks identified in each risk category [18].

2
METHODOLOGY

The methodology employed for this thesis aimed to identify and analyze the technical and financial risks associated with the adoption of smart contracts in construction management processes. In order to gather the necessary data, a combination of methods was utilized, including a literature review and a survey.

A literature review was conducted to gather information on the current state of smart contract technology, its potential applications in the construction industry, and the associated risks. A wide range of academic and industry-related sources was consulted, including journals, books, and online articles. The literature review was conducted using a systematic approach, in which relevant literature was identified, reviewed, and analyzed to provide an overview of the current state of the field.

In addition to the literature review, a survey was conducted to gather expert opinions on the topic from professionals in the construction industry. The survey aimed to gather information on the perceived risks and challenges associated with the adoption of smart contracts in construction management processes, as well as the potential benefits of the technology. The survey was distributed to a sample of experts in the field, including construction managers, architects, engineers, and project managers. This was done to ensure that the survey would include the perspectives of those who have experience and knowledge about the topic of smart contracts in construction management.

For the survey analysis, the Analytic Hierarchy Process (AHP), one of the multiple decision-making methods, was used to analyze the data collected [19, 20]. AHP is a structured method that allows for the comparison of multiple factors in order to reach a final decision. It was chosen as a method of analysis as it is well-suited for dealing with complex decision-making problems, such as identifying technical and financial risks in the adoption of smart contracts in construction management processes.

2.1 Multi-Criteria Decision Making Methods

Multi-criteria decision-making (MCDM) is a systematic approach used to evaluate and rank a set of alternatives based on multiple conflicting criteria. This process is commonly used in different fields such as engineering, business, and environmental management, where there are various criteria and a plethora of alternatives to choose from.

The MCDM process can be broken down into several steps:

- Identifying the problem and determining the alternatives that will be considered.
- Determining the criteria that will be used to evaluate the alternatives.
- Assessing the relative importance of the criteria.
- Collecting and analyzing data on the alternatives based on the criteria.
- Comparing and evaluating the alternatives based on the criteria.
- Selecting the best alternative based on the evaluation.

One popular method for MCDM is the Analytic Hierarchy Process (AHP). AHP is a structured technique that organizes and analyzes complex decisions based on a hierarchical structure of the decision problem. The process involves breaking down the decision problem into a hierarchy of elements such as goals, criteria, and alternatives. Pairwise comparisons are then made between elements in each level of the hierarchy to determine their relative importance.

AHP is widely used in MCDM and has been found to be an effective tool in various fields such as transportation planning, environmental impact assessment, and resource allocation. The method is particularly useful when there are multiple conflicting criteria and a large number of alternatives to consider.

It is important to note that MCDM and AHP can provide valuable insights and guidance in the decision-making process, however, the results should not be considered as the final decision. The decision-making process is often subjective and influenced by various factors such as personal biases and uncertainty in the data. Therefore, the results of MCDM and AHP should be carefully considered in conjunction with other information and expert judgment before making a final decision.

2.2 Analytic Hierarchy Process (AHP) Method

2.2.1 Analytic Hierarchy Definition

The decision to be made is identified, as are the criteria that are important in making the decision. It is then broken down into smaller, more manageable parts, called "subproblems," and each subproblem is assigned to a level in the hierarchy. Pairwise comparison matrices are developed for each subproblem, comparing the alternatives under consideration based on the criteria identified. Using the pairwise comparison matrices and the eigenvector method, the relative importance of each criterion and alternative within each criterion is calculated. The results from all subproblems are aggregated to determine the overall ranking of the alternatives. The decision is made based on the ranking and relative importance of the criteria and then reviewed to ensure that it is consistent with the original objectives and that all important criteria have been considered. [21]

2.2.2 Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP) includes the following steps:

- Identifying the decision and the criteria: The first step in applying the AHP method is to identify the decision to be made and the objectives that are important to that decision. This includes defining the problem and the objectives to be achieved, as well as the criteria that will be used to evaluate the various alternatives.
- Breaking down the decision into subproblems Once the decision and criteria are established, the decision is broken down into smaller, more manageable parts called "subproblems" Each subproblem is assigned to a level in the hierarchy, with the overall decision at the top level and the subproblems at lower levels. The hierarchy is structured to reflect the relative importance of the various subproblems and criteria.
- Develop pairwise comparison matrices: for each subproblem, a pairwise comparison matrix is developed to compare the alternatives under consideration based on the criteria identified in Step 1. The alternatives are compared on a scale of 1 to 9, where 1 represents "equally important" and 9 represents "extremely important" In this way, the decision-maker can assign relative weights to the various criteria and alternatives based on his or her subjective judgment.
- Calculating relative importance: the pairwise comparison matrices are used to calculate the relative importance of each criterion and the relative importance

of each alternative within each criterion. To do this, a mathematical technique called the "eigenvector method" is used, in which a system of simultaneous linear equations is solved. The eigenvector method is used to determine the relative importance of the criteria and alternatives based on the pairwise comparisons performed in the previous step.

- Aggregating the results: The results of all subproblems are then aggregated to determine the overall ranking of the alternatives. This is done by combining the relative importance of the different criteria and alternatives, using a weighted average.
- Making the Decision: A decision is made based on the ranking and relative importance of the criteria. The alternative that ranks highest is generally considered the best choice.
- Reviewing the decision: Finally, the decision is reviewed to ensure that it is consistent with the original objectives and that all important criteria have been considered. This step is important to ensure that the decision is sound and will lead to the desired results. [19]

The general scheme of the AHP method is illustrated in Figure 2.1.

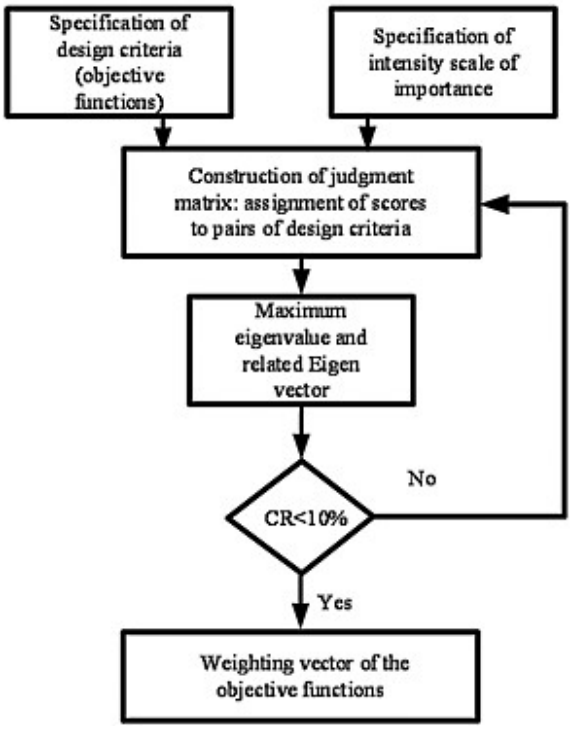


Figure 2.1 Flowchart of the general application of the AHP method.

2.2.3 Analytic Hierarchy Parameters

The Analytic Hierarchy Process (AHP) is a method for making decisions based on multiple criteria. An important aspect of the AHP is the evaluation of the consistency of the pairwise comparisons made by the decision maker.

The Consistency Index (CI) and Consistency Ratio (CR) are measures used to assess data consistency inside a database. To calculate consistency, they utilize different methodologies. The consistency index (CI) is a metric for measuring the consistency of data within a database. It is a numerical representation of the degree to which the data in the database conforms to a predefined set of constraints and rules. CI is calculated by comparing the actual data in the database to the expected data based on a predefined set of constraints and rules. A higher value of CI indicates that the data in the database is more consistent and better matches the predefined constraints and rules. A lower value of CI indicates that the data is less consistent and may contain more errors or inconsistencies. CI is commonly used in academic research and industry as a measure to evaluate the quality of data in a database. It is also used to identify and correct errors and inconsistencies in data, and to ensure compliance with data governance and regulatory requirements.

Consistency Ratio (CR) is another metric for measuring the consistency of data within a database. It is calculated as the ratio between the number of consistent tuples and the total number of tuples in a table. A higher value of CR indicates that the data in the database is more consistent and conforms better to predefined constraints and rules. A lower value of CR indicates that the data is less consistent and may contain more errors or inconsistencies. CR is widely used in academic research and industry as a benchmark for evaluating data quality in a database. It is also used to identify and correct errors and inconsistencies in data and to ensure compliance with data governance and regulatory requirements.

CR, on the other hand, is calculated as the ratio of the number of consistent tuples to the total number of tuples in a table. This metric measures consistency by comparing the number of tuples that comply with a specific set of constraints and rules to the total number of tuples in a table. It is also a ratio method of measurement and can be expressed as a number between 0 and 1, or as a percentage. A higher CR number implies that the data in the database is more consistent and adheres more closely to the set restrictions and rules. A lower CR rating implies that the data is less consistent and may contain more errors or inconsistencies.

Both CI and CR can be used to uncover data mistakes and inconsistencies, but when deciding which measure to use, it is necessary to examine the individual use case and

the type of data being evaluated. It's also worth noting that CI and CR may not be a complete indication of the quality of data within a database, and they may not be the ideal statistic to employ in all circumstances. Other considerations to consider when analyzing the consistency of data within a database include the size of the database, the complexity of the data, and the precise restrictions and rules that are utilized in the calculation.

The CI is calculated by taking the largest eigenvalue of the pairwise comparison matrix and the number of criteria (n) to be compared. The formula for calculating the CI is;

$$CI = \frac{\lambda - n}{n - 1} \tag{2.1}$$

The value obtained is then compared to the consistency ratio (CR), which is calculated by dividing the CI by the random index (RI).

$$CR = \frac{CI}{RI} \tag{2.2}$$

The Random Index (RI) is a metric used to measure the performance of a database by determining the degree of random access performed for a given query. To calculate the RI, the number of page reads (or disk I/O operations) required to perform a given query is measured and compared to the number of page reads required to perform the same query in a database that is completely random.

A database with a low RI value is considered high performing because fewer random accesses are required to retrieve the desired data. RI is widely used in academic research and industry as a benchmark for evaluating the efficiency of database management systems. It is also used to compare different indexing methods and determine the optimal indexing strategy for a given database.

It is important to note that RI alone is not a comprehensive measure of database performance and is not the best metric in all situations. Other factors such as query complexity, data distribution, and database size must also be considered when evaluating a database's performance.

If the calculated CR is less than or equal to the acceptable range for the given number of criteria, the pairwise comparisons are considered consistent. On the other hand, if CR is greater than the acceptable range, it is likely that the pairwise comparisons are inconsistent. In this case, the decision maker should revise their comparisons to ensure consistency.

It is important to note that the CI and CR are not the only indicators of consistency. Even if the CI and CR indicate consistency, this is not a guarantee that the pairwise comparisons will be error-free or that the final decision will be optimal. A consistent pairwise comparison matrix does not necessarily mean that the final priorities and criteria weights will be optimal. Additional steps and analysis, such as sensitivity analysis, may be required to confirm the robustness of the decision. [20]

2.3 AHP Method of Current Study

In this study, the main risk topics were determined firstly such as financial, technical, technological, and time-wise risks considering the contracts utilized in the construction industry. The attendees of the survey first gave significance points for the main risk categories as shown in Table 2.1.

Table 2.1 The main risk categories part of the survey presented to the attendees.

	Financial	**Technical**	**Technologic**	**Timewise**
Financial	1			
Technical		1		
Technologic			1	
Timewise				1

In addition to that, sub-questions were identified according to the thorough investigation in the literature. The sub-questions of each main risk group are listed in Table 2.2.

Table 2.2 Sub-questions of the main risk categories chosen for the study.

Code	Sub-question
FI1	Expensive And Clunky Drafting And Registration Process [22] [23] [24]
FI2	Cost Of Upskilling [24]
FI3	Cost Of Too Many Updates [24]
FI4	Cost Of Adequate Human Resource [24]
TE1	Lack Of Experienced Personnel [24]
TE2	Complexity in The Developing Draft [22] [25] [23] [26] [24]
TE3	Irrevocable Control To TM Machine [25] [23]
TE4	Updating Issues After Changes [22] [27]
TE5	Inaccurate Recorded Information [28] [26] [24]
TE6	Incorrect Coding [26] [24] [27] [29]
TG1	Mg probability leading to permanent failure [22] [30]
TG2	Privacy issues [22] [26] [24] [30] [29]
TG3	Cyber attack to the documents (Hacking, Abuse) [24]
TG4	Lack of technological advancements [23] [24]
TG5	Error prone nature of computers [25] [28] [23] [30]
TW1	Excessive time for approval procedures [31] [27]
TW2	Difficulty in setting deadlines and original time scales [31]
TW3	Time constraints [24] [27]
TW4	Time consuming process of developing the contract draft [24] [27]
TW5	Long lasting negotiation process [22] [24] [31]

After the determination of the main risk topics and sub-questions, eight experts who are highly experienced in construction management and contract administration were chosen to conduct the questionnaire. The details of the experts that completed the survey are given in Table 2.3.

After the completion of the survey with all experts, the answers were processed according to the AHP method as explained in Section 2.X.

Table 2.3 Details of the experts chosen to conduct the questionnaire.

ID	Role	Proficiency	Education Level	Sector	Organization	Experience in Proficiency	Experience in Contract Administration
E-01	Electric Works Chief	Electric Engineer	BSc	Private	Contractor	15	10
E-02	Technical Manager	Civil Engineer	BSc	Private	Contractor	30	30
E-03	Technical Office Engineer	Electric Engineer	BSc	Private	Contractor	10	7
E-04	Contract Office Chief	Civil Engineer	MSc	Private	Contractor	18	4
E-05	Contract Office Engineer	Mechanical Engineer	BSc	Private	Contractor	6	2
E-06	Technical Office Chief	Civil Engineer	BSc	Private	Contractor	23	20
E-07	Fine Works Manager	Architect	BSc	Private	Contractor	20	15
E-08	Project Deputy Manager	Mechanical Engineer	BSc	Private	Contractor	30	25

3
RESULTS AND DISCUSSION

The research conducted in this thesis aimed to identify and analyze the technical and financial risks associated with the adoption of smart contracts in construction management processes. A comprehensive literature review was undertaken to gather information on the current state of smart contract technology and its potential applications in the construction industry, as well as the associated risks. The survey, which was limited to the examination of financial and technical risks, involved gathering expert opinions from professionals in the construction industry. The survey responses provided valuable insights into the relative significance of these risks, highlighting the importance of considering factors such as the cost and complexity of the drafting and registration process, the need for frequent updates, the availability of adequate human resources, and the risks associated with incorrect coding. It is important to note that the survey did not include an in-depth analysis of technological and time-related risks. However, the findings from the survey, combined with the existing literature, contribute to a better understanding of the challenges and considerations involved in the implementation of smart contracts in construction management processes.

Firstly, the results were compared for the main topic in the survey to capture the distribution among the attendees. The answers of each expert were collected in an Excel workbook to process the results. An example answer to the main risk categories of experts is presented in Table 3.1.

Table 3.1 Survey results of the geometric mean belong to the Pair-wise Comparison matrix for the main risk groups.

	Financial	Technical	Technologic	Timewise
Financial	1	1.968	4.039	3.339
Technical	0.508	1	2.188	1.715
Technologic	0.248	0.457	1	0.67
Timewise	0.299	0.583	1.493	1
Σ	2.055	4.008	8.72	6.74

able 3.1 presents the survey results obtained from the geometric mean of the Pair-wise Comparison Matrix for the main risk groups.

In this table, the main risk groups are categorized as "Financial," "Technical," "Technologic," and "Timewise." The values in the table represent the relative importance or priority assigned to each risk group compared to the others.

The values in each cell of the table indicate the strength of the pairwise comparisons between the corresponding row risk group and column risk group. For example, the value of 1 in the cell where "Financial" intersects with itself indicates that there is no difference in importance between the "Financial" risk group and itself.

By comparing the values in each row, it can be observed that the higher the value, the greater the importance of the corresponding risk group. For instance, in the "Financial" row, the values of 1.968, 4.039, and 3.339 indicate that the "Financial" risk group is relatively more important than the "Technical," "Technologic," and "Timewise" risk groups, respectively.

Similarly, in the other rows, the higher values indicate the relative importance of the corresponding risk groups within the context of the main risk groups.

These survey results provide insights into the prioritization and relative significance of the main risk groups based on the geometric mean calculations.

Note: The symbol Σ at the bottom of the table represents the sum of the values in each column, indicating the total importance assigned to each risk group across all pairwise comparisons.

Overall, this table offers valuable information for the analysis and evaluation of the main risk groups using the AHP method within the research context.

Table 3.2 Survey results of the geometric mean belong to normalization of pair-wise Comparison matrix for the main risk groups.

	Financial	Technical	Technologic	Timewise
Financial	0.487	0.491	0.463	0.497
Technical	0.247	0.250	0.251	0.255
Technologic	0.121	0.114	0.115	0.100
Timewise	0.145	0.145	0.171	0.149

Table 3.2 presents the survey results obtained from the normalization of the pair-wise comparison matrix for the main risk groups using the AHP method.

In this table, the main risk groups are categorized as "Financial," "Technical," "Technologic," and "Timewise." The values in the table represent the normalized weights or priorities assigned to each risk group based on their pairwise comparisons.

These survey results provide insights into the relative importance or priority of the main risk groups based on the normalization process applied to the pairwise comparison matrix. The normalized weights allow for a fair and consistent comparison between the different risk groups, facilitating decision-making and resource allocation processes.

Table 3.3 Eigenvector (w) of the main risk categories before the consistency analyses.

Risk Category	**Eigenvector (w)**
Financial	48%
Technical	25%
Time-wise	12%
Technological	15%

After determining the Eigenvector (w) of the main risk categories, consistency analyses were conducted. The variables to evaluate the consistency ratio have been calculated according to the AHP method. The Random Index (*RI*) was according to the suggestions by Saaty [21].

Table 3.3 presents the eigenvector (w) values of the main risk categories before the consistency analyses.

In the table, the main risk categories are listed as "Financial," "Technical," "Time-wise," and "Technological." The eigenvector (w) represents the relative importance or priority assigned to each risk category based on pairwise comparisons.

The percentages assigned to each risk category indicate their respective weights in the overall decision-making process. For example, the "Financial" risk category has

an eigenvector value of 48%, indicating that it holds a significant weight in the decision-making process compared to the other risk categories.

Similarly, the "Technical" risk category has an eigenvector value of 25%, indicating its relative importance. The "Time-wise" risk category holds a weight of 12%, and the "Technological" risk category holds a weight of 15% in the overall analysis.

These eigenvector values provide insights into the relative importance or priority of the main risk categories before conducting consistency analyses. They serve as a foundation for further analysis and decision-making processes related to risk management.

Overall, the eigenvector values in Table 3.3 reflect the relative weights assigned to each main risk category, highlighting their significance in the decision-making framework. These values assist in understanding the relative importance of different risk categories and contribute to informed decision-making in risk assessment and management.

Table 3.4 Eigenvalue (w') of the main risk categories before the consistency analyses.

Risk Category	Eigenvalue (w')
Financial	1.941
Technical	1.004
Time-wise	0.449
Technological	0.611

Table 3.5 Comparison Of Risks

Risk Category	Comparison Of Risks
Financial	49%
Technical	25%
Time-wise	12%
Technological	15%

Table 3.5, titled "Comparison of Alternatives," illustrates the outcomes obtained through the Analytic Hierarchy Process (AHP) for various risk categories. The table presents the relative rankings of the alternatives within each category, expressed in the form of percentages.

The "Financial" category exhibits the highest priority among the alternatives, with a percentage of 49%. This implies that the financial aspect plays a crucial role in determining the preferred choice. In the "Technical" category, the alternative holds relative importance of 25%, indicating its significance within the technical domain.

Within the "Time-wise" and "Technological" categories, the alternatives have been assigned percentages of 12% and 15%, respectively. These percentages reflect their

respective levels of importance concerning time-related factors and technological considerations.

In summary, Table 3.5 provides a concise overview of the comparison results for the alternatives across different risk categories. The assigned percentages offer valuable insights into the relative significance of each alternative within its specific domain. This information can guide decision-makers in making informed choices and prioritizing the alternatives based on their performance and relevance to particular risk categories.

Financial Risks are ;

- (FI1) Expensive And Clunky Drafting And Registration Process (Installing)
- (FI2) Cost Of Upskilling
- (FI3) Cost Of Too Many Updates
- (FI4) Cost Of Adequate Human Resource

Table 3.6 Survey results of the geometric mean belong to Pair-wise Comparison matrix for the financial risks groups.

	FI1	FI2	FI3	FI4
(FI1)	1	3.201	2.734	3.303
(FI2)	0.312	1	0.538	0.806
(FI3)	0.366	1.969	1	1.783
(FI4)	0.303	1.241	0.561	1
Σ	1.981	7.411	4.803	6.892

Table 3.7 Survey results of the geometric mean belong to Normalization of Pair-wise Comparison matrix for the Financial Risks groups.

	FI1	FI2	FI3	FI4
(FI1)	0.505	0.432	0.569	0.479
(FI2)	0.158	0.135	0.106	0.117
(FI3)	0.185	0.226	0.208	0.259
(FI4)	0.153	0.167	0.117	0.145

Table 3.6 illustrates the survey results obtained from the pair-wise comparison matrix specifically focused on the subcategory of financial risks. Through the utilization of the geometric mean values, the relative significance of each individual risk within the financial domain is assessed. The matrix showcases the comparisons made between distinct financial risks, including (FI1) Expensive and Clunky Drafting and

Registration Process, (FI2) Cost of Upskilling, (FI3) Cost of Too Many Updates, and (FI4) Cost of Adequate Human Resources. The numerical entries within the matrix reflect the assigned degrees of importance or preference for each respective risk factor. The cumulative sum of these values presents an overall indication of the relative importance and prioritization of the financial risks under consideration.

Table 3.7, on the other hand, presents the results derived from the normalization process applied to the pair-wise comparison matrix concerning financial risks. By transforming the geometric mean values into normalized values, a fair and standardized basis for comparison is established. The matrix portrays the normalized comparisons among the same set of financial risks mentioned earlier. The numerical entries represent the relative importance of each risk factor after normalization. The cumulative sum of these values provides insights into the overall importance of the financial risks in a normalized context.

When examining the sub-risks within the financial domain, it is important to note that the relative importance of each risk can be inferred from the values assigned within the matrices. The higher the assigned value, the greater the perceived importance of the corresponding risk factor in relation to the others. Therefore, the interpretation of the matrices and the emphasis placed on specific sub-risks will depend on the magnitude of their assigned values and the resulting cumulative sums.

Table 3.8 Eigenvector (w) of the financial risk categories before the consistency analyses.

Risk Category	Eigenvector (w)
FI1	50%
FI2	13%
FI3	23%
FI4	14%

Table 3.9 Eigenvalue (w') of the financial risk categories before the consistency analyses.

Risk Category	Eigenvalue (w')
FI1	2.016
FI2	0.518
FI3	0.924
FI4	0.584

Table 3.8 provides the eigenvector values (w) for the financial risk categories before the consistency analyses. Among these categories, FI1 (Expensive And Clunky Drafting And Registration Process) stands out as the most important sub-risk, with a significant

Table 3.10 Comparison Of Risks

Risk Category	Comparison Of Risks
FI1	51%
FI2	14%
FI3	21%
FI4	14%

eigenvector weight of 50%. FI3 (Cost Of Too Many Updates) follows with a weight of 23 %, while FI4 (Cost Of Adequate Human Resources) and FI2 (Cost Of Upskilling) have weights of 14% and 13% respectively.

Moving on to Table 3.9, which presents the eigenvalue values (w') for the financial risk categories, we can observe that FI1 has the highest eigenvalue of 2.016, reinforcing its importance in the overall assessment. FI3 has an eigenvalue of 0.924, followed by FI4 with 0.584 and FI2 with 0.518.

Lastly, in Table 3.10, the comparison of alternatives for the financial risk categories reveals that FI1 (Expensive And Clunky Drafting And Registration Process) holds the highest importance with a percentage of 51%. This further emphasizes the significance of FI1 as a key sub-risk. FI3 has a percentage of 21%, while both FI4 and FI2 have percentages of 14%.

To summarize, FI1, also known as the "Expensive And Clunky Drafting And Registration Process" sub-risk, emerges as the most crucial aspect within the financial risk categories. It is supported by its high eigenvector weight, eigenvalue, and comparison percentage, highlighting its significance in the overall assessment of financial risks.

Technical Risks are ;

- (TE1) Lack Of Experienced Personel
- (TE2) Complexity In The Developing Draft
- (TE3) Irrovocable Control To The Machine (Once Initiated, The Outcomes Cannot Be Stopped)
- (TE4) Updating Issues After Changes (i.e. Design Change)
- (TE5) Inaccurate Recorded Information
- (TE6) Incorrect Coding (Risks TRom Implementing To Completion)

Table 3.11 Survey results of the geometric mean belong to pair-wise Comparison matrix for the technical risks groups.

	TE1	TE2	TE3	TE4	TE5	TE6
(TE1)	1	0.487	0.912	1.316	0.493	0.416
(TE2)	2.053	1	1.498	2.543	0.764	0.844
(TE3)	1.096	0.668	1	1.342	0.513	0.514
(TE4)	0.76	0.393	0.745	1	0.357	0.391
(TE5)	2.028	1.309	1.949	2.801	1	0.594
(TE6)	2.404	1.1185	1.9.46	2.558	1.684	1
Σ	9.341	5.042	8.05	11.56	4.811	3.759

Table 3.12 Survey results of the geometric mean belong to normalization of pair-wise Comparison matrix for the technical risks groups.

	TE1	TE2	TE3	TE4	TE5	TE6
(TE1)	0.107	0.097	0.113	0.114	0.102	0.111
(TE2)	0.220	0.198	0.186	0.220	0.159	0.225
(TE3)	0.117	0.132	0.124	0.116	0.107	0.137
(TE4)	0.081	0.078	0.093	0.087	0.074	0.104
(TE5)	0.217	0.206	0.242	0.242	0.208	0.158
(TE6)	0.257	0.235	0.242	0.221	0.350	0.266

According to the pair-wise comparison matrices for the technical risks groups, the following insights can be derived:

Table 3.11:

- TE6 (Incorrect Coding) holds the highest value of 2.404, indicating its utmost importance among the technical sub-risks.
- TE5 (Inaccurate Recorded Information) follows closely with a value of 2.028, signifying its significant impact on the overall risk assessment.
- TE2 (Complexity in the Developing Draft) carries a value of 2.053, suggesting its considerable relevance in the context of technical risks.
- TE4 (Updating Issues After Changes) exhibits the lowest value of 0.76, implying relatively lower significance compared to other sub-risks.

Likewise, in Table 3.12:

- TE6 (Incorrect Coding) maintains its prominence with the highest normalized value of 0.257.

- TE5 (Inaccurate Recorded Information) closely trails with a normalized value of 0.217.
- TE2 (Complexity in the Developing Draft) retains a normalized value of 0.220.
- TE2 (Complexity in the Developing Draft) retains a normalized value of 0.220.

Table 3.13 Eigenvector (w) of the technical risk categories before the consistency analyses.

Risk Category	Eigenvector (w)
TE1	11%
TE2	20%
TE3	12%
TE4	9%
TE5	22%
TE6	26%

Table 3.14 Eigenvalue (w') of the technical risk categories before the consistency analyses.

Risk Category	Eigenvalue (w')
TE1	0.648
TE2	1.214
TE3	0.738
TE4	0.519
TE5	1.337
TE6	1.589

Table 3.15 Comparison Of Risks

Risk Category	Comparison Of Risks
TE1	11%
TE2	20%
TE3	12%
TE4	12%
TE5	21%
TE6	27%

Based on the analysis of the eigenvector (w) values provided in Table 3.13, the importance of the technical sub-risks can be determined as follows:

The sub-risk TE6 (Incorrect Coding) holds the highest eigenvector value of 26%, indicating its significant importance in the overall assessment of technical risks. It emerges as the most critical sub-risk.

Following closely is TE5 (Inaccurate Recorded Information) with an eigenvector value of 22%. This sub-risk demonstrates a substantial impact on the risk evaluation and is considered highly important.

TE2 (Complexity in the Developing Draft) ranks third among the technical sub-risks, with an eigenvector value of 20%. It is identified as a significant factor contributing to the overall risk assessment.

Moving on to Table 3.14, the eigenvalue (w') further confirms the significance of these sub-risks:

TE6 (Incorrect Coding) maintains its position as the most critical sub-risk, having the highest eigenvalue of 1.589. This highlights its criticality in the evaluation of technical risks.

TE5 (Inaccurate Recorded Information) follows closely with an eigenvalue of 1.337, reinforcing its substantial influence on the overall risk analysis.

TE2 (Complexity in the Developing Draft) retains its importance with an eigenvalue of 1.214, solidifying its position as a crucial sub-risk.

Lastly, considering the comparison of alternatives in Table 3.15, the relative importance of the sub-risks within the technical category can be summarized as:

TE6 (Incorrect Coding) holds the highest percentage of 27%, indicating its utmost significance among the technical sub-risks.

TE5 (Inaccurate Recorded Information) closely follows with a percentage of 21%, reaffirming its substantial impact on the risk assessment.

TE2 (Complexity in the Developing Draft) maintains its significance with a value of 20%, further emphasizing its relevance in the context of technical risks.

To summarize, based on the eigenvector (w), eigenvalue (w'), and comparison of alternatives, the most important technical sub-risks, in order of significance, are TE6 (Incorrect Coding), TE5 (Inaccurate Recorded Information), and TE2 (Complexity in the Developing Draft).

Table 3.16 Distributions of Risks.

Risk Category	Rank of Risks
FI1	24.60%
FI3	10.30%
FI4	7.10%
TE6	6.70%
FI2	6.70%
TE5	5.30%
TE2	5.00%
TE3	3.10%
TE1	2.60%
TE4	2.20%

The rankings of the risks, based on the provided results, shed light on their relative significance in the financial and technical domains. Topping the list is FI1, which refers to the risk associated with the expensive and clunky drafting and registration process, accounting for 24.60% of the total. This indicates that the cost and complexity involved in the drafting and registration of smart contracts can have a substantial financial impact on organizations. Following closely behind is FI3, representing the risk of the cost incurred due to frequent updates in smart contracts, with a percentage of 10.30%. This highlights the financial burden associated with the constant need for modifications and adjustments in the contract, impacting the overall project budget and resource allocation. Ranked third is FI4, emphasizing the importance of adequate human resources in implementing and managing smart contracts effectively. This risk, accounting for 7.10% of the total, underscores the financial implications of recruiting and retaining skilled personnel with expertise in data science and artificial intelligence. On the technical side, TE6 takes the lead with a percentage of 6.70%, pointing to the risks arising from incorrect coding during the implementation and completion of smart contracts. Flawed or erroneous code can introduce vulnerabilities, compromise the integrity of the system, and potentially lead to financial losses or legal disputes. Additionally, the rankings highlight other technical risks such as TE5 (Inaccurate Recorded Information), TE2 (Complexity in the Developing Draft), TE3 (Irrevocable Control to the Machine), TE1 (Lack of Experienced Personnel), and TE4 (Updating Issues After Changes). Each of these risks contributes to the overall risk landscape with their respective numerical significance, showcasing the importance of addressing technical challenges in smart contract implementations.

4
CONCLUSION

The research findings provide valuable insights into the adoption of smart contracts in construction management processes, shedding light on the significant technical and financial risks associated with this implementation. The survey results not only reveal the presence of these risks but also offer a deeper understanding of their relative importance and prioritization within their respective domains.

From a financial perspective, several key challenges emerge. The expensive and clunky drafting and registration process poses a considerable financial burden on construction companies. The cost of upskilling employees to effectively work with smart contracts is another financial obstacle that needs to be addressed. Additionally, the cost implications of frequent updates and the need for adequate human resources to manage and maintain smart contracts add to the financial challenges faced by construction companies.

On the technical front, a range of risks further complicates the adoption of smart contracts. One significant issue is the lack of experienced personnel familiar with smart contract development and management. The complexity involved in developing smart contract drafts and ensuring their accuracy and functionality presents another technical hurdle. Moreover, the relinquishment of control to machines through irrevocable smart contracts raises concerns about the potential for unintended consequences and the difficulty of making changes or updates once the contracts are deployed. The accuracy of recorded information and the integrity of the underlying code is also technical risks that need to be addressed to ensure the successful implementation of smart contracts in construction projects.

The presence of these risks highlighted by the survey results underscores the need for careful consideration and the formulation of robust risk management strategies during the integration of smart contracts into construction processes. It becomes evident that the successful adoption of smart contracts requires significant financial investment to address the identified challenges effectively. Construction companies need to allocate

resources to upskill their workforce, streamline the drafting and registration processes, and ensure the availability of adequate human resources. Moreover, the complexity of the technology demands thorough planning, meticulous quality control measures, and ongoing updates to address any potential issues and minimize the risks associated with smart contract implementation.

By proactively addressing these challenges, construction companies can leverage the benefits offered by smart contracts while mitigating potential disruptions and financial losses. The integration of smart contracts has the potential to enhance efficiency, streamline processes, and increase transparency in construction management. However, it is crucial for organizations to recognize the significance of these risks and to allocate resources accordingly to manage and mitigate them effectively.

In conclusion, the research findings highlight the inherent risks involved in incorporating smart contracts into construction management processes. The survey results underscore the importance of considering both financial and technical risks, emphasizing the need for careful planning, strategic resource allocation, and the implementation of comprehensive risk management strategies. By adopting a proactive approach to address these challenges, construction companies can successfully navigate the integration of smart contracts and unlock the benefits of increased efficiency and transparency in their operations.

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A
IN-DEPTH ANALYSIS: INSIGHTS FROM OUR SURVEY STUDY

In this section, we take a detailed look at the questions that were posed in our survey. These questions were carefully selected and formulated to elicit valuable insights and perspectives from experts in the field. The survey was distributed to 8 experts, who were chosen for their expertise and experience in the relevant topic. The questions were designed to cover a range of perspectives and to provide an in-depth analysis of the experts' viewpoints. The information presented in this section is intended to give a comprehensive understanding of the questions that were asked in the survey, providing context and background information that will help to understand the responses received.

A.0.1 When considering the main risks that affect smart contracts, which one do you believe is more significant in comparison to the others? Note: If the risk in the row is more important (X), you should answer as if the risk in the column is more important (1/X)

Main Risks	Financial	Technical	Technologic	Timewise
Financial				
Technical	///			
Technologic	///	///		
Timewise	///	///	///	

Figure A.1 Main Risk in Survey Study

A.0.2 When considering the financial risks that affect smart contracts, which one do you believe is more significant in comparison to the others? Note: If the risk in the row is more important (X), you should answer as if the risk in the column is more important (1/X)

Financial Risks	F1	F2	F3	F4
Expensive Clunky Drafting And Registration Process (Installing) (F1)				
Cost Of Upskilling (F2)	///			
Cost Of Too Many Updates (F3)	///	///		
Cost Of Adequate Human Resource (F4)	///	///	///	

Figure A.2 Financial Risk in Survey Study

A.0.3 When considering the technical risks that affect smart contracts, which one do you believe is more significant in comparison to the others? Note: If the risk in the row is more important (X), you should answer as if the risk in the column is more important (1/X)

Financial Risks	T1	T2	T3	T4	T5	T6
Lack Of Experienced Personel (T1)						
Complexity In The Developing Draft (T2)	///					
Irrovocable Control To The Machine (Once Initiated, The Outcomes Cannot Be Stopped) (T3)	///	///				
Updating Issues After Changes (i.e. Design Change) (T4)	///	///	///			
Inaccurate Recorded Information (T5)	///	///	///	///		
Incorrect Coding (Risks From Implementing To Completion) (T6)	///	///	///	///	///	

Figure A.3 Technical Risk in Survey Study

PUBLICATIONS FROM THE THESIS

Conference Papers

1. AIntelia Sciences Notes International Joint Conference on Engineering, Science and Artificial Intelligence IJCESAI 2022, December 02-04, 2022