Empowering Subcontractors in Swedish Construction with Blockchain Technology for Automated Payment Processes

Master’s thesis in Department of Architecture and Civil Engineering

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DEPARTMENT OF ARHITECTURE AND CIVIL ENGINEERING

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ABSTRACT

This study addresses the pervasive issue of late payments in the Swedish construction industry, positing blockchain technology and Smart contracts as potential solutions. It aims to explore the impact of a blockchain-based Smart contract system on project management, with a focus on improving payment processes for subcontractors. By automating and making payments transparent at predefined project milestones, this research investigates the feasibility and impact of integrating blockchain technology into current project management frameworks. The research questions delve into the integration of blockchain-based Smart contracts to automate payment disbursement, the potential effects on payment delays, stakeholder collaboration, and overall project efficiency, and whether blockchain technology is necessary or if simpler solutions exist. Employing a mixed-methods approach, the study combines a literature review with interviews to construct a SWOT analysis and an Impact/Feasibility matrix. These tools are instrumental in addressing the research questions, particularly how the technology can be implemented and what the impacts are. The findings reveal that integrating blockchain-based Smart contracts can significantly streamline payment processes, offering transparency and traceability—key benefits highlighted in the literature. Interviews underscore the economic value of Smart contracts, emphasizing their potential to expedite revenue streams and save money. A recommended strategy involves legal collaboration, recruiting skilled developers, and comprehensive workforce training, ensuring a smooth transition to this new technological paradigm. The study concludes that blockchain-automated invoicing management could markedly enhance financial operations within the industry, promising timely payments and reducing invoicing delays. Such improvements are anticipated to bolster stakeholder collaboration and project efficiency. Despite the nascent stage of blockchain technology, its potential to mitigate financial disputes and delays is evident, presenting a compelling case for its implementation in the construction sector. This thesis contributes a guide for initiating an automated Smart contract payment system, underscoring blockchain technology's transformative potential for the construction industry's financial dealings.

Key words: Blockchain Technology, Automated Payments, Construction Industry, Smart contracts, Sustainability, Ecological Traceability, Financial System Innovation, Web 3.0, Digital Transformation, Decentralization, Economic Efficiency, Security Enhancements, Data Integrity, Stakeholder Engagement, Technological Adoption

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Preface

I am filled with gratitude toward those who have contributed to its completion. The journey of academic research is seldom a solitary one, and this work is no exception. It is my pleasure to extend my sincere thanks to those who have provided their invaluable support and guidance.

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Göteborg February 2024

Sebastian Persson

1 Introduction

1.1 Background of the current state

The construction industry in Sweden faces persistent challenges such as payment delays, a lack of transparency, and contractual disputes among clients, general contractors, and subcontractors. Payments are done on average 3 days after the invoice is due, (Regeringen, 2007). In 2023, Bolagsverket (2024) released numbers on late payments shows that the problem still stands. This might seem like a small problem, but a consistent delay of 3%, translates to a potential loss of 3% in revenue per year in the building sector, which is equal to 30 billion kronor, which is 0.3% of the Swedish BNP (Byggforetagen, 2023). On a project level, this causes financial strain on subcontractors and leads to disruptions in supply chains. These delays harm project timelines, quality, and overall industry efficiency, (March, 2023).

Blockchain technology (BCT), has emerged as a transformative innovation with the potential to revolutionize various industries, including finance, supply chain management, healthcare, construction, and more, (IBM, 2023). Blockchain is a decentralized and distributed digital ledger that securely records and verifies transactions. It is composed of “blocks”, each containing a set of transactions. These can represent various types of data, such as financial transactions, ownership records, or any digital information. A blockchain can be seen as a network of computers, or “nodes”. The bigger the blockchain, the more nodes it has and the more secure it is.

The integration of BCT into the construction industry holds significant promise for overcoming long-standing challenges and inefficiencies, (Hunhevicz et al., 2022). By leveraging blockchain's capabilities in transparency, automation, and secure data sharing, the construction sector can embrace a more collaborative, efficient, and accountable way of working. If the industry adopts and adapts blockchain solutions, the potential for improved project outcomes and stakeholder relationships is significant.

This research aims to explore the transformative potential of a blockchain-based Smart contract system in the context of construction projects. By investigating the implementation of Smart contracts that facilitate automated and secure payments upon predefined project milestones, this study seeks to analyze how such a system could enhance trust, transparency, and efficiency among stakeholders. Presently, the construction sector in Sweden deals with delayed payments, which lead to financial strain and potential disruptions in some cases. This study examines whether a well-defined Smart contract solution could reshape the dynamics of the industry, reducing payment delays.

1.2 The aim of the study

The aim is to investigate the influence of a blockchain-based Smart contract system on project management within the Swedish construction industry, with a particular emphasis on subcontractors. The study will explore how such a system facilitates automated and transparent payments for subcontractors.

The intended outcome is to see if there is a need for automated invoicing powered by blockchain for subcontractors in Sweden and in what way it would influence subcontractors economically.

1.3 Specification of the issue being investigated

The study will focus on developing a conceptual framework for how blockchain-automated invoicing management can enhance efficiency and reduce payment delays in the financial processes for subcontractors in construction projects in Sweden. The objective is to identify theoretical methods and best practices for the implementation and adaptation of automated invoicing management as a potential solution to the late payment challenges faced by the construction sector.

1. How can blockchain-based Smart contracts be integrated into project management processes to automate payments for subcontractors?
2. What impacts could the adoption of such a system have on payment delays, stakeholder collaboration, and project efficiency within the Swedish construction industry?
3. Is BCT needed, or can the problem be solved with easier means?

2 Theoretical framework

2.1 The project planning and organization in the construction sector

Project planning and organization are vital components of the construction sector, and they have evolved significantly over the years. This section provides an overview of the historical development of planning methods, contemporary approaches, and the challenges associated with digitalization.

2.1.1 Historical development of planning methods

Traditionally, construction project planning relied on methods that are more than a century old. One of the classic tools used in project scheduling is the Gantt chart, introduced by Henry L. Gantt in the early 20th century (Friblick, 2009). Gantt charts provide a visual representation of project activities plotted along a timeline, facilitating project tracking and coordination. The Second World War marked a significant turning point in the quest for more efficient planning methods in the construction industry. The urgency of wartime projects led to the development of advanced planning techniques that are still in use today. These methods laid the foundation for modern project planning in the construction sector.

2.1.2 Modern innovations in project planning

In recent years, the construction industry has witnessed the emergence of new scheduling techniques that leverage digitalization and Building Information Modeling (BIM). Notably, the Line of Balance diagram, integrated with BIM technology, has gained prominence in the Swedish construction industry (Alkhatib & Alshammaa, 2023). This innovative approach has demonstrated superior capabilities in detecting clashes and disruptions compared to the traditional Gantt chart. The Line of Balance diagram represents a leap forward in project planning, as it enables a more detailed and accurate visualization of project activities. By integrating BIM data, it provides a holistic view of the construction process, enhancing coordination and reducing potential conflicts.

2.1.3 Benefits and challenges of digitalization

Digitalization has brought about a multitude of benefits for project organizations in Sweden (Engström, et al. 2021). These advantages include increased availability of information, enhanced communication, and the creation of digital archives, among others. However, the digital era also presents its own set of challenges. One notable challenge is the risk of information overload. The abundance of digital tools and platforms can inundate project teams with data, potentially leading to confusion and inefficiencies. Furthermore, the widespread use of smartphones and applications can be distracting, diverting attention away from critical project tasks. Another aspect to consider is the expectation of constant availability. In today's digital age, there is often a perceived need for individuals to be always accessible. This expectation can create stress and disrupt work-life balance for construction professionals. Additionally,

digitalization can inadvertently exclude individuals or groups who may struggle to adapt to new technologies or have little interest in doing so. This exclusion poses a challenge to achieving universal participation and understanding within project organizations.

Planning in the construction sector is mainly done with methods that are less than 100 years old. The Gantt scheme is a common tool that shows activities that lie on an axle of time, (Friblick, 2009). The Second World War was the incentive to make better planning methods which are still used to this day. New schedule applications such as the Line of Balance diagram with the integration of BIM are currently being developed and tested in the Swedish construction industry, (Alkhatib & Alshammaa, 2023). The Line of Balance diagram has shown to better detect clashes and disruption in the planning than a classic Gantt scheme.

The benefits of digitalization for a project organization in Sweden are many, (Engström, et al. 2021). Increased availability, better communication, and digital archive to name a few, but it is a two- sided coin. The risk of overload of information is significant, not only in the projects but distractions from the phone and all its applications. The perceived expectancy is that you need to be available all the time and the exclusion of individuals and whole groups that cannot or do not have an interest in learning the new systems are also challenges to digitalization.

2.2 Late payments in the construction sector and the problems they bring

For a long time, late payments have been an issue in the construction industry (Regeringen, 2007; Shojaei, et al, 2020). In an investigation by Regeringen (2007), it is concluded that twelve percent of all payments within the construction industry are on average late by three days. Of these late payments, 26% are late by more than ten days and twelve percent are more than 30 days. The study shows that it creates a significant Domino effect too. 24% of the companies answered that if they receive a late payment, they in turn pay their clients late too on several occasions. In 2022 the Swedish construction industry stood for 11,6% of the Swedish GDP, which was 693 billion kronor, (Byggforetagen, 2023). This makes a twelve percent delay rate quite significant.

Svenska Statistiska Centralbyrån (SCB), went out asking companies about the late payments, and what was causing them (Regeringen, 2007). The answers they could choose were, “I agree; I partly agree; I do not agree; I do not know” The first question was whether the problem lies with the payment administration. The results show about 50% think that the administration is partly the problem, and the rest say that it is not the problem. The second question was if it was due to the client’s long payment term. The responses are split, with most answering that it is partly the problem. The third question was if the companies saw it to make a profit. The question does not seem to be the answer, 71% answered that they disagree with this, and most of the rest thought it was partly the problem. The fourth question was about the pressure from companies with a dominating position forcing subcontractors to accept it. This question is more of an answer with 76% agreeing or partly agreeing with the statement. Followed by these questions, they also asked large companies if their company requires payments longer

than 30 days, and if the company during the last years has required longer payment terms. The respondents mainly do not agree with these statements. Lastly, company managers from large companies were asked what the cause of late payments was. The incentive for the late payments seems to be economical reasons. They can pay in time but choose not to. This is partly done because subcontractors do not use their right to late payment interest.

Late payment interest has been implemented since 1934 and has been updated several times since, (Regeringen, 2007). It might be an incentive to pay in time if the interest is high enough. In the paper from Regeringen (2007), they asked companies if they had any pressure from their clients to not use their rights to late payment interest. The results show that 24% of the companies agreed on this in the construction sector which aligns with and explains the earlier answers.

The most recent update to solve this matter is a law which has been implemented in Sweden since 2022 to support smaller companies, (Riksdagen, 2022). The law requires companies with more than 249 employees, which buy goods or services from a Swedish company with less than 250 employees, to report the payment time to Bolagsverket. The first reports had a due date of 30th September 2023. All the company's statistics are public, and as such whether they have sent in their reports is accessible information. The statistics that can be viewed are an average of all companies in Sweden and for every specific company, (Bolagsverket, 2023). The statistics are divided into three company size intervals which the larger company has paid, 0 - 9, 10 - 49, and 50 - 249 employees. To divide it into sectors is yet to be implemented. The statistics are updated continuously, the average of late payments in Sweden from large companies to smaller is three days, which is a ten percent delay from the agreed-upon payment term. An entire 30% of all payments, in Sweden from companies larger than 249 employees to smaller ones, are paid on average 2 days late. Some companies are exceeding these numbers, one of the largest construction companies in Sweden has paid 80% of its invoices 10 days later than agreed upon, independently of the size of the company.

Ansah (2011), enlightens the issue with late payments in the construction sector. Late payments create uncertainty in the industry, sometimes it even leads to bankruptcy for contractors due to poor liquidity. It seems accepted in the industry because of the time it takes to execute payments. On the other hand, statistics from SCB show that 50% of respondents say that payment administration is not the problem, (Regeringen, 2007). Many other factors have been discovered as well, such as the client’s inefficient cash flow management policies, disputes, and contractual inefficiencies, (Merwe, Buys & Vosloo, 2011). The construction industry has been a subject of significant concern in the literature due to the prevalent issue of limited collaboration and the severe problem of mistrust among its participants, (Alreshidi, Mourshed, & Rezgui, 2018).

Late payments in the construction industry often trigger a domino effect, leading to further delays, especially among subcontractors working on larger projects, (Das, Lou & Cheng, 2020). This ripple effect occurs because contractors typically withhold payments to subcontractors until they themselves receive payment, highlighting the unequal bargaining power at play.

Numerous factors have been identified as culprits behind late payments, ranging from inefficient cash flow management policies by clients to contractual inefficiencies and disputes (Ramachandra, Rotimi & Hyde, 2015; Ansah, 2011; Merwe, Buys & Vosloo, 2011). Traditional paper-based contracts, by their nature, either facilitate late payments or accept delays due to the administrative time required for payment processing (Bock, 2022).

One promising solution to the problem of late payments is the adoption of Smart contracts, as suggested by several studies (Bock, 2022; Cardeira, 2016; Ansah, 2011). Smart contracts serve as a form of insurance, mitigating uncertainties related to cash flow and irregular payments. Small contractors stand to benefit from this approach, as it frees up their focus for other critical tasks. Moreover, Smart contracts enhance transparency within construction projects, fostering trust among all stakeholders.

The construction industry grapples not only with late payments but also with issues of limited collaboration and deep-seated mistrust among participants (Alreshidi, Mourshed & Rezgui, 2018). In the realm of Smart contract literature, numerous studies have demonstrated that Smart contracts hold the potential to mitigate late payment issues (Ansah, 2011; Akinsiku & Ajayi, 2016). Examining the factors influencing behavioral change in the adoption of Smart contracts reveals various theoretical perspectives, with the Theory of Planned Behavior (TPB) being among the most prevalent (Nguyen, Lobo & Greenland, 2015).

Furthermore, the utilization of Smart contracts not only addresses the issue of late payments but also ensures secure and automated payment processes (Cardeira, 2016). To address the problem of subcontractors' resistance to technology adoption and collaboration, BCT plays a pivotal role. The use of BCT promotes collaboration and trust among stakeholders, contributing to the resolution of the late payment issue.

2.3 Blockchain technology in the construction industry

2.3.1 An overview of blockchain technology

BCT, introduced by a mysterious figure named Satoshi Nakamoto in 2008, is a concept that has the potential to transform our financial system among other systems, (Nakamoto, 2008; Chang, et al. 2020). This decentralized ledger technology offers a secure and transparent way to record transactions and track assets in a business network, which can significantly alter and streamline operations across industries (Rodeck & Curry, 2022). Nakamoto's (2008) pioneering concept of a peer-to-peer electronic cash system laid the groundwork for this innovation. Further, Chang et al. (2020) discuss how blockchain can profoundly impact financial services, highlighting the transformative potential and challenges it poses to the current financial ecosystem. Blockchain's applications extend beyond financial services, offering novel solutions in sectors like construction, where it can enhance transparency and efficiency (Institution of Civil Engineers [ICE], 2018). As the technology evolves, it may render certain traditional legal and regulatory frameworks obsolete, paving the way for more streamlined and efficient systems.

2.3.2 Main opportunities and challenges with blockchain in the construction sector

The field of BCT presents both opportunities and challenges in the construction sector. BCT, known for its breakthrough in financial fields with cryptocurrencies like Bitcoin and Ethereum, holds significant promise for the construction industry despite its under-documented applications in academic literature (Adamska et al., 2021).

The primary opportunity presented by blockchain in construction lies in its ability to enhance transparency and traceability, (Yang et al., 2020). Blockchain's immutable ledger ensures that each transaction or modification is recorded and visible, fostering an environment of trust among stakeholders. This transparency is vital in an industry where projects involve multiple parties and complex transactions. Beyond transparency, BCT introduces significant efficiencies in project management. The ability to automate payment transactions using Smart contracts is a key advantage. These automated transactions, perfect for managing the financial aspects of construction projects, have the potential to streamline processes and reduce the administrative work significantly. Furthermore, blockchain's potential in improving supply chain management cannot be overstated. It offers a new level of traceability and efficiency in the tracking of materials and resources, which is essential for timely and within-budget project completion (Wang et al., 2020).

The integration of blockchain with the Internet of Things (IoT) presents a particularly promising avenue for innovation in construction management and operations, (Elghaish et al., 2021). The combination of these technologies can lead to enhanced data integrity, improved project management, and more efficient supply chain processes. For instance, blockchain can be used to create a transparent and immutable record of all transactions and changes in a construction project, which, when combined with IoT, allows for real-time tracking and management of resources and project progress.

One of the foremost opportunities lies in the application of blockchain through Smart contracts and Building Information Modeling (BIM), (Adamska et al., 2021). These Smart contracts can automate and streamline agreements in both conventional and BIM-based projects, facilitating a reduction in documentation and enabling more manageable payment schedules. This not only aids in breaking down large payments into smaller, more sustainable installments but also aligns payments with project milestones, thereby enhancing budget management and project efficiency.

Furthermore, BCT offers a range of advantages that can significantly benefit the construction sector, (Musa & Akanbi,2022). These include improved reliability, enhanced security, and the facilitation of better collaboration among stakeholders. The technology's transparency, verifiability, and security features, combined with a decentralized network, provide robust protection against data tampering and intellectual property theft, laying the groundwork for innovative payment and contract methods. Musa & Akanbi (2022) also highlight the efficiency and secure payment service that BCT can offer. The adoption of blockchain can streamline the complex and often challenging payment systems prevalent in construction projects, thereby addressing issues of delayed transactions, extra fees, and security concerns. They also state that the implementation of stablecoins and Smart contract payments can significantly reduce the risk of project delays caused by manual payment processes. By ensuring timely

payments, this technology can increase the efficiency of project delivery, thereby positively impacting the overall productivity and success of construction projects.

However, this integration is not without its challenges. One of the primary issues is the technological complexity and the need for substantial investment in both infrastructure and skills development (Elghaish et al., 2021). The construction industry, traditionally cautious in adopting new technologies, may find this a significant barrier. Moreover, integrating blockchain with IoT in construction requires addressing issues such as data privacy, security, and the scalability of IoT devices in complex construction environments. Another significant challenge is the lack of comprehensive regulatory frameworks specific to the use of blockchain and IoT in construction.

The innovative nature of these technologies often outpaces the development of relevant legal and regulatory guidelines, leading to uncertainty and potential legal challenges (Elghaish et al., 2021). This regulatory ambiguity can deter companies from investing in these technologies, slowing down their adoption in the industry. The technology's nascent nature leads to a lack of maturity, and a deficiency in universal standards and clear understanding of its applications and implications, (Adamska et al., 2021). This lack of clarity raises concerns regarding quality control and the establishment of uniform procedures. Challenges like stringent government policies, difficulty in liquidity management, lack of public awareness, and negative perceptions also need to be considered, (Musa & Akanbi, 2022). These factors can hinder the widespread acceptance and implementation of this technology in the AEC industry. Moreover, there are legal challenges, particularly regarding the integration of blockchain-based Smart contracts into existing legal frameworks. Professionals in the construction sector are hesitant to transition from traditional payment methods to cryptocurrency due to a lack of understanding or fear of potential risks. Concerns about the scalability and energy consumption of BCT, particularly for large-scale global implementation, also persist.

The cost of implementing blockchain systems and the need for specific technical skills to manage these systems are other considerable barriers (Yang et al., 2020). Regulatory uncertainty also poses a challenge. The construction sector, like many others, is still grappling with how to regulate and integrate BCT within existing legal frameworks. This uncertainty is compounded by the novelty of the technology and the lack of widespread understanding and trust among potential users (EPRS, 2016). Moreover, the construction industry faces a dearth of practical applications and blockchain research. This gap between conceptual studies and real-world implementations limits the understanding of blockchain's full potential in this sector (Kifokeris, 2020). Additionally, security concerns and implementation constraints need to be addressed. Musa & Akanbi (2022) also enlighten the cyber security concerns regarding the introduction of digital currencies and Smart contracts, which must be taken seriously to ensure the safety of transactions in the construction industry. Furthermore, issues around the transparency of crypto asset issuance and distribution, along with the challenges in converting cryptocurrencies to cash and vice versa, present substantial hurdles. These challenges can affect the usability and effectiveness of BCT in the construction sector.

Despite these challenges, the development of BCT remains one of the most groundbreaking innovations of the century. Its potential benefits, particularly in handling payments and procurement through Smart contracts and its integration with

BIM systems, indicate that it may significantly enhance the efficiency and performance of the construction industry (Adamska et al., 2021). As the technology matures and the barriers to its adoption are overcome, its benefits could spur wider uptake and potentially transform the construction sector.

2.3.3 Understanding of Smart contracts and their relevance for subcontractors in the construction industry.

Smart contracts, powered by BCT, are revolutionizing contractual processes in the construction industry, offering advantages to subcontractors. These self-executing contracts with terms directly written into code enforce agreements automatically upon meeting predefined conditions, streamlining operations and reducing administrative burdens (Mason, 2017; Hamledari & Fischer, 2021). For subcontractors, this translates into more predictable and prompt payments, as Smart contracts can trigger automatic payment transfers once work is verified, thus mitigating delays and disputes (Hamledari & Fischer, 2021). Moreover, the inherent transparency and immutability of blockchain-based Smart contracts foster trust among all parties, essential in the multi-stakeholder environment of construction projects (Elghaish et al., 2021).

However, the implementation of Smart contracts in the construction industry faces challenges. The need for digital literacy and infrastructure investment is significant, as subcontractors must adapt to the complexities of blockchain and Smart contract technologies (Mason, 2017). Additionally, the integration of these digital contracts within the existing legal and regulatory frameworks remains a challenge. The evolving nature of blockchain legislation and the lack of standardized protocols can hinder the widespread adoption of Smart contracts (Elghaish et al., 2021). In the context of Ethereum, Smart contracts extend beyond simple transactional functions, offering a platform for complex applications and autonomous organizational structures. Ethereum's flexibility in coding and executing Smart contracts could potentially revolutionize how subcontractors interact with other stakeholders in the construction industry (Buterin, 2014).

In summary, Smart contracts offer transformative potential for subcontractors in the construction industry by enhancing efficiency, transparency, and trust. Despite the challenges in implementation and the need for further development in legal frameworks, the integration of Smart contracts stands to significantly benefit the construction industry.

3 Methodology

The methodological chapter begins with a literature review, which serves as the cornerstone of this academic investigation. The objective of the literature review is to assimilate and synthesize existing research, providing a solid foundation of established knowledge from which this study can advance. Given the limited research specifically pertaining to the Swedish context, the methodology was meticulously selected to fill this gap. The integration of an interview study was chosen to complement the literature review, with the intention of capturing a more direct and contextual understanding of the subject matter. This interview approach was particularly valuable for discerning the practical application and potential limitations of the technologies in question within Sweden. It allows for an assessment of compatibility with Swedish practices and pinpoints any contextual barriers that may exist.

3.1 Literature study

A literature study will be made to gather information from papers on the subject. The research will be found with Google Scholar with the search words in Table 3.1. Research older than 2010 will be sorted out. Then the abstract of the papers will be read to identify its relevance. To sort out more irrelevant papers, the conclusion is read. The rest of the papers will be read to then sort out relevant information for the subject. These papers were then included in the literature study.

Table 3.1 These search words were used to search in Google Scholar.

Search words
Blockchain in Construction in Sweden for Subcontractors
Smart contracts in Project Management
Automated Invoicing in Construction
Construction Industry Payment Transparency
BCT Adoption in Sweden
Blockchain Projects
Blockchain Solutions for Construction Payment
Smart contracts for Swedish Construction Projects
Blockchain Impact on Construction Project Management
Construction Industry Financial Processes

To construct a comprehensive foundation for this research, a thorough literature study was conducted. The primary goal of this literature review is to collate and synthesize existing research on the application and implications of BCT within the construction industry, particularly focusing on decentralized finance, invoicing practices, and the specific context of the Swedish construction sector. The investigation commenced with an extensive search on Google Scholar, a renowned and widely used search engine for academic literature. The keywords employed for the search were carefully selected to encompass a broad spectrum of relevant topics. Because of the creation of Bitcoin 2008, research before that was neglected. The remaining articles were subjected to a three-

stage relevance assessment. First, the titles of the papers were read to identify relevance. Secondly, the abstracts of the papers were scrutinized to determine their applicability to the research questions at hand. This preliminary review aimed to filter out studies that were tangential or unrelated to the core focus of blockchain in construction finance and management. Lastly, for papers that passed this initial screening, their conclusions were examined to ascertain the significance of their findings and the strength of the evidence presented. This step was instrumental in further refining the pool of literature to include only those studies that provided clear results and valuable insights pertinent to the objectives of this study.

The papers that survived the relevance and significance filters were then read in their entirety. This in-depth analysis facilitated a nuanced understanding of the issues, allowing for the extraction of pertinent data and arguments. The information gleaned from these papers were not only used to inform the current study but also to draw connections between disparate pieces of research, highlighting trends, gaps, and consensus in the field.

An additional layer of rigor was applied by cross-referencing sources. When a selected paper referenced another work that contributed valuable insight into the topic, the original source of that information was retrieved and evaluated using the same criteria as the primary search. This method ensured that seminal works and foundational theories were not overlooked.

3.2 Interview study

The interview study embedded within this thesis is an extensive endeavor, typically characterized by its time-consuming nature, (Kvale & Brinkmann, 2014). However, the depth and value of insights that such interviews provide often substantiate the substantial investment of time and effort. The qualitative facet of this research comprises semi-structured interviews with principal stakeholders in the project, offering a conduit to a more nuanced comprehension of the topic at hand. The choice of semi-structured interviews stems from their inherent flexibility, allowing for a dynamic and explorative approach where new concepts and theoretical frameworks can naturally emerge from the discourse, providing the researchers with the latitude to adapt to the conversation's flow and delve deeper into pertinent themes.

In parallel, the interview study was meticulously designed to bridge the knowledge gaps identified in the preliminary literature review, propelling the research beyond theoretical discourse towards the development of a practical blockchain solution for automated invoicing. This decision-making process involved mapping potential deficiencies within the current literature and determining the specific professions and individuals whose insights could prove instrumental. Building upon the literature review's findings, a structured interview guide was developed to ensure consistency and focus during the data collection phase. The semi-structured nature of these interviews ensures that while the discussion is guided, it remains sufficiently open-ended to encourage the emergence of unanticipated yet relevant information, (Bryman & Bell, 2011). This approach, where questions are posed in a general format, allows for the natural evolution of the dialogue, inviting further inquiries that align with the study's emerging needs and objectives.

In semi-structured interviews, the interviewer maintains a balance between following a predetermined script and allowing for spontaneous, in-depth discussion. This strategy facilitates comprehensive responses and equips interviewers with the flexibility to probe further, based on the answers received. Bryman and Bell (2011) highlight the critical role of possessing a foundational grasp of the anticipated outcomes from each interview.

Contact with potential interviewees was initiated through email correspondence. Out of the 25 individuals contacted, 13 agreed to participate in the study. Their contributions are anonymously documented in Table 1. Each interview was conducted according to a prepared script and was recorded to ensure accuracy and thoroughness. Following each session, the author meticulously reviewed the recordings, taking detailed notes to distill pertinent information. To ensure comprehensive coverage and avoid overlooking any details, the transcripts were then provided to ChatGPT, which was tasked with generating a summary of each interview to aid in the data analysis process.

Table 3.2. List of the interviewees

Acronym	**Role**	**Level of BCT experience**
A	SC CEO	Mediate
B	Client CEO	None
C	Project manager SC	Low
D	Project manager Client	Low
E	Project manager Client	Low
F	Project manager Contractor	Low
G	Consultant CEO	Low
H	BIM expert	Low
I	Project manager Client	Low
J	Blockchain Expert	High
K	Head of R&D	Mediate
L	Business development manager	None
M	CCO of a Contract company	High

3.3 SWOT analysis

To conduct a thorough analysis of the implementation of BCT in facilitating payment systems for subcontractors within the Swedish construction industry, the study employed a detailed SWOT analysis, drawing insights from two sources: literature review and interviews. This approach ensured a comprehensive collection of elements affecting BCT's adoption and application. Initially, a targeted list of SWOT elements related to blockchain was compiled from both the reviewed literature and the conducted interviews. This extensive compilation aimed to capture the full spectrum of strengths, weaknesses, opportunities, and threats associated with BCT, without overlooking any aspect pertinent to subcontractor payment systems. Subsequently, the list was meticulously refined, with irrelevant points being excluded to focus specifically on those directly impacting the payment system for subcontractors. This methodological

step was crucial in ensuring that the analysis remained targeted and relevant to the study's objective, thereby providing a solid foundation for evaluating BCT's potential to address the late payment issue in the construction sector.

3.4 Impact and Feasibility Matrix

3.4.1 How the Matrix was developed

The Impact axis represents the potential effect or significance of each element. Higher impact suggests greater influence on project success, stakeholder satisfaction, efficiency improvements, etc. The Feasibility axis represents how easy or difficult it is to implement each element. Higher feasibility indicates easier implementation, lower costs, fewer resource requirements, etc. High feasibility and high impact should be prioritized because they are relatively easy and cheap to implement, followed by high feasibility and medium impact and medium feasibility and high impact.

Separating Strengths and Opportunities (S and O) from Weaknesses and Threats (W and T) when using an Impact/Feasibility matrix is a strategic approach that acknowledges the fundamental differences in how these elements should be managed. The nature of S and O is being positive aspects which can be leveraged. The focus on these is to maximize and capitalize on these elements. Every S and O were given an impact score and a feasibility score of the actual strength and opportunity. How high would the impact of the strength be if implemented and how feasible it is to implement.

The nature of W and T are the straight opposite, negative and unfavorable that need to be managed or mitigated. Here, the focus is on minimizing the impact of these elements. This separation enhances the clarity and effectiveness of the strategic planning, ensuring that all aspects of the SWOT analysis are appropriately addressed. W and T were given an impact and feasibility score but depending on their given strategy to minimize them. By doing this, the S and O that are prioritized, was found as well as the prioritized strategies to minimize W and T.

3.4.2 The prioritization of the cells

The SWOTs which are in the high impact, high feasibility cell should be prioritized. These are the ones that can relatively easily be implemented if it is a S or O, or the strategy can easily be done regarding to W and T and have a low cost. At the same time, they all have a high impact if successfully implemented. The elements should be addressed and taken into consideration before the project’s start, because they promise the greatest return on investment or the most substantial risk mitigation with the least amount of resource expenditure.

The high impact, medium feasibility is to be prioritized secondly. These elements require careful planning due to their medium feasibility. They are important enough to warrant attention and resources but may need more detailed planning and problem-solving to overcome potential implementation challenges. To be able to mitigate all the risks and make the S and O thrive, these are necessary for a successful project because of the high impact.

Elements in the medium impact, high feasibility cell of the matrix are those that are relatively easy to implement but have a more moderate effect on the project's overall success or risk profile, these should be considered next. Since these actions are highly feasible, they can be executed quickly and with minimal resource investment. They should be conducted efficiently to capitalize on their ease of implementation.

For the high impact, low feasibility cell of the matrix they are indeed crucial due to their potential to significantly affect the project. However, their lower feasibility indicates that they come with considerable challenges or barriers to implementation. These elements require meticulous planning and a robust strategy. The planning should include contingency measures, as their implementation may encounter significant obstacles. While these elements are important, they should not drain resources disproportionately in relation to their feasibility.

Elements that fall into the medium impact, medium feasibility cell in the matrix are next on the list. These are areas that will not necessarily transform the project but can still provide value and should be managed with a measured approach. Find synergies with other projects or initiatives. Medium impact, medium feasibility elements might benefit from or contribute to other ongoing efforts, which can enhance their value. Continuously evaluate the impact and feasibility of these elements. If their impact can be increased or their feasibility improved, they may warrant greater attention. Be ready to reclassify these elements if circumstances change due to projects uniqueness. These are easy to implement but will not significantly impact the project.

Next on the list are the elements that fall into the low impact, high feasibility cell in the matrix. Given their low impact, these actions should be implemented selectively. They are not urgent and should only be pursued if they do not divert resources from higher-impact tasks. Use these tasks to support higher-impact initiatives. They can often help to boost other strategies or serve as foundational steps that enable other, more impactful actions. While these initiatives may not be critical, it is still important to monitor them to ensure that they are delivering the expected benefits and not consuming more resources than anticipated.

The last cells have low to medium feasibility and low to medium impact, they are not to be prioritized. They should be considered if the strategy to mitigate risks are the same as for higher prioritized elements these are affected as well. Knowing this will help the project’s process. In this project no such element were found or was not considered during the SWOT analysis.

In the dynamic landscape of project management, the placement of elements within a SWOT analysis' matrix categorized by their impact and feasibility is not set in stone. It is essential to recognize that these elements can shift positions based on the evolving circumstances unique to each project. For instance, an element considered minimal impact and high feasibility might suddenly take on greater significance due to changes in project scope, market conditions, or stakeholder priorities. Conversely, an item originally assessed as high impact may see its perceived benefits diminish over time as the project environment evolves or as added information becomes known.

3.5 Reliability and validity

When developing qualitative and quantitative research designs, it is crucial to consider usability, ethics, and to ensure that the research design has high reliability and validity. As Le Duc (2011) suggests, high reliability means that the measurement instrument yields the same results at different times and is independent of who conducts the study. To maintain high reliability, all interviews were recorded to allow for a reliable summary of the responses obtained. The approach of the work was based on scientific theories and analysis methods to further increase reliability. The diversity of interviewees were carefully considered to bolster the report's reliability. By including a balanced representation of genders and a wide range of stakeholders within the industry, the study minimizes individual biases that might arise from a homogenous sample. This range of perspectives ensures that the findings are not the artifact of a particular group's experience but are indicative of the sector's broader trends and sentiments.

Validity concerns the sustainability and validity of research results (Le Duc, 2011). Validity can be divided into internal, external, and construct validity. Internal validity is about the extent to which it can be concluded that the independent variable has influenced the dependent variable. External validity refers to the results being sustainable and valid in another context. Construct validity is required to ensure that all research participants, which in this case is only one person, have a correct understanding of what abstract and complex concepts mean to ensure that all participants equally interpret the question. The literature review leveraged Google Scholar, a comprehensive and reliable database for scholarly literature. This platform provided access to a plethora of peer-reviewed articles, books, conference papers, and theses, which have been subjected to rigorous academic scrutiny. The selection of literature was based on relevance, recency, and citation counts, ensuring that only the most pertinent and authoritative sources informed the research.

To ensure that the results of the report are credible and reliable, it is essential to treat the method with source criticism (Nationalencyklopedin, 2024). Initially, the credibility of the sources were checked. Credibility has been assessed based on the three criteria of tendency, dependency, and time. The tendency criterion means how the source of interest can affect the result. This can occur if the source has economic, political, or personal interests in the question. The dependency criterion aims to see how dependent the source is on another source. The less dependent the source is on others, the more credible it is. The time criterion is about how current a source is, with it being more credible the closer in time it is written.

3.6 Limitations and delimitations

Due to time constrains, the study was designed with a focus on subcontractors within the Swedish construction industry, intending to deeply explore the implications of blockchain technology (BCT) regarding payments. The decision to limit the study to a few companies within the Swedish construction sector was a conscious choice to provide depth rather than breadth in analysis. This limitation could have affected the representativeness and statistical significance of the findings, as a larger sample might have provided more robust and generalizable data. This specificity allowed for a detailed examination of practices, challenges, and the potential for BCT

implementation in a market recognized for its innovation and regulation. However, this also meant that the findings of this study were not directly generalizable to other markets or industries, as regional and sectoral differences could lead to different outcomes and interpretations.

The nascent stage of BCT in the construction industry presented a significant limitation. Resistance to change and a lack of awareness of this emerging technology could bias perceptions and hinder adoption rates, thus affecting the study's results. The research presupposed a baseline level of interest and openness to technological advancements among participants, which might not have been representative of the industry. Another constraint was data access. The study's reliance on obtaining accurate and relevant data regarding construction projects and their payment processes was crucial. With blockchain payments still in early stages within the industry, there might have been a lack of comprehensive data, which could have affected the depth and strength of the analysis. The study's theoretical nature also limited its empirical applicability. Although it followed the logic of blockchain technology, no practical program was developed to test the hypotheses. Therefore, the findings remained theoretical and would benefit from empirical validation in future research efforts. The study did not in-depth investigate the acceptance and adaptability of the technology across the industry. While the research may have addressed the potential for adoption, the cultural and organizational dynamics that affected the technology's acceptance were not extensively examined.

4 Literature Analysis

This chapter initiates a thorough exploration of the current literature, focusing on the utilization of BCT and Smart contracts within the construction industry, with a particular focus on subcontractors. The primary purpose of this literature analysis is to provide a foundation and context for the research by surveying prior studies. It serves as the foundational pillar of this paper, setting the stage for the subsequent Interview Study, which will delve even further into the subject matter. This chapter serves several vital objectives in the research endeavor.

4.1 Automated invoicing and payment transparency with Blockchain for subcontractors

Efficient invoicing and transparent payment processes are paramount within the construction industry, particularly for subcontractors who play a pivotal role in project execution. This section delves into the significance of automated invoicing and explores the potential transformative impact of BCT and Smart contracts in streamlining payment procedures. It also presents case studies showcasing real-world applications of blockchain-based automated solutions for invoicing and payments to contractors and subcontractors.

4.1.1 The significance of Smart contract automated invoicing for subcontractors

Contractors are suffering from late payments in the construction industry, even after several tries to prevent them, the last being the requirement to report your payment times under some circumstances as stated before, (Bolagsverket, 2024). Today's normal payment time is 30 days, which is the standard in Sweden. This has been a tradition for the invoice to first be sent to the receiving company, then administered, and lastly paid. Penzes (2019) states that a Blockchain-based Smart contract that handles transactions can result in instant payments to suppliers, subcontractors, and transporters. Smart contracts are one way to automate payments which mitigate the challenges from late payments, which is problematic for subcontractor's liquidity, which in the end affects the whole economy, (Bagheri & Hassan, 2015). Not only securing and automating the payments, but it would also ensure the client can comply with their financial obligations, (Adamska, et al. 2021). Industry experts have a common consensus about Smart contracts and blockchain of which impact it will have on a day-to-day basis in the construction sector, it will if implemented, revolutionize the industry, (Matthew, Kelechi & Sarhan, 2018). To sign this kind of contract, the client makes a Smart contract which all parties need to sign with their wallet. Which is and will always be traceable versus a traditional contract which all parties need to sign physically or with E-sign. Which can be time-consuming and is a risk regarding forging as well as contract modifications, (Bock, 2022). There is to be less administrative work, data errors, wrong addresses, and outages across the supply chain, Penzes (2019). Which leads to time and cost savings, better planning, better change management, and instant delivery notice for the involved contractors.

Because of the poor treatment of subcontractors and smaller players in the construction industry, Smart contracts bring major benefits if adopted, (McNamara & Sepasgozar, 2021). It can offer a secure payment process that can prevent insolvencies and late payments. The Smart contract can manage thousands of micro-contracts which are self-

executing when certain relevant parameters, such as performance achievement, have taken place, which is verified by either a human, external data, or sensor technology. These in turn transfer data and at the same time execute the relevant payment to the responsible contractor. The payment is envisioned to be immutable when specific events have taken place, (Kifokeris & Koch, 2020). The cash flow does not stop there, it can be written certain requirements in the contract, (McNamara & Sepasgozar, 2021). For example, when, where, and how a party is being paid and for what. This makes it possible for the contractor to get the payment from the client after a certain number of days, or directly after a certain work is done and approved. If there is a subcontractor who did the work, then the Smart contract can directly send it through the main contractor to the subcontractor after a percentage markup if it is said in the Smart contract. Such a contract would protect contractors, subcontractors, and suppliers from late payments and insolvencies, (McNamara & Sepasgozar, 2021; Cardeira, 2016).

The innovative approach of Smart contract automated invoicing is not only a solution for timely payments but also a step towards digital transformation in the construction sector, (Hunhevicz & Hall, 2020). According to the insights gathered from the recent studies, Smart contracts, when integrated into construction operations, can lead to significant improvements in project delivery and stakeholder relationships. For instance, the automated execution of contracts as per the set criteria ensures that subcontractors are paid promptly upon completion of their tasks, thereby mitigating the risk of financial instability commonly faced by smaller entities in the industry.

Moreover, the application of blockchain in construction, as highlighted in recent research, offers an unprecedented level of security and transparency in transactions, (Penzes, 2019). Smart contracts record every transaction on a decentralized ledger, providing a transparent audit trail that enhances trust among all parties involved. This transparency is crucial in a sector where project complexity and multiple stakeholder involvement often lead to disputes and mistrust.

Furthermore, the utilization of Smart contracts in construction can significantly reduce administrative overhead, (Abrishame & Elghaish, 2019). By automating invoicing and payment processes, the need for manual intervention and paperwork is greatly diminished. This not only speeds up the transaction process but also minimizes the likelihood of human error, leading to more accurate and reliable financial management within construction projects.

4.3 Blockchain adoption in the construction industry

This chapter delves into the current landscape of blockchain adoption within the Swedish construction industry, with a specific focus on its implications for subcontractors. As the global construction sector transforms digitally, BCT is making significant progress. This chapter examines the application, trends, and areas of use for blockchain in construction projects, including the challenges and opportunities this innovation presents for subcontractors. For digital construction projects in the future to succeed, the key is to have a robust central management system like a Smart contract which allows speed and automation to flourish, (McNamara & Sepasgozar, 2021).

4.3.1 Opportunities and challenges for subcontractors to adopt Blockchain technology

The integration of Blockchain and Smart contracts, presents both significant opportunities and notable challenges. The Construction industry, like many others, is currently undergoing a transformation driven by digitalization. An opportunity for everyone involved using BIM and BCT together, you can create leaner procurement methods which results in cost reductions, (Hughes, 2017). It will also give the client and contractors better control and transparency of cost, time, and scope. Due to the current lack of traceability and accountability, which needs to be reversed in the industry, projects are fundamentally established for blaming each other, (McNamara & Sepasgozar, 2021). A Smart contract system would complement the idea of moving away from the blame culture to take a step towards a more collaborative environment. Through the digital immutable historical record that the Smart contract offers, the traceability of every contractual transaction can be seen and trusted because the data cannot be tampered with. Another opportunity that McNamara & Sepasgozar (2021) state is the potential to reduce disputes with a reliant and robust Smart contract. The information would be transparent for every party, which means disputes would have to be grounded on hard facts. Legal costs could then be reduced because of the transparency and traceability, 50% of all legal costs associated with construction projects are a direct result of disputes, which have the potential to be reduced. Shojaei, et al, (2020) also enlighten the potential to reduce the contracts' disputes significantly, which in turn will result in both cost and time savings.

Tao, et al. (2023) propose a Lightweight Blockchain-as-a-Service (LBaaS) prototype for seamless integration of BCT, where its approach is to integrate with existing design practices. The LBaaS model aims to address the unique demands of construction projects, offering enhanced security, efficiency, and streamlined workflows, while also confronting certain inherent challenges. The LBaaS model enhances BIM design efficiency by securing and automating information exchange, significantly mitigating deployment challenges associated with BCT. Furthermore, Smart contracts automate key processes like information sharing and permission execution, enhancing efficiency in subcontractor operations. LBaaS ensures a secure and efficient environment for design collaboration, crucial for subcontractors in fast-paced projects. It enables reliable BIM data delivery which is crucial when rapid decision-making is needed.

However, the adoption of this technology is not without its challenges. One of the main hurdles is the integration of Smart contracts into the existing legal frameworks within

the construction industry. Ensuring that these digital contracts are recognized and enforceable by law is critical for their effective implementation according to Sigalov, et al. (2021). Additionally, the need for technological infrastructure and expertise cannot be overlooked. The construction sector, traditionally reliant on conventional methods, requires a significant shift in mindset and skills to adapt to this digital transformation, (Youngson & Douas, 2021).

Bock (2022) held several interviews with people within the sector, in which he found that one reason why Smart contracts were not in use already, was due to the client's requirements and the cost of implementation. Another study has shown similar results when a contractor tried to implement the technology, which resulted in a revert to a traditional contract due to the client's lack of understanding, (Seijas et al., 2016). Gurgun and Koc (2022) on the other hand, found that the main challenges were the regulation change, lack of dispute regulation mechanism, shortcomings of current legal arrangements, lack of driving force, and the work were not accounted for during planning. The legal challenges are strengthened by Akanfe, et al. (2024) which enlightens the complicated relationship between BCT and personal data processing, due to the nature of BCT's public information that does not comply with the Swedish GDPR. Who owns the information on a public blockchain is also a question that is yet to be solved. On the other hand, there are no national laws or regulations that specifically regulate the procurement of blockchain solutions. Adamska, et al. (2021) state the technology is facing challenges despite its wide range of benefits. The largest issues are regulatory uncertainty, lack of trust among users, and volatility of cryptocurrencies. There is also a lack of understanding of terminology and vision of Blockchain's purpose. One of the most important steps is to clarify the scope of Blockchain's adoption and ensure all parties get enough knowledge to trust the system and have the same expectations. The legal framework needs to be reinforced in Smart contracts. There is a need for rules and policies to be supported by the government. The use of cryptocurrencies is not needed, but crucial for the transactions to use the Blockchain to its full potential. It is not a common practice to use Cryptocurrencies in the construction industry, which will probably not be the case for some time either due to fear of possible consequences of such a change and lack of understanding of the technology. Due to Blockchain's nature of being transparent, most companies will be against it due to the risk of disclosure of their sensitive company data.

The dynamic nature of construction projects, coupled with evolving client requirements, necessitates continuous updates and adaptations in Smart contracts, (Tao, et al. 2023). This ongoing need for technical upgrades can pose challenges in maintaining an up-to-date and effective blockchain system. There is no room for mistakes in a Smart contract because the code will be executed exactly the way it is written, (McNamara & Sepasgozar, 2021). Loose formulations and wordings, which often is used for different situations that arise during projects, have been noted as a huge challenge for hard-coded Smart contracts, where the multitude of variables encountered in construction projects cannot be coded in the same way. A coded substitute would contain endless "if" statements. Adamska, et al. (2021) also write that the core challenge for Blockchain to be implemented is the complexity of a construction project. It seems to not be suitable to hardcode the contract, therefore making the source code with this in mind, to cover all different scenarios. For that to work, talented developers are needed to make bug-free code, which is extremely rare even when not developed as a contract framework. Other findings from Bock's (2022) interviews of

the benefits of using Smart contracts are faster executions of payments, ease of use, convenience, and up-to-date record keeping. The data is also accessible for everyone with the right info about wallets and keys. His results indicated that the contractors were not ready to implement Smart contracts, partly due to the lack of knowledge in the industry but also because of the staff being comfortable using traditional forms of contracts. Another challenge that McNamara & Sepasgozar (2021) state in their report, is the technological environment which is not developed enough in the construction industry for blockchain applications to thrive. Reliability, storage constraints, and compatibility are some areas that need to be solved before blockchain can be effective.

The cost of using a Blockchain is discussed as a barrier for a client, (Das, et al. 2020). The cost of having a proposed system by Das, et al. (2020) cost $300 to $900, based on Ethereum's price in 2020, $173.31, and how fast and secure the transaction was, the faster and more secure the transaction, the more it costs. The fastest transaction was expected to cost 10 Gwei, 1 Gwei = 0.000000001 Ethereum. It was based on monthly transactions for 3.3 years. The price of a transaction is based on how many use the network and the price of the currency. Comparing the prices then and the time of writing 2023-11-23, the cost of Ethereum is $2791.61 and the price for a fast transaction is 20 Gwei, (Coinmarketcap, 2024). Under the same circumstances, with today's prices, it is $10 366 to $31 098. Das, et al. (2020) also state that the technology is in its initial phases of development. Other more efficient blockchains can now make the transaction for fractions of a dollar instead of multiple dollars as of 2024-02-15, (Coinmarketcap, 2024).

Kifokeris and Koch (2020) identify two primary concerns related to the security and reliability of blockchain technology. Firstly, there is a prevalent skepticism regarding the viability of blockchain as a worthwhile investment, rooted in a general mistrust of its potential benefits. Secondly, the inherent characteristics of blockchain raise fears about potential misuse; the anonymity provided by its distributed network could facilitate illegal activities, the integration of cryptocurrencies might undermine the perceived value of traditional fiat currencies, and the rigid nature of automated transactions within the blockchain could exacerbate conflicts among network participants.

4.3.2 Application, trends, and areas of use for the Blockchain in construction projects

Adamska, et al. (2021) write that several applications can be done in the construction industry. The first is Smart contract and BIM, where establishing a schedule that depends on tasks, which all have a payment attached to it that is paid when certain criteria are met. The contract can be tied to the 3D model where the progress is stored. When a task is done and signed, it will be shown in the 3D model. Which would boost on-site schedule metrics and project productivity. The second possible application is to have ownership of the BIM model and have insurance. BIMChain has explored and developed a traceability system that uses Smart contracts to legally binding agreements. Using this if it would work can limit the risk of copyright, reduce delays, disputes, and thereby expenses caused by those activities. Another application is Smart energy which, with an electricity production system in homes, can be bought, sold, stored, and used by neighbors to be used locally and minimize the use of the power grid. Such an application has been assessed in the US and the UK by several companies, even the EU

has made its Blockchain called Enerchain, (Fovino, et al. 2021). They found several use cases, smart metering, and energy communities to name a few.

Smart governance powered by Blockchain can save time and money, (Adamska, et al. 2021). It could be achieved by automated administration to record, protect, store, and share information. It could also be used to automate tax collection, land and property land registry, and regulatory compliance. The immutability and transparency Blockchains provide would reduce the time needed for administration with indisputable and trackable data.

It can also be implemented in supply chain management, (Adamska, et al. 2021, Hultgren & Pajala, 2018). Due to the complexity and the masses of materials that pass through many locations and organizations, the data of where it is supposed to go next, and the current location of the material need to be correct. There are high transactional costs for errors that occur, and the traceability and transparency that Blockchain brings could give a certain material or product a digital profile for everyone to connect to. This would also increase trust and decrease fraud and counterfeit of goods. All relevant information could be documented within the supply chain. To evaluate if these potentials can be applied, Kiforkeris & Koch (2020) made a Blockchain pilot project, BLogCHAIN a private permissioned blockchain that uses Proof of Authority (PoA) consensus. It was made to explore if it could generate value for construction logistics. It was tested on several suppliers who mostly had positive feedback. Importantly, a permissioned private blockchain enables the preservation of the advantages while restricting access exclusively to individuals involved in a specific project, (Kiforkeris & Koch, 2020). This approach aligns with the security expectations of all project stakeholders who were open to adopting a blockchain solution proposed by logistic consultants in Sweden, as revealed through our empirical analysis.

With Smart contracts, a reduction of human errors can be achieved with the automation of tasks, (McNamara & Sepasgozar, 2021). The quality of the project would increase because of the certification and verification that would be done on-site, which also would increase the health and safety of the contractors. The contractual issues with payment would be reduced with the Smart contract being a trustworthy contract administrator, it would also speed up the payment process. The integration of Smart contracts in project management, especially within the framework of Blockchain-enabled BIM, provides a robust mechanism for enhancing collaboration, accountability, and trust among all project stakeholders, including subcontractors, (Jiang, et al. 2022). These digital contracts automate the execution of agreements based on predefined rules and conditions, significantly reducing the administrative overhead associated with traditional contract management. Thus, Penn (2020) says BIM is much less mature which will make it take longer to implement blockchain financial systems directly in BIM, but relatively easily to implement as a separate financial system because of the known problems there is.

Incorporating Smart contracts alongside cryptocurrencies offers a revolutionary approach to contract drafting within the construction sector, it is not necessary for the Smart contract to work, but is to work effectively, (Cardeira, 2016). This innovative application of technology facilitates secure transactions not only between the main contractor and subcontractor but also extends to dealings with suppliers. Moreover, the utility of Smart contracts in the construction industry transcends mere financial

protection. These digital contracts possess the capability to be interlinked, enabling a cascading payment system where a single transaction to the head contractor can automatically trigger proportional payments to subsequent contracts. Despite the nascent stage of Smart contract technology, its potential to mitigate risks associated with insolvencies and payment delays represents a significant advancement.

4.3.3 Critical factors for Blockchain adoption in construction projects

Amayaw, et al. (2023) found 16 critical factors for the Blockchain adoption to succeed in the construction industry. The first category of factors is trialability, which refers to which extent a technology can be experimented with before implementation. 98% of their questionnaires answered that they would experiment with blockchain before implementation in practice. 83% were in favor of a trial period before adoption, which is favorable to increase the chances of successful adoption of innovations. Amayaw, et al. (2023) write that it will require collaboration, trust, and confidence between stakeholders in a project to higher those chances even more. Trialability and Smart contract integration are not positive in the UK construction industry. The problem might be the lack of engagement in the smart contracts' activities and a lack of knowledge of how Smart contracts operate and their benefits.

The second category is the relative advantage, which has been seen to be associated with an individual's intention to accept BIM. It also has a positive effect on the adoption of AI in the manufacturing industry. Another result suggests that the companies that adopt Blockchain-enabled Smart contract technology will enhance job performance and have a positive impact on efficiently delivering construction projects, (Amayaw, et al. 2023). Their respondents also answered that it has the potential to maximize transparency of time, cost, and scope, providing secured payment transactions, facilitating progress payments, and a reduction of ambiguities in project scope. To conclude, the overall findings show that the practitioners of Smart contracts will be rewarded in terms of project success if used in the right way.

The third category is a competitive advantage, which all companies strive for if they plan to be an industry-leading company, (Amayaw et al., 2023). As companies compete to pioneer the use of technologies to beat their competitors. The respondents agree that the use of Smart contracts will most likely increase the profit levels of organizations on construction projects if adopted correctly. They also answered that the early adopters have a strong competitive advantage and enable them to beat the competition. These advantages will be taken into consideration if they adopt the technology, as they will get an advantage over their competitors if used correctly.

The fourth category is compatibility, which is perceived as being consistent with the company values, prior experience, and needs to adapt, (Amayaw, et al. 2023). If the technology is compatible with the adopters, it has been shown to exponentially increase the chance of a successful adoption. Companies will only adopt the technology if it is compatible with their value and belief systems. The second aspect of compatibility is its practicality, which refers to practitioners' job functions and contract management needs.

4.3.4 Case studies of Blockchain automated solution for payments and transactions for contractors and subcontractors

A practical study was made in two projects, one in Canada and one in the US, by using a Smart contract-based solution for autonomous payments, (Hamledari & Fischer, 2021). It was done by using a laser scanner mounted on an unmanned ground vehicle for the project in Canada and a camera-equipped unmanned aerial vehicle in the US project, for data collection. The test concluded two respectively five payment cycles in the projects with 100% payment accuracy, split on seven different sub-contractors. The method decentralized some parts of the payment process, says Hamledari & Fischer, (2021). However, all steps cannot be, nor to be favorable if, decentralized. The accuracy of the collected data was 5% of which led to a payment mistake, because every building element was classified with a price, (Hamledari & Fischer, 2021). It can still be higher than manual work of an inspector due to lack of knowledge of how it looks inside a wall. The mistake would get solved for the next payment, which would be higher or lower depending on the fault. This is because in the end, 100% of the tasks should be done and paid for, regardless of how the payments are distributed.

Another study made by Hultgren & Pajala (2018), examines BCT in the construction industry's window supply chain. It highlights the complexity of this chain, from tree harvesting to window assembly, emphasizing the importance of traceability and PEFC certification for sustainable forestry. The study proposes a hypothetical blockchain-based supply chain to enhance transparency and tracking. Various ownership models of the blockchain system are explored, including contractor, window manufacturer, joint, and external ownership, each impacting control, and efficiency differently. A key potential of blockchain identified is its ability to automate compliance verification, potentially replacing traditional certification bodies. However, a notable limitation is its inability to verify the authenticity of data at entry. The adoption of blockchain in construction has varied consequences, including market dynamics and administrative simplification. The success of blockchain in this industry hinges on its development through pilot studies and acceptance on an industrial scale.

Yang, et al. (2020) presents two insightful case studies that demonstrate the innovation application of BCT in construction projects, each addressing unique aspects of project management. The first case study explores the use of a permissioned blockchain network in the design process of external cladding for an apartment project. This innovative approach utilizes BCT to manage and streamline the complex workflow associated with the design phase with little focus on payments.

The second case on the other and specifically explores the procurement of expensive equipment, highlighting the transformative impact of blockchain on payment processes the procurement team, as part of their responsibility, signs a supply agreement with the supplier or vendor for a distillation tower priced at AU$43,000, (Yang, et al. 2020). The process initiates with the procurement team paying a 30% deposit of the contract price to the vendor. Following this, the vendor is obliged to supply and deliver the equipment as per the agreement. Upon delivery to the designated warehouse, a joint inspection for quantity and visible damage are conducted by the procurement engineer and the subcontractor, culminating in the signing of an acceptance form and the transfer of care and custody to the subcontractor.

Central to this process is the implementation of a public blockchain on the Ethereum platform, which supports complex modeling and computing through Turing-complete and programmable scripts. A Smart contract is created and deployed for this procurement process. The vendor and procurement team must register to access and administer the work interface on the blockchain platform. This Smart contract facilitates the entire procurement process, broken down into distinct stages and transactions, each added to the blockchain. The innovative aspect of this case study is the automation of the payment process through the Smart contract. After the contract's deployment, crucial information such as the vendor's account details, equipment name, and price are input into the system. The procurement team then confirms the contract and pays a transaction fee to Ethereum, adding this confirmed transaction to the blockchain. This step is crucial for the transparency and efficiency of the process. When the equipment is received and accepted, the procurement team performs a "receive" action, updating the contract and paying another transaction fee to Ethereum. This addition of a new transaction regarding the acceptance of the distillation tower enhances the accountability of the process. The final payment step automatically charges the remaining contract amount to the vendor's account upon clicking the "receive" button, and the contract status is updated to indicate completion and readiness for installation.

A Smart contract solution on the Ethereum Testnet Ganache was made and tested on a real project by Ahmadisheykhsarmast & Sonmez (2020). The contract was first deployed on the Blockchain. The initial schedule, costs, data entry, and transfers were then defined in a Decentralized Application (DApp). The contractor then requested to start with a task, which is to be approved by the Client. If it is approved, resources for next month's payment are locked in the contract to secure the payment. The schedule is revised, and cost data entry and transfer are written into the DApp. When the contractor is done, a payment request is made, if so, and the Client approves, the locked payment is transferred to the contractor, subcontractor, and suppliers. The process starts over at the request of starting a task until the project is done.

Structured interviews were held with the project participants, from clients to subcontractors, to get feedback on the Smart contract system, (Ahmadisheykhsarmast & Sonmez 2020). They thought after using the system that it has the potential to prevent all late payments in all stages which makes it easier to trust each other, no time goes to trying to get cash in time. The knowledge of when the money is received increases the motivation of the contractors, lowers bids from the subcontractors because the risk is lowered, and increases the focus on the actual project which in the end would improve the performance substantially for the whole project.

The downsides from the client's perspective are, that the interest from the money is lost due to the lockup, and the client pays directly to the subcontractor in this case which may force the client into a dispute between the contractor and subcontractor, (Ahmadisheykhsarmast & Sonmez 2020). From the main contractor's perspective, the payment to the subcontractors is usually private information and a part of a company's business secrets. The control of the subcontractors is reduced with this system, which may result in the subcontractors underperforming just because they know they will get paid. Ahmadisheykhsarmast & Sonmez (2020) also asked the interviewees if they would use the system and what could be improved. All participants answered positively, with some changes, such as making the contractor have the control of

approving the subcontract's work and including delay penalties. The participating subcontractors were very positive about this system because of their payment problems.

4.4 Subcontractor's usage of Blockchain-integrated BIM

Within the realm of construction and project management, the integration of BCT with BIM has emerged as a promising avenue for transforming the industry. This chapter delves into the profound implications of this integration, and legally binding BIM models. The paper explores the technology's potential for ensuring the legal validity of BIM data, thereby reshaping how construction projects are managed, documented, and executed.

4.4.1 The framework for autonomous payments in the construction industry using Smart contracts in 5D BIM

Building Information Modeling (BIM) has the capability to integrate with blockchain technology, merging crucial data such as supply chain details, material provenance, and payment information during the construction phase, (ICE, 2018). Additionally, BIM can contribute data to the blockchain, including design choices, data origins, or instructions for model alterations. This bidirectional exchange allows for the information stored within the blockchain to be utilized by Smart Contracts for initiating subsequent processes, such as triggering payments or ordering materials.

A Smart contract is not a legally binding contract just by itself yet, it needs to be set up in a traditional contract with a paragraph that refers to the Smart contract, (Ye & König, 2020). For that to be set up to work, all involved parties need to understand the concept of Smart contracts, which is described in Chapter 2.3.3. Only the bill of quantities and payment part of contractual regulations are assumed to be powered by Smart contracts in the first stage of implementation. A billing model needs to be set, which can be seen as the digital equivalent of a payment plan that contains single billing units, e.g., wall area, tons of concrete, or individual components. Process and interaction conditions are defined which enables automatic payments. The client then needs to confirm the corresponding billing unit for the payment to start. The power of a Smart contract is its complexity and availability to automate tasks, (Shojaei, et al, 2020). The users of Smart contracts must not know exactly how it work to be able to use and trust it. This is the case in most of the technical advice used today. Blockchain can be used because all the time stamps, contributions, and model modifications are recorded and copyrighted which solves the ownership issues, (Adamska, et al. 2021).

By using BIM for the bill of quantities, single items can be grouped into larger billing units, (Ye & König, 2020). These can be grouped however the parties want, each having a globally unique ID. To store the billing units, an XML-based data format can be used, where cost, delivery date, and description are also stored. This data in combination with using a special payload triples documents in a BIM contract container, which is specified with single quantities splits of the bill of quantities elements. A BIM Contract Container is needed in the construction project for storing essential 5D BIM information (the 3D BIM, Bill of Quantities, Quantity Take-Off, and billing model). Lastly, the BIM Contract Container is stored and linked as an ICDD (information container for data drop), which all is demonstrated in Figure 4.4.1.

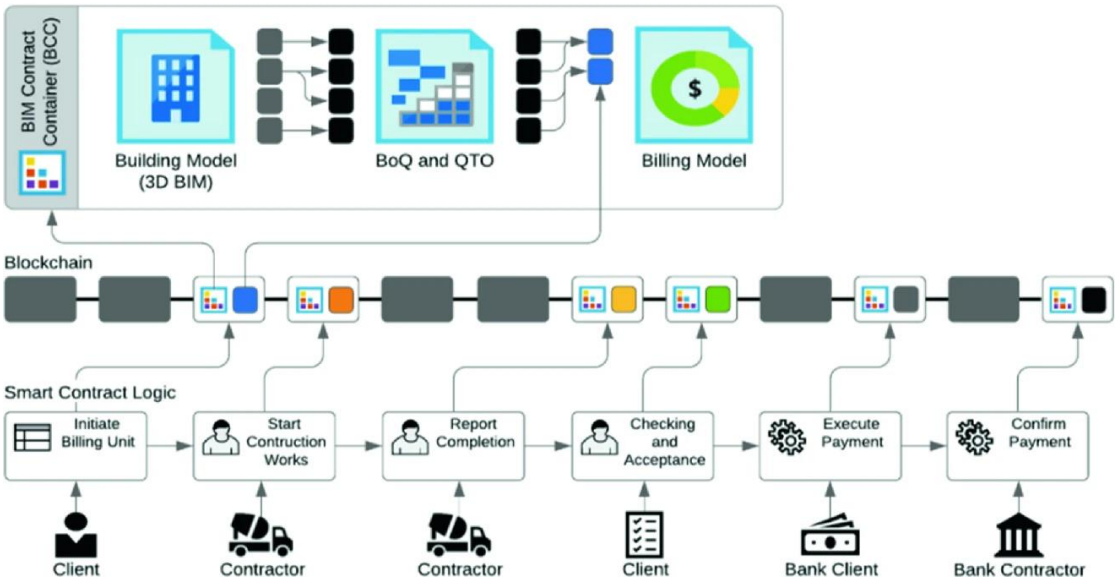

Figure 4.4.1a A possible process and breakdown of a Smart contract's structure in a project, (Ye, & König, 2020).

When all data is set up to be stored in the Smart contract, the next step is to define the contractual regulations, (Ye & König, 2020). Due to the complex nature of the contracts in the construction industry, and loose formulations are not an option, a set of general rule components can be created. These can then be combined to create a complex set of rules. A rule component should consist of an interaction, if-then statements followed by transactions. The standard rule for each Smart contract can follow a simple procedure. The client has in beforehand created a job with a certain billing unit and has activated the contract. The contractor documents the start of the job by interacting with the contract and does the same when the job is done. The client then checks and documents the results. If no defects are found, the payment proceeds automatically as prescribed. If there are defects, the client can claim for subsequent performance. The payment is then divided into a defect payment part, which is held on until an approved correction is done, and a correct payment part. The parts are decided by the client, the defects are requested to the contractor to correct with a deadline. The contractor needs to confirm the correction of defects before it is activated in the Smart contract. If accepted, the correct part of the payments, the automatic procedure is started. If not, an arrangement outside of the Smart contract with legal frameworks is needed. Then the procedure is repeated for the correction work as if it were a normal job.

All transactions and individual information are stored on the used Blockchain, (Ye & König, 2020). A block on the Blockchain will include a link to the BIM Contact Container with the corresponding billing unit. A Smart contract will only be executed if the right conditions are met, then a block will be added to the Blockchain for the record. Only necessary information is to be stored on the Blockchain. The combination of using a Smart contract and the billing model is the key to automated payments. It enables the Smart contract to use sensitive information from outside the blockchain with security. Feedback from participating banks are also stored on the blockchain to make the payments transparent. It works with cryptocurrencies too, which eliminates the banks, which would enable fast payments, (Ye & König, 2020; Mason, 2017).

A BIM Contractor Container was set agreed upon during the negotiations, (Ye & König, 2020). Due to the size of the data and the cost to store it on the Blockchain, it does not make sense to store all information there. It can be done, but a better option might be to only store payments, processes, and other important data on the Blockchain. The rest can be stored in a common data environment, which is usually used to collect, manage, and share all the project info, which all the contractual partners will have access to. Its information is still immutable if a checksum is included in the Smart contract by using Secure Hash Algorithm 3 (SHA-3). The contractual costs of the billing units need to be stored on the Smart contract to enable automatic payments. The checksum can be calculated to make sure the BIM Contract Container has not been modified, which would modify the actual contract. This means that protocols, documents, and various photos that are generated during inspections are also stored in the common data environment. Protocols, photos, and other documents that are created during inspections are also stored in the same way as the other data to ensure safe and true information for the payments to be safe and done on trusted information.

Ye & König, (2020) created tools for making a Smart contract and for checking results. The Smart contract setup tool uses the 5D BIM data which are stored in the common data environment. The 3D BIM and Billing of Quantities can then be used to define the billing model and the Smart contract, then for every billing unit, an acceptance and paying procedure is defined. Predefined Smart contract components are set together to make a complex Smart contract. When the Smart contract is done and all parties have agreed, the Smart contract is signed digitally. When all parts are generated, it is to be uploaded to the common data environment. The URL and hash value of the BIM Contract Container will be returned from the common data environment and will be stored on the Blockchain together with the Smart contract rules.

When the main contract, which preferably still being in paper form, due to the complexity of the construction industry according to Shojaei, et al (2020), is signed, the work on site can begin as usual, (Ye & König, 2020). The difference is the Smart contract which now defines interactions and processes that are all stored on the Blockchain. The tool for checking, starting payments, and documenting should be in the form of an application for a mobile device. The client can navigate through a 3D BIM model during the assessment and take photos as well as fill in checklists that document the entire process. If everything looks fine, the payment automation will begin. The application of this technology extends across various contractual relationships within the sector, from head contractors to laborers. Furthermore, Smart contracts offer additional benefits, such as the ability to link contracts, enabling automated, cascading payments from one contract to another, enhancing efficiency and financial security throughout the construction process, (Turk & Klinc, 2017). A similar process should be implemented when ordering supplies, e.g., a steel beam could be ordered, which itself is a transaction, when the beam has been delivered to the site, another transaction is signed which triggers payment transactions to both the truck company and the supplier, (Shojaei et al., 2020). Information and documents are then uploaded into the common data environment, which in turn, documents the checking process and the URLs and hash values, returned from the common data environment, on the Blockchain.

The usage of the Smart contract is a semi-automated contract, (Shojaei, et al 2020). Executions and verification of obligations are done by people inside the project, which

is checked and controlled by the Blockchain. Figure 4.4.1b, which shows a proposed network of seven participant types, Architect/Engineer, Client, General Contractor, Subcontractors, Suppliers, Inspectors, Regulators. The different types should have different tasks they can interact with. For example, the General Contractor can approve and request for work, while the inspectors can approve that the work has been done correctly.

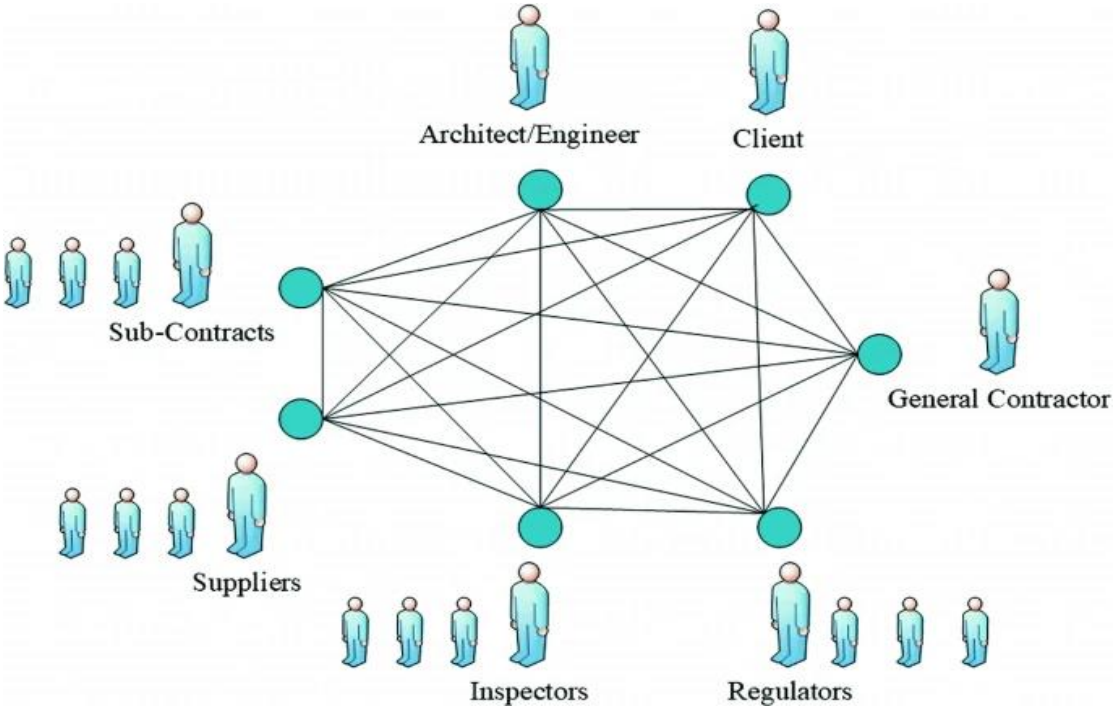

Figure 4.4.1b All the stakeholders are connected to each other, (Shojaei, et al. 2020).

4.4.2 How the Blockchain can be the technology that enables a legally binding BIM model

BIM serves as a channel for sharing vital information, which enables all design stakeholders to collectively address construction and design challenges, (Shojaei, et al, 2020). For it to work properly, legal information management is critical in case of litigations and disputes among stakeholders. BIM is still in need of more trust for it to become a legally binding alternative. Blockchain's strength is the issue of trust because of its decentralized nature, which could overcome the barriers to BIM adoption and enhance the legal reliability of BIM according to Mason (2017). An implementation of Blockchain would enhance recordkeeping, change tracing, multiparty aggregation, provenance tracking, etc., (Turk & Klinc, 2017). This will in turn push towards leaner procurement systems and better collaboration. Smart contracts would result in more transparency and control of costs and duration of the project.

Jiang et al. (2022) made a prototype by combining BIM with blockchain, which records BIM modifications onto a blockchain. This process authentically logs changes to the BIM model, allowing for traceability back to the origin. Such a mechanism not only enhances the security and dependability of BIM data but also fosters a greater sense of accountability and engagement among all involved parties. Simultaneously, this system boosts collaborative efforts and streamlines communication between designers and

constructors, ensuring a more cohesive project development process and will probably make it legally binding.

In conclusion, this literature analysis underscores the unexplored potential of BCT in the Swedish construction industry. Given the limited depth of existing research within the Swedish context, conducting an interview analysis becomes essential. Such an analysis can provide valuable insights into the specific challenges, opportunities, and practical applications of blockchain for subcontractors, offering a deeper understanding of its relevance and potential impact within this industry.

5 An Interview Analysis of Blockchain Would Benefit Subcontractors

This part of the paper delves into the critical insights and perspectives gathered through semi-structured interviews with key stakeholders in the Swedish construction industry, with a particular focus on subcontractors. These interviews serve as a crucial part of the research into the integration of blockchain-based Smart contracts in project management. The aim is to understand how these innovations can automate payment disbursement at project milestones and examine their broader impacts on payment delays, stakeholder collaboration, and overall project efficiency. In this chapter, the outcomes of these enlightening conversations will be presented, providing a real-world perspective on the feasibility and potential challenges of implementing blockchain and Smart contracts in construction projects. These insights bridge the gap between theory and practice, offering a deeper understanding of how these technologies may revolutionize the industry.

5.1 Problems with today's payment processes

5.1.1 The problem with payments to subcontractors

All businesses are built up around money. If you do not get money into your company in time it will create a domino effect which causes smaller companies to have liquidity problems, says several interviewees. Interviewee A stated that their management team needed to focus on how to get cash into the company to prevent insolvency. Sometimes they went to their trusted clients for payments in advance but with a percentage cutoff, which is a good short-term solution, but affects the revenue in the end. Their focus was on the wrong things, if the payments worked out like they should, then the management team could focus on the right things. Interviewee C stated that their solution to such a problem was to take short-term loans to be able to pay their employees. Because of the nature of invoices, you get paid for the work that was done 59 days ago, even though the payment is on time. If they were to do a big and expensive operation just days after they usually send their invoice, they waited with sending it, to get that expensive operation on this month's invoice. Interviewee A also stated that the smaller companies are banks for the bigger companies during the construction. First, they buy the supplies, which sometimes need to be paid for on the delivery day, they then build something in their workshop for months, for the product finally to be mounted on site. They then send their invoice which is due 30 days from sending it.

Even though the invoice has a due date, Interviewee B stated that they, according to the contract, pay the invoice 30 days after they get the invoice to their address. Interviewee B also said the major cause for of payments is invoice address errors. This occurs because they have several subsidies, and their contractors need to send it to the right company, otherwise, it will get sent back. Interviewee A's invoices state, "If something is wrong with the invoice, come back to us at least seven days prior to the due date". According to Interviewee A, the clients sometimes call days after the due date, which then leads to a change and a new invoice is made which is due in 30 days again. Another significant problem they encounter is when the job is done, the invoice is sent, but the client does not think the job is done correctly, not good enough or the client says they got costs due to changes, the client may only pay 80% of the invoice. Interviewee A states that they cannot do anything in this situation due to the difference in revenue

between the parties. If they go to court trying to get 100% of the invoice, they have fewer resources for lawyers, and in the end, it might end with a conciliation, ending with the client only paying 50%. Interviewee A says that the late payment interest is nothing you can use due to the dependency they have on the client. Some have threatened not to collaborate with them anymore if they do not cancel the fee.

Interviewee D and E state that it is very important to pay the right amount in time to their subcontractors to have a healthy project. Everyone should earn money for what they have done. Interviewee D says that paying on time builds up trust which results in getting lower offers of getting a job done, due to the knowledge that they will get paid on time.

5.1.2 Why today's payment processes are slow and inefficient

Until this day, some companies still use invoices in paper form, they print it all out and store it all in binders, which can sometimes take hours to manage according to Interviewee C. The other interviewee's payment systems are digital, but the larger the organization, the more attests are done for every invoice. When two people in the organization already have been looking into the invoice, many of the interviewees think it might be unnecessary for a third and a fourth person to try to understand what is to be paid for. The last person in the attest order is usually not active in the project, making it very hard to understand what is paid for, says Interviewee G. The attests can in some cases make the payments take more time than necessary because the payment basis is incomplete, and you want an answer of what is to be paid. This is a common situation, which Interviewee G says can occur when you do not have good enough guidelines of what should be included in the invoices for them to be paid on time. Interviewee I is working on a project where the attest procedure is very long, which is a vulnerability. All it takes is one in that organization to not have time for admin, for the payment to be paid late. Interviewee I think some of the invoices could be passed through the organization faster by excluding some persons within some circumstances, payments under a certain amount for example. The attests may take time, but Interviewee F pointed out the importance of the attests, due to earlier bribe scandals. This still is a problem to some extent in smaller companies, where you can make a fake invoice. The other party knows it is fake and pays it to bribe the other party.

Several interviewees did say that it is the subcontractors who often have a slow process making the invoices too, errors are made, slow response rate when the invoice needs to be supplemented. Interviewee says that even though it is written in the contract to come back with potential changes at the latest seven days after receiving the invoice, their clients often come back to them after the invoice's due date. That makes them bank for the larger companies for months. In some cases, they buy materials and build modules in their workshop for three months before mounting it on site, then they can send their invoice. Interviewee A also said, a deal can be closed, but when it is time to pay, the last person in the organization to confirm the order, can say they cannot approve the full amount of the contract. The excuse is that the person who made the deal did not have the authority to close such an expensive deal. Again, they could not go to court due to the risk of getting even less money. Some larger companies choose to not pay in full just because they can. One company is so big that they can push their suppliers and subcontractors to the limit, knowing there are plenty who are waiting to work for them on the next project.

5.2 Why a Smart contract solution would be beneficial for every involved stakeholder

5.2.1 The benefit of getting payments directly after the job is verified

If all companies would get paid on time, the projects would become cheaper to build, says Interviewee G. If there is an overall improvement in payments, there would be better liquidity for subcontractors, which results in less solvency, which in the end makes the projects cheaper, according to several interviewees. If a subcontractor gets insolvent, a new subcontractor needs to be procured, which takes time and causes delays.

There would be better planning opportunities for the subcontractors who could then be focusing on doing a good job instead of trying to get cash into the company, says Interviewee A. The overall efficiency in the companies would be higher because of the improvement of the cash flow, says several interviewees. The smaller companies would no longer be the bank to the same extent as the larger companies, which creates opportunities to streamline. Interviewee A also points out, that BCT could enforce the security of getting the money and at the same time tell you how much is to be paid out. Then it is solely the build controller who can say if the work is done the right way or not, making the client unavailable to change the contract price after the job is done.

5.2.2 The transparency of payments between stakeholders

A major benefit of the transparency that comes with the Blockchain is to see who has been paid and for how much. Several of the interviewees point out the problem that some of the subcontractors down the ladder do not get paid fairly, or not at all. Some even do not pay their employees, who often come from foreign countries. Some interviewees state that it could be a major problem to show others how much they are paying their subcontractors, who their suppliers are etcetera. This would take away the competition by revealing the company's secrets. Several interviewees mentioned they would not like to show who their suppliers are, nor how much they are paying them. If this would be known, the client could choose to work directly with the main contractor. The line of transparency would be developed thoroughly before implementing it into the market for the majority to accept it.

Interviewee J says several studies have pointed out that partnering projects where all cards are on the table perform the best. Interviewee G however says it would take a lot of time and effort to be able to understand how all the different stakeholders in a project are working and earning their money. This could be a problem because it could cause confusion and misunderstandings. For example, if the project's cash is about to run out, and everyone in the project sees this, it could cause uncertainty even though it might be a normal situation. Thus, many of the interviewees stated that it would be good to not show all the details of the payments.

Many of the interviewees say it would be beneficial to know how different companies have managed payments in earlier projects. This would be beneficial for all parties to know if a company will be able to pay in time with the right amount, also if a subcontractor has done the work in time. They also said that it would be good to make the controlling procedure of a company’s financials before they get procured, faster and easier. It could be done by making more financial data public. Today, it is a time-

consuming and expensive task to make a control, which might be done for nothing if you miss something, says Interviewee C. The risk of procuring a contractor who is about to go solvent, who takes a job for a low price just to have jobs for their employees, is that they will not be able to fulfill the procured work. This is something that has happened to Interviewee C, which could have been prevented by knowing more financial statistics.

Interviewee A also thinks BCT has the potential to make classifications on payment notes, which today prevents companies from taking jobs if they have one. A payment note could be a parking ticket not being paid in time, which affects the company for months. Such a payment note should not affect which jobs you can take according to Interviewee A.

5.2.3 The traceability to see what is paid for

Traceability of what is bought could prevent fake invoices. Making all invoices connected to a model would make them hard to fake, compared with the system that is used today according to Interviewee K. It would be great to have a partnering project when all books are already open, to see what is paid for, which often cannot be done due to the lack of information. The acceptance of who pays who and how much, would not be a problem in this case. The project Interviewee works on, they are proactively working with invoices with every stakeholder involved which makes the mistakes taken care of even before the invoice is sent. Then it can be accepted by the client's organization without taking too much time looking at it. Even though this is done, a subcontractor's due date was 15 days before the main contractor's invoice due date. Which makes the payment to the subcontractor late by 15 days, if the contractor does pay it after they get their payment from the client, which is common in the construction industry.

Interviewee I also think it would apply perfectly to Alteration and Additional Work which is paid by the hour. There is a problem with the traceability and transparency of what is paid for. If you could force every stakeholder to link their expenses related to the job, it would be of great value to the client. You are usually not getting any documentation of what is to be paid for, which leaves you to trust the other party. It will make sustainability easier to monitor and track if you know what is bought, where all the different materials and components come from etc, says several interviewees. Today, there is an uncertainty of what is paid for, and where it is produced.

5.2.4 The security and way to choose who you want to work with regarding their payment time

According to the interviewees, the world economy is not ideal. Construction is paused on many fronts, creating a shortage of work for contractors, forcing them to take work for less profit or even a loss just to survive, according to interviewees. In the best of worlds, when you can choose a company, it is great to see their payment time. It makes it easier to calculate the budget concerning how much risk there is working with a certain company, says Interviewee F. Interviewee G says, that if a company has a bad payment history, they will force their client to pay in advance to secure their payment, which is a privilege smaller companies might not have. Being a large consultancy company, if they are aware of their client's bad payment history, they can push them to

make their payments on time to their contractors. Interviewee D thinks it will be a great tool for decisions about who do not work within the best of worlds.

5.3 Barriers to implement a Smart contract solution

5.3.1 The cost and technology barriers

The margins on today's projects are usually a few percent leaving little room for testing out new technology. It always comes down to if it is a good investment. Implementing such a system will most likely not be profitable, especially not in the beginning. The question is, if it can save you money in a project, says Interviewees B and K. Most of the admin and cost would be when defining the Smart contract with its predefined tasks which some interviewees say will be hard to follow due to changes during the project. If you could define it, you would save a lot of admin time during the construction.

There will be a high initial cost to set up the contract in the form of time followed by deployment on a Blockchain. A framework is needed for what information needs to be stored on the Blockchain because of the high gas prices that come with interacting. With high initial cost, comes risk. Interviewee M thinks it will be a question of cost if the client wants to have this system because it will cost X amount of money the run it on the Blockchain.

Some interviewees pointed out that possible resistance which might come from the clients and the main contractors who need to pay earlier than before, leaving no room for earning interest rate on the cash they hold. Some companies have this as their actual business model. Some interviewees think that Blockchain needs to become an industry standard for them to be willing to change. Interviewee D thinks it would be a short-term resistance, but at the same time would change to using the new framework to benefit from it instead.

Who is to be responsible for the confirmation if a job is done correctly, needs to be worked through thoroughly, says Interviewee B. As a client, they want someone from their organization to confirm the job, while Interviewee A points out one of today's problems. Blockchain could decentralize the project by having the third party who is normally just an inspector, also have the authority to start the payment process. Then the client's power to reduce the amount being paid would vanish. If something is built correctly according to the building deed, it will trigger the entire contract fee. If the tasks were to be small, there would also be a lot of small inspections which are expensive, says Interviewee L. The attestation would still be required to not be able to bribe the inspector.

There is also a high cost that comes with changing the economic system in a company in the form of implementation and educating the employees, says Interviewee K. A possible solution to this is to implement it in an already used system, such as Fortnox, which is very common, making the implementation even more smooth. Interviewee M suggests that while blockchain offers certain advantages, alternatives might achieve similar results with less complexity and cost. He stresses the importance of assessing the benefits against the economic implications. Interviewee L suggests a higher rate of late payment interest, and maybe enforce it into contracts to not exclude it.

5.3.2 Lack of social acceptance

An industry standard of 30 days due date is something Interviewee D says would be unnecessary if a system like this was implemented, but there would be short-term resistance from clients and main contractors. Interviewee C thinks those changes would need to be initiated by the government or the largest companies in Sweden for everyone else to eventually do the same. Interviewee M notes that the construction industry is dominated by a few key players. Their acceptance and adoption of BCT could significantly influence its wider adoption across the sector.

With new system integration, there is a need for a security framework, says Interviewee K and G. The Blockchain can make the most secure transactions there are, but due to the immatureness of the technology, some blockchains are getting exploited by hackers. Phishing is also common, which could be a problem if someone were to send a link, it could drain the wallet from crypto. It could be prevented by using traditional banks, then the wallet would only contain crypto for gas payments. Interviewee K says the real security risk would be the management of private keys and seed phrases for the wallets. They cannot be written online due to the risk of being hacked. They should be stored offline, preferably in a safe. If those were to be lost, the funds and access to that wallet or account would be lost forever. This could be particularly challenging for smaller firms that may not have extensive knowledge or resources to manage such security demands. Interviewee J says there are broader industry concerns about technological maturity and security, making it even harder to understand a new technology as well as the limitations of subcontractor's resources. Every stakeholder must have a foundational understanding for acceptance, says Interviewee I.

Interviewee F believes there may be resistance from workers due to an increase of admin, which they would like to avoid as much as possible, not having to do more. Some education about why and what it does for the contractors would be required for them to be willing to use it. The user interface needs to be easy to use, self-explanatory, and secure. Interviewee A on the other hand thinks it would not be a problem to implement if the application would be user-friendly. They already work similarly, by documenting every step in their workshop on paper for example. Documentation is the key to a successful project and to not get into conflicts. Interviewee G mentioned the importance of showing how blockchain could enhance existing documentation and transparency practices from the customer's perspective. But also highlights a general unease in the digital environment and notes that people often feel suspicious and uncertain when it comes to relying on digital information that they cannot verify themselves. This uncertainty extends to BCT, which, despite its potential for accuracy and control, may be perceived as abstract and provoke a sense of insecurity among people. This resistance might stem from various factors, including lack of understanding, fear of change, or concerns about the practical implications of implementing such technology, says Interviewee K.

The system excludes the companies that still use paper and binder, as well as people who cannot manage a cellphone, says Interviewee B. Interviewee J emphasizes the importance of the need for simplicity and ease of use in blockchain systems for it to be accepted. Interviewee G also acknowledges the need for educating people on how BCT works, and its benefits compared to current methods. The importance of explaining the technology pedagogically, discussing the risks involved and how they are mitigated by blockchain, to foster better understanding and acceptance.

Interviewee K suggests that while BCT might offer solutions on paper, there are often more straightforward solutions available for regular transactions. This implies that the complexity and novelty of blockchain might be seen as unnecessary for certain applications, affecting its acceptance and implementation. Interviewee K also expresses skepticism about whether BCT alone could solve the problem of late payments, a common issue in business transactions. This doubt indicates a perception that blockchain might not be the comprehensive solution that some proponents suggest it is.

Interviewee A observes that many people associate blockchain solely with cryptocurrencies like Bitcoin and are unaware of its broader applications and benefits. This misconception and limited understanding could hinder the wider acceptance of BCT. The challenge of establishing trust in BCT might also be a concern. There might be a period during which people are hesitant to trust and rely on this technology for important transactions, especially in the context of automated payment systems.

Interviewee J acknowledges the challenges in integrating blockchain with traditional data storage methods, like cloud services. This difficulty could hinder the smooth connection and maintenance of desired features such as privacy, posing a challenge to its widespread acceptance. The acceptance of the increased transparency offered by BCT is debatable. While some may see the benefits of transparency in collaborative projects, others may be hesitant to adopt this level of openness, which interviewees A and G also stated.

5.4 Implementation of a Smart contract solution

5.4.1 The first step of implementation

Interviewee K says the way we work today would not be changed if the system were to be implemented. It is just a different payment system, whilst BIM for example changes how we work completely which is a reason it is taking so long to be 100% implemented. One of the first steps would be to raise capital for developing an application and then assess it on a project, says Interviewee M. It would be beneficial to test out a project with several stakeholders to get as much different data and input as possible. The necessity of partnerships in the industry to initiate the adoption of BCT suggests that a collaborative approach might be a good approach.

For it to be implemented in a client’s project, they would have to fully understand and know what is in it for them. Due to the cost of running such a system, they would need incentives other than economic profit, to begin with, other kinds of value need to be created, to begin with. The subcontractors are the ones who truly benefit from it, which is how it needs to be sold. Interviewee J says a huge step is required to implement BCT in construction. He suggests starting with applications like avoiding late payments to demonstrate the technology's feasibility and gradually overcoming resistance, to then continue implementing BCT until its full potential is met. Interviewee H thinks there is a possibility to add it into the background of BIM as a first step. In some way, quantity data would be needed, which could easily relate to payments when being in the same system.

5.4.2 What needs to be in place for it to be accepted

A clear and secure framework is essential to have before trying to implement the systems, says Interviewee K. There cannot be any unanswerable questions about how the system works. According to Interviewee G, the contract needs to be bulletproof, no loopholes are allowed to exist. There also needs to be a well-structured way of storing and handling wallet seed phrases and keys. Interviewee J says that the application that the workers are going to use, needs to be easy to use, as well as safe.

Interviewee A says the system needs to be shown to be a profitable way of working. It must save you or make you money, otherwise, it might need to become an industry requirement before companies start to use it. Interviewee M shares the same thoughts, saying that any blockchain solution must not adversely affect a company's cash flow or liquidity.

For BCT to be effectively implemented, there is a need for a common platform where all parties involved can register and participate, says Interviewee B. This platform needs to be independently controlled and monitored to ensure fairness and transparency. Interviewee A points out that for BCT to be widely accepted in industries like construction, there needs to be a significant shift at the industry level, possibly requiring new regulations or standards. This suggests that acceptance might be slow due to the conservative nature of some industries.

For successful implementation, it is important that the technology is not only accepted but also complies with existing laws and regulations, says Interviewee B. Because of the legal framework in Sweden regarding LOU, a certain number of companies from other countries are required to be procured. The system needs to be able to include their country's legal framework and banks do not exclude them. Interviewee M believes that current regulations do not pose significant barriers to the adoption of blockchain. However, he acknowledges that legislative processes, especially at the EU level, can be slow and may not keep pace with technological advancements. Further on Interviewee M emphasis facilitating digital contract negotiations in a secure manner compliant with banking regulations, which can be an entry point into the legal field as well.

Interviewee J suggests that regulation could play a significant role in enforcing transparency, aligning it with sustainability goals. This regulatory push could make BCT more appealing, especially in terms of material use and project management. Interviewees also says, for an accurate and comprehensive legal framework recommendation, it would be essential to consult specific legal and industry guidelines regarding blockchain technology's integration into construction, which might include regulatory compliance, data privacy (such as GDPR compliance), and the establishment of standards for Smart contracts.

6 Analysis and Discussion of the Proposed Framework

In the realm of BCT in the construction industry, understanding the multifaceted perspectives and underlying dynamics is crucial for developing comprehensive insights. This study embarks on a meticulous exploration through two distinct yet complementary approaches: a SWOT analysis of the existing literature, and a SWOT analysis derived from an interview study focusing on the same subject. Together, these dual SWOT analyses offer a holistic and multifaceted understanding of BCT in the construction industry. This approach not only bridges the gap between theory and practice but also unveils a more nuanced and comprehensive picture, paving the way for informed decision-making and strategic planning in the field.

Building upon the insights gleaned from the SWOT analyses of both the literature review and the interview study, the next phase of my research involves a risk-reward evaluation. This evaluation aims to quantitatively measure the potential risks and rewards associated with each factor identified in the SWOT analysis. To achieve this, each element within the Strengths, Weaknesses, Opportunities, and Threats categories has been assigned Low Medium or High impact and feasibility. For Strength and Opportunity, it represents reward and for Weakness and Threat will represent reward of solving the risk.

The first letter in the acronyms is dependent on if it is a Strength (S), Weakness (W), Opportunity (O) or a Threat (T). The second is based on if it is from the interviews (I) or the literature (L). It also got number the keep them apart.

6.1 Separate SWOT analysis of the literature study and the interview study

6.1.1 SWOT of the Literature Study

The literature review serves as a foundation, offering a broad overview of the current academic and theoretical landscape. It meticulously identifies the strengths and weaknesses inherent in the existing body of knowledge, while also highlighting the opportunities for advancement and potential threats that could impede progress in this field. The result of the analysis can be seen in Figure X. These are to be broken down and given different strategies.

Figure 6.1.1 The result of a SWOT analysis of the Literature Study

6.1.1.1 Strategies to take advantage of strengths from the literature

Firstly, the main activities to take advantage of the strength shown in Table 6.1.1.1, are using them as selling points and making sure the process of using the application is seamless. To ensure the strengths will meet the expectations, the Smart contract need to be bullet proof, which is done by hiring a great BCT developer. Every stakeholder needs to be considered when setting up the transparency level of the project to prevent new disputes.

Table 6.1.1.1 Identified strengths from the literature.

ID	Strength Literature
SL1	Enhanced transparency and traceability in transactions.
SL2	Automation of tasks with Smart contracts, reducing errors and improving project quality.
SL3	Efficient and fast payment processes.
SL4	Improved transparency for stakeholders and control over project costs and durations.
SL5	Reliable and transparent record system combining BIM and Blockchain.

SL6	Protection against late payments which prevents insolvency, benefiting subcontractors and suppliers, which benefits the project.
SL7	Effective task management for subcontractors and vendors.
SL8	Decrease of disputes

6.1.1.2 Strategies to compensate for weaknesses from the literature

The weaknesses from the literature are displayed in Table 6.1.1.2. To address WL1 and WL4, investing in highly competent developers is crucial to ensure a solid foundational code. Collaboration with regulatory bodies is necessary to establish standards and a secure framework to lower the WL2 weakness. To tackle WL3, hiring BCT security experts to manage risks and educate the workforce.

WL4 and WL5 also suggests starting with pilot projects to demonstrate viability before wider application and scaling. Lastly, WL6 can be addressed by proactively decide for a blockchain integrated project which will attract the desired people and companies.

Table 6.1.1.2 Identified weaknesses from the literature.

ID	Weakness Literature
WL1	Technological complexity and the need for substantial infrastructure and skills development.
WL2	Nascent nature of the technology, leading to a lack of maturity and universal standards.
WL3	Security concerns and implementation constraints, including cybersecurity risks.
WL4	Cost of implementing blockchain systems and need for specific technical skills.
WL5	Lack of real-world applications and practical research, limiting understanding of blockchain's potential in construction.
WL6	Every stakeholder in a project needs to be on board for the technology to reach its full potential.

6.1.1.3 Strategies to take advantage of opportunities from the literature

Firstly, the opportunities that comes with BCT should be considered when planning to start a project. However, these are still theoretical due to lack of real BCT integrated projects. With that said, when projects start to integrate it, it will be beneficial to be prepared to adopt, these can be seen in Table 6.1.1.3.

Table 6.1.1.3 Identified opportunities from the literature.

ID	Opportunity Literature
OL1	Enhances project management via blockchain and BIM.
OL2	Early adoption yields competitive edge.
OL3	Secure, transparent data sharing enhances collaboration.
OL4	Streamlines transactions and reduces admin work with Smart contracts.
OL5	Builds stakeholder trust with immutable records.
OL6	Revolutionizes payment processes for accuracy and timeliness.
OL7	Mitigates disputes with transparency and traceability.
OL8	Addresses industry issues like late payments and inefficiencies.
OL9	Solves extensive payment problems.
OL10	Profitability from BCT can lead to widespread adoption.
OL11	Contributes to a more efficient economy.
OL12	BCT increases profit margins.

6.1.1.4 Strategies to respond to threats from the literature

The threats from the literature are displayed in Table 6.1.1.4. For TL1, the anticipation of developer shortages and the establishment of in-house training programs are critical to building a robust blockchain workforce. Addressing TL2, the investment in elite developers will lower the risk of integration issues with existing technologies. In response to TL3, making partnerships with regulatory bodies will help in creating a stable legal and regulatory environment for blockchain application in construction.

Education and promoting efforts post-project completion are the focus of TL4, aiming to pave the way for blockchain adoption by setting industry standards. TL5 emphasizes the importance of hiring security experts to safeguard the blockchain infrastructure to then educate the workforce. TL6 suggests that pilot projects are vital in establishing the profitability and practicality of blockchain within the construction industry's tight margins. Lastly, TL7 acknowledges the need for demonstrating the economic viability of blockchain through successful pilots to attract potential government incentives.

Table 6.1.1.4 Identified threats from the literature.

ID	Threat Literature
TL1	Technological complexity and significant infrastructure and skill development requirements, it might become a shortage of developers.
TL2	Integration challenges with existing construction technologies and IoT.
TL3	Regulatory uncertainty and lack of legal frameworks specific to blockchain in construction.
TL4	Nascent nature of blockchain leading to a lack of maturity and universal standards.
TL5	Security risks, including cybersecurity threats associated with digital currencies and contracts.
TL6	Due to the nature of low margin in the construction industry, innovation is generally not thriving too good.
TL7	There are no incentives from the government to implement such a technology, which makes it expensive

6.1.2 SWOT of the interview study

The interview study provides a more grounded and practical perspective. By engaging directly with individuals who are strongly associated with the construction industry and some with both the construction industry and BCT. The SWOT analysis of these interviews' sheds light on the real-world implications, practical challenges, and unexplored opportunities that emerge from the lived experiences of these participants. The result of the analysis can be seen in Figure 6.1.2.

Figure 6.1.2 The result of a SWOT analysis of the Interview Study

6.1.2.1 Strategies to take advantage of strengths from the interviews

Firstly, the main activities to take advantage of the strength shown in Table 6.1.3.1, are using them as selling points and making sure the process of using the application is seamless. To ensure the strengths will meet the expectations, the Smart contract need to be bullet proof, which is done by hiring a great BCT developer. Every stakeholder needs to be considered when setting up the transparency level of the project to not show sensitive details.

Table 6.1.2.1 Identified strengths from the interviews.

ID	Strength Interview
SI1	Prompt and direct payments upon job verification.
SI2	Enhanced transparency and traceability of payments between stakeholders.
SI3	Increased security in choosing collaborators based on their payment timeliness.

SI4	Elimination of errors regarding invoices sent to the wrong address
SI5	Ability to manage tasks more effectively using blockchain technology.
SI6	No need for 30-day due date on payments
SI7	Prevention of late payments enhancing the operational efficiency.
SI8	Better economic decision-making based on blockchain data.

6.1.2.2 Strategies to compensate for weaknesses from the interviews

The weaknesses from the interviews are displayed in Table 6.1.3.2. Starting with WI1 and WI11, the implementation of small-scale pilot projects is pivotal. These projects harness the expertise of skilled developers to manage technical complexities and contain costs. For WI2, WI3, WI4 and WI10, the strategy includes a strong emphasis on educational initiatives and the development of user-friendly interfaces prior to full-scale implementation, which are integral to overcoming industry resistance. Addressing WI5 involves investing in specialized BCT security experts to ensure robust cybersecurity measures are in place which could inform and educate the workforce.

The complexity of coding for Smart contracts, as indicated in WI6 and WI8, necessitates the involvement of top-tier developers to assure both adaptability and reliability in dynamic project environments. In response to WI7, collaborative efforts with regulatory bodies are essential to establish a standardized framework that can ease the transition from traditional to digital methods. Finally, WI9 highlights the importance of setting up blockchain systems that address privacy and transparency concerns, ensuring that stakeholder consent and satisfaction are at the forefront.

Table 6.1.2.2 Identified weaknesses from the interviews.

ID	Weakness Interview
WI1	Cost and technological barriers for implementing blockchain and Smart contracts.
WI2	Lack of social acceptance and resistance to change among industry stakeholders.
WI3	A potential resistance from craftsmen to get more admin

WI4	Need for digital competence and infrastructure investment for effective adoption.
WI5	Concerns over the security and cyber risks associated with digital currencies and contracts.
WI6	Complexity in coding and executing Smart contracts for dynamic construction projects.
WI7	Reluctance to shift from traditional to digital contract methods among industry professionals.
WI8	Obstacles in updating and adapting Smart contracts to meet evolving project requirements.
WI9	Concerns about transparency and data privacy in public blockchain systems but also between stakeholders in a private blockchain.
WI10	Every stakeholder in a project needs to be on board for the technology to reach its full potential.
WI11	Concerns about quality control and uniform procedures in blockchain implementation.

6.1.2.3 Strategies to take advantage of opportunities from the interviews

Firstly, the opportunities that comes with BCT should be considered when planning to start a project. However, these are still theoretical due to lack of real BCT integrated projects. With that said, when projects start to integrate it, it will be beneficial to be prepared to adopt and can be seen in Table 6.1.3.3.

Table 6.1.2.3 Identified opportunities from the interviews.

ID	Opportunity Interview
OI1	Improves subcontractor payments for better project management.
OI2	Subcontractors can enhance business operations and financial stability.
OI3	Blockchain fosters collaboration and trust among stakeholders.
OI4	Encourages growth and innovation for subcontractors using blockchain.

OI5	Tackles construction industry challenges like late payments and inefficiencies.
OI6	Offers new business models and strategies via blockchain.
OI7	Delivers significant industry-wide impact.
OI8	Extending the potential of BCT is very high if a payment system already is in place

6.1.2.4 Strategies to respond to threats from the interviews

The threats from the interviews are displayed in Table 6.1.3.4. For TI1, the focus is on implementing a small-scale profitable pilot project to get stakeholder acceptance through demonstrated success. In tackling TI2, the approach involves collaborating with regulatory bodies to create a framework that supports blockchain's integration into existing systems, thus reducing legal and operational uncertainties. Addressing TI3, investment in BCT security experts is crucial, providing the dual benefit of enhancing system security and educating the workforce on emerging digital threats. In consideration of TI4, a comparative analysis of blockchain with other methods is advocated to ensure the most efficient resolution for late payments. Finally, for TI5, a pragmatic stance is adopted, with readiness for the substantial costs associated with altering the economic system to accommodate blockchain, emphasizing the importance of strategic financial planning.

Table 6.1.2.4 Identified threats from the interviews.

ID	Threat Interview
TI1	Resistance to change and lack of social acceptance among industry stakeholders.
TI2	Difficulties in aligning blockchain with existing legal and regulatory frameworks.
TI3	Security and cyber risks related to digital currencies and contracts.
TI4	Easier means can be done to get a similar result regarding late payments.
TI5	High cost to change economic system

6.2 Impact/Feasibility matrixes

6.2.1 Matrix strengths and opportunities from the literature

In Figure 6.2.1, it can be found that there is no element in the high impact high feasibility cell that should be the prioritized, which means SL6, SL8 and OL4 followed by SL1, OL5, OL7, is to be considered firstly. Most elements are in the high impact, low feasible cell. This brings some uncertainty due to their nature of being hard to implement. For individual projects, some elements would be more important than other to implement, these needs to be identified and then distribute resources accordingly.

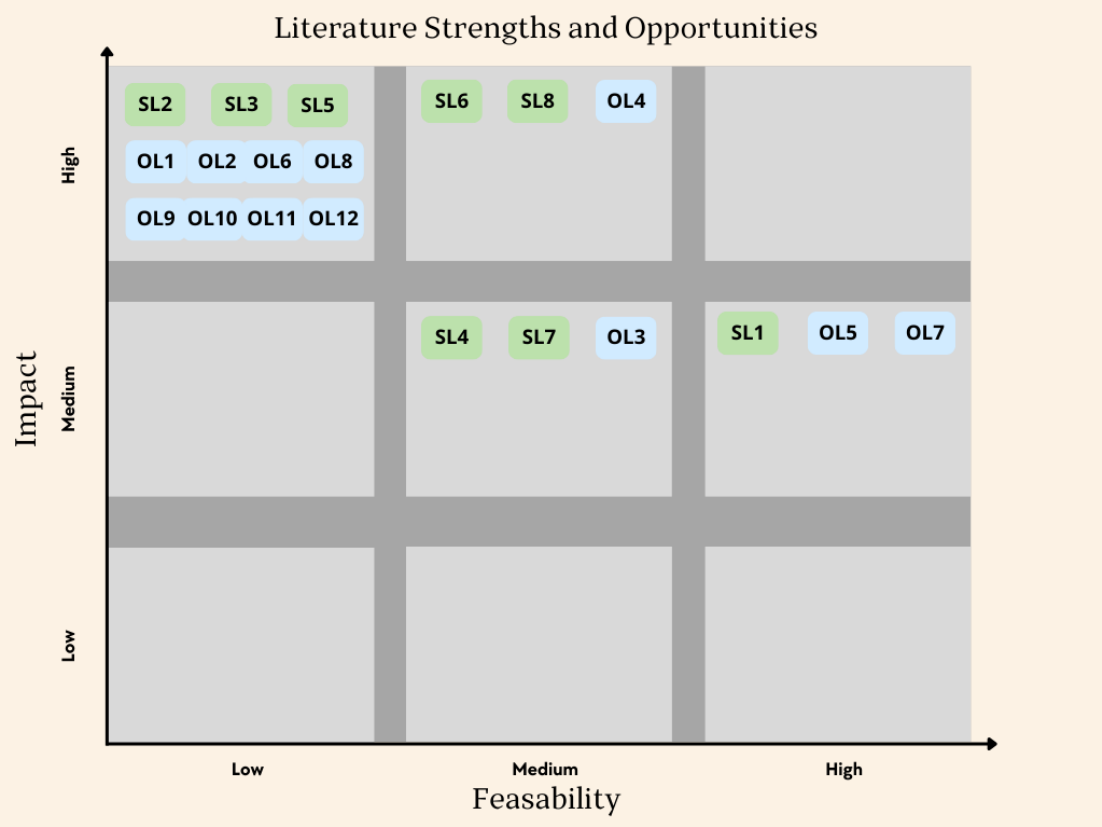

Figure 6.2.1 Strengths and opportunities assigned one of nine cells depending on their impact and feasibility.

6.2.2 Matrix weaknesses and threats from the literature

In Figure 6.2.2, it can be found that there is one element which should be prioritized at first, WL6 “Every stakeholder in a project needs to be on board for the technology to reach its full potential”. It can also be seen that most of the weaknesses and threats have a high impact if the strategy to mitigate them is successful. It also means if the strategies are not successful, they could have a significant negative impact. The high impact, low feasibility cell needs to be analyzed for every specific project to calculate the risk of these not being mitigated. In some projects all elements might not be relevant for example.

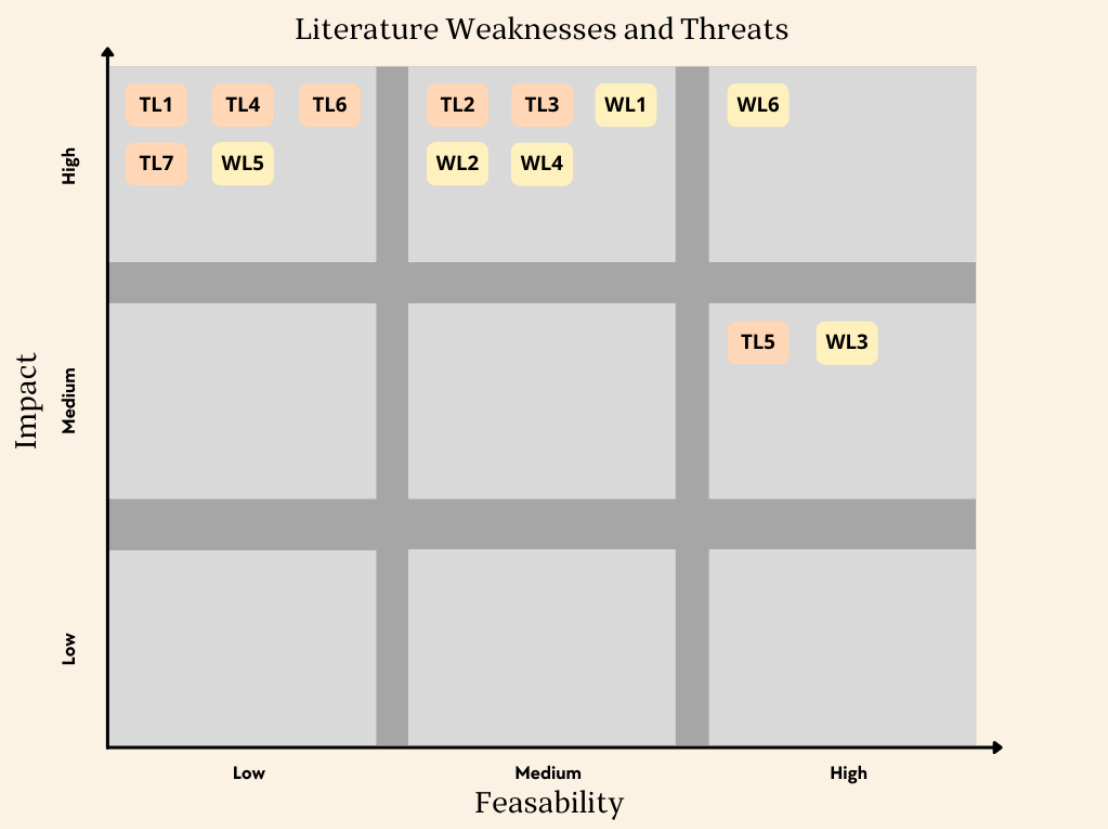

Figure 6.2.2 Weaknesses and threats assigned one of nine cells depending on their strategy’s impact and feasibility their strategy.

6.2.3 Matrix strengths and opportunities from the interviews

In Figure 6.2.3, it can be found that there are two elements, SI6 “No need for 30-day due date on payments” and SI8 “Better economic decision-making based on blockchain data” which is to be prioritized.

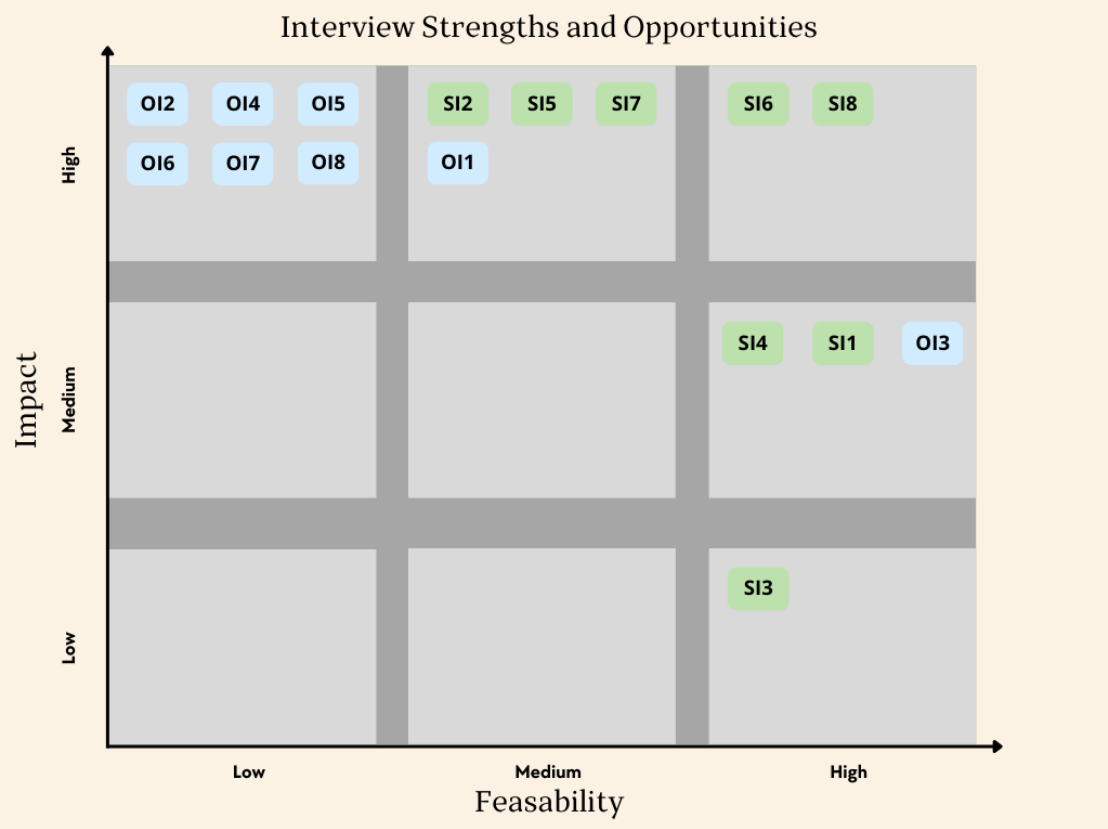

Figure 6.2.3 Strengths and opportunities assigned one of nine cells depending on their impact and feasibility.

6.2.4 Matrix weaknesses and threats from the interviews

By viewing Figure 6.2.4, the most feasible and impactful elements are WI2, WI4 and WI10. It can also be seen that most of the weaknesses and threats have a high impact if the strategy to mitigate them is successful. Most elements have been categorized with medium or high feasibility which is positive for mitigating the elements in the Swedish context.

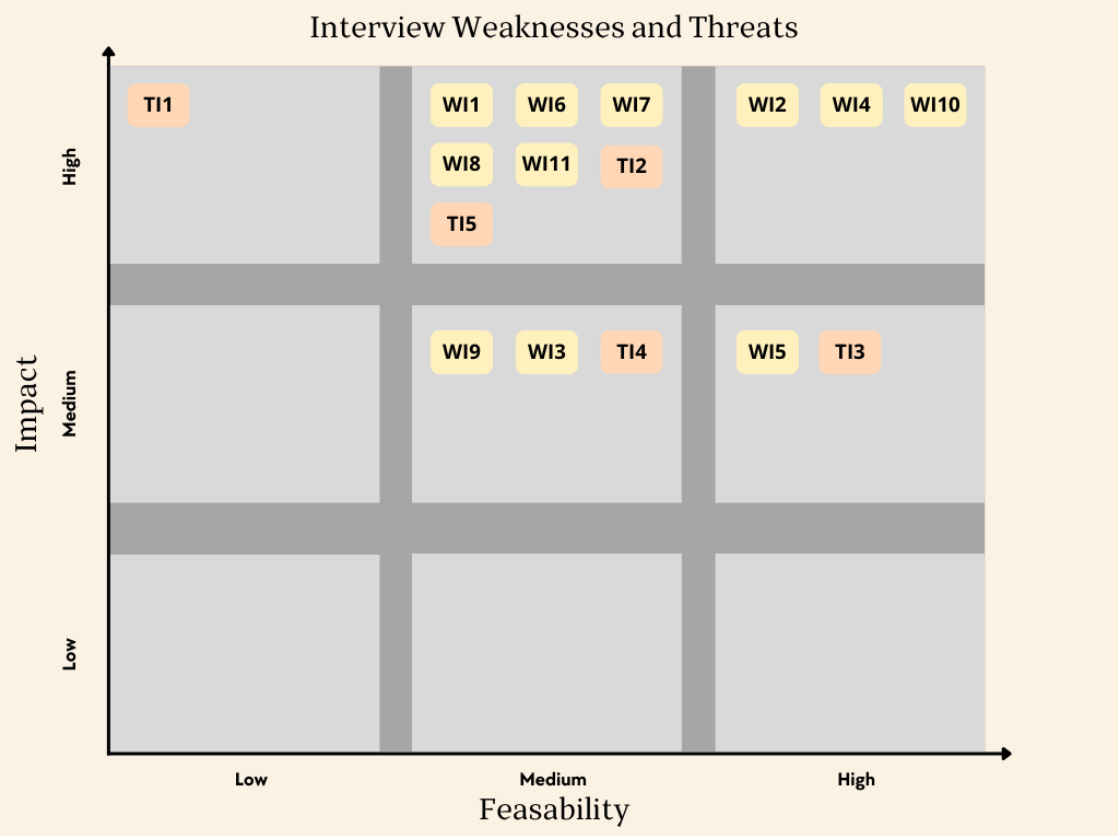

Figure 6.2.4 Weaknesses and threats assigned one of nine cells depending on their strategy's impact and feasibility their strategy.

6.3 Similarities and differences between the literature and interviews

The identification of similarities between the literature and interview responses underscores the universality of certain aspects of blockchain technology's application in the construction industry. These parallels suggest that foundational principles and successes of blockchain technology, as documented in the literature, are indeed observable and applicable in the real-world experiences of Swedish construction. When similarities are noted, it bolsters the argument that lessons learned from diverse geographical and sectoral settings have relevance and can be adapted to the Swedish context.

Conversely, the differences that emerge between the literature and the interview findings highlight the unique challenges and opportunities within the Swedish construction sector. Discrepancies may indicate that certain theoretical benefits or challenges of blockchain technology are not universally experienced or that the Swedish construction sector has specific characteristics that influence the adoption and impact of such technologies differently. However, due to the nature of a qualitative methodology, all aspect might not have been gathered.

6.3.1 Similarities and differences of the strengths and opportunities

In the analysis of strengths and opportunities related to the implementation of BCT in construction projects, both the literature and interviews highlight key benefits. However, from the high impact, high feasibility cell, the elements SI6 and SI8 are emphasized in interviews but not explicitly mirrored in the literature, which is shown in Figure 6.3.1, and explained in Table 6.3.1. These differences offer insights into the practical versus theoretical perspectives on BCT implementation.

Both sources underscore the transformative potential of BCT in construction, particularly in terms of streamlining processes and improving financial management. The overarching themes include enhanced efficiency, transparency, and the optimization of project workflows, all of which are core benefits that BCT is known to offer.

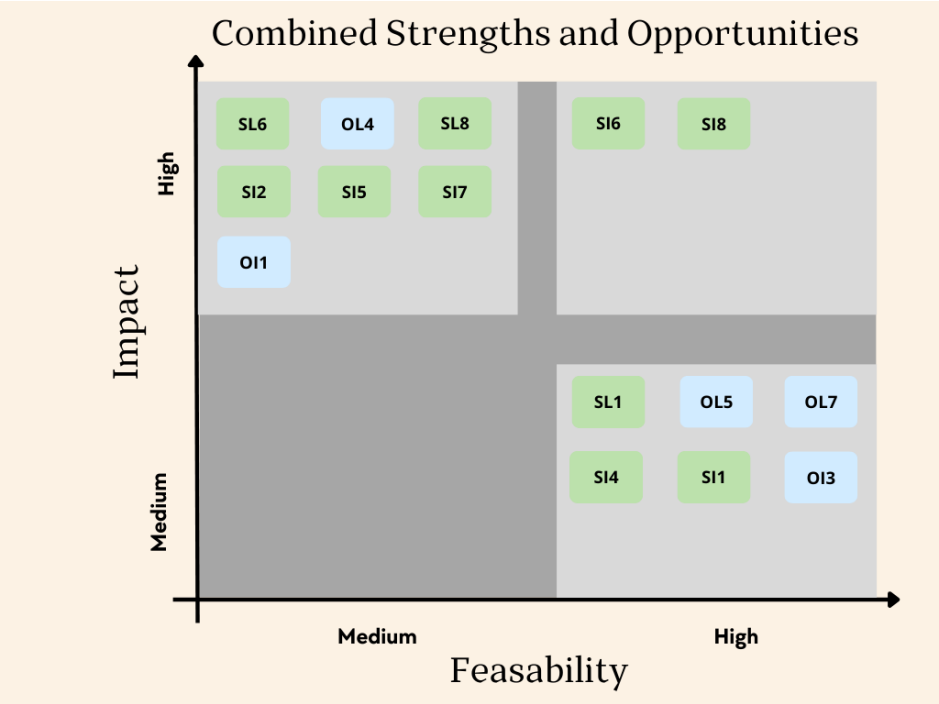

Figure 6.3.1 Combined literature, and interview matrix, only 3 of 9 cells included.

Table 6.3.1 Strengths from the high impact, high feasibility cell and the common strategy.

Major selling points, especially to subcontractors	
SI6	No need for 30-day due date on payments
SI8	Better economic decision-making based on blockchain data.

6.3.2 Similarities and differences of the weaknesses and threats

The similarities between the weaknesses identified in the matrix, shown is Figure 6.3.2, are both from the literature (WL6) and the interviews (WI2, WI4, WI10) that are described in Table 6.3.2 underscore a fundamental challenge in adopting BCT. The strategy common to these weaknesses involves making an early decision to implement BCT. This decision serves as a signal to potential collaborators about the project's innovative direction, acting as a beacon to attract the right people and companies who are ready and capable of working with this technology. This early commitment also sets the expectation that BCT will be a core component of the project, laying the groundwork for stakeholder acceptance and support from the outset.

Once the decision to implement BCT is made, education becomes a central pillar in addressing these weaknesses. Education efforts aim to increase social acceptance (WI2) and build the necessary digital competence (WI4) among all stakeholders. These efforts help mitigate resistance to change by enhancing understanding of BCT's benefits,

addressing misconceptions, and building a solid foundation of digital skills necessary for effective adoption.

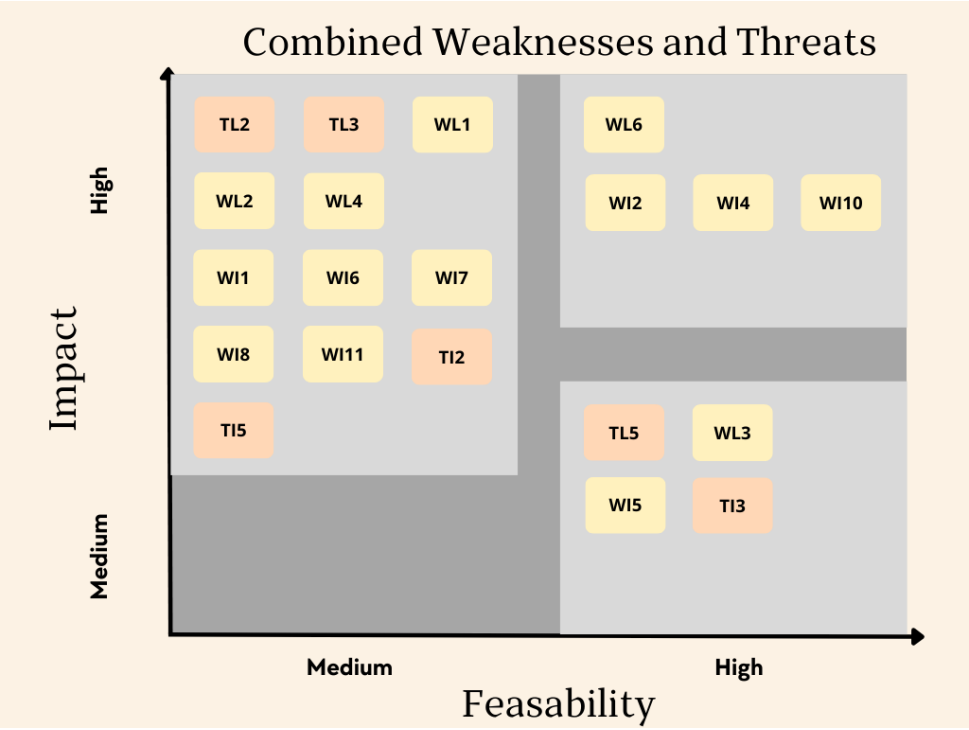

Figure 6.3.2 Combined literature, and interview matrix, only 3 of 9 cells included.

Table 6.3.2 Weaknesses from the high impact, high feasibility cell and the common strategy.

Decide before the project starts that this should be implemented to attract the right peoples and companies.	
WL6	Every stakeholder in a project needs to be on board for the technology to reach its full potential.
WI2	Lack of social acceptance and resistance to change among industry stakeholders.
WI4	Need for digital competence and infrastructure investment for effective adoption.
WI10	Every stakeholder in a project needs to be on board for the technology to reach its full potential.

7 Discussion

This chapter delves into the author's perspective on the potential evolution of automated payments and other applications of Blockchain Technology (BCT) in the coming years. These insights are synthesized from observations made during the project, rather than relying on external sources. It's important to note the author's conviction that blockchain will find its application within the construction industry due to its inherent potential; the timing of its adoption remains the primary question.

The comparison between the transformative impact of the internet on our lives and the potential of blockchain is frequently made by researchers and industry experts. The internet, initiated in the early 1970s, did not see widespread adoption until the 1990s, marking the beginning of the global internet era. This evolution continued with the advent of Web 2.0, characterized by the social media revolution, the ubiquity of mobile devices, enhanced internet speeds, and increased data storage capabilities. Blockchain as the foundation of Web 3.0, is representing the next significant leap in internet technology. The social acceptance of this technology is on a positive trajectory, as evidenced by the approval of a Bitcoin ETF as of January 2024.

BCT holds the promise of serving as the technical backbone for the financial system, aligning with the democratic ideals that the current financial system falls short of. Its implementation in the construction sector could address long-standing industry challenges, benefiting the global economy. Smaller entities stand to gain significantly from enforced payments upon job approval. The economic incentives presented by BCT are compelling enough to attract interest from most stakeholders. The current system, which averages 48 days to process payments post-job completion, contrasts starkly with the efficiency BCT could bring, reducing payment processing to a mere few days through Smart contracts, including site inspections by building controllers, attestations as well as the actual payment execution.

Beyond its immediate benefits, BCT offers numerous long-term incentives. It has the potential to streamline and secure operations on construction sites. For instance, access to a site could require a digital signature from a participant's wallet, offering a more secure and traceable method of entry compared to current systems, such as ID06, which can be tampered with.

BCT is poised to be an invaluable asset across the three pillars of sustainability: social, economic, and ecological. Socially, it aims to reduce disputes; economically, it seeks to enhance efficiency; and ecologically, it offers the potential for traceability of resources and products. In the current information-driven society, where data is a critical asset, the capacity of BCT to record transactions becomes an imperative for entities involved in information gathering, such as social media platforms and technological innovators like Tesla, which has been collecting data from its customers for autonomous driving research since the release of their first car.

The adoption of Blockchain Technology (BCT) is crucial for enabling subcontractors to enter secure contracts with the assurance of payment. However, it is possible to address the issue of late payments through alternative, more immediately implementable solutions that achieve similar outcomes. In that case without getting the full spectrum of benefits offered by BCT. While these alternatives might offer a partial

solution to the late payment issue, they do not leverage the wider benefits of BCT, which include not only reducing project costs without sacrificing quality but enhancing it. Moreover, BCT's full implementation supports sustainability objectives across various dimensions, beginning with economic sustainability. While alternative solutions can provide temporary relief from late payment issues, BCT presents a comprehensive package that not only resolves this challenge but also enhances project efficiency, quality, and sustainability.

8 Conclusion of the Applicability of Blockchain Technology for Subcontractors

This section digs into the proposed framework for the integration of BCT within the Swedish construction industry, addressing the critical issue of late payments to subcontractors. It critically examines the practicality, implications, and potential challenges of implementing this solution. It focuses on when the framework should be used, the project should adopt a Proof of Authority consensus mechanism with the building controller as the owner of authority nodes. The analysis aims to compare the technical potential with real-world constraints by evaluating how this approach could eliminate late payments. It also aims to provide a comprehensive understanding of the feasibility and impact of the system.

This thesis has contributed with a guide of what and where an automated Smart contract payment system should start with. The literature seams the value of transparency and traceability is one of the major impacts of Smart contracts in the construction industry whilst the interviews show the only this that Smart contracts can add value is if it saves you money or make you revenue stream faster.

The integration of blockchain-based Smart contracts into project management processes, specifically for automating payment disbursement at project milestones, can be effectively achieved by adopting strategies derived from the SWOT analysis. This involves a multifaceted approach: collaborating with legal bodies to ensure regulatory compliance and legal soundness of the contracts; recruiting highly skilled developers to create robust and error-free Smart contracts; and implementing comprehensive educational programs to prepare and acclimate the workforce to this technological change. The synergy of these strategies will facilitate a seamless and efficient integration of blockchain technology, thereby revolutionizing payment processes for subcontractors.

The adoption of blockchain-automated invoicing management is anticipated to have a profoundly positive impact on the financial processes within the Swedish construction industry. The analysis indicates significant benefits, such as timely payments and the elimination of traditional 30-day invoicing delays. This efficiency in payment processing is expected to enhance stakeholder collaboration, as it inherently reduces financial disputes and fosters a more cooperative project environment. In turn, this improved collaboration and streamlined financial process will contribute to overall project efficiency, marking a substantial advancement in the sector.

The necessity of implementing such a system hinge on the current challenges faced in the industry. In an ideal scenario without disputes and where collaboration is seamless, the urgency for this system might be lessened. However, this scenario is far from the prevailing reality in the construction sector. The high impact identified in most of the SWOT analysis underscores the potential success and benefits of this technology. If executed with the proposed strategies, blockchain-automated invoicing management could not only offer competitive advantages to early adopters but also establish a new industry standard. This technology is not just a tool for efficiency, it is a means to provide all stakeholders with enhanced terms and security, leading to a scenario where every participant emerges as a winner. The implementation, therefore, is not just beneficial but necessary to transform and elevate the construction industry's financial

dealings, setting a precedent for future advancements. Although BCT being in its initial stages, its potential to safeguard stakeholders within the construction sector from financial instability and delayed payments may fulfill a long-standing need. This emerging technology promises enhanced security and reliability in financial transactions, addressing critical industry concerns.

9 Future research topics

The integration of blockchain in construction raises significant security and privacy concerns, especially for subcontractors cautious about revealing sensitive data like suppliers and costs. The author considers the need for separate Common Data Environments (CDEs) for subcontractors to safeguard their sensitive information. The feasibility of encrypted transactions to adhere to GDPR and other privacy laws need to be addressed. Furthermore, the author proposes a software solution that permits stakeholders to selectively store information on the CDE and blockchain, thus balancing transparency with privacy. A suggestion is a Smart contract DApp where you can select what to be transparent and not, in the initializing of the main contract.

Another intriguing application of BCT is in the realm of self-regulatory compliance. By embedding self-control mechanisms into a Smart contract, there is an opportunity to track and verify site activities with high precision. The potential of BCT to log critical information such as who performed specific tasks, along with the timing and location of these activities. The challenge lies in developing a technological infrastructure capable of supporting real-time data capturing and validation within a blockchain network.

Blockchain technology could significantly enhance ÄTA (changes in work scope management) in construction projects by providing a transparent, immutable, and secure platform for documenting, verifying, and executing changes. By leveraging Smart contracts, blockchain can automate the approval and implementation of changes, ensuring that all parties are instantly updated and agreed upon modifications are enforced promptly. This could reduce disputes, streamline administrative processes, and ensure that all changes are recorded and traceable, leading to increased efficiency and trust among stakeholders in the construction process. Another research area is how a Smart contract could relate to the entire payment chain, from client to the last subcontractor and suppliers to have transparency to secure everyone’s payment.

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