CHALMERS
UNIVERSITY OF TECHNOLOGY

How the blockchain technology can enhance sustainability for contractors within the construction industry

Master's Thesis in the Master's Programme Supply Chain Management

JONAS JOHANSSON
CHRISTOFFER NILSSON

Department of Technology Management and Economics
Division of Service Management and Logistics
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2018
Report No. E 2018:057

MASTER'S THESIS E 2018:057

How the Blockchain technology can enhance sustainability for contractors within the construction industry

JONAS JOHANSSON

CHRISTOFFER NILSSON

Tutor, Chalmers: Gunnar Stefansson
Tutor, NCC AB: Christina Claeson-Jonsson

Department of Technology Management and Economics
Division of Service Management and Logistics
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2018

How the blockchain technology can enhance sustainability for contractors within the construction industry

JONAS JOHANSSON

CHRISTOFFER NILSSON

Master's Thesis E 2018:057

Department of Technology Management and Economics
Division of Service Management and Logistics
Chalmers University of Technology

SE-412 96 Gothenburg, Sweden
Telephone: + 46 (0)31-772 1000

Chalmers Reproservice
Gothenburg, Sweden 2018

Acknowledgements

This master thesis is within the master's programme Supply Chain Management at Chalmers University of Technology. It has been performed during the spring of 2018 in collaboration with the construction company NCC AB in Sweden. This process has involved several professionals, which has enabled the outcome of this thesis.

We would like to give a special thanks to NCC AB and our company supervisor, Christina Claeson-Jonsson. With her guidance, advises and engagement, she has supported us throughout the process which has contributed to the results of this thesis. We have, except knowledge regarding the construction industry and the blockchain technology, also gained other valuable knowledge in approaching issues methodologically in a successful way.

We also would like to sincerely thank all professionals and organizations that has contributed to this thesis through interviews. You have provided us with perspectives and knowledge beyond the literature, which aided in a better understanding. This has been very educational and interesting for us, both for the thesis as well as personally. Thank you for your time.

Lastly, we would like to thank Gunnar Stefansson, our supervisor at Chalmers who has supported us through the academical process of this thesis. He has provided us with very valuable advices and has asked the right questions that has guided us in our thesis beyond the academical.

Chalmers University of Technology
Gothenburg 2018-05-30

Jonas Johansson

Christoffer Nilsson

Abstract

Today, sustainability is considered as a high priority and it is on the management agenda for major corporations. It has experienced an increase in customer demand, pressuring corporations to act in a more sustainable way to stay relevant and competitive. One industry that is experiencing an increased request to act sustainable is the construction industry. The construction industry differs quite a lot from other industries since it is project based and built on temporary relationships. Subcontractors are temporarily engaged in the projects, often by a main contractor, to perform tasks which they are specialized in. The subcontractors additionally engage their own respective subcontractors. This makes it harder to control and ensure that all involved actors are acting in a sustainable way due to the multiple tiers of contractors and complex nature of the projects.

A technology that recently has gotten a lot of attention is the blockchain technology. It can be described as a shared, distributed ledger technology, which was created as an enabler for the cryptocurrency Bitcoin. The technology has, in the recent years, been widely discussed as a potential business enhancer. It can for example provide immutable record-keeping; enables the usage of smart contracts; and enhance transparency within the network. The blockchain technology has the potential to disrupt current business practices and decrease the required amounts of trust needed in business relationships.

Because of the increasing demand of sustainability practice within the construction industry, technologies that can enhance it becomes of interest for further investigation. Therefore, this thesis has been investigating if the blockchain technology can enhance sustainability for contractors within the construction industry. To achieve the purpose, data has been gathered from literature, interviews as well as benchmarking of existing blockchain solutions in business. The empirical gatherings resulted in identifying seven issues related to sustainability within the construction industry, and relevant information regarding blockchain that is not mentioned in the literature. The issues found in the empirical data were analysed by a framework which consist of three blocks. The first one concerns whether the issues found are within the scope of sustainability. The second block concludes, using a proposed blockchain decision tree, if the issues have a potential blockchain solution. The final block is a SWOT analysis, where the blockchain solution for each issue is evaluated in isolation.

The issues of non-sustainable material used by the contractor, undeclared work, accidents, employee payment and limited contractor base where concluded to potentially be prevented, or mitigated, with a blockchain solution. It is, however, still a immature technology that needs to be further developed and understood in order to bring out its true potential. Several of these issues can be prevented, or mitigated, by the same kind of blockchain setup, which makes it to a more profitable alternative than separately evaluating them.

Key words: Blockchain, Sustainability, Construction Industry, Contractors

Table of content

List of Figures

List of Tables

1. Introduction

Sustainability has experienced an increased importance for business practices in recent years. Van Weele (2014) states that international corporations see it as a high priority on the management agenda today. Sustainability is often understood as environmental aspects, but it also includes the social and economic aspects of the corporation (Elkington, 1998). Sustainability is becoming a customer requirement, pressuring corporations to further consider it. It has, however, often a positive effect on the profit as well since it often becomes more efficient in its use of resources (EU, 2011). Thus, practicing CSR, Corporate Social Responsibility, can make companies more sustainable and at the same time become more profitable.

The construction industry experiencing an increasing sustainability awareness within their projects. This includes both materials that have less impact on the environment which are fair produced, as well as labour conditions and other social aspects during actual construction (Presley & Meade, 2010). The main contractor is the actor who has overall responsibility for construction, thus placing them in a position where they are the ones responsible for realizing the sustainability demands. The main contractor has the coordinating role in construction projects as well performing tasks during construction. However, it is highly unusual that they possess all the skills required for the entire project, which why they engage subcontractors. The subcontractors themselves also engage subcontractors to support their operations. This creates a complex chain of several tiers of subcontractors within the construction project where the monitoring and control of actors is a challenging and resource demanding task (Sears et al., 2015).

New technologies that have emerged throughout time have changed the world, how to run businesses and the way we live our lives. Equal to what the electricity did for the society at that time, the network-based digitalization is the driving force today for both businesses and private lives (Vogelsang, 2010). One technology that is widely discussed as a potential enhancer of business and everyday life is the blockchain technology. Blockchain is today most associated with cryptocurrencies, especially Bitcoin. As stated by Gupta (2017), the technology was created as an enabler for Bitcoin, and has had its biggest area of usage within cryptocurrencies so far. The technology has, however, been discussed as to have beneficial features for other business practices as well.

The blockchain technology can be explained as a shared, distributed ledger technology, that records transactions that are made within a network (Gupta, 2017). The ledger is held by the nodes within the network, which are peer to peer replicated against each other. Peer to peer replication can be described as a continuous synchronization against all nodes within the network, at all times. This enables the use of a consensus-based model, where the true version of the ledger lies in the majority of the network members, compared to today where the ledger is often held by a central authority that is trusted to hold the ledger at a true state (Dhillon et al., 2017). This is referred to as the trust-based model. The blockchain technology enables transactions to be recorded and stored in an immutable way (Morabito, 2017). The main purpose with the blockchain technology, since it was developed as an enabler for the cryptocurrency bitcoin, is to move the governance of the system from a central party to the

distributed mass. This creates an assurance of a true ledger, since the majority of the network otherwise need to coordinate a manipulation of the same record at the same time to make it pass through unnoticeable (Gupta, 2017). Even though the blockchain technology was created as an enabler for Bitcoin, it has been widely discussed to be a technology that can be used in a business context.

The blockchain setup can be designed so all actors within the network are visible to each other. This can enhance the transparency in the business network which enables the business relationships to not only rely on trust. The blockchain technology can substitute this trust thanks to the immutability and visibility it provides, giving the actors the opportunity to trace the information (Dhillon et al., 2017). These characteristics of the blockchain technology may be potential to enable a more sustainable environment for all actors within the network. Since there is a general demand within the construction industry to actively work towards a more fair and sustainable industry. This thesis was initiated by, and made in collaboration with, NCC AB. NCC AB is one of the major Swedish main contractors within the construction industry. They are interested in finding out how the blockchain technology can contribute to enhance the sustainability for contractors within the construction industry. This is why it is an area of interest for further investigation.

1.1 Purpose

The purpose of this thesis is to investigate how the blockchain technology can enhance sustainability for the contractors within the construction industry. To achieve this, the blockchain technology will be investigated regarding its potential in business, to identify transferable solutions to sustainability issues. General characteristics and sustainability issues of the construction industry need to be identified to evaluate the potential of the blockchain technology to this specific context. This thesis will result in outlining how the blockchain technology as a mean can facilitate a more sustainable environment for contractors within the construction industry.

1.2 Research Questions

To fulfil the purpose of this thesis, it has been broken down into four main research questions that need to be answered to achieve this.

As stated by Gupta (2017), the blockchain technology has recently become a buzzword that is spoken to change the need for trust. Even though the technology was created in 2008, as an enabler for Bitcoin, it did not become a hype until several years later. The blockchain technology can be seen as an operative system where cryptocurrencies are just one application of this technology, and is stated to be useful in many different industries. The technology could have a positive effect of several things, e.g. enhance trust, traceability and transparency. To find out the potentials of this technology, the first research question is as follows:

- *RQ1: What is the blockchain technology and how can it potentially be used in business?*

The construction industry differs from many other sectors due to its project-based characteristics. The industry is very fragmented and is built upon temporary relations with suppliers and subcontractors where cost is the main driver (Benton & McHenry, 2010). To achieve the purpose of this thesis, the general characteristics of the industry needed to be investigated before any further actions could be pursued. In accordance to this, the second research question is:

- *RQ2: What are the main characteristics of the construction industry?*

Since the construction industry is quite differentiated in regard to other industries, the actors within it face different challenges. The purpose of this thesis relates to understand what issues in regard to sustainability that the industry is experiencing, and how these issues can potentially be mitigated, or solved, by facilitation of the blockchain technology. To achieve this, the issues within the industry need to be identified and categorized as sustainability related issues. In accordance to this, the third research question is:

- *RQ3: What issues related to sustainability are experienced within the construction industry?*

The blockchain technology has, by its characteristics, been proven to be beneficial for several business areas in different contexts. The blockchain technology is said to do the same for business transactions as the internet did for communication (Gupta, 2017). The construction industry is today associated with being an industry that is lagging behind and arm's length relationships (Bygballe & Ingemansson, 2014). Because of this and the increased focus on sustainability mentioned by Presley and Meade (2010), the actors within the construction industry need a more trustworthy, safe and transparent environment to facilitate better relations among actors, which can result in improved performance. The purpose of this thesis is to investigate how the blockchain technology can facilitate in preventing sustainability related issues for contractors, which leads to the fourth and last research question:

- *RQ4: How can the blockchain technology facilitate in preventing, or mitigating, sustainability related issues for the contractors within the construction industry?*

Since the first and second research question are independent on each other, they could be studied in parallel. The third research question is dependent on the data collected from the second research question, hence the third research question could not be started until the results from the second were brought to light. The third research question is studied as an analysis, in combination with the fourth research question. The fourth research question combines the information from both the first and the third research question, thus it requires the information from all. The connections between the four research questions is visualized in figure 1-1.

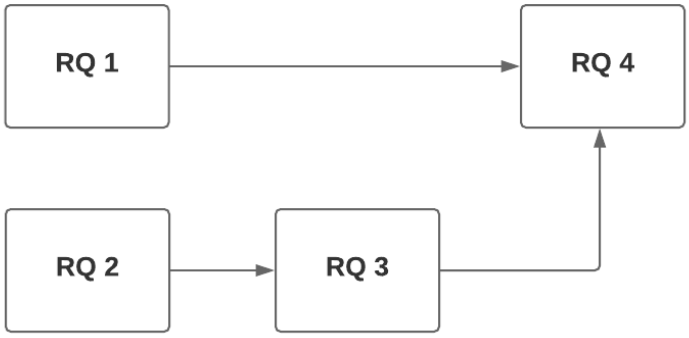

Figure 1-1. The Connections Between the Research Questions.

1.3 Delimitations

The focus will mainly lie on what impact that the blockchain technology potentially could have on business associated with construction. There are other areas of business within the construction sector e.g. investments and development of facilities, which will not be covered in this thesis. This is partly because of time limitations, but rather that the big changes will most likely occur within the construction business. As the construction industry characteristics differentiate themselves depending on both legal aspects as well as how business is done, this thesis will have a sole focus on the Swedish market. It will focus on issues related to sustainability that appears among contractors, from a main contractor perspective, within the construction industry, i.e. material supplier or similar will not be directly treated in this thesis, rather indirectly since they supply the contractors with materials. This is because the contractor issues are not as tangible as the material issues are, which is why NCC wants this thesis to have this focus. This thesis will not cover the technical aspects of the blockchain technology, rather it will have a focus on how blockchain potentially can mitigate or prevent the sustainability issues for contractors. Because of the recent hype and its limited number of existing real use cases in business context so far, this thesis will be seen as a pre-study. Hence, the thesis will not cover the actual implementation, requirements and other practical aspects.

2. Method

This chapter will cover how the Master thesis was conducted. The selected strategy and the chosen approach for the data collection will be presented.

2.1 Research Strategy

Bryman and Bell (2015) states that there are two types of research strategies, Qualitative and Quantitative research. A distinction that is often being made between these two are that qualitative research uses words rather than numbers, as quantitative does. Meaning that qualitative data collects information that needs to be interpreted when analysing it, while quantitative data collects data that is of a measurable state.

The purpose of this thesis relates to outlining whether the blockchain technology can enhance sustainability for contractors within the construction industry. Thus, the data that has been collected in this study needed to be of an interpretative character, thus the report adopts a qualitative research strategy.

2.2 Research Design and Method

In the early stage of the project, the areas of investigation were not precisely defined. In most cases, the purpose of a master thesis aims to identify a certain problem which is then solved by the students. Contrarily, this thesis attempts to foresee how a technology will impact a certain industry in the future. This means that there was an uncertainty regarding scope and what areas to investigate, both for the students as well as for NCC. There has, however, been mainly two ways of gathering data for this thesis, namely literature as well as empirical gatherings in forms of interviews and benchmarking. The theoretical areas of blockchain and the construction sector were studied before the final aim and scope was decided since they were associated with literature studies and collecting of general information. These were necessary regardless of the final area of investigation. The processes and areas of the main contractor were investigated in order to understand what was most affected by the technology, which were the ones selected as focus of the study. With a lack of defined purpose, the method for answering the next following research questions could not be decided during the initial weeks. All parts involved in this master thesis agreed to proceed under these conditions. Even though it was not clear what areas to study, the method related to how to collect the data could still be determined. After gaining knowledge about blockchain and the construction industry from literature studies and discussions between the students and the company, a final purpose was then decided. The final purpose was to focus on how the blockchain technology can prevent, or mitigate, issues related to sustainability for contractors within the construction industry.

The findings from the first and second research questions laid the foundation for the analysis, as well as for the interview templates and general understanding of the issues. The third research question was to gain general understanding as well as to identify issues within the industry. The fourth research question was answered by combining the findings from the previous ones. To do so, all data needed to be analysed in a structured and consistent way, so a framework were established to do this, as can be seen in chapter 5. *Establishing of*

Framework. The framework allowed for all identified issues from the construction industry that were brought to light during the empirical findings to be categorized. This resulted in that the issues outside the area of sustainability were eliminated from the process directly. Then, a decision tree was developed aiming to consistently and structurally discover what issues that have a potential blockchain solution. The framework then further investigates the issues that has a potential blockchain solution through a SWOT analysis. SWOT was chosen due to the coverage of relevant aspects it provides and the consistency. The SWOT analysis tool evaluates both internal and external aspects of the subject at hand, which was required in order to provide an objective and full picture view of the subject. This resulted in that the authors could establish a foundation of how the blockchain technology may solve the issue at hand, compared to today's solutions.

In order to gather the data required to perform a well thesis, different sources of information and approaches needed to be used. The two sources of information that were used were literature studies and interviews, with different methods, as described in the subchapters below.

2.2.1 Literature

The literature searches were made mainly dedicated to three topics, blockchain, the construction industry, and sustainability. The literature searches were made in a structured and consistent way in order to cover as large portions of the existing literature. Search strings with different combinations were set up so that as much literature could be covered in a structured way. After that, the results from each search string were skimmed through, and the relevant literature was selected. The relevant literature was then more closely analysed as to identify if any significance to the thesis. The literature that had a significance was saved and then processed. Both the first and second research questions are based and/or have their foundation in literature.

The first research question relates to what blockchain is and how it can influence businesses in general. This question has been treated mainly with two sources of data. The first is a literature study of the area of blockchain in general to grasp the key characteristics of the technology. Then searches for how it has been used in business and what its main implications have been made. The literature search also laid the foundation for the interview templates that later were used when interviewing the researcher and the consultant-interviewee.

The second research question concerns the main characteristics of the construction industry today. Information was gathered from literature to gain a general understanding of how the industry is structured, e.g. what actors involved, the characteristics of the construction supply chain, the construction process etc. These are all explained with the reason to provide an understanding of the industry in general and what characterizes it. Later, based on the literature finding, interview templates were developed with the foundation within the literature.

2.2.2 Interviews

During this thesis, several interviews were held with different stakeholders and professionals. The interviews that were made were a combination of both exploratory and benchmarking, which were semi-structured and unstructured. The interviews were held within the topics of the construction industry characteristics and issues; CSR within the construction industry; and blockchain. Information regarding the interviewees can be found in Table 2-1. Interview templates were used for the semi-structured interviews, which can be found in Appendix A.

The interviewees in this thesis were carefully selected and considered in order to receive correct information within the subject. In the interviews with NCC, the authors were very keen on getting perspectives from several, qualified directions. Therefore, several roles within the company were contacted and interviewed. The chosen interviewees were all experienced within the topic of the interview. The person responsible for the process development at a strategic level for the NCC group purchasing was interviewed to gain this person's view of what the market generally looks like and what issues that are generally experienced. This person is hereby referred by as the PPM in this thesis. As this person's perspective is very valuable to gain trustworthiness, additional professionals were interviewed to broaden the perspective. One purchasing manager from one of the business areas was interviewed in order to get a complete picture of the process. The interviewee has worked with purchasing a long time and hold solid experience within the topic. The interviewee works operatively which provides a complete perspective, both from a strategic point of view as well as the operative one. This person is referred to as PM. However, in order to even further complement these, a contractual engineer that is physically present at construction sites, working closely with subcontractors was interviewed. This person is hereby referred to as the CE. To broaden the perspective even further, a project manager for a construction site was interviewed. A site manager is heavily involved in the decisions regarding subcontractors. This person holds the experience of the actual cooperation and contracting with the subcontractors within the projects. This person is referred to PRM later.

Since the focus of the thesis is related to the area of CSR, the CSR manager for NCC was contacted in order to gain her perspective on how the industry is regarding CSR, what issues that are experienced and how they are prevented or mitigated today. This person is referred to as the CSRM in this thesis. The person has a very strategic overview of the area, so it was complemented with a environmental specialist working operatively with CSR related to materials within NCC. In this study, this person is referred as the ES. These interviewees complemented each other by having different perspectives and thoughts on the matter. To even further complement these, an independent industry organization, Sveriges Byggindustrier, was contacted where several persons specialized within sustainability, environment and safety/health were interviewed. Later, these are referred as Sveriges Byggindustrier. During these interviews, an industry solution of identification called ID06 was brought to light. Since this is highly relevant for the thesis, the ID06-responsible who is working at the HR department at NCC was contacted. An interview was performed regarding the solution, its strengths, weaknesses and upcoming versions of it. In this thesis, the person is referred as HRS.

The interview regarding the blockchain technology, its potential and potential areas of usage were made mainly in two ways, exploratory interviews and benchmarking interviews. As there is no standardized definition of the blockchain technology, the authors wanted to get perspectives from different areas. A researcher within the topic of blockchain from RISE, a large research institution in Sweden was interviewed. The purpose was to gain knowledge of the technology and to get the researchers view on how it can be put into practice. This person is referred to as the Researcher. After that, an interview with IBM was held. The consultant has a solid experience within blockchain and brought another perspective than the researcher did, since they define the technology differently. The person from IBM is referred to as the IBM. Benchmarking interviews were made with both the Swedish tax authority, Skatteverket, and the Swedish land registry, Lantmäteriet, since both organisations are currently investigating how the blockchain technology might be used in their respective business. Both interviewees from these organisations have key roles in their respective blockchain projects. These interviews aimed to gain knowledge on how these organizations want to draw advantage from the blockchain technology, the effects of it and how it will be done. Since this technology has no fixed definition, it was clear to the authors to have this in mind at all time during these interviews, since the different interviewees have differentiated perception. In this thesis, these two interviewees are simply referred as Skatteverket and Lantmäteriet.

Table 2-1. Interviewee Information.

Title	Referred to as	Company/Function	Responsibility
Purchasing Process Manager	PPM	NCC, Purchasing	Working with process development at Group-level
Purchasing Manager	PM	NCC, Purchasing	Manager for the project-related purchasing
Contractual Engineer	CE	NCC, Construction	Located at the construction site. Working with the economy and contracts related to the project
Project Manager	PRM	NCC, Construction	Manager for the operations at the construction site
CSR Manager	CSRM	NCC, Sustainability	Head responsible for group's sustainability strategy
Environmental Specialist	ES	NCC, Sustainability	Develop and perform environmental classification
HR Specialist	HRS	NCC, HR	Responsible for ID06 at NCC
Researcher	Researcher	RISE Victoria, Digital Innovation	Senior researcher within Digital Innovation
Salesman	IBM	IBM, Software	Sales within cloud-services and emerging technolgies
Digital Strategist	Skatteverket	Skatteverket, Strategy development	Working with digital strategy development
Chief Digital Officier	Lantmäteriet	Lantmäteriet, Strategy development	Head responsible for the digital development
Working Environment Specialist	Sveriges Byggindustrier	Sveriges Byggindustrier, Working Environment	Expert on working environment issues
Environmental Specialist	Sveriges Byggindustrier	Sveriges Byggindustrier, Environment	Expert on environmetnal issues

The data gathered from these interviews was used to complement the results of the first and second research question, as well as to provide information for the third and fourth research questions that were later answered in the analysis.

The interviews regarding the blockchain technology and its potential were all semi structured. As stated by Bryman and Bell (2015), semi-structured interviews allow for follow-up questions and relevant information that otherwise would not have been presented might be brought to light. This gave the authors an opportunity to discover aspects that otherwise would not have been considered.

The initial interviews regarding the second research question, concerning the characteristics of the construction industry, were made in a unstructured way. As described by Bryman and Bell (2015), unstructured interviews are more of a conversation rather than a formal interview. The thesis was at early stage so informal conversations were to prefer due to the

unfamiliarity of the industry, both as a good introduction and in order get to know each other. When the focus of the thesis was established, additional interviews were held related to what issues in general that are experienced within the construction industry, which was semi-structured. They were semi-structured in order to get more concrete information, but also to allow for information to reveal itself that otherwise would not have been discovered.

As the third research question relates to what sustainability issues that are experienced within the construction industry, interviews with several stakeholders were held. These interviews were often combined with answering the second research question, to be efficient and avoid waste of the interviewees' time and resources. To not mislead the interviewees with their perspective of sustainability, they were asked to mention all issues they could think of, regardless of sustainability. This was made to avoid that issues are not brought to light due to different views on sustainability. The issues identified during the interviews later had to be analysed to conclude if they fit into the sustainability framework or not. So, by that, the questions aimed to bring as much information as possible to light, that later could be sorted out.

The fourth research question aims to answer how the blockchain technology can prevent, or mitigate, the issues related to sustainability for contractors within the construction industry. This question was answered through several approached. Benchmarking other industries was made through interviews and literature searches, to investigate if these solutions would be applicable in the context that is covered within this thesis. Semi-structured interviews with industry professionals such as consultants and other stakeholders were held. The interviews had the purpose of bringing perspectives to the literature foundation the knowledge was built on, mostly because the definition of blockchain is not standardized and that it and that it can be used for different purposes, but also to find inspiration of what a blockchain solution within the construction industry might look like.

2.3 Ethics

Since this thesis include interviews with different persons representing organizations, it is of great importance to act in an ethical way. As stated by Bryman and Bell (2015), ethical involves four principles, which are: *harm to participants; lack of informed consent; invasion of privacy* and *deception*. Harm to participants refers to that people that the researchers been in contact with during the work has not been exposed to any physical harm in any way, stress, or other bad experiences. The research includes interviews with several people and organizations, where everybody has been treated with respect and been well informed that they are not obligated to answer or do anything they are not comfortable with. All interviews have been decided to be held anonymous to protect the interviewees from conflicts from their respective organizations.

Lack of informed consent refers to provide the participants of the research with information enough for them to make an accurate decision whether they want to participate or not (Bryman & Bell, 2015). It was very clearly stated to all participants before the interviews took place. No one in this study has been interviews or observed without their consent in advance.

During a study, the researcher should not invade the privacy of the participants. The level of needed privacy may vary among people so all individuals must be threatened in a careful way (Bryman & Bell, 2015). The questions in this thesis were shaped in the way so it was not perceived as offensive. All participants were also given the possibility to not answering question that they thought were too sensitive for them personally.

Deception refers to when the researcher is not being honest in regard to the purpose of the research (Bryman & Bell, 2015). The participants should be provided with correct information about the purpose without any hidden agenda. Therefore, all participants were well informed about the real purpose of the thesis initiators and no exploitation of people's good faith has been made. An example of deception could have been that we were only stating that we are student in order to get an interview with a competitor or similar, something we clearly did not do.

2.4 Trustworthiness

The trustworthiness of a thesis is highly important and need to be considered throughout the entire process. There are several aspects that need to be considered. As stated by Bryman and Bell (2015), there are four criteria that need to be met for a qualitative research paper to be trustworthy: *Credibility, Transferability, Dependability* and *Confirmability.* Credibility refers to what degree a study has been carried out with the right practices. This is especially important when there are several social realities, i.e. not one absolute truth. In order to enhance the credibility of this thesis, experienced professionals have been interviewed in the gathering of empirical data, as can be seen in table 2-1. Relevant and qualifying professionals were interviewed within their respective field of expertise to get as accurate data as possible. Professionals with similar positions were interviewed in cases where it was possible to do so, with the purpose of getting several perspectives within the same area.

Transferability refers to the universality of the thesis. Bryman and Bell (2015) mention that qualitative research has more depth than width and is often dependent on contextual factors explaining the results that may only be applicable to a certain situation. As this thesis investigates how sustainability can be enhanced by the facilitation of the blockchain technology for contractors within the construction industry, it is quite based on contextual factors. However, a lot of the potential solutions and features with the blockchain technology have universal value for other contexts. Also, a decision tree for when a blockchain solution is viable has been developed, which is of a universal character.

Dependability addresses that the results drawn from the data gathered is logically made. Bryman and Bell (2015) states that the researchers should adopt an auditing during the work. Records of problem formulation, selection of participants, notes, transcriptions etc. should be stored in order for the auditor to trace back the conclusions. In this thesis, all literature is carefully referred to, the interviews are transcribed and have been held with professionals regarding their respective field, to be as accurate as possible.

Confirmability refers to that the researcher should act in good faith and be as objective as possible. The researcher should not be influenced by personal values or similar that would alter the results (Bryman & Bell, 2015). The authors of this thesis have no personal connection to the subject at hand, and can therefore ensure the objectively when conducting

it. To further ensure this, all materials gathered during the work has been carefully stored for auditing purposes.

3. Literature Framework

The purpose of this thesis is to investigate if the blockchain technology can facilitate in enhancing sustainability for contractors within the construction industry. Literature regarding blockchain, sustainability and the construction industry needed to be studied to achieve this. All literature studied in this thesis lay the foundation to keep building on. It also aims to provide the reader with an understanding of the characteristics and features of the different areas of literature. The chapter starts with studying the area of blockchain which aims to lay the foundation for the report and to provide an understanding of the area. After that, a section regarding sustainability is presented, where it is defined and outlined what is included within the term. Lastly, a section regarding the construction industry is presented. This section aims to define the different actor roles within the industry; identify the characteristics of the construction supply chain; define the different project delivery systems and describe the process of a construction project.

3.1 Blockchain Technology

According to Gupta (2017), the technology of blockchain came to life when the unknown person or persons, who went under the pseudonym Satoshi Nakamoto, invented the first digital cash system, Bitcoin. Bitcoin was developed in 2009 with the purpose of addressing the vulnerabilities, inefficiencies and costs of transactions of regular banking. Nakamoto states in his/her white paper “Bitcoin: A Peer-to-Peer Electronic cash system”, that the need for a financial institution to serve as a third party that is trusted works for some transactions. The current system has a great weakness and that is the trust based model it is built on. Bitcoin as well as other cryptocurrencies eliminates the need for trust in a third party, in this case a bank. However, it is the underlying technology, blockchain, that enables this consensus based model.

The technology has also been proven to be very useful for other applications because of its features. The following sub-chapter will explain the technology more in-depth in terms of what it is, how it works, types of blockchains, blockchain in business and limitations.

3.1.1 What is Blockchain Technology

Blockchain is a shared, distributed ledger that records transactions within a network. The blockchain technology is built on ledgers distributed over several nodes (participants) within the network, which are peer-to-peer replicated (Gupta, 2017). The peer-to-peer replication can be explained as every node is acting as both publisher and subscriber to the transactions made within the network. They receive and send transactions to others, where the information is synchronized with all nodes in the specific network. This method eliminates the need for a trusted third party for transactions, e.g. a financial institution. Instead, the massive distributed network where the validity of a transaction is agreed upon by all nodes are providing immutable records. Blockchain is using a consensus based model to ensure validity, meaning that all nodes must agree upon the transaction. Since the data within the network is distributed to all nodes and that peer-to-peer replication prevents tampering of data, the distributed network requires no central governing organ to be the trusted party since the independent nodes creates a consensus (Dhillon et al., 2017).

3.1.2 How the Blockchain Technology Works

Laurence (2017) describes that the blockchain is made up of blocks that contain a number of transactions made, which are then linked (chained) together through cryptographic, forming the blockchain. Blockchains consist of three main parts: blocks, chain and network. The block is where all the transactions are recorded to a ledger during a given period. Depending on the objective of the blockchain, the size, period and triggering events for every block is determined, i.e. it is not the same for all blockchains. The blocks are replicated over the entire network to create the validity and consensus as intended. The chains are blocks that are linked together, creating the blockchain. The glue that links the blocks together are cryptographic hash functions, which can be explained as the fingerprint of the data from the previous block that it “chains” itself to, which is referred to as parent block. This process is referred to as game theory since the full nodes compete against each other to find the correct hash function and collect the reward, which usually is a token of a cryptocurrency.

Laurence (2017) further states that when the correct hash function is found, the block is then locked to the previous block in the chronological order and is time stamped by the hash created. The network is maintained by all nodes within the network. Laurence (2017) refers to the nodes that hold the ledgers as full nodes. Each of these nodes hold a complete record of all transactions made within the blockchain which creates the consensus the network is built upon. The full nodes secure the network since they generate the cryptographic codes that chains the blocks together, and that they hold the ledger that create the peer-to-peer replication within the network. Within the cryptocurrency world, the full nodes are referred to as miners. These nodes are decentralized and operates all over the world. Anyone can operate a full node, and is rewarded for it because of the difficulty and expensiveness of running it. The reward depends on the network but is usually in forms of cryptocurrencies or a token. This process of a transaction may look like as it is illustrated in figure 3-1.

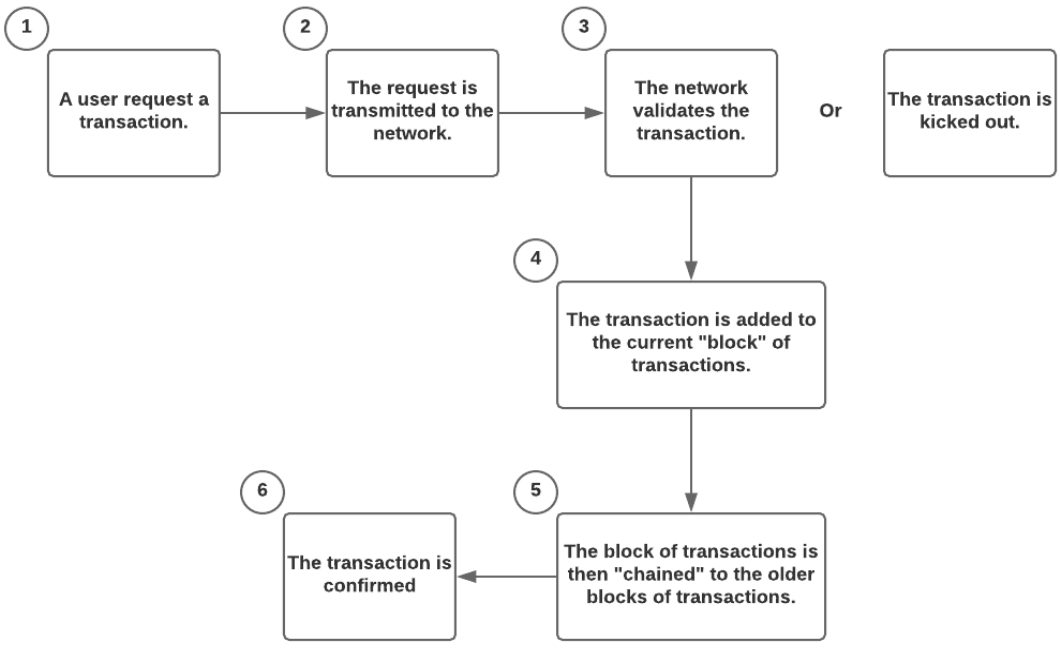

Figure 3-1. The Process of a Transaction in the Blockchain, Adapted from Laurence (2017).

Figure 3-2 illustrates the components of a blockchain in a simplified way, adapted from Morabito (2017). The nodes illustrated are full nodes that holds the ledger i.e. the blockchain. This ledger is distributed over all full nodes in the network is replicated against the other full nodes that create the consensus. A block within the blockchain consists of all transactions made within the network during the given period, before the block is chained and a new block is created. Each transaction holds the information regarding the sender, the receiver, and what the transaction consists of. This transaction data is encrypted, preventing the network from decipher the information even though it is visible. This provides an anonymity for the nodes as it at the same time makes the transaction verifiable.

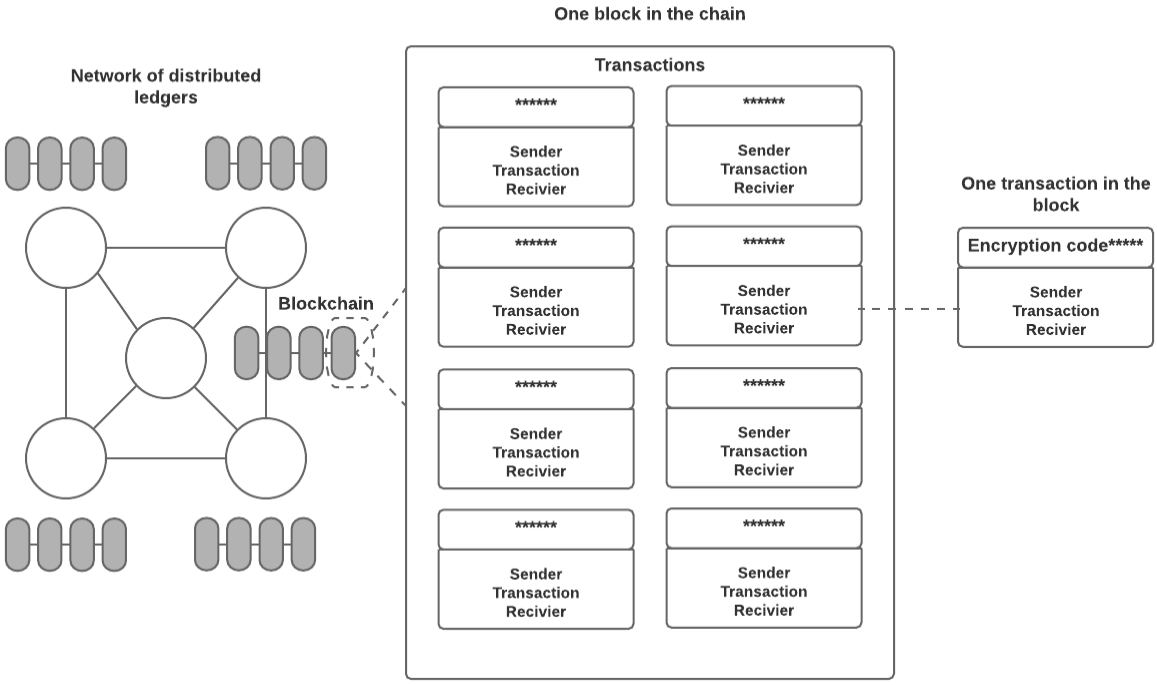

Figure 3-2. The Main Components of Blockchain, Adapted from Morabito (2017).

Dhillon et al., (2017) states that the blockchain technology is based on consensus, which makes the agreement between shareholders that are commonly mistrusting possible. The single node does not need to trust another single node, rather the network as a whole, creating consensus. In other words, it is a self-correcting and honest system that does not require any enforcement of the rules by a trusted third party.

3.1.3 Types of Blockchains

Blockchain is a way of structuring data that allows for ledgers to be held digitally and shared between independent nodes in the network (Dhillon et al., 2017). The blockchain technology has several areas of use, which will be further discussed in chapter 3.1.4 *Blockchain in Business*. Depending on the requirements or context of the situation blockchain is set to meet, there are different types of settings to the blockchain that can be used to fulfil its purpose.

Dresher (2017) states that there are two conflicting goals that determine the type of blockchain. The conflicts are whether it should be transparent or private, and, security vs. speed. Transparency vs. privacy relates to the conflict regarding the need for transparency to clarify the ownership of a tangible/intangible asset, and the requirements of privacy of the users. The ownership is determined by the whole history of transactions that can be seen as a public ledger or transaction register since it is available to the public. The core concept to verify transactions and ownership within the blockchain is transparency and openness. However, a conflict arises with the concept of privacy, relating to the level of privacy regarding the transaction data and other details, such as accounts or amounts involved, publicly hidden.

The other conflict relates to the effort required to secure the transaction history of the blockchain versus the scalability and speed that is required for some commercial applications of the blockchain. Due to the need of solving a hash-puzzle/algorithm to chain a block to the previous parent block, securing the transaction history of the blockchain in a tamper-free character, makes the process very time-consuming and decrease the speed at which new transactions can be registered to the blockchain.

When blockchain is usually described, it is the public and permissionless type since it is the fundamental one, occurring in most cryptocurrencies (Dresher, 2017). There are however two fundamental operations of a blockchain structure, which are reading the transaction data history and writing transaction data. By this, Dresher (2017) defines four types of blockchains out of these operations: Public & Permissionless; Private & Permissionless; Public & Permissioned; and Private & Permissioned.

Reading can be related to the conflict between transparency and privacy, where the decision of whom to grant reading access is made. Only a limited number of nodes or everyone can be granted access to reading the history of transactions. There are two types of blockchains that relate to this: *Public blockchains* and *private blockchains*. All users have access to reading all transaction history and to create new transactions within public blockchains, compared to private blockchains where access is limited to a predefined group of nodes.

The actual writing of transactions can be related to the conflict between security and speed, where the decision related to who will have the right to write transactions is made. If everyone is granted to write transactions, the effort required will be advanced, i.e. very expensive, since the network need to be secure. But if the access is restricted to trustworthy nodes, a less advanced effort is required. There are two types of blockchains that are related to this: Permissioned blockchains and permissionless blockchains. Permissionless blockchains allow everyone to write transactions, giving every node the opportunity to verify transactions, as well as create and add new blocks. Permissioned blockchains have a predefined trusted group of nodes that are granted writing access within the network. Meaning that only this group of nodes be a part of the distributed consensus structure and verify transactions.

Hofmann et al. (2018) state that permissionless public blockchains are limited towards more comprehensive use due to the need for additional effort since it is time consuming. They further state that several financial institutions are looking at having their own blockchain

networks with predefined and trusted parties to limit the requirements of effort and increase the transaction throughput.

3.1.4 Blockchain in Business

As mentioned in the previous chapter, the blockchain technology has mostly been used for cryptocurrencies at the time of writing. It is a common misperception that blockchain is the same as Bitcoin. As stated by Gupta (2017), blockchain can be seen as an operating system, like Windows or Linux, and bitcoin together with other cryptocurrencies can be seen as just an application on it. Applications such as Smart contracts, Record-keeping, Supply chain transparency are areas that have emerged from the blockchain technology. These are presented in the chapters below.

3.1.4.1 Smart Contracts

A contract is an agreement that gives the involved party a legally binding documentation that defines what rights and obligations that promotes long-term relationships, according to Morabito (2017). A contract has a certain intention, and is voluntary to agree upon. A contract is only valid and enforceable, from the perspective of the law.

Morabito (2017) states that not all contracts are required to be put in writing to be binding but it will protect the parties if, for example, there is a breach and the dispute needs to be settled by a court of law. The breach can be when one party does not live up to the agreed upon performance that the contacts states. There are some contracts that are required to be put into writing to be irrevocable and binding. This can be selling or buying real estate, rental agreements, the financing of a leasing agreements of policies of a home insurance.

All these contracts are fit for use when the relationships within the environment is based on trust. Ryan (2017) describes that businesses rather do business with organizations or people that they trust which can be based on reputation or previous business experience. The agreement between the parties is often made through a conversation and a handshake. The rationality behind this is that the trust is more important than the contractual content, since the cost that the uncertainty may bring would injure the business.

A more trustworthy and efficient alternative to the traditional contracts are smart contracts. The term smart contract has several definitions. Ryan (2017) states that smart contracts are applications, that is programmable, that manage online exchanges, which can be exchanging assets for value. Mik (2017) states that smart contracts are contracts that are written in code that are enforced by computers. They are created within the blockchain and is validated by the peer-to-peer consensus within the distributed network. Idelberger et al. (2016) state that a smart contract is a software that stores and implement the contractual agreement while providing the contractual parties with transparency, validity and trust.

The definition of a smart contract can however be defined as codes that uses a logic where one event triggers the next, called “if this then do that”, which reside within the blockchain (Morabito, 2017). It can be visualized by the domino effect where event A needs to occur for event B to being executed. The contract is saved and stored in the same, immutable way as transactions. Because of the validity and the providing of trust, the middlemen are not

needed to act as the trusted third party that enforce the agreements. A smart contract unlike a regular contract, is written in code rather than in words. It runs on a logic that requires one event to occur to trigger the next event.

According to Morabito (2017), for smart contracts to function properly, they require information that verify the terms for the agreement to being executed. Some contracts require information outside the blockchain to perform in accordance to the set terms. This require the need for links to the external data that are trusted. There are two types of smart contracts: deterministic and non-deterministic. Deterministic contracts only require information available on the blockchain, i.e. no outside information is required. This makes that deterministic contracts can execute and work efficiently since it only requires the information available within the blockchain, i.e. no outside information, meaning that the network has enough information to execute the contract.

Non-deterministic contracts are smart contracts that need additional information, than is available within the blockchain network (Morabito, 2017). For these types of contracts, a trusted third party from outside the blockchain needs to be brought in to provide the information required to execute the contracts. As stated by Morabito (2017), these third parties are called Oracles and is agreed upon by the contractual parties. The Oracle can be seen as an agent that is programmable to provide the smart contract with the information required. The Oracles only pass along the information that is required, making it efficient, secure and ensures privacy. It can be seen as that the data is pushed onto the blockchain by the Oracle rather than pulled in by the smart contract.

Morabito (2017) states that a smart contract can be used for, example for car rental. Internet of Things can enable the smart contract in terms that it unlocks the door of the car when an event has been triggered on the smart contract. Szabo (1997), who laid the foundation to smart contracts, states that a smart contract can be used to finance a purchase of a car. If the payments are not made in time, the car will not unlock the doors with the digital key the buyer has. Businesses that profit from running a platform as a trusted party, such as Airbnb, may be excessive in the future due to blockchains. Morabito (2017) states that, by using Internet of Things, a business model such as Airbnb's would get eliminated, since a smart contract can carry out the sublet of an apartment with digital keys that only works for the time interval the tenant has paid for. These digital keys can be in the tenants' smartphone and only be used if all terms of the agreement are met.

Smart contracts have several areas of usage and is highly beneficial in many terms. Sklaroff (2017) states that since the contract is written entirely in code, the cost of ambiguities in the written text, judicial counselling and the drafting of the contract, is avoided. The risk for opportunistic behaviour is also mitigated since the potentially written interpretations of the terms are eliminated. Sklaroff (2017) further states that smart contracts are seen as a possible replacement to traditional contract law. This since businesses can negotiate without the need for laws and courts, since they can negotiate the terms on their own and connect the smart contract directly to the parties' internal information systems to enforce the transactions. So regular business to business transactions can draw benefits from the technology. It is, however, of great importance to point out that smart contracts are not supposed to replace all semantic contracts. Smart contracts are most useful in areas such as routine transactions that are made on a frequent basis. Sklaroff (2017) further states that

firms today see contractual flexibility as a crucial necessity for conducting business and smart contracts that fail to deliver the flexibility will be of limited usage.

3.1.4.2 Record-keeping

Record-keeping refers to the storage of data history, which blockchain can provide in a close to immutable way (Morabito, 2017). Record-keeping can take form in transaction history, smart contracts, licensing, among others. Several benefits are found when holding these on a blockchain compared to today's solution.

A license is used to give parties permission to use properties that is not their own, to carry out activities in a legal way. An example could be that the rightful owner of music or a software, the licensor, grants permission to another party, the licensee, to use it (Morabito, 2017). Blockchain driven licensing, called smart licensing, is made possible through the emerge of smart contracts. As stated by Morabito (2017), smart contracts allow for mass distribution of, for example, software. The blockchain technology provides the rightful owner i.e the developer, the opportunity to monitor the due date of the license distributed.

Smart licenses have already begun to impact the real world, within the arts, music and journalism industries (Morabito, 2017). As stated by Bello Perez (2015), the paper trails of today that authenticate art works, the license, cannot be 100% certain. The risk for multiple copies made by the author cannot either be eliminated. But through publishing the arts work under a smart license, the risk of falsification can be mitigated. Morabito (2017) states that this is made possible through the trailing and verifying ownership authenticity methods that is possible to perform on a blockchain with smart contracts and licenses. The record-keeping and immutability blockchain provides creates the trust that is required in these situations.

According to Lemieux (2016), the reliability and transactional history blockchains have the ability to hold, provide the means for other types such as properties. It will make it harder to steal a property since the record of the ownership is stored in a secure, distributed way, and the trust does not need to lie in a single authority that have the ability to tamper with the information. Lemieux (2016) describes an example of this is the land registry of Honduras, where it is very common that a piece of land that one person has been the rightful owner of for decades, suddenly gets evicted due to that the public authority records state another name as the rightful owner. This has been made possible since the system for record-keeping for land registry in Honduras has been vulnerable to manipulation of data, since it has been maintained and governed by a central authority. Honduras later got in contact with a firm with the purpose of solving this issue with the blockchain technology. A blockchain record-keeping solution would prevent these kinds of issues that Honduras has experienced.

Dhillon et al. (2017) states that the ownership of an asset can, in practice, be represented by the possession of one or several tokens that represent the ownership on the blockchain. These digital tokens are referred to as coloured coins. The coloured coins can hold any type of data that can represent real world value. Depending on the setup of the blockchain, the information may only be visible to the parties within the network that holds a certain key, i.e. not visible for everyone, but only the ones who are granted access to the registry. Thomas (2017) state that a coloured coin is a coin that is coded with information that represents the

ownership of the asset. By using this on a blockchain network, the asset ownership can be both transferred in an efficient way and traced.

3.1.4.3 Supply Chain Transparency

The transparency within the supply chain has become greater throughout the years. D'heur (2015) states that it is very common that the end customers want information of the product they have acquired, relating to the origin of it and sustainability aspects. Sustainability can be seen as a form of branding for the companies, as well as potentially increasing efficiency. Stakeholders expect that the big corporations should use their power to inspire the actors upstream to work proactively with sustainability.

One of the fundamental features of the blockchain technology is that single actors cannot manipulate information. Francisco and Swanson (2018) mean that this characteristic makes it suitable for transparency applications. Since every transaction is stamped, the ledger can show the history back to the origin as well as pinpoint where in the chain errors occur. The end-users are more confident in that the information shared about the product is true (Francisco and Swanson, 2018; Mougayar, 2016). Mougayar (2016) states that the authenticity, quality and the origins can then be determined, which results in providing the customer with the information demanded.

A study performed by Kairos Future (2017) was conducted related to the usefulness for the transparency within the food industry. The issues related to questionable suppliers where labour conditions, environmental aspects and quality makes it hard to audit and control them, ensuring the terms are being met. The food industry would draw benefit from a higher degree of transparency, which can be achieved through blockchain. The agreed terms or requirements of the product can be verified through digital history, e.g. a photo of the fish that can show that it has been caught in the area or way as stated. It is, however, very difficult to know if the photo is connected to the product or not, but it mitigates the risk. Random audits are, however, recommended to see if the photo correspond to the requirements of the product. Internet of Things can beneficially be used for requirements such as temperature, humidity or other measurable data, and automatically update the blockchain.

3.1.5 Limitations With the Blockchain Technology

The blockchain technology has several benefits as can be seen in the subchapter above. However, there are limitations that must be considered with the technology. Those are presented below.

3.1.5.1 Social and Economic Limitations With the Technology

As mentioned earlier, when a block is to be chained to the previous block, a hash puzzle need to be solved. This hash puzzle is expensive and relates to the security of the network. To make the transaction history immutable, the complexity of solving the hash puzzle is difficult. Drescher (2017) states that the cost of computational power needed to host a blockchain network, is expensive, in terms of energy consumptions, which depends on the complexity of the hash puzzle. Cocco et al. (2017) further state that the cost of hardware, as well as the high cost of the computing power that is required to operate the blockchain, are

major limitations. However, this relates to the public permissionless blockchains, since they are the ones requiring that kind of algorithms.

According to Drescher (2017), it is of great importance to consider the legal implications and acceptance with a blockchain solution. Aspects as security and sophistications are not evaluated and determined. The user acceptance is another issue. The technology is very complex and difficult to understand. Without knowledge and education, the use and trust for the blockchain technology will be negatively affected. Morabito (2017) states that there is a potential risk in that it is quite few people today who understands what the technology is and its features, which may create a societal resistance.

3.1.5.2 Technical Limitations With the Technology

As stated earlier by Drescher (2017), there is a conflict between the level of security and the speed of the network. As data cannot be erased within a blockchain setup, new transaction data in new blocks are introduced and chained to the old, parent blocks. These blocks cannot be tampered with. However, the speed of processing will be reduced since a growing network results in more transactions to be recorded, and more complex algorithms to secure the network.

Drescher (2017) also highlights that it is very challenging to change and upgrade the structure and the architecture of the blockchain once it is implemented. The cryptographic must be used for the whole lifetime of the blockchain and cannot be configured. In other words, it also very difficult to fix bugs or make other adjustments. From that perspective, the blockchain technology is then less flexible than other technologies. Morabito (2017) also states that it is good to remember that the blockchain is written by humans and it is not flawless in terms of bugs and poor written code.

3.1.5.3 Security

The security is one of the strengths with the blockchain technology according to Dresher (2017). The cryptographic setup makes it almost an unbreakable network combined with the number of nodes that need to be hacked simultaneously. So, by this, the network holds a very high security. But for the individual nodes, i.e. the ones holding a key to an account, it is a very fragile system. To get access to the property connected to a certain account, you must possess a private key. Only then, you can perform a transaction. This makes the private key the only thing that can identify the owner of the account. Drescher (2017) also states that in the case of blockchain, there is no element that protect the property associated with the account if the private key is involuntary shared with another part. If the member loses the private key, the assets on the accounts are lost, since there is no guarantee or third party that can facilitate this. Compared to a setup today with a third party that holds the information, they provide the service of protecting your assets in these cases. This is a great weakness of the blockchain solutions.

Moreover, Drescher (2017) describes that the characteristics of blockchain is that it is collectively controlled by the network. It is based on the assumption that the majority has only good intentions and is unknown to each other, preventing coordinated manipulation of data. If the network consists of a low number of nodes and these are known to each other, it becomes easier to reach majority i.e. 51 percent, which is seen as the truth in a blockchain

model. Hence, for a blockchain network to function properly, it need to have a large number of nodes to make it as truthful as possible.

3.2 Sustainability

The thesis aims to identify issues related to sustainability for contractors within the construction industry. Sustainability within the corporate world is often referred to as CSR. To do so, a general understanding of what Corporate Social Responsibility is, what is included in the term, its drivers and barriers need to be understood and defined.

3.2.1 Definition of 'Corporate Social Responsibility'

There is no set definition of Corporate Social Responsibility, CSR (Paetzold, 2010). EU (2011) has previously defined CSR as "a concept whereby companies integrate social and environmental concerns in their business operations and in their interaction with their stakeholders on a voluntary basis", but has updated this definition to "the responsibility of enterprises for their impact on society". Paetzold (2010) states that the concept regards that corporations should have more than just duties towards their shareholders, i.e. long-term wealth of the organization, they should also imply duties towards the society. Paetzold (2010) states that CSR aims to bring a stronger consideration towards the natural environment, stakeholders, consumers, employees, the community and governments. EU (2011) further states the concept regards the actions taken above the legal obligations of the organization, towards the society and environment.

3.2.2 Perceptions of CSR

There are different perceptions of what CSR is and what it includes. Elkington (1998), a very renowned author who coined the term triple bottom line, argues that CSR has three main areas: social, environmental and economic. The economic bottom line refers to the conventional bottom line companies have, the profit. The social bottom line refers to the social capital, where public health, skills and education, as well as society's health and welfare are considered. It also includes, for example, labour conditions, child labour and slavery that need to be considered. The environmental bottom line refers to taking the natural environment into consideration. This can, for example, include materials choice, emissions, waste products etc.

Another very renowned CSR model is the four stage CSR pyramid with the categories, or components, economic, legal, ethical and philanthropic (Carroll, 1991). The foundation of the pyramid is the economic component. It states that a corporation needs to be profitable in order to proceed and bear the other components of the framework. Carroll (1991) states that a corporation need to maintain a strong competitive position, maximize earnings, be consistently profitable and hold a high level of efficiency. The next layer of the pyramid is the legal component. It refers to that a corporation is expected to operate within the law. The corporation provides products that at least meet minimum requirements, abiding the law, comply with regulations, and perform in a consistent manner in accordance with government and law. The third layer is the ethical component. This component refers to the ethical responsibilities a corporation is expected to meet even though they are not included in any laws. This could, for example, be societal standards or norms, that are regarded as fair, or

just, by the community. The fourth and highest layer is the philanthropic component, which refers to be a good corporate citizen. Carroll (1991) states that business is expected to provide resources, both financial and human, to the community with the purpose of improving the quality of life.

The Global Reporting Index, GRI, has adapted the perception of triple bottom line in their sustainability reporting standards (2016). Wilson (2015) states that the Global Reporting Index is one of the leaders in developing sustainability reporting standards in the world. They have further developed several aspects within each category to indicate on what the different categories include, as can be seen in Table 3-1.

Table 3-1. Aspects and Subcategories of Triple Bottom Line, Adapted from Global Reporting Index (2016).

Economic	Social	Environmental
Economic performance	Labour Practices and Decent Work	Material
Market presence	Human rights	Energy
Indirect economic impact	Society	Water
Procurement practises	Product responsibility	Biodiversity
		Emissions
		Effluents and Waste
		Products and services
		Compliance
		Transport
		Overall
		Supplier Environmental assessment
		Environmental Grievance Mechanism

The ‘Economic’ and ‘Environmental’ categories are divided down to aspects while ‘Social’ is divided into subcategories that includes several aspects to consider. These subcategories are presented in Table 3-2.

Table 3-2. Aspects Within the Sub-Categories of the Social Category

Sub-Categories of the Social Category			
Labour Practices and Decent Work	**Human Rights**	**Society**	**Product Responsibility**
Employment	Investments	Local Communities	Customer Health and Safety
Labour/management relations	Non-discrimination	Anti-corruption	Proudct and Service Labeling
Occupational Health and Safety	Freedom of Association and Collective Bargaining	Public Policy	Marketing Communications
Training and Education	Child Labor	Anti-competitive behaviour	Customer Privacy
Diversity and Equal Opportunity	Forced or Compulsory Labor	Compliance	Compliance
Equal Remuneration for Women and Men	Security Practices	Supplier assessment for impacts on society	
Supplier Assessment for Labor Practices	Indigenous Rights	Grievance Mechanism for impacts on society	
Labour Practices Grievance Work	Assessment		
	Supplier Human Rights Assessment		
	Human Rights Grievance Mechanism		

3.2.3 Drivers

CSR can bring a lot of advantages to an organization. EU (2011) states that it becomes more important because of competitiveness. They further state that cost savings, risk management, customer relationships, innovations capacity amongst others are benefits that can be experienced by an organization. Employees of organization that address social responsibility tends to stay within the organization on long-term basis, which enhance the chances for an organization to grow and become more innovative (EU, 2011).

Agudo-Valiente (2017) states that most CSR strategies are implemented because of stakeholder pressure. Corporate reputation is also a factor that is a driver that is common. The trend of the respective sector is also a driver for CSR, since otherwise the organization will not be able to keep their position within the market.

Huang (2013) states that there are three main motives driving a CSR strategy for a corporation being stakeholder demands, performance and motivation. Stakeholder demands relates to that corporations may have to engage in CSR activities, otherwise stakeholders might withdraw their support towards the corporation. Performance relates to the statistical relationship between CSR and finance, which may justify the practise of it from a managerial perspective. Motivation relates to the moral obligations corporations may feel, extrinsic factors, as well as reputation of the corporation.

However, companies that do not practice CSR driven business often do so to benefit their own self-interests. Van Weele (2014) states that the self-interest could be in terms on monetary value or similar. There may be actions in a contractual agreement where one party can act unethical and opportunistic to its own advantage. This will be in violation of the CSR approach.

3.3 Construction Industry

The purpose of this thesis is to outline how the sustainability practices for the contractors within the construction industry can be enhanced by facilitation of the blockchain technology. To achieve this, a thorough understanding of the construction industry is required.

Rumane (2016) states that the construction industry has evolved throughout time and has always been a central part of our society. The design, building process and material has become more sophisticated and the building techniques have evolved, in order to meet the requirements from the society. The sector has become more industrialized with prefabrication of concrete blocks, mechanization and system building, making it more efficient. Like other industries, safety, health and environmental requirements have become more central within this sector.

Rumane (2016) further states that construction projects can either be procured by the private or the public sector. When the owner comes from the private sector, the project can be commercial buildings such as warehouses, industry facilities, retail stores, as well as housing. Construction projects initiated by the public sector can be e.g. schools, universities or hospitals. There are of course exceptions for this due to, for example, private schools and hospitals where it is a private initiative rather than a public.

The chapter starts by with defining some common actor roles that are presented during a construction project. After that, a description of the construction supply chain is presented in order to identify its characteristics and how it differs from other industries. This is followed by the description of different types of project arrangements and a overview of the building process.

3.3.1 Actor Roles

There are several different actors involved in a construction project and the kind of actors differs depending on the project arrangement (Kelley, 2012). De Marco (2011) states that a project is an outcome of a joint effort by all actors involved that can contribute with finance, design, construction, consulting and other operational services. Although the actors involved depending on the project, there are, however, two actors that are always involved. First the initiator, commonly named as client or owner. In this thesis, these actors are referred to as the owner. The second actor is a contractor. In most cases, actors such as architects and engineers (A/E), main contractor, subcontractors and material suppliers are involved in the project (O'Brien et al. 2008; Kelley, 2012; Benton & McHenry, 2010). These are described more in-depth in the coming sub-chapters. However, there are other roles that may occur during a project such as construction managers and project managers, which mainly have supervising roles (Rumane, 2016). Winch (2012) has a more extended view of actors involved and the author also mentions external actors such as landowners, local governments and environmentalists, as stakeholders in the project. However, these will not be discussed in detail during the following actor description.

3.3.1.1 Owner

It is the owner that initiates the project, which can either be a public or private organization (Rumane, 2016; Sears et al., 2015). The owner identifies the need for a construction project

and requests the assistant from other actors, dependent on the type of project (Rumane, 2016). The other actors then operate in accordance with the request from the owner. The owner can either have direct contact with the construction actors or is represented by another actor, for example an architect (Kelley, 2012; Benton & McHenry, 2010). The owner is not necessarily the one using the construction after completion. A private actor may initiate a project with the purpose of renting out space, in forms of apartments or offices. A public actor may initiate the project to enhance the traffic situation, in forms of bridges or tunnel, or projects with other societal purposes (Sears et al., 2015).

3.3.1.2 Architects and Engineers

It is common that the owner does not have the in-house capability to run the design phase themselves. The owner often hires a third party to transform the requirements and needs into a specification that is the foundation for the actual construction (Kelley, 2012; Rumane, 2016). This actor is referred to as A/E, which stands for architects or engineer, or other kinds of consultants that provide similar types of services (Rumane, 2016). The design phase can include many kinds of services, which could be functional drawings with basic design specifications for approval, to technical drawings with specifications needed for actual construction (De Marco, 2011). This type of actor can also be responsible for other tasks in preparations for the project, such as the evaluation of the construction site, environmental effects, soil conditions, upcoming traffic situations etc. (Kelley, 2012).

3.3.1.3 Main Contractor

The actor at the top of the construction project hierarchy, is referred to either prime contractor, general contractor or main contractor, which is the latter that is referred to in this thesis. According to Sears et al. (2015), they are often the ones that are contracted directly by the owner and have a direct link to the owner. The main contractor takes a central role during construction and has the responsibility to manage overall coordination efforts during construction. They have the responsibility for the entire construction process and for all suppliers and subcontractors. The resources used for the actual construction is a combination of main contractor's own employees, temporary staffing and specialized subcontractors. The main contractor can be hired to be responsible for the designing as well as the financing of the project. The involvement and responsibility of the main contractor depends on the type of project delivery system, which is further described in chapter 3.3.2 *The Construction Supply Chain*.

3.3.1.4 Subcontractor

The subcontractor refers to the parties who perform different types of services on the construction site which are not performed by the main contractor. For the services, the subcontractor might also bring the material which is required to perform the task. Sears et al. (2015) state that the subcontractors are usually contracted by the main contractor and thus there is no contractual connection between the owner and the subcontractors. The hiring of subcontractors is common for those areas where the main contractors do not have specialized skills and where it is assumed that the subcontractor can perform it more efficiently. Some tasks might require special equipment, certain licences, assurance etc. which is too expensive or excessive for the main contractor to pay for a single project. According to the De Marco (2011), the use of subcontractors has increased by the time, where the drivers are that they hold specialized knowledge but also local presence, lower

cost and movement of risks from the main contractor. Benton and McHenry (2010) emphasize the greater risk with a subcontractor in comparison to a material supplier. A construction services requires more effort from both the buying contractor and the subcontractor in terms of defining tasks, scope and planning the task etc. Thus, this type of agreement is difficult to cancel if something goes wrong.

3.3.1.5 Supplier

The supplier relates to the actor who provides material directly to the construction site, alternatively to a subcontractor who use it in their services. In comparison to the subcontractor, the supplier does not perform any type of services on the construction site (De Marco, 2011). The relationship between the supplier of products or material and a contractor is often of a transactional character and it is less risk with type purchasing in comparison to services since it is more difficult to define and specify the terms (Benton & McHenry, 2010).

3.3.2 The Construction Supply Chain

A study of the literature shows that the construction industry differs in many aspects from other industries, especially from a supply chain perspective. Chopra and Meindl (2016) defines the supply chain as "*consist of all parties involved, directly or indirectly, in fulfilling a customer request*". They further states that the concept has a holistic view and involves all actors that are involved, such as customers, manufacturers, warehouses, transporters etc. The actors are connected by flows of products, information and monetary means. The typical structure of a supply chain is illustrated as in figure 3-3.

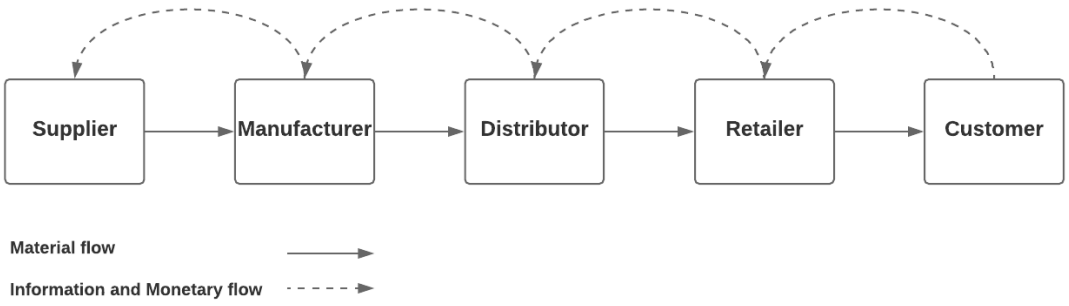

Figure 3-3. Typical Structure of the Supply chain, Adapted from Chopra and Meindl (2016).

Due to the characteristics of the construction supply chain, it is difficult to apply the knowledge of the traditional supply chain design and features. The involved actors, as mentioned in chapter 3.3.1 *Actor Roles*, are not the same as the traditional ones (Benton & McHenry, 2010). The construction supply chain is visualized in figure 3-4.

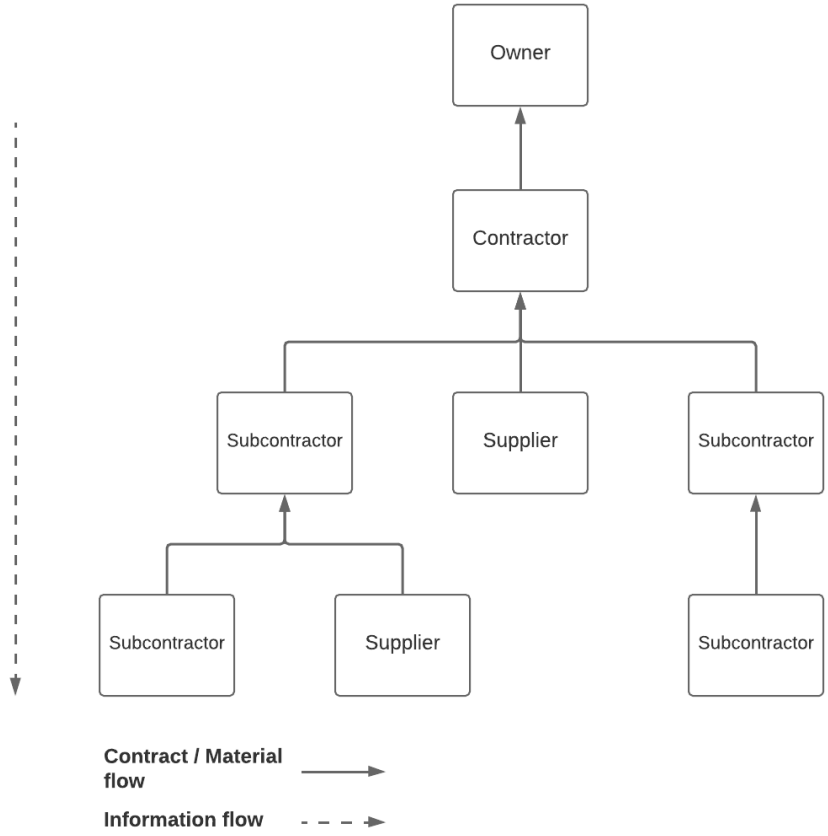

Figure 3-4. The Construction Supply Chain, Adapted from Benton and McHenry (2010).

The typical supply chain is a flow of product through value-adding activities which is then distributed out from the manufacturer towards the customer segment. When looking at the construction supply chain, the flow is instead converging to construction site where the materials are processed together to form the final construction (Segerstedt & Olofsson, 2010). Another important characteristic is that the construction industry is mostly project based (Segerstedt & Olofsson, 2010; Benton & McHenry, 2010; Annan, 2012). Each project is unique and customized according to the owners' requirements (Benton & McHenry, 2010; Annan, 2012; Segerstedt & Olofsson, 2010). In comparison to the traditional supply chain where the actors are somewhat fixed during a certain time, the actors in the construction supply chain are organized differently for each new project. It means that most of the relationships and the production set-up is short-term and only temporary (Annan, 2012; Benton & McHenry, 2010). Further, Benton and McHenry (2010) highlight the characteristics of a low-price driven industry. The project-form with temporary relationships results in that the procurement is often characterized by competitive bidding which is then pushed further down in the chain to the suppliers and subcontractors.

The construction industry is also highly fragmented (O'Brien et al. 2008; Benton & McHenry, 2010) with a high number of companies involved such as contractors, sub-contractors, architects, engineers etc (Benton & McHenry, 2010). As Segerstedt and Olofsson (2010) as well as Benton and McHenry (2010) mention, the construction company that manage the project only perform a portion of the project with its own personnel and resources. Segerstedt and Olofsson (2010) also states that in comparison to other industries, the actors

in the construction industry do have more shifted roles in the supply chain from a project to another in terms of how close they are the owner. A summary of the differences between the traditional Supply Chain and the Construction Supply Chain are presented in table 3-3.

Table 3-3. A Comparison Between the Characteristics of the Traditional Supply Chain and the Construction Supply Chain.

Traditional Supply Chain	Construction Supply Chain
Divergence	Convergence
Static	Project-based
Long relationships	Temporary relationships
Partnerships	Competetive bidding
High level of uncertainty	Low level of uncertainty
Consolitated	Fragmented

There are several types of arrangements regarding the project hierarchy, called project delivery systems. According to Rumane (2016), common project delivery systems are integrated and separated project delivery systems, as can be seen in figure 3-5. The main contractor can be responsible for both the design and the construction, i.e. the whole project, as they are in an integrated structure. There can also be an external A/E that is responsible for the design hired directly by the owner, whereas the main contractor is only responsible for the construction part of the project. In both project delivery systems, the main contractor has the overall responsibility for the construction and hires subcontractors to a certain degree to fulfil it. The subcontractors are contracted by the main contractor and thus do not have any responsibility and obligations towards the client or A/E (Rumane, 2016; De Marco, 2011). As can be seen in figure 3-5, the fundamental difference between these systems are whether the design is integrated or not. The construction part is still structured in the same way regardless of what project delivery system is used.

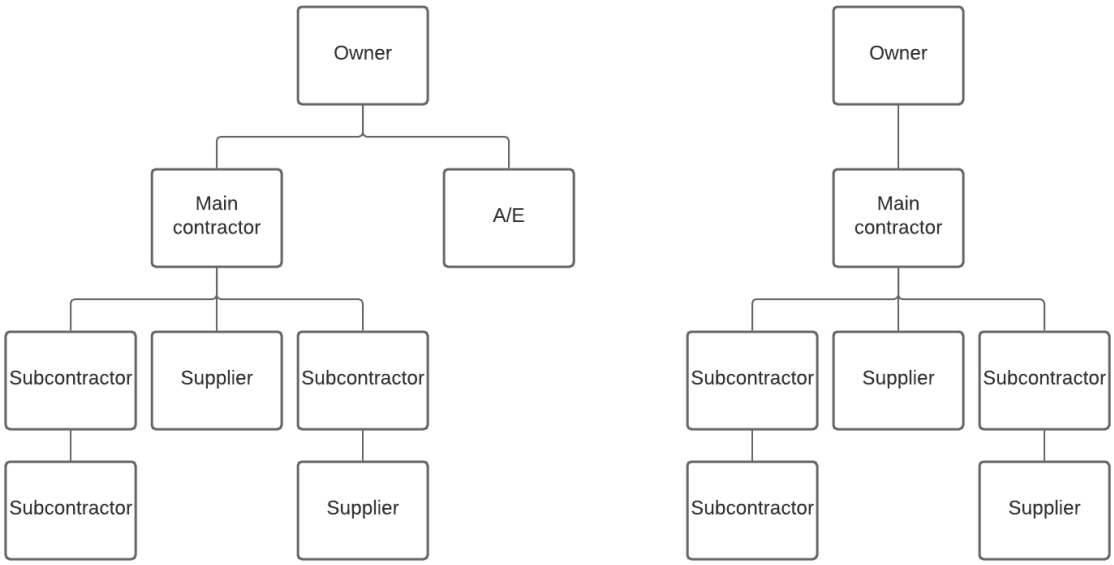

Figure 3-5. Project Delivery Systems, Separated (to the left) and Integrated (to the right), Adapted from Rumane (2016).

3.3.3 The Construction Project Process

One essential part in the understanding of the construction industry is processes during the construction project. As stated earlier, a construction project is totally unique in its character. Rumane (2016) means that the different project phases during a construction life-cycle depends on the complexity, the number of processes included in a project, technologies involved etc. which makes it difficult to generalize one view of the phases.

The number of phases in a construction project differs between authors. Sears et al. (2015) identifies three phases, while De Marco (2011) identifies four, and Behera, Prakash and Mohanty (2015) has identified five. Rumane (2016) has also identified five phases. However, all authors have three overall phases in common that are the main ones. These phases are design, which commonly includes concept and detailed design. The next phase, procurement, usually includes preparation of documents and tender processes. The last phase is the actual construction, which includes pre-activities, execution and maintenance. This illustrated in figure 3-6.

Figure 3-6. The Phases of the Construction Project Process.

3.3.3.1 Design Phase

Once a need from the owner is recognized, the first phase starts. Initially, different conditions and aspects such as land review, permit requirements, risk analysis etc. need to be investigated (De Marco, 2011). If conditions allow to proceed, the main objectives are set by the owner (Rumane, 2016). This is followed by, according to Sears et al. (2015), overall requirements and budget constraints are considered. When the frames are set, it is followed by planning of budget, time-schedules, quality and technical requirements etc. During this phase, the owner selects an appropriate project delivery system for the projects which should be based on the projects characteristics.

An initial activity is to develop conceptual design (Rumane, 2016). De Marco (2011) and Sears et al. (2015) describes it as a basic design before the more detailed ones. Rumane (2016) mentions elements that should be stated in the conceptual design such as site plans, floor plans, roof plans, elevators, water systems, landscape etc. De Marco (2011) states that this design is made to get construction permits and other authorizations. It also a basis for further signing of project partners.

The conceptual design is followed by the stage of detailed design or detailed engineering according to both De Marco (2011) and Rumane (2016). The documents should be based on the design in the earlier stage and changed according to the owner's comments to ensure the goals and objectives. The phase of detailed design includes the process of analysing and design with respect to codes and standards as well as the performance. It is also performed to provide the contractor with instructions such as drawings and specification so it will be built in accordance to the owner's requirements. During this phase, design professionals, architects and other types of engineers with specialized knowledge are involved. The design goes more in details with sections drawings and the construction is supported and controlled by calculations. These are then compared with set standards.

3.3.3.2 Procurement Phase

De Marco (2011) defines procurement as *"set of activities designed and performed to ensure regular flows of material and services, according to the plan"***.** Further states by De Marco (2011), the definition of procurement includes material, sub-contracts, equipment and other types of services. During this phase, the question whether the services should be carried out in-house or to be performed by an external subcontractor is decided (De Marco, 2011). If a material or a service are supposed to be provided by an external actor, construction documents should have been made. The supplying unit should be provided with sufficient information so they can estimate their cost for fulfilling the requirements. Required documents could be detailed design drawings; codes and standards which should be followed; environmental requirements; project schedule etc. All the documents are then structured in suitable way so they could be released for the following tender process (Rumane, 2016).

Once these are ready, the process can start by sending out documents, commonly to actors who are rated and approved from earlier projects (De Marco, 2011). The selected suppliers or contractors are then coming back with bids. These are then reviewed so they actually meet the set requirements (Rumane, 2016). All the bids are then compared with each other. The selection is made directly or after a negotiation with one or several bidders (De Marco,

2016). The contract is then awarded to the winning actor (De Marco, 2011; Rumane, 2016). The selection could be based on price, quality, technological level and financial reliability. The procurement phase is completed by an order is placed at the selected supplier or subcontractor (De Marco, 2011).

3.3.3.3 Construction Phase

The construction is executed by a contractor according to the owner's requirements which are the basis to fulfil the goals and the objectives according to Rumane (2016). Same author states that it should be kept within the timeframes and the budget limitations. Before the execution starts, it is time of planning activities. Commonly, there is a kick-off meeting where the involved actors are represented, where responsibilities, scope of each actor, time plan etc. may be presented. Instructions for the construction site might also be reviewed. For instance, how to handle waste of material, safety guidelines, claims and other circumstances that are good to discuss beforehand.

A fundamental part of a construction project is execution and the site operations. The tasks that are normally associated with construction is the physical building which is performed by the contractor's own staff or subcontractors (De Marco, 2011). The tasks are performed either sequential or in parallel. Examples of tasks are construction of foundations, assembly of pillars and beams to building, landscape works, electrical system installation etc. (Rumane, 2016). During the project, it is important to have an overview of how the project progresses. For instance, if the project runs accordingly to the time schedule (De Marco, 2011; Rumane, 2016). Other aspect that should be considered are the owner's requirements, cost, quality, and the safety on the construction site (Rumane, 2016). It is also important to control and monitoring the progress in order to solve the problems that may occur. A project can also be very complex with many companies involved, and it requires management and communication between all actors in order to run the project smoothly (De Marco, 2011).

According to Rumane (2016), when all the task is completed, the construction is tested and checked. Normally, a checklist is designed where certain elements in the construction is reviewed. Those which not fulfil the requirements are corrected. This stage is followed by a commission of the construction which means that the owner is provided with technical manuals and documents, warranties and guarantees. The owner, or the potentially final end-user, is invited for a review. Finally, the construction is handed over to the owner (Rumane, 2016). A post-stage within a construction project is maintenance. The construction should be maintained in proper way in order to retain the lifespan. Normally, the owner is provided with documents about how to operate and maintenance procedure. Common for the owner is to sign a maintenance service contract where another part takes care of the future activities related to maintenance.

4. Empirical Data

The empirical data has been collected from the interviews made in this thesis. The interviewees were selected based on their positions and knowledge connected to the topics of blockchain, the construction industry and CSR. The interviewees and their respective positions can be seen in table 4-1. The purpose of this thesis aims to evaluate how the blockchain technology can facilitate in enhancing sustainability for contractors within the construction industry. Because of this focus, the areas that are of interest which are presented in this chapter includes data regarding blockchain and subcontractors. The chapter is only empirical; hence no analysis or own interpretations of the information is made.

Table 4-1. Interviewee Information.

Title	Referred to as	Company/Function	Responsibility
Purchasing Process Manager	PPM	NCC, Purchasing	Working with process development at Group-level
Purchasing Manager	PM	NCC, Purchasing	Manager for the project-related purchasing
Contractual Engineer	CE	NCC, Construction	Located at the construction site. Working with the economy and contracts related to the project
CSR Manager	CSRM	NCC, Sustainability	Head responsible for group's sustainability strategy
Environmental Specialist	ES	NCC, Sustainability	Develop and perform environmental classification
HR Specialist	HRS	NCC, HR	Responsible for ID06 at NCC
Researcher	Researcher	RISE Victoria, Digital Innovation	Senior researcher within Digital Innovation
Salesman	IBM	IBM, Software	Sales within cloud-services and emerging technolgies
Digital Strategist	Skatteverket	Skatteverket, Strategy development	Working with digital strategy development
Chief Digital Officier	Lantmäteriet	Lantmäteriet, Strategy development	Head responsible for the digital development
Working Environment Specialist	Sveriges Byggindustrier	Sveriges Byggindustrier, Working Environment	Expert on working environment issues
Environmental Specialist	Sveriges Byggindustrier	Sveriges Byggindustrier, Environment	Expert on environmetnal issues

4.1 Blockchain Technology

The empirical findings in this chapter relate to how blockchain is defined by different actors, when it is needed, where it has potential, different setups, limitations/barriers and smart contracts. The findings below are based on interviews with different stakeholders within the subject, from both the public and private sector, as well as from the research field. The empirical data were gathered with a focus on blockchain for business. As mentioned in chapter 2.2.2 *Interviews*, the data was gathered from one researcher specialized in blockchain, one IBM consultant as well as persons from organisations and companies developing blockchain solutions.

4.1.1 Differences in Definition of the Blockchain Technology

The definition of a blockchain is not standardized yet and it depends on the person's own interpretation. The Researcher states that a blockchain must be peer to peer replicated, based on game theory and that it must be distributed. It should not have a governing node, i.e. that it should not be one node with higher authority than others. It is worth mentioning that the Researcher only defines a blockchain if it is public, and to some extent private, as a blockchain. Further, blockchains are data storages where no one can tamper with the data without everyone else knowing about it.

The IBM states that it is very common that people believes that blockchains are equal to Bitcoin, which is not the case. Fundamentally, a blockchain is a shared, distributed database, a network containing several actors. IBM emphasize that the blockchains used in a business context are permissioned blockchains, where the users are not anonymous in the same way as they are in cryptocurrencies or other open blockchains. From their perspective, they describe it as when an existing business process is looked at to see how it can be made more efficient with a technology that enhances visibility to data in real time, which is guaranteed to be immutable. It builds on common processes and smart contracts on how the data is added to the blockchain and the rules relating to that.

IBM further states that there is a big difference when the nodes are identified. Completely different algorithms can be used that are not as data intensive as they are for cryptocurrency blockchains. The gaming theory algorithm requires that you have a huge amount of computing power, which is not needed to run a blockchain business network. Other algorithms are required, such as who has the permission to see other transactions within the chain, who can add what information etc. The blockchain is set-up in accordance with the parameters of, for example what the business process looks like, where the payments go, how things are purchased and distribution.

4.1.2 When are Blockchains Needed

The blockchain technology does not fit into all context, it fits better into some context than others, according to the Researcher. Blockchains are needed in situations where value is exchanged and the environment is hard to coordinate, or where trust is not part of the exchange. Blockchain fits into environments where no one should own the integration and the coordination. It does not necessarily need to be an environment where the individual does not trust each other, rather that it ensures that the information is mathematically

secured. An example of this can be that individuals do not want to trust a single actor to have responsibility of their patient records, rather that it is distributed and mathematically secured so no one can tamper with it. The Researcher mentions that it is in these two areas where the technology is needed and that we already have existing solutions for the other ones. Elements of lies, no trust, people trying to manipulate data and that no single actor should be in control of the network are factors needed for a blockchain solution.

The IBM on the other hand states that blockchains are a solution where all nodes within a supply chain need to have access to data in real time that can be trusted. Blockchain solutions should be evaluated from what the problems are and what is the best solution. Another potential solution that involves blockchain could be when the actors do not trust each other in a business relationship. This could be situations where the origin of a product needs to be traced to ensure the labour conditions, quality etc.

4.1.3 Potential Applications of Blockchain

The blockchain technology has several applications that can be used beneficially within the construction industry as well as other industries. The Researcher states that tokens are a very important part of blockchains. According to the same, blockchains cannot exist without them, and they are not necessarily connected to a cryptocurrency. It can be linked to voting rights, insight, data, licenses and many other applications that you can use for monetary benefit. It can also be a token as in payment of salary that are converted into money on the next step. A license can easily be linked to a coloured coin, as described in chapter 3.1.4.2 *Record-Keeping*, that are linked to a certain person. Technically speaking, there is no problem with a solution such as this. However, it is very important to assess if a blockchain solution in these terms of record-keeping solves the problems that are experienced.

The Researcher further states that all transactions within a network is possible to trace with perfect auditability but there are no incentives for it since the cost may exceed the potential gains. It almost has to be a regulatory demand for this to happen. The Researcher describes that a possible solution is that a 2nd or 3rd tier supplier makes their transaction data public. The focal company can then verify that the payments are made upstream to prevent illegal activities and enhance social aspects of the trade. The interest of this also lies within the supplier to get paid for their products.

The real benefits of blockchain will come when the applications are further developed according to the Researcher. The technology that blockchain is and what it will lead to can perhaps be compared to the internet. The internet was built as a foundation and all applications on the top of it made the internet to what it is today. The Researcher thinks that the same thing will happen to blockchains. The IBM states that the CEO of IBM refers to the blockchain technology as "*What the internet did for communications, blockchain will do for trusted transactions."*

Supply chain management is an area where the IBM sees a lot of potential, even in the short-term perspective. Today, supply chains are integrated transactions, which are made through, for example, Enterprise Resource Planning (ERP) systems. The format needs to be integrated with the supply chain partners, where it is translated into the appropriate format for the other party. This is a very expensive process that can cost a lot of money per

message that needs to be translated. A blockchain solutions for this will, however, not be made in the short term, rather the problem areas that are not yet automated or digitalized.

IBM states that the financial sector sees a great potential with the blockchain technology. It is an ongoing project where eight banks in Europe are in a consortium, developing a trade platform based on the blockchain technology. The driver behind this consortium is to facilitate international trades for Small Medium Sized Enterprises, SMEs. International money transfers are today very expensive and involved a lot of manual work, which can be minimized by the blockchain technology. It will facilitate a more transparent and trusted environment within the supply chain network for the customers where the processes become digitalized.

Blockchain has proved its potential as a good way of tracing materials. The Researcher states that some items can be traced back correctly, such as meat where DNA can be tested. It is, however, impossible with, for example, metals since ore from several mines are melted together, making it impossible to trace. The Researcher further explains that the technology can make it easier to identify the source of errors within the supply chain. It can reduce the effort to trace the errors back in a beneficial way. The blockchain technology provides the means to more easy and efficient trace where in the supply chain there is an error, compared to the manual tracing occurring today.

4.1.4 Smart Contracts

As stated by the Researcher, smart contracts have existed a while. A great advantage with smart contracts running on blockchains are that they are self-executing. All parties within the contract knows it is going to be executed as designed, i.e. if all the parameters of it is fulfilled. The Researcher means that this could not be done before, where every party of the contract had to trust the operator running the server or the software program. Overall, it is hard to foresee what implications these contracts will have since the whole economy is built on trust, which is not a necessity any longer.

However, the Researcher states that since the smart contracts are based on code, they are very static and eliminates the flexible advantages that traditional contracts, which are semantic, offers. The IBM agrees on the fact that smart contracts are good in any situation where it is somewhat static. Since the external world outside the blockchain is changing all the time, there is a risk that the contracts can get locked and never be executed. For example, if the Oracle within a contract is dependent on outside information provided by a company that then go bankrupt, the contract will lock itself. The Researcher mentions that an Oracle is not necessarily based on software, it can also be a person if that is desired.

A smart contract can contain anything, according to the Researcher. Examples can be cryptocurrencies, an asset or a traditional currency. It is just a software program that operates under the terms that it can either send or receive information from it. There are both positive and negative aspects when there is a total certainty that a contract will self-execute. It can be a problem to define what is to be delivered for the contract to be executed. For instance, it is easy if the delivery means a brick with a hole in it but it is a question of definition if the delivery should be a beautiful poem.

The Researcher thinks that a potential application area of smart contracts is a contractual agreement where one party is to deliver a service of some value to the other party. Both parties can agree upon an oracle that is to be trusted to assess the outcome. If the Oracle confirms, the money is paid, otherwise, the money is frozen into the contract waiting for the verdict. An advantage of having the money in escrow in the smart contract is that there are no incentives to act unethical by any party in the agreement. The contract can also be set up to portion out the money to the different parties involved to make sure that everyone is getting paid and no misunderstandings are made. It is common to start in a small scale, and as the hypotheses are validated, the blockchain network is then expanded.

4.1.5 Blockchain Setup

There are several options for a blockchain setup, depending on the purpose of it. The Researcher states that if you do not want it to be publicly readable, you can hash the whole chain. The drawback is that it will hampers other parts, for example the transparency. In those cases, a consortium chain may be used instead.

IBM mentions another setup, which is to base the blockchain on Hyperledger. Hyperledger is a part of the Linux Foundation and contains several blockchain-setups with the aim on different application areas. One setup is Hyperledger Fabrics that was developed by IBM, which they shared with the open source community. Hyperledger Fabrics is an industrialized form of blockchains, aiming at business networks in different shapes and sizes.

4.1.6 Use Cases

According to the Researcher, few applications based on blockchain technology is being used today. This is because he defines a blockchain as public where the trust should be distributed, alternatively eliminated. However, one example that he mentions is the Switzerland based logistics company Modum that use the blockchain technology to achieve a self-regulating logistics flow. They use Internet of Things to ensure the validity of the information that is uploaded on the blockchain. The sensors provide the information of what has been done in which step of the transport. For example, sensors are placed in the package to ensure that it is opened at the right step of the process, as well as it can be traced back to where the error occurs in the logistics flow. This opens up for a trustless environment, where there is no need to build trust among the partners.

Skatteverket has started to investigate how they could use the blockchain technology. For instance, the cash register where they are looking at a solution to replace the existing hardware system with a software system that can ensure that the information is correct and immutable. In other word, if they can secure the information they receive, they do not have to perform a manual control of the it, rather just control the process. The manual validation of it can be minimized and they can focus their resources on other processes, which exceeds their capacity today.

Skatteverket needs to have two perspectives of the technology: how they can use it, as well as how they will handle the situation of when other actors start to use it. They do, however, just see the technology as an alternative solution where there are other fully functional solutions today. The technology needs to be developed to be useful for them. A potential use

area of the blockchain is of split transaction relating to the VAT payments. For example, a grocery store can directly pay its VAT when the customer is buying products at their stores, which will reduce administrative work for the actors. Skatteverket states that the blockchain technology cannot prevent untaxed incomes in the society. But since the technology can emancipate resources from controlling tax information, they can be redirected to focus their resources on other things.

Lantmäteriet also investigate the potential use of the blockchain technology within their organisation. They are the authority that holds the ledger of all real estate transactions within Sweden. The driver for using the blockchain technology is to prevent manipulation of transaction data and to hold the ledger in a more secure and safe way. Lantmäteriet states that they will not be superfluous even though the ledger can be held on a distributed blockchain. They need to exist since they can provide the assurance and security that the Swedish people wants, as well as that they are the only organisation that both can and are willing to take responsibility if something goes wrong. The immutability that a blockchain solution provides is also assuring as in the eyes of the public, where they want to see their transaction records as safe and secure as possible.

Everledger is a very famous use case of the blockchain technology, described by the IBM. They are a company that provides the service of traceability for luxury items, such as diamonds. By marking the diamonds from its origin, information can be provided related to how the diamonds have been excavated and prevent frauds on the marketplace. The diamond industry experiences several problems due to its rarity and exclusiveness. The IBM further states that by having this information stored on a blockchain, it is a quality labelling of the diamond, where it can be traced back to its origin, eliminating the risk of buying blood diamonds. The Everledger projects are expanding their area to other luxury items, such as wines.

Another example stated by IBM is the Maersk-IBM joint venture, aiming to develop a trade platform. The first step in the development of the platform is to focus at dock-to-dock, where Maersk operates. The blockchain technology has made it possible to make the administrative processes more efficient during shipping. The involved actors can get the information they require to proceed their own operations visible in the blockchain. An example is a shipment of flowers from Africa to Europe, where the administrative costs exceeded the value of the shipment, where 200 documents needed to be handled. This is just the first step of the platform, which will include other process flows in the transportation chain.

IBM also mentioned that Walmart has started an initiative in cooperation with them where they are investigating two scenarios where the blockchain technology can be a potential solution. The first scenario concerns mangos from South America where the vision is to create a process, a support, for the consumer to scan a QR-code attached to the mango and see the whole history of transactions for it. This can provide the customer with the security of buying foods that are fair trade, locally produced, etc. Is has also a great potential for Walmart as well, for example if someone gets sick from eating a certain food, they can trace back to a specific batch, instead of taking down all the same product of the shelf.

4.1.7 Limitations and Barriers

The general purpose of the technology is to store data in a secure and immutable way. One limitation is that it cannot verify that the input data is correct. If incorrect information is written onto the blockchain, it stays there and cannot be adjusted. A tool to mitigate that incorrect data is added to the blockchain is needed to prove its validity according to the Researcher.

The same mentions that a barrier that needs to be overcome for this is ensure the cyber-physical link when the purpose is to trace material to its origin. It is very hard since you need a link between the digital and the physical, and if this cannot be done, the blockchain is useless in this area. However, if these links are achieved, blockchains are invaluable. This can partly be solved by Internet of Things. Connected things are generally increasing in our society, both within industry as well as in everyday life. It is, however, important to consider that sensors are reliable, but cannot provide the fully credible truth since there is always a risk of manipulation. Further, the marking of objects is today doable in many cases, but can be very expensive for certain products A trade-off between price and traceability need to be made. IBM states that since the price of IoT sensors is decreasing, it will enable more applications of the blockchain technology as it will be cost efficient.

IBM also states that the blockchain technology is still in an immature stage and is very hyped. Since it is very immature, it is not ready to replace existing solutions in a beneficial way. There are also few experts on the subject, equipped to lead a blockchain implementation project. The numbers of the initiators are also very limited at this stage.

As mentioned by IBM, in business-adapted blockchains, which are usually permissioned, the visibility and power is unequally distributed over the network. This setup contradicts the fundamental idea of a blockchain that is should be distributed and visible for everyone within the network. However, all blockchain setups do not require visibility in that sense and provides other advantages.

From a technical perspective, the main limitation is, as in most digitization projects, the connectivity. The blockchain technology requires connectivity to replicate and distribute information within the network. IBM means that if this cannot be achieved, the blockchain technology cannot be used.

4.2 Subcontractors

As shown in the chapter 3.3.2 *The Construction Supply Chain*, the interaction and involvement of subcontractors takes place during construction. In order to arrange the actors for each project, the procurement of subcontractors is of high importance as well. The content in this chapter will therefore cover the procurement phase and the construction phase, described in the construction process in chapter 3.3.3 *The Construction Process***.** In the section below, if nothing else is stated, the information is based on the gatherings from the interview with the PPM.

The procurement of NCC can be divided into a central unit and a project-related. The central unit has traditionally worked with procurement of framework agreements of indirectly material and services. The project related procurement is performed by each business unit.

Overall, the company has 350 people in total where 250 is located in the business units, close to the projects. The rest working centrally.

The procurements by the business units are those which are not contracted centrally. The majority relates to service i.e. signing of subcontractors. Although the material is mostly contracted centrally, some smaller purchases are performed by the project. The procurement in the business units is performed and managed by the purchasers with support from construction. The project leaders or others is then involved in the initiation of the contracted services to fit the project plan.

Internal or external labour force depends on whether NCC perform the task on their own or not. External labour is used directly through staffing agencies which only provides labour resources. NCC also integrates indirectly with external employees in the case of a service. According to the PPM, they aim to use their own employees to the greatest extent. The drivers for that are that the internal employees mean lower cost since an external company wants to cover its own margins. Another reason to supply the construction with own personnel is the possibility to control that the worker fulfil all the requirements to operate safely on the construction site.

Common in the construction industry is labour from outside Sweden due to lower salary levels. The drawback is that it is much more difficult to check the staffing agency or the individual employee. In some cases, the staffing industry is not ethical with criminal elements involved. Recently, NCC started their own internal staffing agency in Poland to move the external labour forces into their own company. The initiative has been successful. They now control the chain since they own it by themselves and thus this reduces the risk for unfair business. A similar initiative of NCC is their own wholesale business, NCC supply, where they have their own production of material. That material is considered as cheaper in comparison to buy it externally.

When the alternative above is not used, labour can be bought in through external staffing agencies. The way of using labour from external sources is more expensive but it can be useful for a company to reduce the risk of having employed workers which could not be used due to lack of job. The last alternative is when buying a whole service including both material and workers. The sub-contractor often performs a task with a special knowledge.

Whether the project needs external actors is up to the project leader. A reason for buying a complete service is lack of management, resources and time. The use of NCC supply can be a way of control the material is approved and thus more sustainable. A potential way of procuring to a project is to steer the subcontractors to NCC supply. As the same as above, the resources required by management may be a barrier for that.

As stated by PM, the arrangement and the coordination of subcontractors are almost the same regardless of what type of project delivery system that is selected. Even though the project may include actors such as A/E or other actors at upper level of the structure running the design or the managerial tasks, the contractors are in the most cases organized in the same way. Hence, the project delivery system will not impact how the contractors operates. The interaction between the contractors takes place during the procurement and construction phase. NCC do have different business areas within construction, such as

building and infrastructure. The coordination of subcontractors is however similar to each other. Hence the view that is provided and described below is of a general character, not differentiating subcontractors of different business areas.

4.2.1 Requirements

As in accordance with *The Construction Process*, the requirements take place as an initial activity within the procurement phase, named as preparation of documents. PM states that, the overall requirements that control the project is based on the project description which is set by the owner. It includes basic drawings and function, but also the environmental criteria and other sustainability requirements. Those requirements are in the contract with the main contractor. The same is then head responsible for that they are fulfilled which means that those requirements are further transferred to the sub-contractors. However, both PM and CE state that NCC do have their own standard requirements which are included in all projects regardless of the owner's requirements. In the contract between NCC and the subcontractor it is stated that all actors have to follow NCC's working environment rules on the construction site including safety guidelines. It also includes required certificates, licenses and other documents for the workers which allow them to perform a certain task during the construction.

The PM further describes that the requirements are transferred through the contract. When the subcontractors sign it, they guarantee that they will act according to those as well transferred it further if they will hire an additional subcontractor to perform some task. If a subcontractor aims to hire an additional subcontractor to perform their task, that company needs to be approved by NCC.

The contract is designed to build a frame and condition for the overall work and how to operate, according to the CE. The content and its requirement can be seen as extensive from the main contractor so it covers many areas which put hard demands on the sub-contractor to fulfil. It also means that if something does not align with the requirements, NCC has very good documents which strengthen their position in a legal process. The PPM mentions that in order to still have flexibility, the contract does not cover exactly how their subcontractors should operate e.g. plan the incoming material deliveries and what machine to use.

The ES states that the subcontractors do have the authority to choose material themselves from their own supplier base. The contracts are often written with technical specification. It is normal to refer to a product and require similar characteristics. According to the PRM, it is difficult to not choose a material which does not fulfil the requirements due to the requirements are tough. If using inappropriate material, it will not pass the following inspection. It's difficult to cheat with the material without breaking the laws.

The CE highlights that although the requirements are very extensive and the intention to operate in a good and appropriate way, the contracts are not a guarantee for what will happen. The subsequent control if the requirements are fulfilled is limited today. Several states that if you only put something in the contracts you are protected. To some extent, the contract is not so important until something goes wrong and it goes to a legal process.

According to Sveriges Byggindustrier, the monitoring of the contracts agreements is limited and not sufficient. The fact that the requirements is not controlled, you indirectly send a message to the involved parties that those are not so important which undermines the requirements. When some contractors do not fulfil the set requirements and act differently, they will have an advantage in comparison to those which follow the instructions. If so, there is an unhealthy competition among the contractors. It is a problem according to Sveriges Byggindustrier and something that should not exist. It is necessary not only unethical behaviour is the reason behind it though. There could be a lack of knowledge in these questions and the level in general varies.

Sveriges Byggindustrier mentions that there are several national systems in the construction industry that aim to certify material and products which could be seen as more environmental friendly. The systems are Basta, Byggvarubedömningen and Sunda Hus. These are voluntary initiative which are financed by the users. In the Basta system, it is the producer which document and register the material or products in the system. By that, the producer certifies that it fulfils the requirements and it also responsible to always keep it updated. Every year it performs audits on around 10% of the producers. Both to validate the certification but also as a support for the producers to achieve the requirements. The organisation behind Basta also provides indications if somethings seems incorrect. According to Sveriges Byggindustrier, this system works well today. Producers are aware that if they try to cheat, the products can be removed from the system. Since it is a common requirement, it also good for the marketing to have registered material and products in the system. The overall impression from Sveriges Byggindustrier is that the system is reliable.

Sveriges Byggindustrier highlights that since mentioned system is on a national level, it is not compatible with other system globally. In a case of import materials and products from supplier abroad by the contractor, the process to register in the system may be seen as too extensive. Instead, an assessment is made on the existing documentation about the material or product which can lead to a temporary approval. Overall, the strength with the Basta system is that the criteria are set in collaboration between the producer and the users (contractors).

As mentioned, the final driving force to use environmentally materials or products is the owner, according to Sveriges Byggindustrier. From its requirement of registered materials or products, it is then the contractors who shall verify what they have chosen within the frames of the systems. As stated earlier, the competence varies among the contractors about the environmental systems and to what extent they use it. The practise further back in the chain does not work as it should all the time. This area is developing and has a great potential.

In order to evaluate the material from an environmental point of view, the ES means that NCC needs to track back the subcontractor’s material as close as possible to its origin. Mentioned systems can be a way to assure that material used is approved for the construction. Even though the certification of products and materials enhances sustainability, the process of finding the information about it and what to present still exist. The fact that no single standard exists on how to present materials and products is a problem due to that it is unclear what to fill in.

Today, the information about the products or materials used in the construction are found manually by NCC when they evaluate the projects, according to the ES. An issue is that the information is not gathered anywhere and NCC needs to search for it. Often, the article number which is connected to a specific product changes on its way from the origin and forward. The producer names its product with one number which is then changed to another by a wholesaler. In the end, the contractors might have their own designation for a product. This makes it even more difficult to trace back the material which is used by the subcontractors. The whole process of finding information is time consuming. It is also hard to motivate these resources spent in a profit driven environment. Overall, not spending resources to find this information creates a uncertain environment over what is used during the projects and thus, it is a risk of non-environmental friendly material or products on the construction site.

4.2.2 Assessment

The assessment of subcontractors relates to the tender process within the procurement phase described in chapter 3.3.3 *The Construction Process*. Based on drawings and other documentations, the request is sent out to the subcontractors by the purchasers, according to the PM. The request is only sent to those contractors that NCC is willing to buy from. NCC has a purchasing system where they stored all contractors that they have previously worked with. The contractors are categorized according to their specialization and the location. The PM states that the subcontractors are rated according to price, quality, lead times, environmental aspects, health & safety as well as creditworthiness. This rating is based on the evaluation of previous projects. The time spend on the assessment varies depending on what risk the sub-contractors constitutes. Normally, the potential contractors in a certain area are well-known from before and the purchaser does not search for new contractors if they have a sufficient number to select between. The impression from the PPM is that they want to have, several known contractors competing for the contract to get lower prices but the same believes that it is not the best way. The PPM would prefer more long-term collaboration with a few instead where you can develop the relationships and the operations even more. The PM on the other hand states that there is a general interest to invite more small-scale actors to bid on their projects, but lacks the resources and trust to assess a more extensive number of actors.

The PRM states that new contractors are introduced after recommendations or that they contact NCC before a project. Common is that the new contractor is tested in a less critical project. However, new subcontractors are seen as a risk and the production prefer contractors that fulfil its task without disruptions. The assessment templates are, according to the PPM, not sufficient today and can be improved. The choice is to some extent made from previous experience and not according to the ratings in the system.

As mentioned earlier by the PM, if the subcontractor wants to use subcontractor, they have to inform NCC so it is clear which company that is operating on the construction site. NCC might also have the requirement from the owner that they should have control of how all actors are connected. However, there is no standardized assessment of those subcontractors though. It is a challenging task to control the whole chain. Mostly due to the resources that is required. The problem is then that the contractors back in the chain do not fulfil the sustainability requirements. The CSRM also mentions that another challenge is

when contracting different types of works which supposed to be performed quickly e.g. scaffolding or cleaning. In cases of urgency, the subcontractor may hire a sub-subcontractor without informing the main contractor, which is in direct violation of the contractual terms. In those services, there may also exist criminal elements that can include corruption of illegal work.

4.2.3 Selection

The selection is the final activity in the tender process and procurement phase presented in chapter 3.3.3 *The Construction Process*. The fact that the construction industry is project-based and driven by lowest prices means that the economic factors is normally the qualifier during the selection. If analysing the cost after a project, the variation of material cost is small according to the PPM. He also means that the greatest risk factor is rather the production cost which can rapidly exceed from the pre-calculated. If one task does not run as expected, it becomes a chain effect. The man-hour will increase, renting the machines longer than calculated, potential penalties for delays etc. With that perspective, the PRM states the price is not the important one but the total cost is crucial when selecting subcontractors. It means that a trustworthy contractor is preferable. The PPM mentions that the CSR-aspect is a requirement to be considered in the selection. The reason is that they do not want unethical contractors on the construction site. The final decision during the selection is primarily made upon the lowest cost.

The project-based and price-driven industry result in a competition among contractors for winning the contracts, stated in chapter 3.3.2 *The Construction Supply Chain*. During booms, the PM states that it is problematic to hire subcontractors due to that the most of them are already engaged in other jobs. In some cases, it is the main contractor that needs to convince the subcontractors to sign up for a project.

4.2.4 Control and Monitoring During Construction

Aligned with the construction process, presented in chapter 3.3.3 *The Construction Process*, the CE states that after the requirements are set and the actors are organized, the responsibility from purchasing function to the construction shifts and the construction phase starts. The control and monitoring during construction can mainly be connected to the execution under the construction phase.

The structure to manage the project differs depending of the project. However, the project is always run by a project leader in some sense. According to the PRM, the responsibility may be divided between an overall project manager, sub-project managers for different sub-areas in the construction, foremens and workers. The project managers and the foremen supervise construction, including both internal and external workers. There are planned meetings involving the different actors on the construction site to check the proceeding. Additionally, there is also supervision continuously out on the construction area. Before the start of each task, it is common with a preparation meeting with involved parties in order to run the work according to the requirements and to secure that the work is done in a safe way.

Overall, NCC does not want too many sub-subcontractors at the site due less control over the involved actors at the site, according to the PRM. However, because of specialized skills

it can be motivated to hiring an additional layer. A larger project also makes it harder to control the construction site. Earlier, the different contractors worked independently. Today the view is that all parties collaborate to greater extent and where they put an effort in to reach a common goal. Even though it is existing problems in the industry, NCC trusts its subcontractors until the opposite is proven. The PRM also states their own responsibility in the relationship with the contractors to act ethical and being a role model.

In the construction industry, they have a standard called *ID06* which aims to identification and attendance. In other word, a digital personnel ledger with a physical card for identification. This standard was introduced 2006 in the construction industry. In May 2018, a new standard was implemented which is considered as powerful in terms of security and reliability (ID06 AB a., 2018). Therefore, ID06 in this thesis relates to this new standard. All project where the cost exceeds SEK 180 000 must use the ID06 system (ID06 AB b., 2018). The HR-specialist at NCC describes the purpose of the system as to control who are on the construction site and prevent that unauthorized people enter it. If it is a control mechanism that control who actually operates at the site, that information could then be checked with taxes paid by the contractors. With this, the standard aims to mitigate undeclared workers. Another reason is that each person is identified which could be checked with the required licenses and education for the specific tasks they are supposed to perform. The expected outcome is that no task is performed by unskilled workers which will result in less accidents.

The HRS explains that the identification is a physical card. On the card edition, it is printed the name of the employee, its employer, the employer's corporate identity number, the period of validity and a photo of the employee. The system was governed earlier by the trade association Sveriges Byggindustrier but has been moved to a new company called ID06 AB. ID06 AB holds a central database with all registered cards. It also works as a competence database where the educations and licenses are connected to each card and thus each member.

In order to secure the reliability around ID06, a process is developed with different validation nodes. In each company, a number of personal are delegated authority from the company signer to apply ID06-cards for the employees. One of these fill in the worker's personal information and verify its own identity with a mobile bankID, which is a Swedish mobile application for personal identification. The application is then sent to the card supplier which is authorized by ID06 company. That supplier registers the personal data in their system and sends back a new ID06 card. The information is also sent further to ID06 competence database. To activate the card, the individual has to validate its identity with a mobile bankID. ID06 does have their authorized education provider which train the workers for special tasks. After a completed course, the information is sent to the ID06 central database and connects to the individual. The processes related to ID06 are presented in figure 4-1 below.

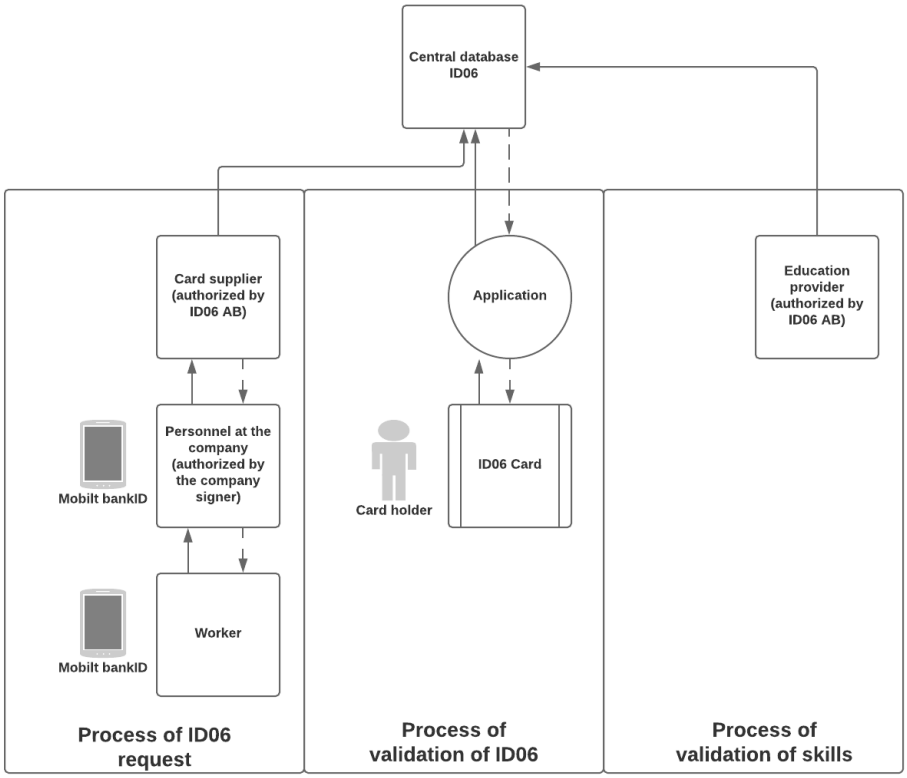

Figure 4-1. The Processes of ID06, Based on the Interview with the HRS.

The HRS further describes that it is common that it is an enrolment process in the beginning of each project. The worker's ID06 card is controlled by an application which checks the card in the central database. It reads whether the card is approved for access as well as what license the person holds. Once the project has started, there is no control if the person who enter the construction site is the person who is connected to the card. It is no follow-up to check if the card is still in the period of validation. During the construction work, the card must be visible. There is unannounced visitation at sites to check the number of workers in comparison what is stamped in the system.

According to Sveriges Byggindustrier, there is an issue with that the educations provider do not have that quality and length as expected. When it comes to license from abroad, it is a limited control. Even though cheating is present, Sveriges Byggindustrier states that the majority acts ethical. There is also a barrier of identification of mobile bankID. While the technology is commonly used in Sweden, it is no guarantee that all has that application. Especially workers outside Sweden who do not have mobile bankID. In that case they need to validate their identify at the card supplier which is time consuming.

As mentioned, one of the drivers for ID06 is to prevent unauthorized individuals and thus reduce the accidents due to unskilled workers. According to Sveriges Byggindustrier, the individual has the final responsibility for his/her own safety and it should not only be governed by laws for working environment. Overall, most of the accidents can be derived to the human factor. In many cases, it is possible to foresee a potential accident. However, the trend for accidents is declining in the construction industry. In relation to the accidents, Sveriges Byggindustrier states that repetitive strain injuries are a greater problem even

though the accidents get higher attention. These injuries affecting the individuals and result in permanent suffering.

Sveriges Byggindustrier means that material waste on the construction site is a serious issue within the construction sector. The amounts material produced and delivered aimed for the construction is not often fully used. A driver for exceed the calculation of how much material is needed is that the actors will ensure against the risk that the material does not cover the actual amounts needed. That will result in additional transportation cost, disruption in the construction and delayed process. Another situation is when the construction design does not correspond with standardized dimensions, which generates waste. The material handling on the construction site is also a reason for material waste. When the material is sawed, cut or otherwise modified, the material might not be fully utilized. Overall, according to Sveriges Byggindustrier, this is a problem along the whole chain of actors. The same also mentions that there is a lack of resource efficiency thinking in the industry in general, including idea and design, ordering, material handling on site etc.

4.2.5 Evaluation

The evaluation of subcontractors is outside the construction process and is more related to a general purchasing activity which are performed after the project in order to gather data for future projects and its assessment. Both the PM and the PRM agree upon that in general, the construction function evaluate the subcontractors' performance. The most project end with a final evaluation meeting where the production personnel gives feedback to the purchaser what has been good and things that could be done in a better way. PM states that the purchasing function is then responsible for updating their purchasing system with the information for future projects. This tool is used to some extent but not sufficiently. According to the PRM, there is no standardised process to upload the information. This means less data to use in the supplier assessment which result in that the assessment is not based on quantitative data.

4.2.6 Monetary Flow

The different phases during the construction process emphasize the activities towards a finished construction. Besides that, there is also a monetary flow which compensates the actors involved for their contribution in the construction process. The CE states that when the contractors have completed the tasks, an invoice is sent to that company who has ordered the job. The invoice is then checked if the sum corresponds to the contracted sum. The time for sending the invoices could either be when the whole tasks is completed but it can also be split into a payment schedule which is set according to milestones in the construction, according to the PRM. The CE further explains that in the administrative process, it is normal that this process involves more than one person in order to secure that the payment is correctly. If something occurs that not correspond to the agreement, the buying firm can withhold the payment until it is corrected. Usually, the contracts sum that is offered by the subcontractor is fixed without no detailed specifications of the cost which the price is based on. There may, however, rise unexpected tasks that is not included in the contracts. Therefore, it is common that additional cost is added to the existing contracts, which is called ÄTA. It can include extra cost, new tasks that was not set from the beginning etc. This payment is sent separately. Overall, and according to the PM, the payment time in

the contracts is set both in order to administer the invoice and to match the incoming invoices in order to keep a good liquidity. A long payment time is therefore an advantage and a shorter could imply that it will be hard to finance the operations with the current structure and information flow.

The structure of actors in the Construction Supply Chain, visualized in figure 3-4 and in the project delivery systems mentioned in chapter 3.3.2 *The Construction Supply Chain***,** shows the hierarchy during a project. This means that it will govern the monetary flow and the actors' financial responsibility towards other actors. The CE's view aligns with this, and that the payment to the company that is contracted by NCC is the only concern. Even though the main contractor has the overall responsibility for the project, what is agreed between the subcontractor and the subcontractor under them is their business. The PM mentions the fact that in order to not expose the cost structure, the subcontractor does not divide the cost in detail. It is Common to offer a final price. Further, the salary for the sub-contractors is not presented in the contract. Today, there no control regarding whether the subcontractor's employees are compensated. Hence, there exists is not any control mechanism in place that ensures that lower tiers of subcontractors are compensated for their contribution.

The CE agrees upon that undeclared work has traditionally been an issue in the construction industry. Due to that, four times a year, NCC sends a list to the Swedish tax authority, Skatteverket, with the number of contractors which have been involved in any projects. Skatteverket checks whether they have paid the taxes correctly. If not, NCC informs and pushes the subcontractor to either pay or spread it further if it aims to a subcontractor under them. Sveriges Byggindustrier points out that the majority of the contractors do not have an intention to avoid paying taxes. They also believe that no main contractor is actively hiring undeclared workers as subcontractors, rather that it is made further down the chain in the 2nd or 3rd tier. Still, it exists and that is an issue. On the other hand, Sveriges Byggindustrier states that the industry has worse reputation than its deserves. As mentioned by the PM, the Swedish government is considering introducing a new law which where the main contractor is responsible paying the salary towards employees who are not compensated by their employer, the subcontractor.

4.2.7 Summary of Found Issues

During the interviews, several issues within the construction industry was brought to light by the interviewees. The issues they stated were from their roles as professionals within their respective areas of expertise. There was a total of seven issues that were brought to light that has been summarized, which can be seen in table 4-2.

Table 4-2. Summary of Issues Within the Construction Industry.

Summary of issues
◘ Material Waste
◘ Non-sustainable material used by the contractors
◘ Undeclared work
◘ Repetitive strain injuries
◘ Accidents
◘ Employee payment
◘ Limited contractor base

5. Establishing a Framework for Analysis

In order to achieve the purpose of evaluating how the blockchain technology can mitigate the identified problems within the sustainability scope within the construction industry, a framework had to be developed. The framework needs to be able to identify and categorize the issues within the scope of sustainability, as well as evaluate whether a blockchain solution is viable, where identified sustainability issues are eliminated if they do not withhold the elements needed for an appropriate blockchain solution. The framework also needs to be able to evaluate the blockchain solution in an objective and structured way. So, the framework was complemented with a SWOT-analysis, to make this possible in a systematic and objective way. The sequence of how the issues are analysed by the framework is visualized in figure 5-1.

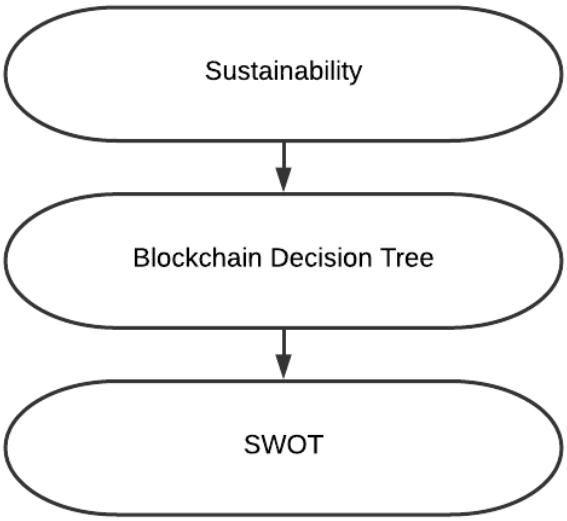

Figure 5-1. The Sequence of how the Issues are Analysed by the Framework.

5.1 Sustainability

To be able to classify the issues identified within the scope of sustainability, a framework that guidelines and categorizes them is required. The framework needs to include the relevant aspects, which were found in the definition of CSR, the social, environmental and economic perspectives. So, the Triple Bottom Line framework, as presented in chapter 3.2.2 *Perceptions of CSR,* has been identified as highly appropriate to provide these features. The framework outlines the three bottom lines of an organization, people, planet and profit. People refers to the social aspect of the bottom line, planet to the environmental and profit to the economic aspect.

When developing the framework based on the Triple Bottom Line, the categorizing has been broken down into subcategories and aspects, with the purpose of identifying the problems relevant for this thesis. The subcategories are based on the guidelines and standards of the Global Reporting Index (2016). As stated by Wilson (2015), the Global Reporting Index, GRI, are one of the leaders in developing sustainability reporting standards. The subcategories that GRI has included in their standards are shown in Table 5-1. Their standard is developed

with the purpose of sustainability reporting, which covers the relevant aspects of the Triple Bottom Line framework. These aspects is to be used in this thesis to act as subcategories for the problem categorization.

Table 5-1. Aspects and Subcategories of Triple Bottom Line, Adapted from Global Reporting Index (2016).

Economic	Social	Environmental
Economic performance	Labour Practices and Decent Work	Material
Market presence	Human rights	Energy
Indirect economic impact	Society	Water
Procurement practises	Product responsibility	Biodiversity
		Emissions
		Effluents and Waste
		Products and services
		Compliance
		Transport
		Overall
		Supplier Environmental assessment
		Environmental Grievance Mechanism

The categories ‘Environmental’ and ‘Economic’ are broken down to aspects, while ‘Social’ is broken down to subcategories that includes aspects that need to be assessed and evaluated. The aspects within the subcategories were presented earlier in Table 3-2.

5.2 Blockchain Decision Tree

To identify if the blockchain technology is a suitable solution for the defined problems, as can be seen in table 4-2, a decision tree is used. The decision tree is based on the characteristics of the blockchain technology as a solution is applicable and beneficial. The development of the decision tree has been made through studying the characteristics of the blockchain technology. The main purpose of the decision tree is to eliminate the problems that do not fit the scope of the blockchain characteristics, hence highlighting the ones where it may fit. The questions that needs to be answered to proceed in the decision tree are further described below:

As defined, blockchain is a distributed, peer to peer replicated database that provides consensus (Gupta, 2017). Hence, storage of data is a prerequisite for using a blockchain solution. Thus, the identified issue needs to be dependent on data storage, otherwise a blockchain solution is not applicable. The underlying requirements of this lead to the first question of the decision tree:

- Is a database required?

Regardless if it is a permissioned or a permissionless blockchain, data needs to be added to the blockchain. This can either be done by all nodes, i.e. a permissionless type, or by a predefined group of nodes, i.e. a permissioned one (Dresher, 2017). The blockchain is therefore dependent on that more than one node has writing access to add data to it, otherwise a blockchain loses one of its fundamental purposes. Therefore, the second question is:

- Is shared write access required?

The blockchain technology relies on a consensus based model where the validity of a ledger is based on the majority of the ledgers distributed within the network. This creates a immutability of the records being kept, eliminating the need for trust (Dhillon et al., 2017). Therefore, blockchain is suitable in environments where the parties are not trusted. This leads to the third question that needs to be answered:

- Are the writers trusted?

Even if the writers are trusted, there may still be a risk for opportunistic behaviour among the parties depending on differing interest. If this risk exists, the blockchain technology can provide the assurance needed by ledgers that cannot be manipulated (Dhillon et al., 2017). The motivation leads to a first sub-question:

- Is there a risk for ununified interest?

There may, however, be situations where both trust and unified interests are present. In these cases, blockchains may, however, still be a viable solution. IBM states that the blockchain technology has other benefits than consensus, it can also improve efficiency within a business network. The blockchain technology has been proven to reduce administrative, as well as coordination, costs in several cases, e.g. the Maersk/IBM-consortium where the handling of documentation for a shipment was made more efficient, requiring less manual work. This leads to a second sub-question:

- Can it reduce the costs of coordination and/or administration?

It is important to consider if there is a need for a trusted third party within the transaction. As stated by Lantmäteriet, they act as a third party in keeping record of all transactions made in Sweden. They could theoretically be replaced by a blockchain solution, but in practise, this would not be sustainable since they provide the assurance that errors are prevented or corrected, which a blockchain solution without a third party cannot arrange for. This is a central question in the consideration of a blockchain solution since it will not be a need for it if there is a need for a trusted third party. This leads to the fourth question:

- Is a trusted third party required?

If, however, a third party is required, it does not necessarily eliminate blockchain as a potential solution. Even though the blockchain technology is associated with disintermediation, the intermediaries can still provide value to their services. The immutability and transparency that blockchain may provide can be a driver for a blockchain solution even though the third party is still required. An example of this can be the assurance that the Swedish Land Registry, Lantmäteriet, provides to the public, or the increasing transparency and efficiency that the Maersk-IBM consortium provides to their customers. Hence, added value from a third-party provider can be a driver for a blockchain solution itself, which motivates the sub-question to the fourth question:

- Does the 3rd party provide additional value?

The decision tree is proposed as can be seen in figure 5-2. It consists of four questions that need to be answered with either yes or no, the output determining if a blockchain solution is applicable.

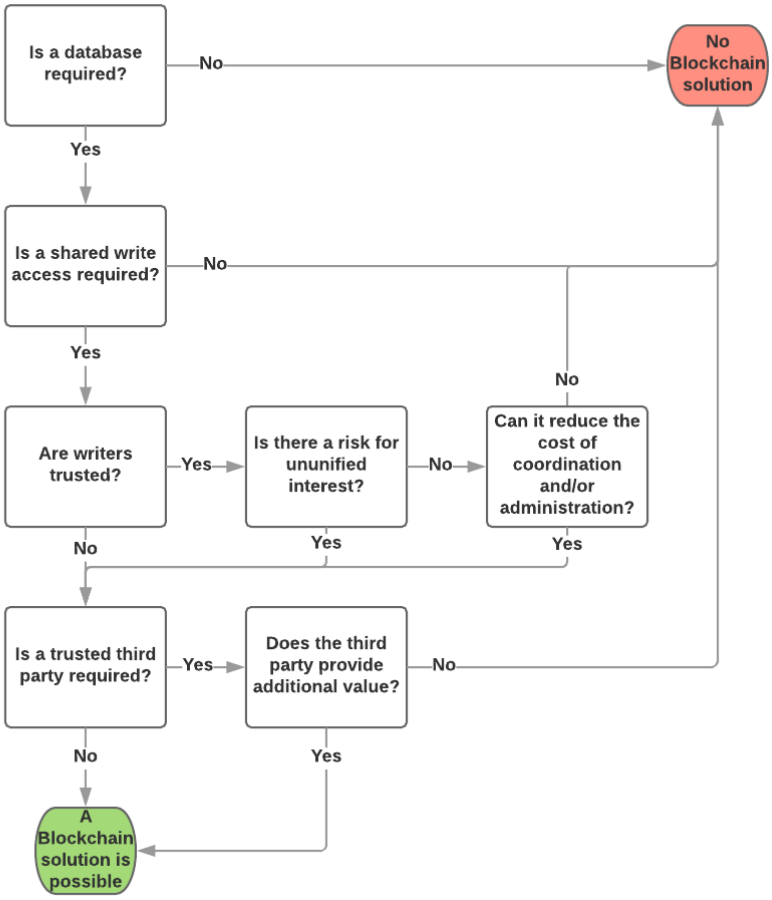

Figure 5-2. Blockchain Decision Tree.

5.3 SWOT

In order to assess a possible blockchain solution for the identified issues in a uniform, objective and structured way, the SWOT analysis tool has been chosen, where the matrix is presented in figure 5-3. The tool is one of the best-known strategic techniques that provides perspectives and evaluates objectives and/or subjectives with their respective strengths, weaknesses, opportunities and threats that can be used to assess e.g. new technologies or directions of an organization (Andersen, 2007). Gould (2012) states that the SWOT analysis highlights how advantage from the external opportunities can be taken given the internal strengths of the evaluated subject, as well as how to minimize the internal weaknesses and how the subject can be safeguarded against external threats. A SWOT-analysis consolidates the internal strengths and weaknesses of the subject with the opportunities and threats from the external environment (Gould, 2012). Strengths refer to how the subject is considered to distinguish itself in a superior way relative to other subjects, i.e. what makes this subject into

a competitive advantage. Weaknesses are outlined which refer to how other subjects are more prominent than the given subject, to provide an objective view. Opportunities and threats refer to what benefits and disadvantages the external environment brings to the subject, in terms of e.g. political climate, technological developments, economic situation etc.

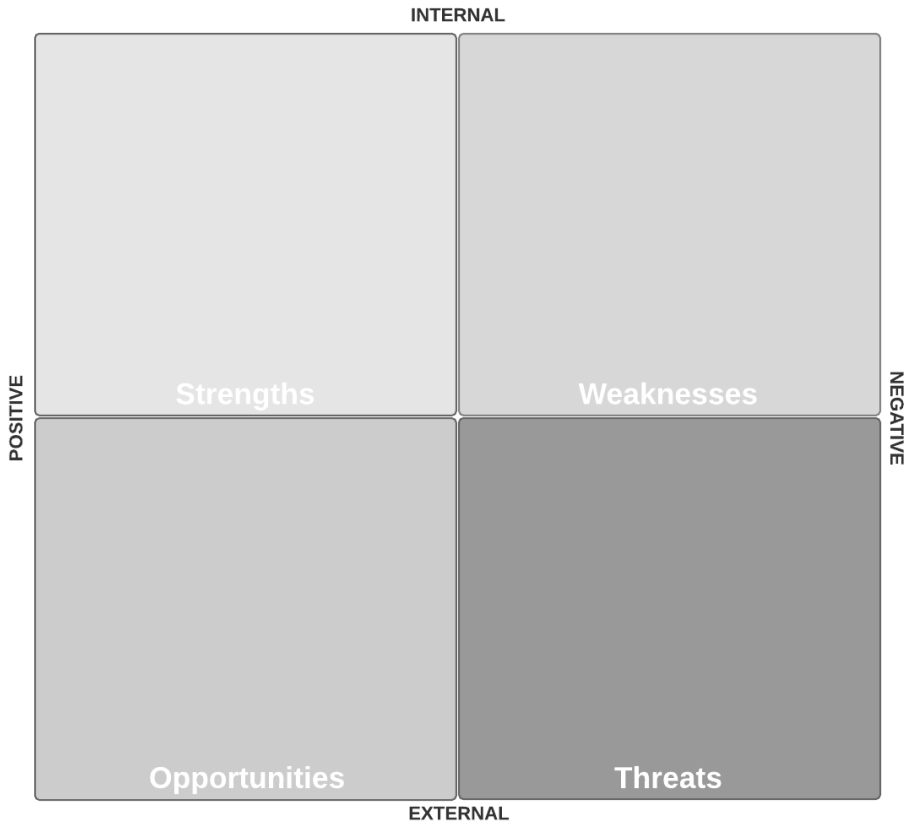

Figure 5-3. SWOT Analysis.

The SWOT analysis tool will be used to evaluate how the blockchain technology can affect the different issues in an objective way. Therefore, a SWOT-analysis will be performed for every defined problem within the scope of the study. This will be an effective approach to objectively assess the blockchain technology in different context in a uniform way. The SWOT analysis tool can, in a logical and pedagogical way, be used to assess a problem in combination with a possible technology solution.

6. Analysis

The analysis is made with the framework that was developed in chapter 5. *Establishing a Framework for Analysis*. Seven issues within the construction industry were brought to light from the interviews with the construction industry professionals during empirical study. A summary of the issues can be seen in table 6-1. The issues are processed in the sequence of first classifying them within the Triple Bottom Line categories, followed by the proposed blockchain decision tree, and finally evaluated through a SWOT-analysis. Each issue has to pass in order to be further processed to the next block. This procedure will decide if the issue is within the scope of this study, if a blockchain solution is applicable and finally evaluate the potential of the suggested solution for a specific issue.

Table 6-1. Summary of Issues Within the Construction Industry.

Summary of issues
◘ Material Waste
◘ Non-sustainable material used by the contractors
◘ Undeclared work
◘ Repetitive strain injuries
◘ Accidents
◘ Employee payment
◘ Limited contractor base

All issues that reach the SWOT-analysis have their specific strengths, weaknesses, opportunities and threats, which are therefore evaluated in isolation. However, there are several opportunities and threats that are in common for all issues. For instance, several of the issues may be solved by the same kind of blockchain setup. This enables an opportunity to each an economic benefit of the solution in terms of economies of scope. There is also a societal demand for all industries and organizations to act more sustainable in general, which is a opportunity for a new technology that have the potential to enhance it. Threats that occur that are common for all issues due to the characteristics of the construction industry at large. There are some elements that relate to all issues mentioned. As mentioned earlier, it is a inertia where the construction industry has historically been lagging behind in innovation, which a potential blockchain driven solution also may suffer from. As discussed as a limitation in chapter 3.1.5.1 *Social and Economic Limitations with the Technology*, there might also be a resistance within the network of actors to adapt themselves to this change. As stated in chapter 3.3.2 *The Construction Supply Chain*, the construction industry is fragmented with many small actors, in particular sub-contractors. This fact is a market limitation where several actors may be excluded due to their lack of resources and

knowledge to adapt to the blockchain network. Due to the mentioned characteristics of the construction industry being project-based with short-term relationships, some actors may be reluctant to share their data to other actors in the business network.

6.1 Material Waste

Material waste has been identified as a issue within the construction industry. As stated by Sveriges Byggindustrier, it is common that the order quantity often exceeds the needed amounts during construction. It is stated that the cost of ordering too much material can be justified since the cost for a production stop can be very expensive. Another reason is that the construction design are not optimized to standard dimensions, so adjustments often have to be made. This results in that all material is not utilized and need to be disposed. Hence, material waste may be difficult to avoid since it is intentional.

Triple Bottom Line

Material waste is an environmental issue, since the excessive material has to be disposed to due regulations. The issue fits under the Environmental category of the Triple Bottom Line framework, under the aspect ‘Effluent and Waste’. Since the issue fits within the Triple Bottom Line framework and thus the scope of the thesis, the issue is further investigated.

Decision Tree

This issue of material waste does not have a potential blockchain solution, as can be seen in figure 6-1. The issue does require a database since you need to store the information, in this case, the specification drawings that provide the information of the needed amounts. However, the amount of material is based on the information within the database, without any further input by other actors. The project interprets the amounts required by themselves. Thus, write access for several actors is not required in this case. The selection of dimensions does not relate to shared write access since it is determined of one actor which should then be the basis for all other actors involved for the project. In case of local adjustments, it is connected to a physical handling of material where the question of shared write access is irrelevant. According to the framework, the issue of material waste is not a subject for further investigation for a potential blockchain solution.

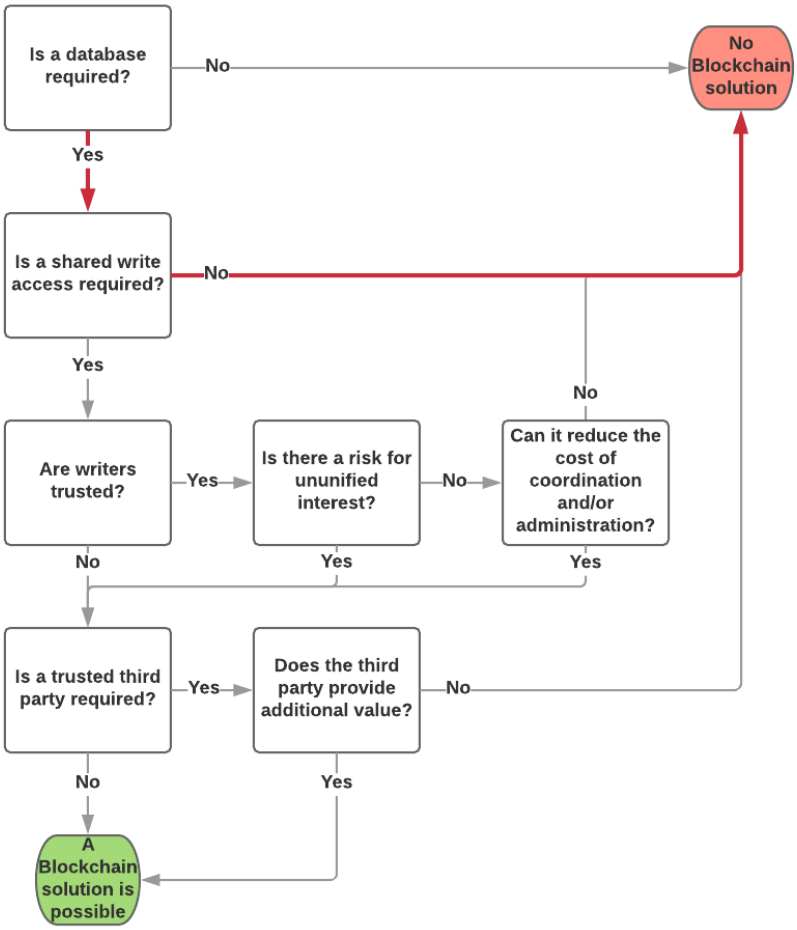

Figure 6-1. The Path of the Issue Material Waste in the Decision Tree.

6.2 Non-Sustainable Material Used by Contractors

Today, it is of crucial importance to use sustainable materials in constructions. When the main contractor procures material themselves, the level of sustainability can be controlled more easily. But when a subcontractor is hired to perform a task, they are often responsible for the purchase of the materials themselves. Sustainable materials relate to materials that are both ethically produced and environmentally friendly. The issue mainly occurs when the subcontractor is responsible for the procurement themselves. This because it is one additional step to trace and verify back in the chain.

Triple Bottom Line

The problem of controlling the usage of sustainable materials in construction relates to several aspects that fits in to the Triple Bottom Line categories. The environmental effect of when the material is produced is an important aspect of sustainability. It also relates to what materials that are included in the end product that have an effect on the environment. Aspects considered are for example dangerous substances, energy used to produce the end product and material waste. Within sustainability, social aspects are included. It is important that the products are ethically produced and that no one has been harmed. Both labour practices, as well as human rights, are to be considered in this category. This relates to, for

example, the employment, salary, working conditions, no child labours etc. The problem of controlling sustainable material usage relates to both the aspect of the material itself from an environmental perspective, as well as under what terms the material is produced, relating to ethics and social aspects.

Decision Tree

The issue of controlling sustainable materials can potentially be solved by the blockchain technology, as can be seen in figure 6-2. The first question of whether a database is needed is considered as required. This is because in order to control the material selection, what is actually produced in the physical world need to be digitalised. Therefore, a database is fundamental. In order to see what happens in the supply chain, there must be several actors with shared write access. Several actors are affecting the material outcome throughout the whole chain, motivating that all of them should provide documentation of the material separately. As it concerns each actor's own business, all are responsible for their own information. The writers, i.e the supply chain actors, are considered as trusted until the opposite is proven. Even though the actors are considered as trusted, the material choice may, however, experience a risk for not having unified interests in this matter. There is a risk that a contractor or supplier may act opportunistic to benefit their own agenda. This could relate to that they procure a material that is less expensive but do not fulfil the requirements, or that there is a semantic flexibility within the contract giving them the opportunity to do so. There is no third party required in this process. The responsibility lies in the hands of the actors themselves, to provide the actor downstream with this information. Since no third party is required in this problem, a blockchain solution may be possible to solve this issue.

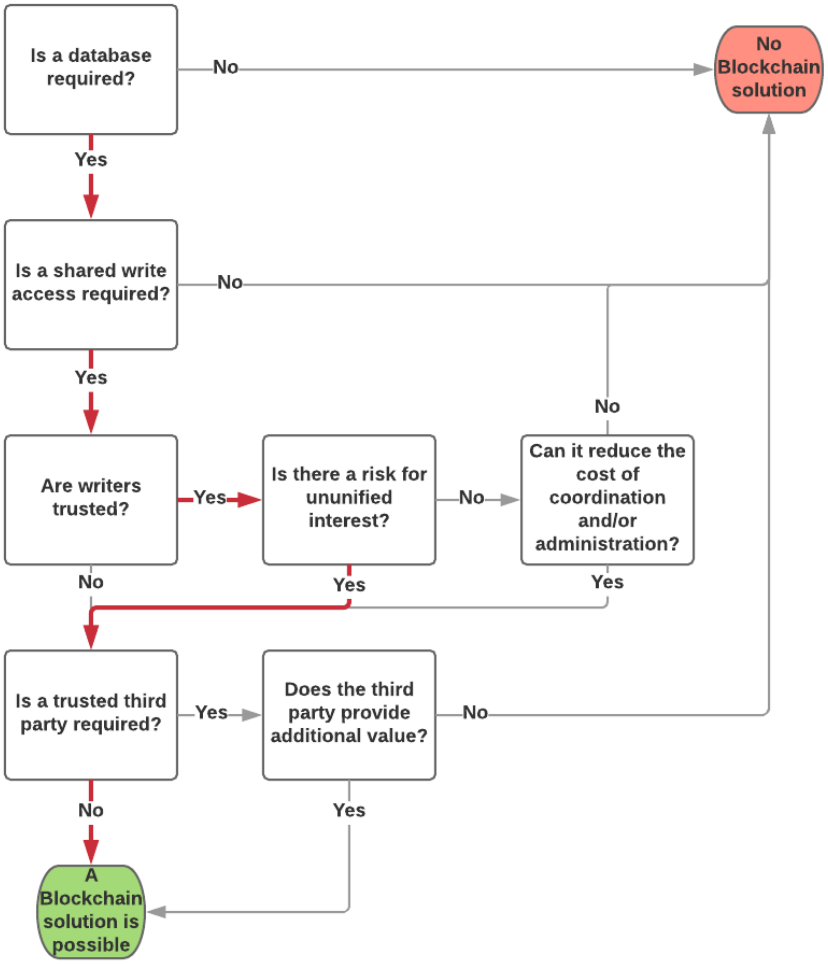

Figure 6-2. The Path of the Issue Non-Sustainable Material Used by the Contractors in the Decision Tree.

SWOT

A potential blockchain solution would be that the actor along the chain of materials provide documentation on to the blockchain where they state which product, including those requirements which are requested in the contract. This solution would also make it possible to trace the material to its origin and under what circumstances the product has been made. The evaluation of this issue is presented in figure 6-3 below:

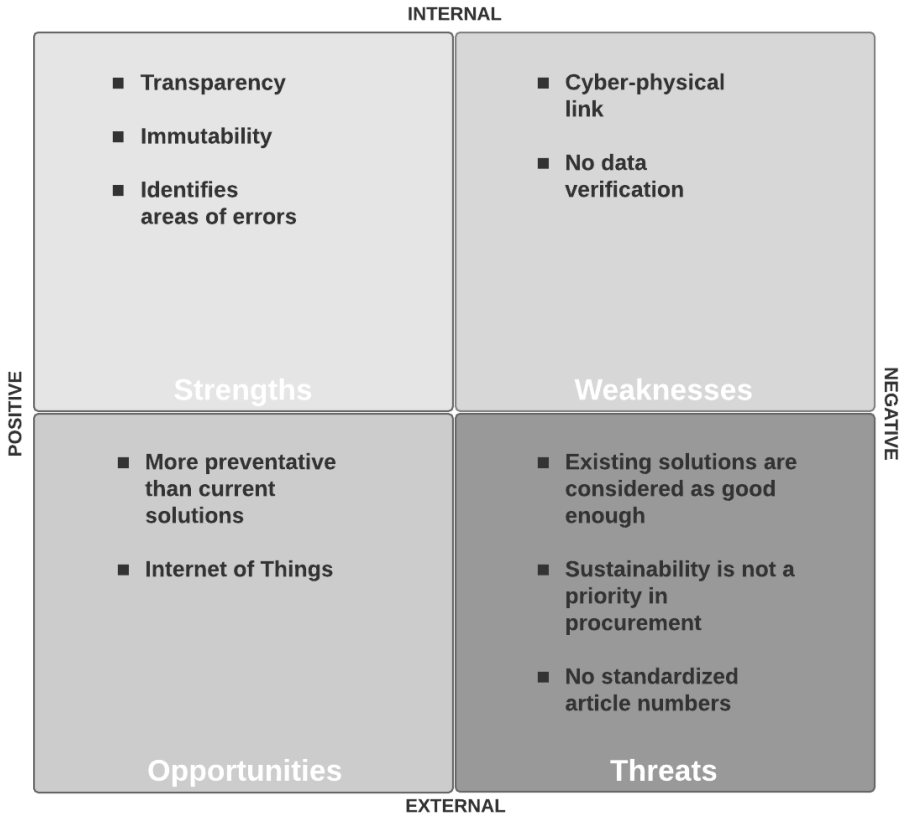

Figure 6-3. A SWOT Analysis of a Blockchain Solution to Prevent Non-Sustainable Material Used by Contractors.

Strengths

Today, the specifications of sustainability requirements related to materials is provided to the subcontractor, which is hired by the contractor for a certain task. Sveriges Byggindustrier states that the actual material used by the subcontractor is not controlled, but rather based on trust. The motivation being that they are trusted until the opposite is proven. As stated by Dhillon et al. (2017), two of the main characteristics of blockchain are that it can enhance the transparency and immutability. These are characteristics that can provide the necessary means to trace materials throughout the supply chain. Hence, the blockchain technology can provide the advantages so the actual usage of sustainable materials does rely less on trust.

Lantmäteriet is currently investigating the potential advantages a blockchain solution may provide. One of these advantages is that it can store the transaction history in an immutable way, providing Lantmäteriet with the opportunity to trace back where a potential error has occurred. This area of usage can be transferred to the construction industry, where it will be more convenient to trace material. According to the ES, it is very time-consuming to evaluate the used material in a construction project since the information is not presented in a common and standardized way. The transparency that blockchain could provide can reduce the resources needed. Further, with the transaction history, it becomes easier to find where errors have occurred in the supply chain. The Researcher states though that the blockchain technology cannot fully guarantee that the input data is correct due to the cyber-physical link. However, it can still aid in identifying deviating patterns throughout the supply chain. This can be exemplified with if one node in the supply chain wants to manipulate the data in order to achieve the requirements set. If the other actors have different data registered, the area of

deviation will be located. From that, future audits can then be targeted in a better way. IBM states that there is still a value to trace at batch level, as Walmart aims to do.

The food industry would draw benefit from a higher degree of transparency, which can be achieved through blockchain. The agreed terms or requirements of the product can be verified through digital history, e.g. a photo of the fish that can show that it has been caught in the area or way as stated. It is, however, very difficult to know if the photo is connected to the product or not, but it mitigates the risk. Random audits are, however, recommended to perform, to see if the photo correspond to the requirements of the product. Internet of Things can beneficially be used for requirements such as temperature, humidity or other measurable data, and automatically update the blockchain. Even though the construction supply chain differs from other industries as described in 3.3.2 *The Construction Supply Chain*, the structure for the material supplied to the contractors is still the same as other industries. Therefore, this approach for the food industry can be transferred to the construction industry as well.

Weaknesses

As stated by the Researcher, it is critical to establish a strong cyber-physical link, i.e. connect the physical object with the digital. This can, for example, be labelling that cannot be tampered with. He further states that if this link cannot be achieved in a secure way, the material cannot be verified to be the one stated in the blockchain transactions. This issue occurs with the verification of sustainable materials as well. The material cannot be verified to have been produced under certain labour conditions and processing methods if this link cannot be established. As mentioned by Kairos future (2017), there are potential solutions to establish this link, for instance, with complementing the information with an evidential photo. However, this will not be evidential since there is a risk that the photo is not connected to the specific object.

The Researcher further states that the materials that are processed, for example melted or treated in other ways, it can be hard to trace the material at a micro level since the marking it cannot be guaranteed. As mentioned under Strengths, the tracing can rather be made at a higher level, for example pallet or batch. This may, however, not provide the same accuracy as it otherwise would.

The ES states that if there is an issue today of getting the correct data, since the materials may be presented as sustainable, when in fact the parameters have been tampered with. This is not an issue that can be solved by the blockchain solution since verifies data. As stated, the blockchain technology is design to only store data, not to verify it.

Opportunities

One opportunity for this solution is that there are no existing solutions today that offers the same potential. As stated by Sveriges Byggindustrier, the certifying systems used today (BASTA, Sunda Hus etc.) allow the material providers to certify their materials, without any further investigation made by the organisations that validate these statements which undermines the importance of the requirements. In comparison to the existing system, the blockchain solution allows for transparency and immutability which will show the real picture of the industry. It will also result in minimizing the resources for verification, and since the

system is consensus based, the network will be notified if an actor tampers with the data. Thus, the blockchain technology has the potential to prevent this issue to a higher degree than the current solutions.

As stated by IBM, the cost of IoT devices, i.e. connected sensors, has decreased in recent years. This makes it more economically justified to tag products with sensors that collects data and stores it on to the blockchain. This is an enabler for a blockchain solution where the sensors can store the data. There are in general more products, both directly and indirectly, equipped with connectivity both within the industry as well as everyday life, facilitating a shift towards more digitalized processes across all industries.

Threats

One threat is that the existing solutions, such as BASTA, Sunda Hus etc., are seen as good enough, according to Sveriges Byggindustrier. Based on that, the urgency for a new solution may not be of interest within a short time-frame. Generally, according to the PPM, cost and quality are prioritized during procurement even though the sustainability is important for them as well. This results in that sustainability comes after them in the list of priorities. This prioritization may be a threat towards a blockchain solution due to commitment.

Furthermore, the ES stated the problems with tracking material back in the chain due no standardized article number, i.e. it shifts along the chain and that there is not clear regarding how to present the sustainable data. Even though blockchain can enhance the transparency in the supply chain, it will not add any value if the data stored is incorrect.

6.3 Undeclared Work

One issue in the construction industry is the risk of undeclared workers. Undeclared work is an illegal activity that needs to be prevented as much as possible. Undeclared work often occurs in several tiers down in the subcontractor structure, often when it is critical to hire an actor quickly and no background check is made. Those criminal elements often buy a company with a clean record so it is not visible at first sight. Alternatively, these elements occur in further steps downstream of subcontractors where they are not assessed and verified by the main contractor. The problem has its roots in supplier assessment and that incorrect information is not verified.

Triple Bottom Line

The issue of undeclared work can be connected to several aspects in the Triple Bottom Line framework. Employees that work under the conditions of undeclared work do not have same the rights as someone who is employed in a legal and correct way, which can be related to employment under the social category. There are no taxes paid for undeclared work with the purpose of lowering the labour costs of the company. This is in direct violation of the Swedish taxation system. This relates to the aspect of public policy under the subcategory society, within the social category. As no taxes are paid, this provides the opportunity to offer a lower price than the competitors. This can be considered as unfair competition and falls within the aspect of anti-competitive behaviour.

Decision Tree

Blockchain might be a potential solution to preventing the issue of undeclared work, as can be seen in figure 6-4. A database is required within this area, both in terms of employee ledgers for all the actors involved, as well as for the accounting activity, where the income is declared. Since all contractors need to register and declare for all their employees, as well as provide Skatteverket with information, write access needs to be granted to all actors. When selecting subcontractors, the contractor makes their choices based on experience, where the subcontractors selected are trusted until the opposite is proved. The verification of actors further down the chain is not made since the 1st tier contractors are trusted and responsible for their own contracting. There is, however, a risk for not having unified interests, where some subcontractors may want to gain advantages of not declaring their work, which reflects negatively on the contractor. Every single contractor is responsible for their own accounting and declaring of work to the Swedish tax authority, i.e. no third party is required to control this process. It is also the contractor's responsibility to control that they are hiring a subcontractor that is approved from a legal point of view. Since no third party is required to do this, the blockchain technology may be a potential solution for this issue.

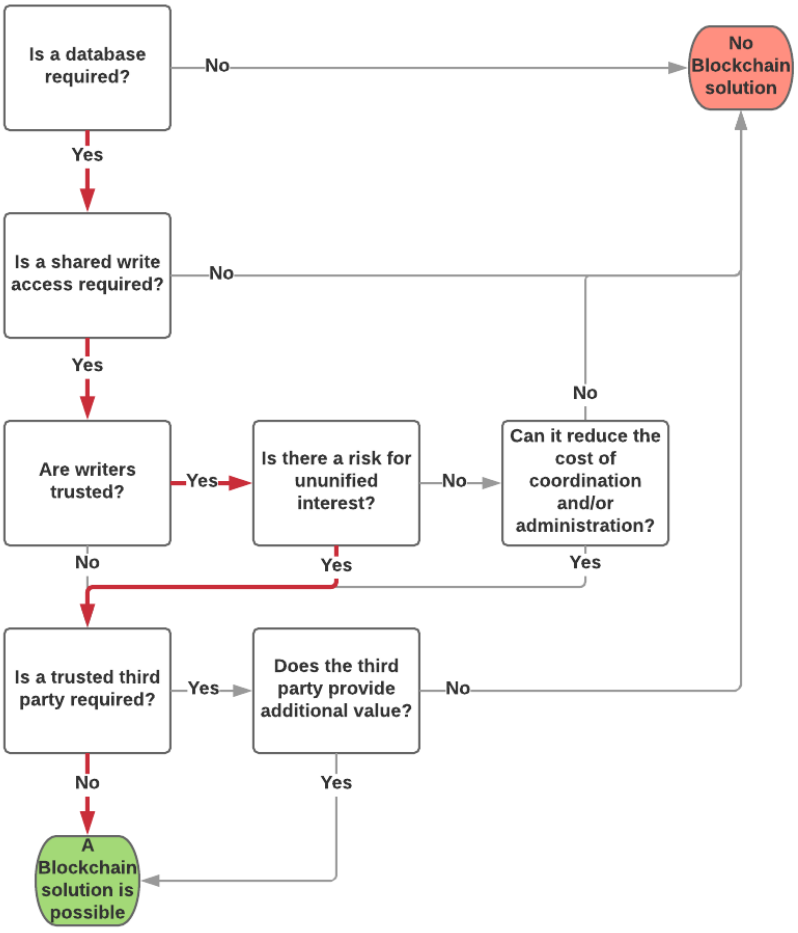

Figure 6-4. The Path of the Issue Undeclared Work in the Decision Tree.

SWOT

One application of the blockchain technology is smart contracts. By using blockchain driven smart contracts, the main contractor can force the subcontractors to declare what personnel that will work on the construction site. They will then be connected to the smart contract, being visible for the main contractor. This solution can beneficially be used together with the existing ID06-system which can secure the identification of the personnel. As stated by the HRS, the ID06 system can validate the identity through Mobile BankID. By connecting these systems, only the declared personnel will have access to enter the construction site, hence preventing unauthorized people to enter. The evaluation of this issue is presented in figure 6-5 below:

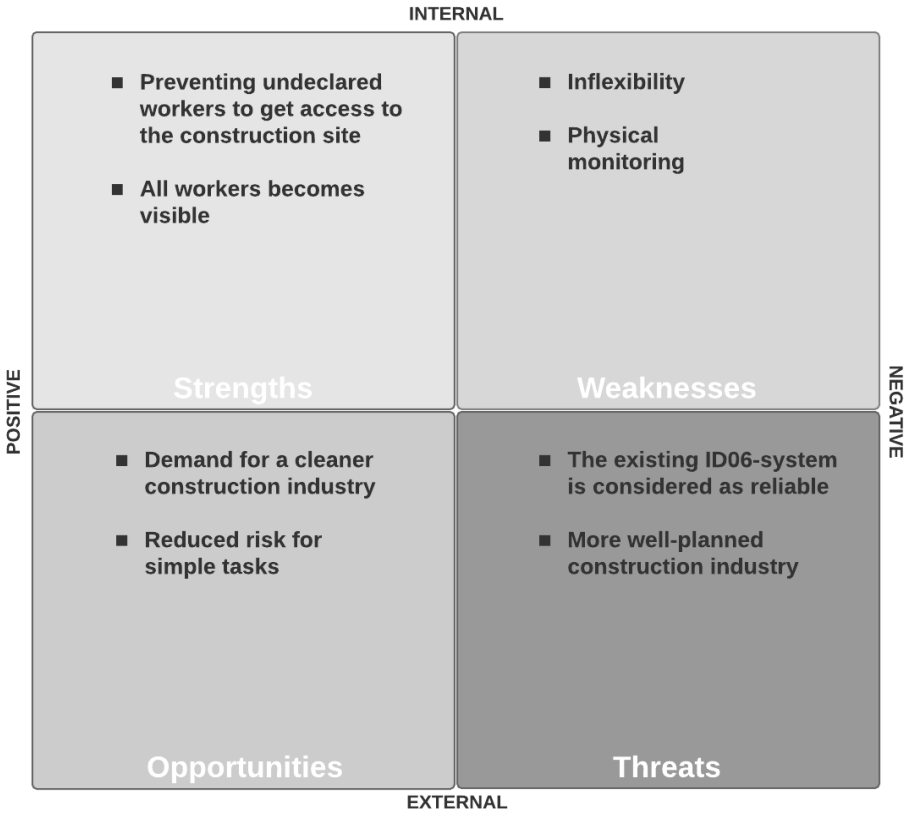

Figure 6-5. A SWOT Analysis of a Blockchain Solution to Prevent Undeclared Work.

Strengths

As stated by the PM, all subcontractors are alleged to declare for all their subcontractors they hire to the project. This is very hard to actually control, especially in large projects. This may result in undeclared work on the construction site. With a smart contract solution that is connected to the existing ID06 system, the employees will not be able to enter the construction site if they are not connected to the smart contract that governs this activity. This will enhance the control and monitoring of the construction site, preventing unauthorized personnel to work at site. This will mitigate undeclared workers as well as the costs for controlling this. Even if actors with criminal intentions are contracted in projects, their employees will still need to be declared for in the smart contract to enter the site. This will make all workers and actors visible towards the Swedish tax authority, Skatteverket, preventing them from practicing illegal activities.

Weaknesses

The main weakness of the smart contracts is that they are in general inflexible. Both the Researcher and IBM state that they are inflexible since they are based on code rather than on semantic language, which makes it hard to adjust. An issue arises when an employee on the project is absent, for instance due to illness, rotation between different projects etc. This may require temporary replacement of labour during the project to stay on schedule. Depending on the setup of the smart contract, they may be too inflexible to handle the labour, since it is not static. As stated by IBM and the Researcher, the smart contracts work best in static processes, without making adjustments that are costly.

The PM states that the subcontractors have a fixed price that they offer during the bidding process, then during the project they charge additional costs, mentioned earlier as ÄTA-bills. The PM further state that contractors are only interested in the total cost, not the estimation before the project. The selection of subcontractors is based a lot on experience within these matters. However, it is not necessary to have the cost set in the contract, rather just have it as a governing system.

Even though the blockchain technology and the smart contracts can govern the workers' access to the construction site, still it is only a stored database with information that is shared. What actually happens in the physical world is out of its control. According to the HRS, today there is no control of that the persons who enter the construction site is the actual person that is associated to the card. Hence, a subcontractor can have workers that are approved stored within in the blockchain background but in the reality, they may use undeclared workers instead. As long as the physical control is limited as today, the blockchain technology cannot fully prevent this risk.

Opportunities

The CSRM and Sveriges Byggindustrier state that there is a demand to remove the illegal elements, or at least make it harder for them with the purpose of creating a cleaner construction industry. According to the CSRM, it is within the simple tasks that are hired urgently where there is a risk for illegal elements. So, by increasing the transparency when hiring these tasks, illegal activities can be mitigated. Actors can be brought in for unplanned task without the risk for illegal activities since they hired under smart contracts that give them permission to enter the site. The background check can be made more efficiently and still provide the safety required for the given situation.

Threats

As stated by the HRS, the new updated version of the ID06-system that will require the employees to legitimize themselves when they are activating their cards by Mobile BankID. The HRS further states that the ID06-system will lead to that the fake cards that are used today will be mitigated, hence preventing undeclared labour since all actors will have to legitimize themselves. As the problem with undeclared work have decreased a lot the recent years and the new ID06-system is more advanced, this solution may be seen as reliable. This may trump the need for a blockchain solution and smart contracts that are connected to ID06.

As stated by CSRM, the problem with illegal activities often occurs when labour is required urgently, where the background check may be flawed. According to Rumane (2016), the construction industry is becoming more well-planned and industrialized, mostly because of efficiency, that limits the need for these urgent contracting's. Since this blockchain solution is most beneficial for these activities, a more well-planned construction industry will reduce the need for this solution.

6.4 Repetitive Strain Injuries

As stated by Sveriges Byggindustrier, a very common issue within the construction industry is that the employees get repetitive strain injuries due to their performed tasks over a period of time. The injuries occur due to that the work is repetitive, where correct ergonomics is very important to prevent these injuries.

Triple Bottom Line

This problem affects the employees directly both in their working life as well as in their leisure time. It affects the employees' health and aligns with the Occupational Health and Safety Aspect within the subcategory of Labour practices and Decent Work, under the social category.

Decision Tree

Repetitive strain injuries are caused by non-ergonomic and repetitive tasks, as can be seen in figure 6-6. This is an issue that can be indirectly related to knowledge for correct lifting, but has its roots from the actual tasks performed. Even though educations and licenses are required to work at a construction site, correct ergonomics are necessarily not fully preventative against repetitive strain injuries. The repetitive nature of the tasks themselves tear on the workers' health even though the ergonomics are correct. Thus, a database is not required to mitigate or prevent this issue. Since the blockchain technology is a distributed database, the need for a database is required to have the technology as a possible solution.

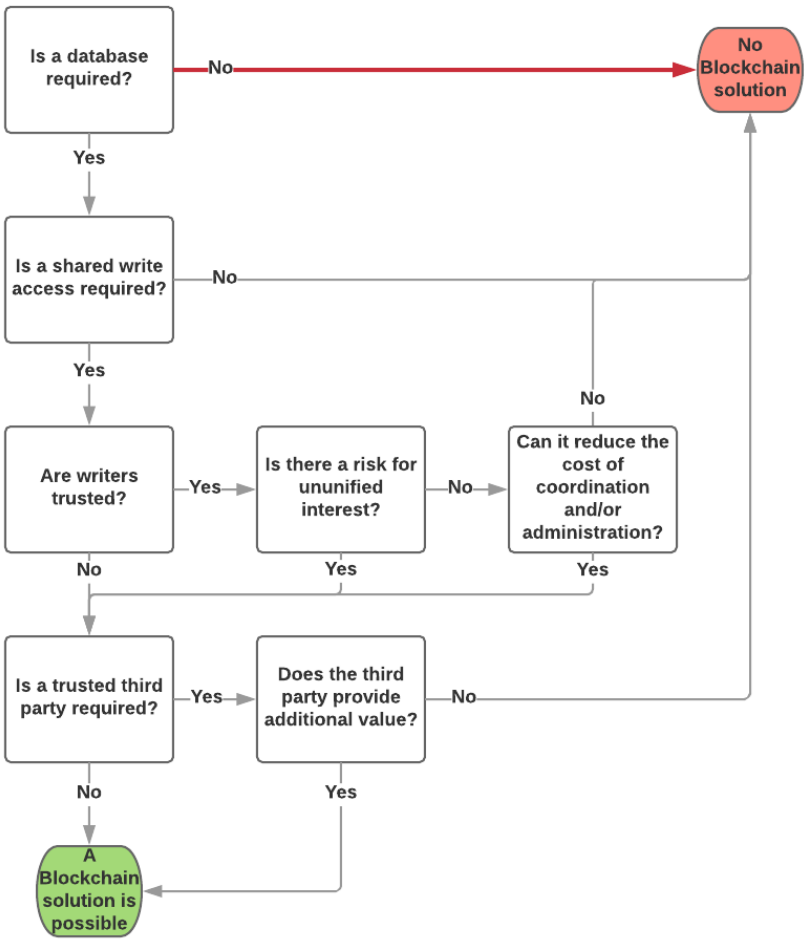

Figure 6-6. The Path of the Issue Repetitive Strain Injuries in the Decision Tree.

6.5 Accidents

Accidents may occur at construction sites. As stated by Sveriges Byggindustrier, the roots of accidents may be derived to some degree of human error when performing tasks on the construction site. This can also be related to flawed licensing of different work tasks that are required to be present at a construction site. It can be licenses within safe working or welding for instance. The licenses are controlled to some degree but it can be hard to control their validity as well as the expiration date of them. This may result in that employees are not familiar with routines and preventative actions.

Triple Bottom Line

The problem of accidents occurring at construction sites can be directly related to Triple Bottom Line. The problem related to overall safety at the site and the health of the employees. It aligns with the aspect of Occupational Health and Safety within the subcategory Labour Practices and Decent Work, under the social category.

Decision Tree

Blockchain can be considered as a potential solution to preventing and mitigating accidents on the construction site, as can be seen in figure 6-7. The accidents can be derived to some extent to the workers' insufficient knowledge. The knowledge is provided by education that is proved by licenses. In order to secure that the workers do have the correct education, licenses are used to validate their knowledge. Hence, a database is required. Each actor within the network should have write access to validate its employees, showing the main contractor that they possess the required educations. Further, the writers in this context are considered as trusted, until the opposite is proved. However, there is a risk of involved parties not having a unified interest, where the incentives may be to save time and cost for educations. It can also be that the licenses have expired but the actor may not provide the main contractor with this information. This problem requires a third-party organisation to provide the education and issue the licenses to the workers. These third parties do, however, provide additional value than just vouching that the employees have fulfilled the education since they also provide it. Hence, this kind of third party organisation provide value in terms of quality assurance and they are required in order for solve this issue. Thus, a blockchain solution is a possible solution to this issue.

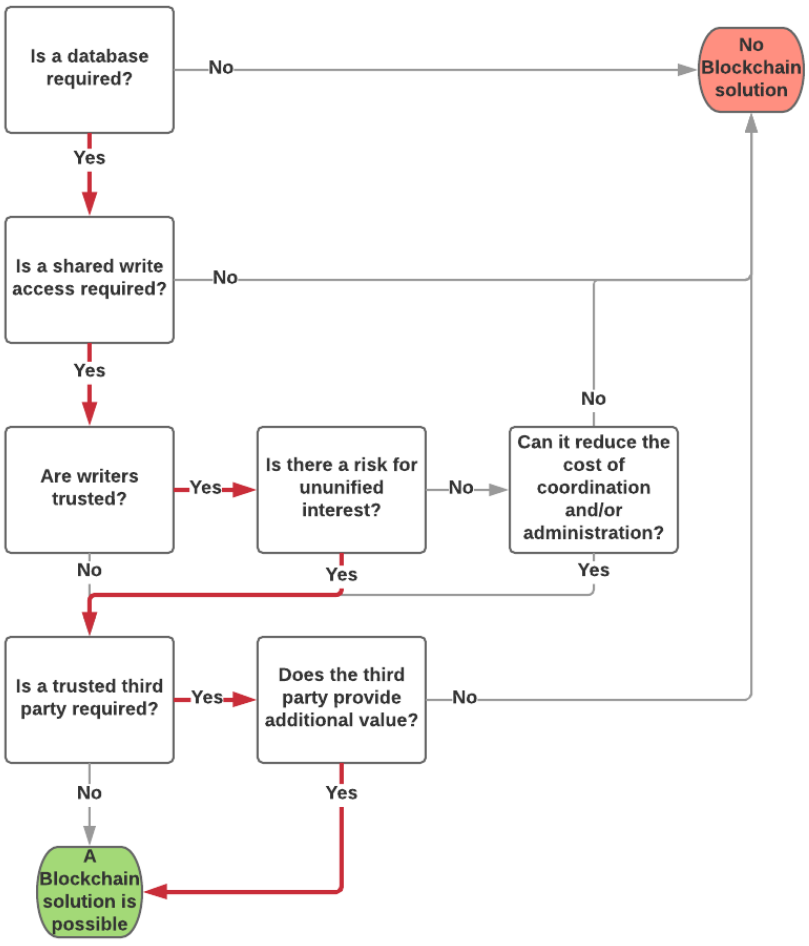

Figure 6-7. The Path of the Issue Accidents in the Decision Tree.

SWOT

The potential blockchain solution in this case is that all licenses are stored on a blockchain, where permissioned actors are able to add information to it. The setup can potentially be similar to the setup of today's ID06-system, where the education providers are authorized by a independent third party. This is further described in figure 4-1 as the process of validation of skills. Today, the authorized actors send information to the ID06 central database which is connected to the physical cards. In the case of an implemented blockchain solution, the record-keeping will hold information provided by these authorized actors. The licenses can be stored in a immutable way, connected to a certain person, where the educations and the validity time are defined. This will provide a transparency regarding the workers skills. The HRS states that there is a problem with expired licenses today. The blockchain solution can solve this. It can prevent the workers that do not possess the required licenses, or expired ones, from entering the construction site with a self-executing mechanism, until they are fulfilled. The evaluation of this issue is presented in figure 6-8 below:

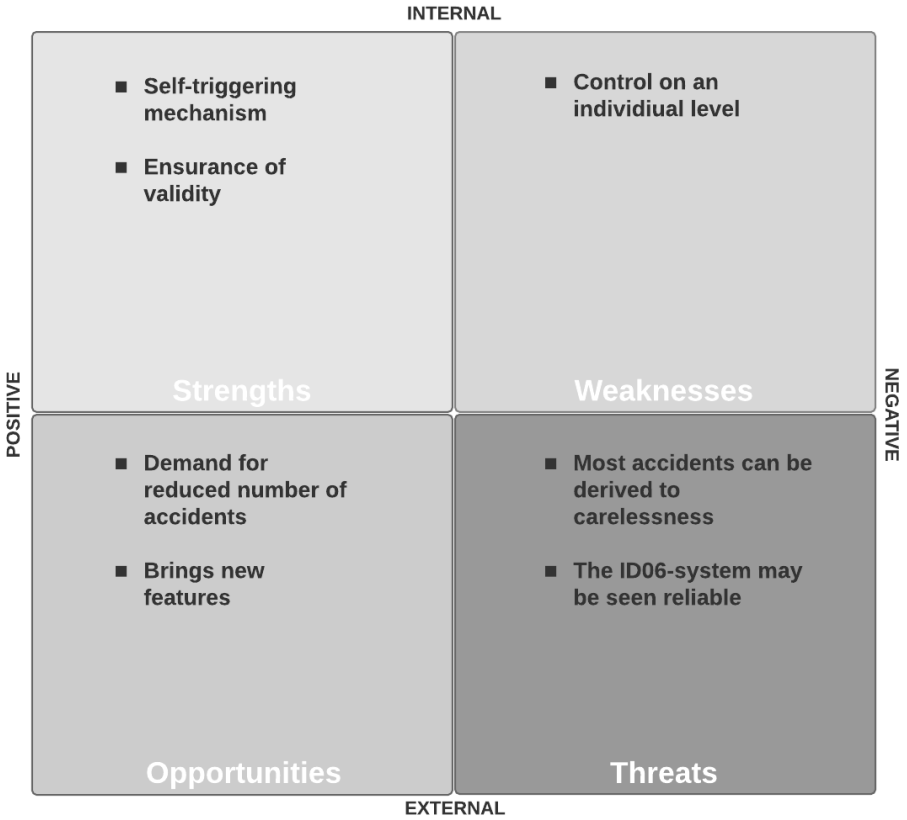

Figure 6-8. A SWOT Analysis of a Blockchain Solution to Prevent Accidents.

Strengths

A main strength with this solution is that the licenses do not need to be controlled manually. Smart contracts allow for a self-triggering mechanism that can lock an employee from entering the construction site if the required education and licenses are missing. One of the main characteristics of the blockchain technology is that it provides an immutability of records (Dhillon et al., 2017). A blockchain setup that only permit certain actors that are controlled and trusted to add information the blockchain regarding the skills, will prevent

contractors to neglect educations for their employees. This will create a greater insurance of validity.

The HRS further states that the licenses that are required by the personnel at construction sites are time-bounded, where the main contractor responsible for the construction site need to control the validity. As stated by the Researcher, a blockchain solution can be self-executing and decrease the need for control. Thereby, workers with expired licenses will locked-out from the construction site. All mentioned will enhance safety and health on the construction site since everybody are alleged to hold the requirements.

Weaknesses

One weakness with this solution is that it will be hard to control the requirements of education and licenses on an individual level. To achieve this, quite extensive administration work is required since all workers within the same project do not require the same kind of educations and licenses. Thus, all workers ID06 cards need to be connected to educations and licenses within their individual tasks they are to perform on the construction site. Even though it might be general requirements to enter the site, the individual educations and licenses needs to be controlled anyway. Since the solution can relate to general educations and licenses all workers at a construction site must have. This can result in a risk that a worker which does not possess the required skills for their specific tasks can enter the construction site and still perform those tasks.

Opportunities

Sveriges Byggindustrier states that the construction sector's ambition is to reduce the number of accidents on the construction sites. The implementation of the new ID06 system is a further step towards less accidents. However, something that can facilitate in mitigating this issue with new features creates the opportunity for a potential blockchain solution. Even though ID06-system is considered as powerful, a blockchain solution can be more beneficial since the technology may be used in other areas as well.

Threats

Sveriges Byggindustrier states that many accidents occur due to human error, which is not related to the licenses itself. The blockchain technology can prevent that there are no workers on the construction site which do not have required skills but it will not eliminate the human error. Since the majority of accidents are related to human error, more resources may be spent on establish safer construction sites and inform about potential risks.

As described by the HRS and visualized in figure 4-1, the ID06 system is built up by a powerful structure where the cards are connected to a central database where authorized license providers distribute this information. Even though the ID06-system does not have the features of immutability and history record, it has the capability of providing reliable information, i.e. the workers educations and licenses. This fact might slow down the demand for a blockchain solution for solving this issue.

6.6 Employee Payment

Another problem that has been identified is when the contractors do not pay the salaries to the employees. The contractors do not monitor and control payments down the tiers of subcontractors since everyone is responsible for their own compensations. During the conducting of this thesis and as mentioned by the PM, there is a law proposition in Sweden that the main contractor should be responsible for that all subcontractors' employees are paid when they have performed tasks at their sites. This will in practise mean that the main contractor can be legally obligated to compensate the employee. This results in double compensation paid for the work performed if their subcontractor does not compensate their employees themselves.

Triple Bottom Line

This issue relates to whether the employees of a contractor at a construction site are compensated for their work or not. This issue can be divided into several aspects within Triple Bottom Line. It can be related to Labour Practises under the Employment subcategory as well as compliance under the Society subcategory, both included in the social category.

Decision Tree

Through the aid of the decision tree, as can be seen in figure 6-9, it can be stated that blockchain is considered as a potential preventative mean to mitigate this issue. The payment of salaries by the employer to its own employees are made through a digital transaction. This means that a database is required in order to make the actual transactions. Since all contractors make their own payments to their employees, it requires that every transaction is made by the contractors themselves. As the main contractors do not monitor the monetary flow to verify that the employees involved in the project receives their salaries, the parties are considered as trusted. There is, however, always a risk for that the interests for the parties are not unified. It lies within the main contractors' interest that everyone receives compensation for their labour, since they might be held responsible and the subcontractor might act opportunistic to keep the money for themselves. There is no third party required to verify that the employees are compensated. The bank might be seen as a third party, but it is not the actual transaction that is the problem, rather that the transaction is initiated by the employer. Given the characteristics of this issue, a blockchain solution might be viable to solve it.

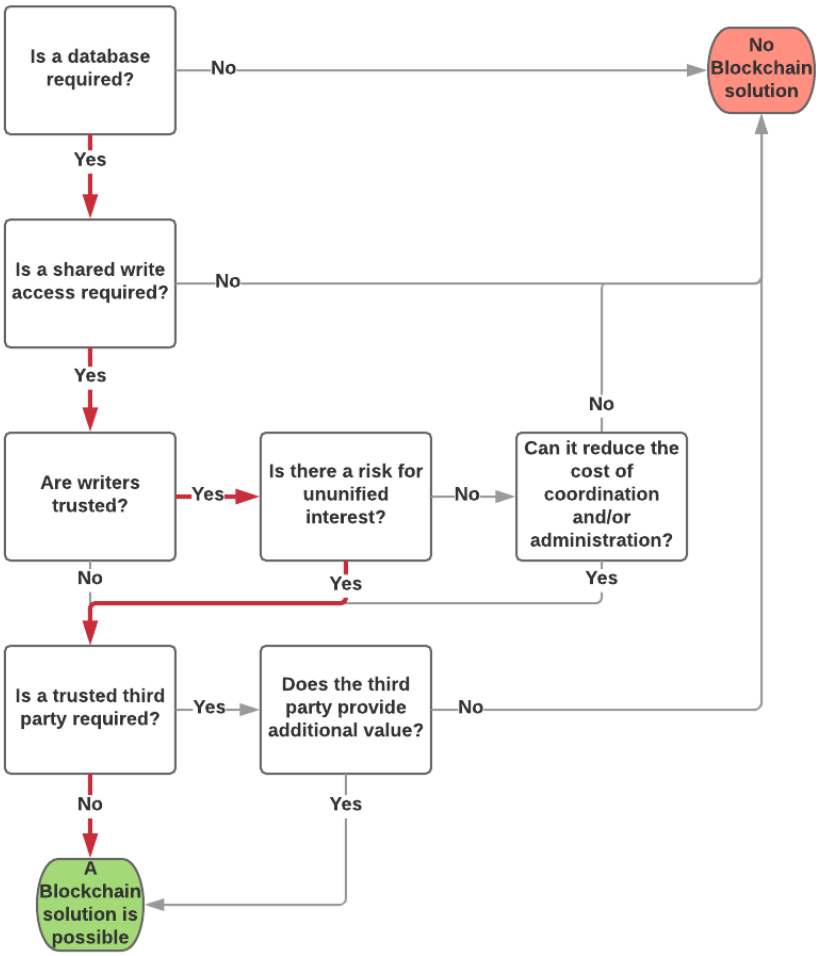

Figure 6-9. The Path of the Issue Employee Payment in the Decision Tree.

SWOT

The solution would be to connect the employees' bank accounts to a blockchain, making the transaction records visible towards each other. However, there might be a resistance towards making this public, both the margins for the employer as well as the income for the employees. Thus, encrypted transactions are to prefer. It means that the activities between the accounts becomes visible but not the exact amount transacted. The information regarding the compensation of the employees will depend from case to case. If the employee is active within the project for a short period of time, this information will most likely become visible afterwards. If the employee is active within the project for a long time, the information will most likely become visible during the project, giving the main contractor the opportunity to act. The evaluation of this issue is presented in figure 6-10 below:

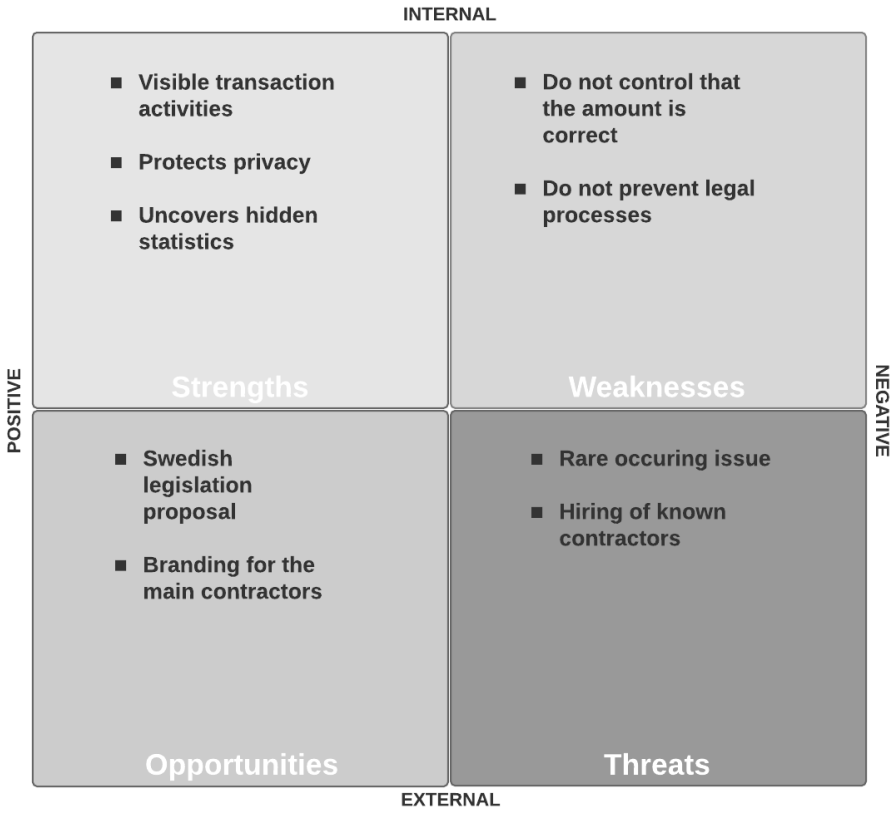

Figure 6-10. A SWOT Analysis of a Blockchain Solution to Secure Employee Payment.

Strengths

As stated by the CE, there is no mechanism today where the main contractor actually receives confirmation that the employees of subcontractors receive their salaries. As stated by both IBM and the Researcher, the blockchain technology has the ability to be connected to bank accounts in order to trace transactions. The blockchain solution enables the main contractor to actually confirm that the subcontractors' employees have been compensated for their work. To avoid exposing the employees for invasion of privacy, the information regarding the transactions should be encrypted. Although the exact amount is not visible, it may create a preventive environment against this issue.

Even though the blockchain solution cannot force the payment to be made, it provides a visibility that brings the issue to light. This gives the main contractor the opportunity to act upon this. Although it is within the employees' interest to receive compensation, there might a number of hidden statistics of employees that for some reasons to not pursue action upon this. The main contractor will receive information regarding those subcontractors and based on that, exclude them from future collaboration.

Weaknesses

As stated by the Researcher, even though it lies within the interest of employees to get paid, they may not want to share the information of the amounts they receive. This is also the case for the employer who may not want to show their margins for their customer. For this solution to be viable, the transactions need to be encrypted, showing that a transaction has been made but not the exact amount. However, this does not actually confirm that the

subcontractors' employees receive their salaries, it only shows that there has been an activity between these accounts, regardless of the amounts. Thereby, a great weakness is that it does not prevent that employers do not pays the salaries in accordance to the employee agreement.

As stated by the Researcher, the blockchain technology can enhance the transparency and visibility for monetary transactions. This can provide the main contractor with the information that the subcontractor pays its employees. However, this is not a mechanism that force payments, rather highlights them which not are made. Regardless of a blockchain solution, an employee has to pursue this legal process by himself/herself anyway.

Opportunities

When this thesis was conducted, and according to the PM, there was a legislation proposal in Sweden stating that the main contractor will be held responsible to compensate the subcontractors' employees if they do not receive payment from their respective employer. Thereby, the main contractors may experience double spending issues since the employees' salaries are included in the contracts too. This creates a great opportunity for a blockchain solution to preventing this.

As stated by Sears et al. (2015), the main contractors are responsible for the whole construction, both towards the owner as well as the society. Therefore, it is of great importance that the construction is built under fair terms for all actors involved during the project. It is within the interest of the main contractor to facilitate a sustainable working environment with good terms, where the subcontractors' employees are compensated fairly. This may give the main contractor a branding opportunity since they may be seen as a fair employer as well as accountable in the eyes of the society.

Threats

As stated by Sveriges Byggindustrier, the majority of the contractors behave in an appropriate and responsible way and hence, this issue might be rare. The main contractors do not want to be associated with dishonest subcontractors, so when information regarding withheld payments arise, these subcontractors will most likely not be hired again. So, a potential blockchain solution may not be requested by the actors.

As stated by PRM, contractors work a lot with subcontractors that are already known, which they have work with previously. Those actors are seen as serious and trusted by the contractors. Since an element of trust is included within those relationships, there is no need for a blockchain solution.

6.7 Limited Subcontractor Base

The contractors in the construction industry have a target to minimize the costs through competitive bidding between a number of subcontractors. This contradicts with the aim of having long-term relationships with the subcontractors. This in order to ensure quality, reduce risks, enhance trust as well as limit the number of subcontractors on the site. This means that the contractors cannot utilize the whole market of subcontractors due to trust and cost reasons which limits their alternatives.

Triple Bottom Line

This problem means that some subcontractors may be overlooked and, thus, have difficulty to compete on the market. This limits the market offerings to some extent, where some subcontractors are not considered due to resource limitations and trust issues. This issue can be derived into several aspects within Triple Bottom Line. First, the actors that are excluded suffer from not being inside the market network. This can be categorized within the aspect of Market Presence under the Economic category. Secondly, the resources needed to evaluate and consider all subcontractors within the market are very high for the contractor, which limits the options on the market. This can be derived to Procurement Practices within the Economic category.

Decision Tree

According to the decision tree, as can be seen in figure 6-11, a blockchain solution might be a potential solution to prevent the issue of a limited subcontractor base. The uncertainty with unknown subcontractors can be connected to a general lack of transparency in the sector among the subcontractors. In order to verify a company, a database is required. A shared write access is required since each actor need to provide their own data as basis for the assessment. This data can include certificates, licenses, financial statements etc. As the contractors do not have that experience with the unknown subcontractors, they do not possess any trust towards them at this point since it is not yet achieved. Since all buying firms do their own market analysis and assessments, there is no third party required to provide this for them. Given these characteristics of the issue, a blockchain solution is viable.

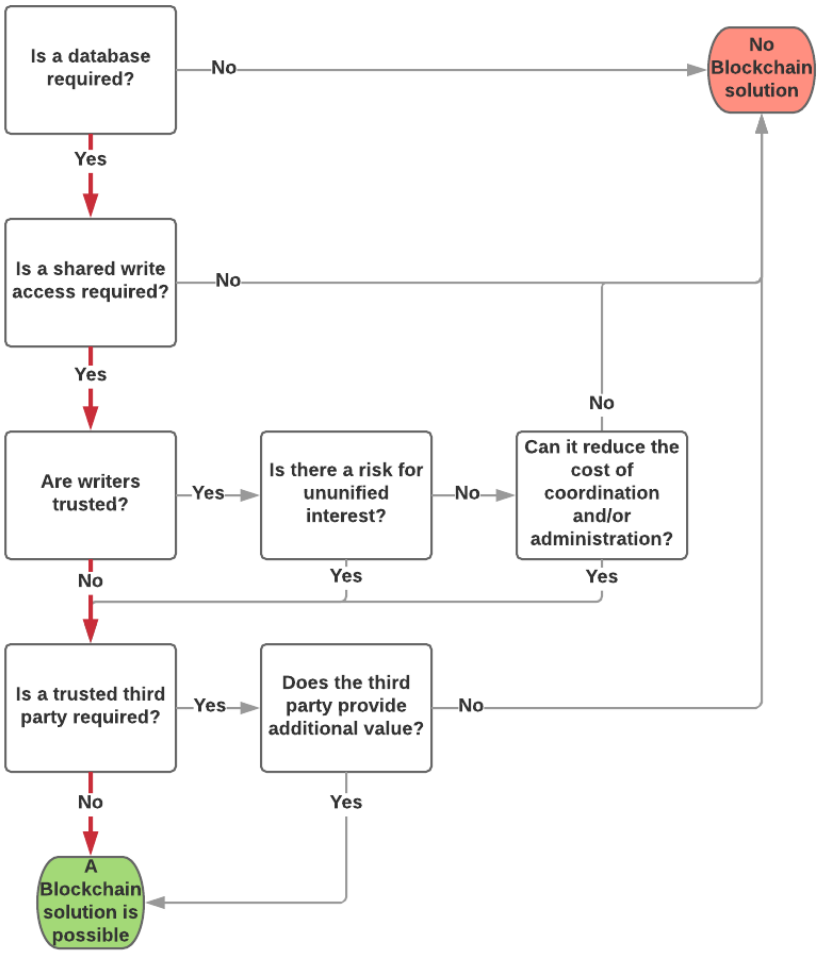

Figure 6-11. The Path of the Issue Limited Subcontractor Base in the Decision Tree.

SWOT

As can be seen in chapter 4.1.3 *Potential Application of Blockchain*, the financial sector has created a trading platform based on the blockchain technology. A similar solution can be applied in the construction sector where the proposed blockchain solution would be a blockchain driven spot market, where subcontractors can bid on projects of which they fulfil the requirements. Those requirements that are decided for the projects should be possible to verify securely through a blockchain. This can potentially prevent dishonest subcontractors from competing. The evaluation of this issue is presented in figure 6-12 below:

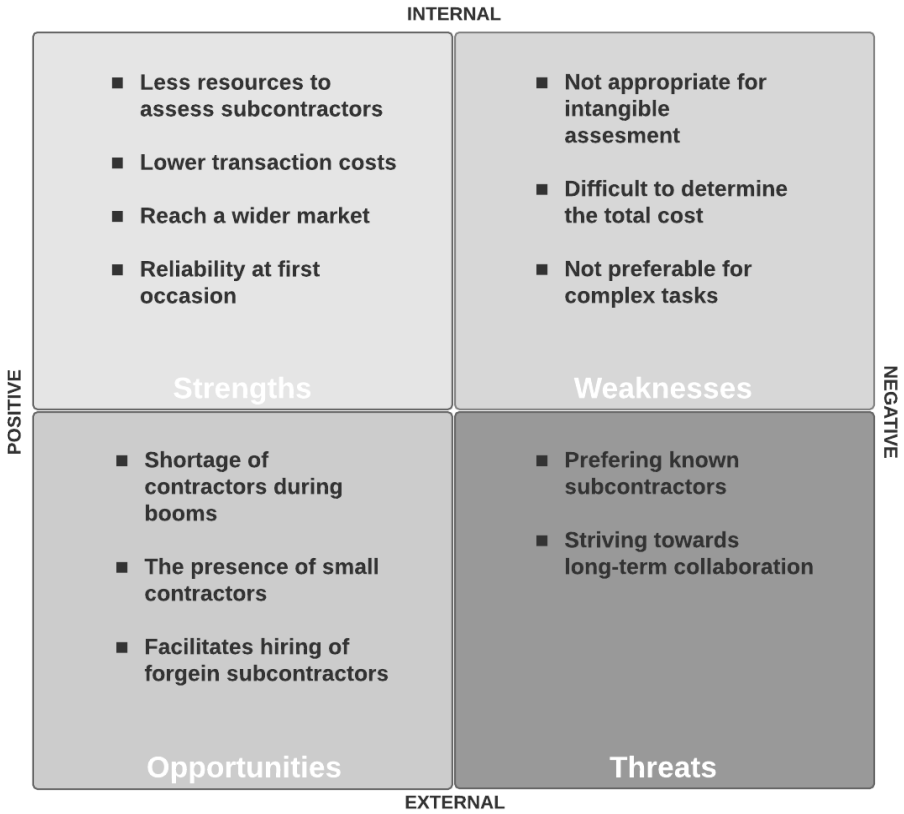

Figure 6-12. A SWOT Analysis of a Blockchain Solution to Prevent a Limited Subcontractor Base.

Strengths

As stated by PM, it is a matter of resources to assess all potential subcontractors for a contractor. They often hire known subcontractors since they do not need to assess them to the same extent as for new subcontractors. One of the main strengths of the blockchain technology is that it has the ability to provide transparency (Dhillon et al., 2017). With this transparency, the blockchain solution provides the contractor with the required insight they need to assess a new subcontractor using less resources.

As seen in the IBM-Maersk case in chapter 4.1.6 *Use Cases*, a blockchain solution can decrease the transaction costs. Since transaction costs limit invitation of new subcontractors to the market, a blockchain solution, where the background check is made automatically with trustworthy results, can open up the market, thus reaching a wider spectrum of subcontractors. As less resources are required to hire subcontractors, the contractors can focus their resources on other tasks. As stated by the PRM, new subcontractors are at first hired for tasks that are not classified as critical because it gives them a chance to evaluate the reliability of the new subcontractor. This solution will eliminate the trust issues that otherwise arise when contracting new subcontractors, resulting in a broader market offering.

Weaknesses

It is more difficult to assess subcontractors than it is to assess material suppliers. The requirements are more intangible in subcontractor assessments than they are for materials. As the blockchain technology is based on code, it is quite static, making it hard to define

intangible requirements based on code. As stated by the PPM, their subcontractors initial tender are usually not the same as the total cost in the end. They charge for added costs throughout the projects, which is why the purchasers mostly contracts known subcontractors. This makes it hard to have a blockchain driven platform since the outcome will not provide the full truth in terms of total cost. This means that it will be difficult to compare subcontractors tender. As stated by the Researcher as well as IBM, smart contracts are quite static, not leaving any semantic flexibility as a regular contract does. This limits the usage of this solution to less complex tasks that are easier to define.

Opportunities

As stated by the PM, there is a shortage of subcontractors during booms since there are more construction initiatives in those times. Today, the main contractors need to sell in the projects to the subcontractors, and not vice versa. During times of booms, it is desired to reach more subcontractors. The blockchain solution provides them with the necessary means to do so without extensive use of resources, compared to the manual administrative work for sending out requests for quotations.

The PM also states that there is a general interest to invite small scale subcontractors to the market but there are not enough resources to do so today. A blockchain driven spot market would provide the contractors the opportunity to invite small scale subcontractors without any additional resources required as well as to verify that they meet the requirements. It also facilitates the contracting process for the actors that do not possess the deep experience or network that is otherwise required. Additionally, it will facilitate the contracting of foreign subcontractors without extensive resources spent. The reason behind the initiative for NCC's own internal staffing agency mentioned in chapter 4.2 *Subcontractors* by the PPM, was to control the labour forces in a better way due to the difficulty to control foreign subcontractors. A blockchain solution can mitigate this issue and involve more foreign subcontractors. Hence, the contractor base can be expanded and the construction industry can keep the low cost driven industry without compromising with the sustainable aspect.

Threats

As stated by PRM, when the main contractors contract an actor to perform a task, they hire subcontractors that they can trust. This is built on experience from working with these subcontractors in previous projects, so the main contractor knows that the subcontractor is reliable. The PPM also argued for that NCC should strive towards more long-term collaboration with the subcontractors. This is with the purpose of trying to develop the relationships and the operations with the actors they are contracting. This contradicts the desire to invite new actors to the market, which is partly because main contractors do not want to hire new subcontractors for projects or tasks that are critical. The PRM states that when they give new subcontractors the opportunity, it is first for tasks that are not critical, to see if they can be trusted and classified as reliable.

7. Conclusions

This study has examined how the blockchain technology can prevent or mitigate issues related to sustainability within the construction industry. In order to achieve this, the blockchain technology and the construction industry needed to be understood to lay the foundation of further investigation. Then, the issues related to sustainability within the construction industry needed to be identified, which then were put in relation to the blockchain characteristics to evaluate if there is a potential blockchain solution.

The blockchain technology is mostly associated with cryptocurrencies since it was created as an enabler for them. Cryptocurrencies are, however, just one of several applications of the technology. The technology is, in its fundamental state, a shared, distributed ledger, that is peer to peer replicated against each other. Blockchain is built upon a consensus model, which means that all nodes need to agree on the true version of the ledger, which eliminates the trust based model that most transactions rely on today. Different types of blockchains provide different types of features and benefits. Features such as smart contracts, supply chain transparency and record-keeping are very valuable for different business contexts. Thus, this answered the first research question.

The construction industry differs quite a lot from other industries. The industry is characterized by that it is project-based; low-cost driven; and temporary relations with subcontractors. The projects are to a high degree staffed with subcontractors that are specialized in different areas of a construction. The projects are structured in different ways depending on the size, complexity, and project delivery system. It is, however, very common that it is a main contractor on top of the hierarchy, taking the overall responsibility. The main contractor is responsible for the construction part of the project, but can also be responsible for the design. Thus, mentioned answered our second research question.

Seven issues within the scope sustainability were identified for the construction industry, which answered the third research question. As a result of our proposed blockchain decision tree, five out of these seven could be prevented, or mitigated, by a blockchain solution. One issue that is identified with a potential blockchain solution is the one concerning the use of sustainable materials by the subcontractors. The main strengths that the blockchain technology enable are traceability, immutability and that it can more easily be identified where and when errors occur. However, there are weaknesses in terms of that it is hard to establish the cyber-physical link, as well as that the technology only stores data and cannot verify it. There exists no solution that requires less resources spent on this matter, but the cost of IoT-devices is decreasing which creates an opportunity for a blockchain solution. There is a risk that the sustainability issues are not prioritized in relation to cost, and therefore, existing procedures to ensure sustainability can be seen as sufficient.

By combining the blockchain solution with smart contracts to the existing identification control system ID06, the main contractor has the ability to automatically only let the individuals connected to the smart contract enter the construction site. This can result in preventing undeclared labours to enter the site, increasing the control and monitoring mechanism. By having this solution, all workers become visible in the system, making it visible if any illegal activities take place. The smart contracts are, however, static compared

to regular contracts, which makes it hard to make post-contractual adjustments which can for example complicate employee rotations at different construction sites. The blockchain solution cannot prevent the actual presence of unauthorized workers on the construction site without a secure physical infrastructure, which otherwise will require physical monitoring anyways. The opportunities for a blockchain solution is that there is a societal demand for a cleaner construction industry, where illegal activities are prevented. The illegal activities often occur during routine tasks that are brought in urgently to the project, something a blockchain solution could possibly provide. There are, however, threats in terms of that the existing solution ID06 combined with the physical monitoring that already take place, are seen as enough as a preventative mean. The industry is also becoming more well planned and structured, which mitigates the need for urgently bringing new actors in to the projects, which mitigated the risk for illegal activities itself.

The main strength with the blockchain technology is that it enables an automated validity check of licenses. The blockchain technology could aid in mitigating the number of accidents and at same time decrease the need for manual checks. This will save the main contractor resources within this task. As the licenses have expiration dates, the blockchain solution can provide a self-triggering mechanism which may lock the access card for the employee to enter the construction site. This will force the actors to have the necessary education provided in advance to their employees since they will otherwise not be able to perform their tasks. It will, however, be a challenge to control the individual license requirements with a blockchain solution, without excessive resources. The general requirements to enter a construction site can be applied, but is is more difficult with the task-dependent ones. However, there is a opportunity for a blockchain solution since there is a demand and desire to reduce the number of accidents that occur on the construction site. If blockchain is used when contracting subcontractors, there can be an economical benefit in terms of economies of scope as well. However, most accidents can be related to human errors and not whether a license has expired or not, which may be seen as a threat to the solution. Also, ID06 has the ability to store information on the employee profile as well, which may be seen as good enough solution.

A blockchain driven solution for the issue concerning workers payments can provide the main contractor with the information of payments being made, through activities within different accounts. The information can as well be encrypted in order to prevent the contractor to present their margins, as well as invasion of privacy for the employee. The main contractor will be able to see if an activity has been made between the accounts but not the amount. This solution may also uncover hidden statistics that are not brought to light otherwise, which may because of afraidness or illegal intentions. This can also be seen as a weakness, if encryption is considered, the main contractor will see the activity, but not what amount, which may not correspond to agreeable salary levels. The employees that have not received their payments will still have to pursue the legal process, so the blockchain solution will not prevent that. A great opportunity for a blockchain solution to this issue is the proposed legislation in Sweden that could hold the main contractor responsible to compensate the worker in these situation, forcing them to pay double for the work done. Another opportunity is the branding of the main contractor, showing the society that they take these issues seriously and that all workers at their sites work under fair terms. However, since these issues rarely occur, there might not be a demand for a solution of this sort, since

most actors that are in collaboration with the main contractor are already known due to experience, which makes them trusted.

A blockchain driven platform solution for the issue of limited supplier base will make it possible for the main contractor to consider more actors with less resources, since the solution will have requirements that the actors must hold in order to be able to join. This solution will lower the transaction costs, at the same time as a wider market is reached. The subcontractor can also be seen as reliable at first occasion since they can be assessed from immutable records. A weakness is, however, that parameters for subcontractor are not as tangible as they are for e.g. material suppliers. This makes it harder to assess them. The tender is also often not the total cost, which can lower the potential of a solution such as this. The contracting itself is also quite static, which only makes it advantageous for routine tasks. During times of boom, there is often a shortage of subcontractors, making it hard for main contractors to provide their projects with the necessary resources. This solution will make it more accessible to reach out to a wider market. There is also a general interest within the industry to invite small scale actors to be directly hired by the contractor, which this solution may make available. It will also aid in hiring foreign contractors since the controlling process will be facilitated. However, most contractors do have their preferred subcontractors that they use as often as they can, closing the market for other actors, and hence is a threat to this solution. There is also a contradictory goal of inviting small scale actors to the market, which is that long term collaboration is strived towards, mitigating the request of a solution such as this.

The blockchain technology was not consider as a potential solution, according to the framework, in two of the identified issues related to sustainability: material waste and repetitive strain. In both cases, the issues are more connected to the processes itself and not related to any type of information sharing in that sense. In the case of material waste, a blockchain solution will neither solve the decision regarding the amount of ordered material nor the local adjustments on the construction site. When it comes to the repetitive strain injuries, they are related to poor working conditions during a longer period of time. Since it about the actual working position, licenses will not prevent that. Thus, blockchain is not a potential solution. The evaluation of potential blockchain solutions for the seven issues identified answering the fourth and last research questions for this thesis. This also fulfils the purpose of this thesis of investigating how the blockchain technology can enhance sustainability for contractors within the construction industry.

However, for blockchain to be seen as a potential solution for the five issues, the opportunities must outweigh the threats. Some issues have existing processes to mitigate these errors, which may be seen as enough and that the investment may be too excessive that there are no gains seen with a blockchain solution. Within this thesis, the issues have been separately evaluated with a blockchain solution. It is, however, important to consider that several of these issues may potentially be solved by the same kind of blockchain setup, creating an opportunity to gain economies of scope, hence making it more economically arguable.

8. Discussion

The blockchain technology is a highly potential technology that can bring a lot of value and advantage to businesses. It has, however, been described as closely to the solution of everything, which is a overstatement. It is of great importance that industry professionals have a healthy view of the technology and its capabilities. Worth mentioning is also that the industry professionals should not look at a technology and what problems it can solve. They should rather identify the problems, get to the root of them, and see what kind of digital tools or technologies that can be used to solve them. The only driver to implement a new technology is that it should be used to solve an existing business process issue. In the construction industry for instance, the existing solution of ID06 provides a high enough level of security within identification and document holding. Hence, the blockchain technology will not add value in these areas to the industry, in that case. This means that the blockchain technology, even though it is viable, will not be considered as a solution if the threats outweigh the opportunities it brings. It can, however, be a branding opportunity as well to show the society that the company is in frontline of development.

It is also of great importance to consider that there is no standardized definition of the blockchain technology. How a researcher defines blockchain is often quite different from how a blockchain implementation consultant defines it. There is, however, at least one common element and that is that it should be a distributed ledger over several nodes within the network, to provide the immutability, and that it should be peer to peer replicated. The game theory element is not a necessity in business cases where the actors are known, which allows for other kind of settings. There are general discussions that the blockchain technology will create a disintermediation since it is a self-regulating system. This is not the view of the authors of this study, they rather see it as that the intermediaries, or third parties, who bring other values than coordination will still be present due to that they are desired. The existing blockchain decision trees was considered as too basic by the authors where not all aspects that need to be considered in an implementation. That motivated the development of a more extensive decision tree with more relevant questions asked.

All issues identified within this study has been evaluated with a blockchain solution separately. It is not beneficial for some of these issues to use a blockchain solution individually just for the issue. However, as mentioned in the conclusion, many issues can be consolidated under the same kind of blockchain setup, which provides the economic opportunity to achieve economies of scope. By using, for example, smart contracts for contracting, licenses, authority to enter the construction site, the platform solution etc., they can be similar in setup.

The law of General data protection regulation (GDPR), introduced by EU, entered into force in 2018. The law aims to protect the personal integrity by requiring the corporations to inform their customer how the personal data will be handled and stored. The corporations are also obligated to erase the data from their system if the customer requests it. Since the blockchain technology, by its characteristics, cannot manipulate or erase data, this has not been discussed throughout this thesis. However, this is not considered as an issue since the data can be encrypted, which provides the individual at hand the request of not showing their personal data.

One issue that arises with a blockchain solution is to establish the cyber-physical link. This involved both identification individuals, i.e. it cannot be ensured that it is the same person digitally as it is physically by a system solution. For example, if there is an actor acting opportunistic and hires undeclared labour, it is still a possibility if there are not extensive security measures taken on the construction site with physical control. To clarify, a blockchain solution will not eliminate the risk for undeclared or unskilled work forces for a specific moment, but it will mitigate the continuous cheating. Another difficulty is the tracing of material, where the material cannot be ensured to be the same as it is declared for in the blockchain. As it is today, it is close to impossible to trace material at individual item levels, but there is still, a value in tracing batches, which more likely can be made without extensive resource investments.

Measures have been taken in order to mitigate risks with subcontractors to limiting the allowed number of tiers within the activities. This has been made to increase the control on the construction site as well to decrease the resources required to assess all actors. This solution is very logical in this sense since the transparency increases with limited numbers of subcontractors back in the chain. The consequences of this solution is that specialized competence may be harder to reach, as well as it is a large investment for the subcontractors to cover the need. In order to fill the gap at booms, they will have labour they have to compensate at times of recession when the number of construction projects decrease. This solution will also create a barrier for small scale subcontractors to enter the market. A greater transparency with the blockchain technology could eliminate the reasons behind this logic, since the information will be visible in a more transparent way.

However, the main driver for a potential blockchain implementation within industries is that it brings economic benefits, e.g. it creates more efficiency with less resources. Even though sustainability often is considered as a fundamental aspect of business, and that it often brings economic benefits, the financial aspects need to be visible to pursue this change. So the aspects the issues in this thesis have been studied from may not be the main driver and enough of an incentive to implement a blockchain solution, they will most likely have economic benefits and thus be a potential mean to mitigate the issues identified.

8.1 Future Research

As this thesis has been investigating blockchain technology as a solution to business issues from a sustainability perspective, it does however, require further investigation in other areas. The technology may affect the industry in a broader sense, from all aspects rather than just from a sustainability point of view. This needs to be considered before a potential implementation. The blockchain technology is considered as a driver for disintermediation, which means that third parties are eliminated. This may disrupt current business models within industries. A future blockchain implementation may lead to a change in the power dynamics among actors where some becomes more relevant while others may suffer. Construction projects are arranged as tree structure where the contractor has to some degree the role of a coordinating third party. Therefore, the construction industry may be affected as a whole and it requires further investigation.

References

Agudo-Valiente, J.M., Garces-Ayerbe, C. & Salvador-Figueras, M. 2017, "Corporate Social Responsibility Drivers and Barriers According to Managers' Perception; Evidence from Spanish Firms", *Sustainability,* vol. 9, no. 10, pp. 1821.

Andersen, B. 2007, *Business Process Improvement Toolbox, Second Edition,* 2nd edn, Asq - American Society For Quality, US.

Annan, C. 2012, "IMPROVED INTEGRATION IN CONSTRUCTION SUPPLY CHAIN", *International Journal of Construction Project Management,* vol. 4, no. 2, pp. 107.

Bello Perez, Y. 2015. *How Blockchain Tech is Inspiring the Art World*. Coindesk. Available at: https://www.coindesk.com/blockchain-technology-inspiring-art/ [Accessed 2018-06-01].

Benton, W.C., McHenry, L.F. 2010, *Construction purchasing & supply chain management,* illustrat edn, McGraw-Hill, London;New York;.

Bryman, A. & Bell, E. 2015, *Business research methods,* 4.th edn, Oxford Univ. Press, Oxford.

Bygballe, L.E., Ingemansson, M., Centrum för teknik- och vetenskapstudier, Ekonomisk-historiska institutionen, Humanistisk-samhällsvetenskapliga vetenskapsområdet, Uppsala universitet & Samhällsvetenskapliga fakulteten 2014, "The logic of innovation in construction", *Industrial Marketing Management,* vol. 43, no. 3, pp. 512-524.

Carroll, A.B. 1991, *The pyramid of corporate social responsibility: Toward the moral management of organizational stakeholders*, Elsevier Inc, Greenwich.

Chopra, S. & Meindl, P. 2016, *Supply chain management: strategy, planning, and operation,* 6., Global edn, Pearson Education, Harlow, Essex.

Cocco, L., Pinna, A. & Marchesi, M. 2017, "Banking on Blockchain: Costs Savings Thanks to the Blockchain Technology", *Future Internet,* vol. 9, no. 3, pp. 25.

D'heur, M. 2015, *Sustainable Value Chain Management: Delivering Sustainability Through the Core Business,* 1st edn, Springer International Publishing, Cham.

De Marco, A. 2011, *Project Management for Facility Constructions: A Guide for Engineers and Architects,* Springer Berlin Heidelberg, Berlin, Heidelberg.

Dhillon, V., Metcalf, D., Hooper, M. 2017, *Blockchain Enabled Applications: Understand the Blockchain Ecosystem and How to Make It Work for You,* Apress L. P, Secaucus;New York;.

Drescher, D. 2017, Blockchain basics: a non-technical introduction in 25 steps, 1st edn, Apress, Berkeley, California.

Elkington, J. 1998, "ACCOUNTING FOR THE TRIPLE BOTTOM LINE", *Measuring Business Excellence,* vol. 2, no. 3, pp. 18-22.

EU. (2011). *A modern understanding of corporate social responsibility*. EC Brussels, 25 Oct 2011 COM(2011) 681 final. A renewed EU strategy 2011–14 for corporate social responsibility, Bruxelles. Available at: http://www.europarl.europa.eu/meetdocs/2009_2014/documents/com/com_com(2011)0681_/com_com(2011)0681_en.pdf [Accessed 2018-06-01].

Francisco, K. & Swanson, D. 2018, "The Supply Chain Has No Clothes: Technology Adoption of Blockchain for Supply Chain Transparency", *Logistics,* vol. 2, no. 1, pp. 2.

Global Reporting Index. 2016. *Consolidated set of GRI Standards.* Amsterdam. [pdf]. Available at: https://www.globalreporting.org/standards/gri-standards-download-center/?g=067f593a-5be5-4573-bc1b-e2b4241831c6 [Accessed 2018-06-01].

Gould, R. 2012, *Creating the strategy: winning and keeping customers in B2B markets,* 1st edn, Kogan Page, London;Philadelphia;New Delhi.

Gupta, M. 2017. *Blockchain For Dummies*, IBM Limited Edition. [E-book]. Available at: https://www-01.ibm.com/common/ssi/cgi-bin/ssialias?htmlfid=XIM12354USEN [Accessed 2018-06-01].

Hofmann, E., Strewe, U.M., Bosia, N. 2018;, *Supply Chain Finance and Blockchain Technology: The Case of Reverse Securitisation,* Springer International Publishing, Cham.

Huang, S.K. 2013, "The Impact of CEO Characteristics on Corporate Sustainable Development: CSR Drivers, CSR CEO Characteristics, Hypotheses, Method, Discusssion", *Corporate Social Responsibility and Environmental Management,* vol. 20, no. 4, pp. 234-244.

ID06 AB a. 2018. *Om kortet*. Available at: https://id06.se/om-kortet/ [Accessed 2018-06-01].

ID06 AB b. 2018. *FAQ*. Available at: https://www.id06.se/fragor-svar/ [Accessed 2018-06-01].

Idelberger, F., Governatori, G., Riveret, R., & Sartor, G. 2016. “Evaluation of logic-based smart contracts for blockchain systems”. *International Symposium on Rules and Rule Markup Languages for the Semantic Web*, pp. 167-183.

Kairos future. 2017. *Blockchain use cases for food traceability and control*. Available at: https://www.sklkommentus.se/globalassets/kommentus/bilder/publication-eng-blockchain-for-food-traceability-and-control-2017.pdf [Accessed 2018-05-30].

Kelley, G.S. 2013, *Construction law: an introduction for engineers, architects, and contractors,* 1. Aufl. edn, John Wiley & Sons, Hoboken, N.J.

Laurence, T. 2017, *Blockchain*, John Wiley & Sons, Hoboken, NJ.

Lemieux, V.L. 2016, "Trusting records: is Blockchain technology the answer?", *Records Management Journal,* vol. 26, no. 2, pp. 110-139.

Mik, E. 2017, "Smart contracts: terminology, technical limitations and real world complexity", *Law, Innovation and Technology,* vol. 9, no. 2, pp. 269.

Morabito, V. 2017, *Business Innovation Through Blockchain: The B³ Perspective*, Springer International Publishing, Cham.

Mougayar, W. 2016, *The business blockchain: promise, practice, and application of the next Internet technology,* John Wiley & Sons, Inc, Hoboken, New Jersey.

O'Brien, W.J., Formoso, C.T., Ruben, V. & London, K. 2008, *Construction Supply Chain Management Handbook,* 1st edn, CRC Press, Baton Rouge.

Paetzold, K. 2010, *Corporate Social Responsibility: An International Marketing Approach,* 1. Aufl.;1; edn, Diplomica GmbH, Hamburg.

Prakash, A. & Mohanty, R.P. 2015, "Understanding construction supply chain management for road projects", *International Journal of Logistics Systems and Management,* vol. 22, no. 4, pp. 414-435.

Presley, A. & Meade, L. 2010, "Benchmarking for sustainability: an application to the sustainable construction industry", *Benchmarking: An International Journal,* vol. 17, no. 3, pp. 435-451.

Rumane, A.R. 2017, *Handbook of construction management: scope, schedule, and cost control,* CRC Press, Boca Raton.

Ryan, P. 2017, "Smart Contract Relations in e-Commerce: Legal Implications of Exchanges Conducted on the Blockchain", *Technology Innovation Management Review,* vol. 7, no. 10, pp. 14-21.

Sears, S.K., Sears, G.A., Clough, R.H., Rounds, J.L. & Segner, R.O. 2015, *Construction Project Management,* Sixth;6; edn, John Wiley & Sons Inc, New York.

Segerstedt, A., Olofsson, T., Institutionen för ekonomi, teknik och samhälle, Industriell Ekonomi, Institutionen för samhällsbyggnad och naturresurser, Luleå tekniska universitet & Byggkonstruktion och -produktion 2010, "Supply chains in the construction industry", *Supply Chain Management: An International Journal,* vol. 15, no. 5, pp. 347-353.

Sklaroff, J.M. 2017, "SMART CONTRACTS AND THE COST OF INFLEXIBILITY", *University of Pennsylvania Law Review,* vol. 166, no. 1, pp. 263.

Szabo, N. 1997 ”Formalizing and securing relationships on public networks”, First Monday, Vol. 2, no. 9

Thomas, R. 2017, "Blockchain’s incompatibility for use as a land registry: issues of definition, feasibility and risk", *European Property Law Journal,* vol. 6, no. 3, pp. 361-390.

Vogelsang, M. 2010, *Digitalization in open economies: theory and policy implications,* 1st edn, Physica-Verlag, New York;Heidelberg;London;Dordrecht.

Wilson, J.P. 2015, "The triple bottom line", *International Journal of Retail & Distribution Management,* vol. 43, no. 4/5, pp. 432-447.

Winch, G. M. 2010, *Managing construction projects*, 2dn edn, John Wiley & Sons, GB.

Appendix A -Interview Templates

NCC Purchasing

1. Can you describe yourself and the responsibilities you have?
2. How is the purchasing function organized?
3. How does the purchasing process of contractors look like? Steps, who is responsible etc.
4. How are the functions purchasing and con linked?
5. How do you control the materials and labour used by a subcontractor?
6. How do you control the sub-subcontractors?
7. How is CSR considered in your purchasing process?
8. What issues are experienced from your perspective? How do you prevent it?

NCC CSR

1. Can you describe yourself and the responsibilities you have?
2. How is this function organized?
3. What are your (NCC) fundamental CSR requirements?
4. How is the CSR aspect transferred out in your organisation as well as to the other contractors?
5. How does the client affect the CSR-focus?
6. What issues are experienced from your perspective? How do you prevent it?

NCC Construction

1. Can you describe yourself and the responsibilities you have?
2. How are the construction function organized?
3. Could describe the process from when you are initiated to the project to hand-over?

4. Evaluation of subcontractor performance?
5. How are the relations with the subcontractors characterized?
6. How do you determine whether to use own people, NCC montage or subcontractors?
7. What issues are experienced from your perspective? How do you prevent it?

NCC HR

1. Can you describe yourself and the responsibilities you have?
2. How does the ID06-system work?
3. What issues are experienced in the construction industry which ID06 aims to prevent?
4. What are the incentives to not follow the requirements?
5. How do you control licenses and education for domestic and foreign workers?

Sveriges Byggindustrier

1. Can you describe yourself and the responsibilities you have?
2. What are the greatest issues connected to your field?
3. What initiative or tool do the construction industry have to prevent those?
4. What can you do local, national and on a EU-level to prevent this?
5. What are the incentives to not follow the requirements?
6. How do the construction industry control global contractors/suppliers?
7. How would a more transparent environment enhance the issues within your field?

Blockchain Researcher

1. Can you describe yourself and what you do more specific in the field of blockchain?
2. How would you define the blockchain technology?

3. In what industries are blockchains currently being implemented and used?

4. How do they use them?

5. How can the blockchain technology enhance the transparency and trust within supply chains?

6. How does a smart contract work?

7. What are the limitations for smart contracts to be used in the physical world?

8. How do B2B payments work in practise within a blockchain network?

9. How useful is blockchain in project environment, i.e new set-ups?

10. How are inactive actors taken out of the network so they do not see the potentially sensitive information?

11. What do you think about industry-wide blockchains?

12. What are the limitations for the blockchain technology?

Blockchain Professional

1. Can you describe yourself and how you are working with the blockchain technology Would you like to describe yourself?

2. How would you define the blockchain technology?

3. What potentials do you see with the technology?

4. In what areas/industries do you see potential of it?

5. In what industries are blockchains currently being implemented and used?

6. How will the blockchains be set up for industry usage?

7. How can the blockchain usage be structured in a project based environment?

8. What limitations do you see with the blockchain technology?

Blockchain Benchmarking

1. Can you describe yourself and what are you doing more specific in the field of blockchain?

2. What potential do you see in the blockchain technology for your business?
3. What are the current limitations for an adoption?
4. How would an blockchain setup in your business look like?
5. Does it require a govern actor?
6. What cooperation with other parties is required?
7. In a potential implementation, where do you start?