UNIVERSITY OF GOTHENBURG
SCHOOL OF BUSINESS, ECONOMICS AND LAW

Gothenburg School of Economics and Law, Graduate School

Blockchain Smart Contracts, the new rebar in the construction industry?

Master Thesis within M.Sc. in Logistics and Transport Management

Authors:
Viktor Björklund 931127
Tim Vincze 900723

Supervisor:
Jonas Flodén

Blockchain Smart Contracts, the new rebar in the construction industry?

By Viktor Björklund and Tim Vincze

© Viktor Björklund and Tim Vincze

School of Business, Economics and Law, University of Gothenburg
Vasagatan 1, P.O. Box 610, SE 405 30 Gothenburg, Sweden
Institute of Industrial and Financial Management & Logistics

All rights reserved.

No part of this thesis may be distributed or reproduced without the written permission by the authors.

Contact: viktorm.bjorklund@gmail.com; tim.vincze@gmail.com

Abstract

Problem discussion and purpose - The blockchain technology, and its subset technology - smart contracts, has the potential to redefine the structure of future networks. Due to its underlying technology and its characteristics, there is a potential that blockchain smart contracts could provide benefits both within supply chain management as well as supply chain financing. The construction industry is associated with low digitalization, poor productivity and inefficient processes. Hence, this is an industry that could benefit greatly from new digital IT applications. Therefore, in this thesis, we gage the knowledge surrounding blockchain and smart contracts in the construction industry. Furthermore, we present where and how blockchain smart contracts can increase efficiency within supply chain management and supply chain financing. Lastly, we propose the most suitable smart contract solutions for the construction industry.

Methods – The case study object for this thesis was a Swedish concrete producer where semi-structured interviews were conducted. Additionally, five major Swedish construction companies were also interviewed. Furthermore, to increase the ability to generalize, a questionnaire has been sent out to these companies as well. Additionally, semi-structured interviews within following areas of expertise has been conducted; blockchain smart contracts, supply chain financing and law.

Results and Conclusion

The results show that there is limited knowledge surrounding the technologies within the construction industry. Moreover, blockchain smart contract has the potential to increase the efficiency within supply chain management and supply chain financing. However, these efficiency improvements have the potential to be attained using other technological solutions. Furthermore, the low level of digital maturity and still paper-based processes makes it difficult to utilize and feed the blockchain smart contract with enough data. The complexity to secure the input data is also an aspect that all physical goods supply chains need to overcome. An area where the blockchain technology could add value is by incorporating it with the BIM technology. The results further indicate that the most suitable blockchain for the construction industry is a consortium configuration and the most suitable blockchain for a network including governmental agencies construction procurement seems to be a public permissioned configuration. To conclude, the study shows that blockchain smart contracts is not the new rebar in the construction industry at the current level of digital maturity.

Keywords: *Blockchain, Smart contracts, Construction industry, Concrete industry, Supply chain management, Supply chain financing.*

Acknowledgements

Firstly, we would like to give a big thanks to our case company Thomas Betong AB for helping us get in contact with the many industry professionals throughout the Swedish construction industry. The help and support from Carina Edblad, CEO of Thomas Betong, has been essential and greatly appreciated throughout this thesis. Furthermore, we would like to thank all the respondents, including industry professionals and experts from different fields, that took their time to meet with us, answer questions and give us valuable information pertaining to the thesis topic.

Our gratitude also goes to Jonas Flodén, the supervisor of this thesis, for leading us on a good path throughout the thesis and for providing essential insights throughout the process. Our gratitude also extends to the staff at the Institute of Logistics and Transport Management at the Gothenburg School of Economics and Law who have helped throughout the writing of this thesis.

Gothenburg, Sweden
May 27, 2019

Viktor Björklund

Tim Vincze

Table of Content

List of Figures

List of Tables

Abbreviations

API – Application Programming Interface
BIM – Building Information Modeling
C2C - Cash-to-Cash Cycle
CSC - Construction Supply Chain
DSC - Digital Supply Chain
IoT - Internet of Things
RFID - Radio Frequency Identification
RMC – Ready-Mixed Concrete
SCF - Supply Chain Financing
SCM - Supply Chain Management
UI – User Interface

1. Introduction

This first chapter will introduce the reader to the topic, presenting the background to the field. After this a problem setting and discussion is presented highlighting the focus areas. Following this, the research questions which the study aims to answered are stated followed by the delimitations of the study. Lastly, the disposition of the thesis is presented.

1.1 Background

Technological advancements and innovations constantly changing how companies do businesses to stay ahead on a more competitive market than ever. Digital platforms have significantly transformed relationships between actors and the methods for communication and collaboration has drastically changed. New networking methods and opportunities constantly develop over time. Historically, these platforms have been built on a centralized system architecture. (*Hukkinen et al., 2019*) However, there is a growing interest around the blockchain technology, and its subset technology - smart contracts, due to its technical characteristics and its potential to redefine the structure of future networks (*Weber et al., 2019*). Therefore, blockchain is considered as a new technological paradigm and is seen as the next disruptive computing paradigm after internet and social/mobile networking (*Swan, 2015*).

Blockchain technology was initially designed as a *peer-to-peer electronic cash system* to eliminate the involvement of a trusted third party and facilitate transactions between two untrusted parties *(Nakamoto, 2008; Alharby and Moorsel, 2017*). The technology was introduced in 2008 when a person or a group under the pseudonym Satoshi Nakamoto released a white paper and proposed a digital platform system for electronic transactions, also known as the cryptocurrency Bitcoin or now referred to as Blockchain 1.0 (*Nakamoto, 2008*; *Gupta, 2018*). The financial industry is considered the main application area of the blockchain technology (*Nofer et al., 2017*). Blockchain 1.0 was followed by the introduction of the programmable Ethereum version, also referred to as Blockchain 2.0.

In its simplest form, the blockchain technology can be described as a shared ledger, built on a distributed peer-to-peer network, where transactions are cryptographically registered in chained blocks in a chronological order. This ensures security, transparency and traceability of transactions in a distributed network where all actors are equally powerful. The subset technology, smart contracts, can be described as contracts built using code applying a 'if-this-then-that' logic (*Morabito, 2017*). These contracts are recorded and stored on the blockchain, thereby providing the benefits of the blockchain technology.

There is agreement among researchers within the field of blockchain technology and business practitioners that blockchain technology and smart contracts can be applied to other solutions than cryptocurrencies. This is referred as the third generation of the technology and hence under the name Blockchain 3.0. Other potential application areas are asset registry and transactions of both tangible and intangible assets (*Swan, 2015*). Hence, it opens the possibilities for other industries and application areas where supply chain management (SCM) is particularly promising (*Andoni et al., 2019; Weber et al., 2019; Casey & Wong, 2017; Kamble et al., 2018*). SCM is the term of efficiently manage and coordinate the physical flow as well as the flow of information and financial transactions, in turn minimizing system wide costs while still meeting customers demanding requirements (*Le May et al., 2017*).

In addition, Hofmann et al. (2018) argues that blockchain technology in combination with a smart contract solution has the potential to enable collaboration across supply chains and supply chain financing (SCF) solutions especially could gain benefits and speed up cash flows and reduce the cash-to-cash (C2C) cycle.

Tate, Bals and Ellram (2019) describe SCF as a financial instrument and method, by which a company uses technology or other applications, to improve working capital and manage the liquidity embedded in the supply chain. This involves collaboration between supply chain actors; buyers, suppliers and financial institutions. The aim is to improve the financial performance, measured using the metric C2C cycle. This measurement reflects the time between investments into raw material and the inflow of cash from sales.

One industry that could gain benefits from improved digital IT applications is the construction industry (*Irizzary et al., 2013*). Traditionally, the industry has an inertia to change its processes and the way it operates, leading to inefficiencies and poor productivity (*Liu et al., 2017*). However, digital development in especially supply chains has become a central topic during the last decades for companies to stay competitive in the market (*Kamble et al., 2018*).

The construction industry plays an important role for economic growth since it is one of the biggest industries in the world. In Sweden, the construction industry contributes to 6.4 percent of the total GDP year 2018 (*UNEC, n.d.*). A construction supply chain (CSC) differs from a standard manufacturing supply chain due to its project-based construction rather than process-based production (*Behera et al., 2015*). One trend is that main contractors purchase more material and labor than before. Consequently, they become more dependent on other actors in the supply chain and therefore there is a need to evaluate their supply chain strategy and trading relations (*Vrijhoe & Koskela, 1999*). Moreover, it results in a fragmented supply chain where each actor primarily protects their own interests (*Marks, 2017*). Eventually this leads to poor C2C cycle where payment delays are prevalent within the construction industry (*Chia, 2018*).

The construction industry will be facing several challenges in the coming digital era, the industry will be forced to adapt to new and disruptive digital innovations to keep pace with the global economy (*Penzes, 2018*). Some of these challenges facing the industry and its SCM and SCF practices will be further investigated and elaborated in the following section.

1.2 Problem Discussion

The digitization movement has affected almost every industry imaginable (*Rosman, 2017*). However, the construction industry is in many ways an industry cemented in a pre-digitalization era. Segerstedt and Olofsson (2010) argue that the construction industry is behind the curve when it comes to digitalization and productivity in comparison to other industries. The companies within the construction industry faces many challenges and obstacles as the world moves towards becoming more digitized. Companies are going to be pressured into adapting else becoming outcompeted by new or current competitors. (*Entech, 2018*).

Deloitte reported in 2017 that the construction industry ranked the lowest on the percentage of budget spent on IT out of all the industries they researched. The construction industry spent on average 1.51

percent of their budget on IT while all other industries spent on average 3.28 percent, see Fig. 1-1. However, it was found that the construction industry is seeing an increase in the amount of money spent on IT. Comparing 2016 to 2017, there was a 45 percent increase in investment on IT for the construction industry, the majority pertaining to business operations. (*Klark et al., 2017)*

Figure 1-1: IT budget as percentage of revenue (Klark et al., 2017).

The previous lack of investment into IT has had consequences in the industry today. A report by McKinsey shows that labor productivity within construction has not kept up with the total economic productivity levels in the world. Labor productivity within the construction industry is around 25 percent lower when compared to Germany's labor productivity on a country level which can partly be attributed to the low digitalization. Several disruptive digital trends have been identified within the construction industry; Internet of Things (IoT), completely non-disruptive information chains and automation (*Quist, 2017; McKinsey & Company, 2016*)

The CSC is heavily based on vast amounts of manual administration and physical transaction tracking in the form of paper invoicing and paper delivery notes. This pre-digitization workflow affects the entire supply chain, leading to outdated raw material ordering system and stock keeping systems, slow financial administration and inefficient account receivable administration causing long C2C cycles. (*Chia, 2018*) There are several reasons why low digitalization becomes an issue for companies. Some of these include; becoming irrelevant, the loss of a competitive advantage and threat to the market share, low analytics and ability to analyze trends, hard to attract and keep valuable staff, reduced revenue and increased costs (*O'Brien, n.d.*). Currently, the construction industry is ripe for technological disruption. Technological innovation within the construction industry could allow for enhanced goods tracking, real time planning, less administration, improved efficiency throughout the supply chain and improved financial flows. New systems, automated process and reduced manual labor could help to increase SCM efficiencies via improved forecasting ability, goods planning and accurate stock levels. These improvements can potentially be gained by using a blockchain smart contract solution. This is further supported in a report from Penzes (2018) where the research shows that blockchain can help with an improved procurement and sales process, while also alleviating complexity and fragmentation. (*Hofmann et al.,2018; McKinsey & Company, 2016; Tapscott & Tapscott, 2017*)

However, not all issues within the construction industry are due to substandard digitalization and outdated systems. McKinsey have also identified in their report from 2016 that the contracts that are currently used within the construction industry are poorly composed and worded. The biggest issue is the unclear and uneven risk distribution in the contracts that the industry uses. More specifically, one actor may be overrepresented, and the risk is not shared among the responsible parties. However, in a more comprehensive and improved contract this risk will be shared more fairly among responsible actors. As McKinsey (2016) states, the first movers will see great competitive advantages if they can solve this deficiency within the construction industry. Hofmann et al. (2017) argue that smart contracts can improve financial agreements between parties and ensure that all actors are paid accordingly and within a reasonable time limit. This is further supported in Penzes (2018) report were smart contracts in construction are shown to reduce administration, automate the process, increase efficiency, reduce cost and ensure an outcome that aligns with the contractual terms. Clearly, smart contracts can be a possible solution for some of the contractual issues within construction. (*McKinsey & Company, 2016; Hofmann et al., 2018)*

The construction industry does not only need to improve digitization and contracting. Another key area of improvement is the increased efficiency of the company's financial flows and the SCF within the industry. Due to the manual administration still heavily present in the construction industry, C2C cycles are long and require excessive manual labor. Reducing the amount of manual administration required in the supply chain will allow for faster C2C cycles which reduces costs within the companies in terms of lower borrowing costs for raw materials as well as reduced administration costs. This was shown in Tapscott and Tapscott's (2017) research where they found that the blockchain technology can help reduce the need for intermediaries, automate processes and improve the payment systems. (*Tapscott & Tapscott, 2017; Hofmann et al.,2018; Seifert & Seifert, 2011; Holland FinTech, 2017*)

One problem surrounding blockchain and smart contracts within the construction industry is the limited amount of case studies and studies pertaining to real-world applications. Most of the studies within the field of smart contracts and blockchain in construction industry aim to investigate the pros and cons of the technology, lacking real world application (*Saberi et al., 2018*). However, there are several studies that tackle application of blockchain on SCM within other industries or on a broader spectrum. One such case study, by Tönnissen and Teuteberg (2018), found that SCM, specifically procurement can use blockchain technology together with ERP systems to create more efficient and transparent processes. The addition of smart contracts has the ability to improve efficiency even further. This shows that these technologies have the potential to be beneficial within SCM and SCF. However, Tönnissen and Teuteberg´s (2018) study are conducted on highly technical industries that have far greater digitization and technological ability than the industry investigated in this thesis.

Research by Saberi et al. (2018) show that one of the biggest challenges facing a blockchain technology implementation in the supply chain is the technological barriers of the industry. Concurrently, the low digitalization, as highlighted in the Deloitte's report from 2017, can cause issues for the construction industry when implementing a smart contract blockchain solution (*Klark et al., 2017*). Hence, the results from Tönissen and Teuteberg (2018) are not able to be translated to the construction industry, specifically the construction industry, and it needs to be evaluated and examined separately.

One study which has investigated blockchain and smart contracts within the construction industry is a study by Lanko, Vatin and Kaklauskas (2018). They examined the potentials of using blockchain technology to track goods in combination with RFID (Radio Frequency Identification) technology. The study clearly defines many of the positive aspects of using these technologies like; automation, increased efficiency and improved tracking. However, a RFID solution is a highly technical solution and the real-world implementation will be limited due to the construction industries low digitization

(*Klark et al., 2017*). Furthermore, this does not tackle the additional real-world implementation of smart contracts on the blockchain within construction. Another study by Mason and Escott (2018) that examined smart contracts in construction industry from the view of the different stakeholders in the UK. They found that there was low confidence in an automated system. The study however only examined stakeholders' thoughts on smart contracts while only five percent answered that they knew anything about smart contracts. There is a disconnect here between understanding of the technology and making decisions on its usefulness. This study also does not examine the real-world potential of the technology and its potential use cases. (*Mason & Escott, 2018*)

While research exists pertaining to smart contract and blockchain technology in the construction industry, the prevalence is still very sparse. Furthermore, the research that exists does not evaluate the specific technical challenges when implementing a smart contract and blockchain solution based on experts and industry professionals. The studies that exist lack the aspect of real-world application evaluation and the technical evaluation of specifically smart contracts technology in the construction industry. This indicates a research gap within the application of smart contracts in construction. This thesis will attempt to reduce this research gap by investigating the application of smart contracts with blockchain technology within the construction industry.

1.3 Research Purpose and Questions

The purpose of this thesis is to first gage the general knowledge surrounding smart contracts and blockchain technology within the CSC. Furthermore, evaluate potential smart contract solutions, in combination with blockchain technology, and investigate if it can improve SCM as well as SCF within the construction industry. Moreover, providing potential blockchain solutions and contribute to the research area of blockchain smart contracts while filling the existing research gap.

Based on the purpose of this study, following three research questions has been formulated:

RQ1: *What is the current state of knowledge surrounding blockchain technology and smart contracts within the construction supply chain and what is the sentiment and perceived readiness for implementing such a solution?*

The first research question will help to identify the level of understanding for the technologies, blockchain and smart contracts, within the CSC. Due to the complexity of blockchain technology there needs to be an understanding of how the technology works and what it can be used for within companies. Without the proper knowledge adaption is unlikely to occur. Furthermore, the first question will also evaluate the level of sentiment towards implementing a blockchain smart contract solution and the perceived readiness among actors.

RQ2: *Can smart contracts, in combination with blockchain technology, be used to increase efficiency in supply chain management and supply chain financing within the construction supply chain? If so, how?*

With the second research question the authors aim to gain an understanding of if and how the technology can create beneficial results from an implementation standpoint. The question is designed to look at the effects of smart contracts that are built on a blockchain and how it potentially could lead to improvements within SCF as well as SCM.

RQ3: *How would a blockchain smart contracts solution be designed to be suitable for a construction supply chain?*

The final research question will attempt to identify what blockchain smart contract solution would be suitable for a CSC, taking all the actors concerns and expert recommendations into account. The aim is not to identify a specific system but rather the traits which the system will have to adhere to for it to become functional and adopted for the industry. This will allow for a general guideline for real-world applications of smart contracts and blockchain technology.

1.4 Delimitations

Firstly, a delimitation with this study is that it will not evaluate all contracts that are used within a CSC. Focus will be on those contracts that directly govern the procurement and sales of physical goods. Furthermore, SCM and SCF are two broad terms that encompasses several different areas. However, this study will focus on specific aspects of these two areas. Within SCM there will be a focus on increased efficiency, improved tracking ability and the aspect of trust between actors in the supply chain. SCF will focus on the aspect of improving the automation of the financial flows and administration efficiencies. Lastly, another delimitation is that this study does not take smaller companies into consideration since all the companies included in this study are among the biggest construction companies within the Swedish construction industry. The research is also limited to the Swedish construction industry.

1.5 Disposition

The disposition for this study is as outlined in Fig. 1-2.

Figure 1-2: Disposition of the study. Own model.

2. Theoretical framework

This chapter will give the reader the necessary theoretical review given the subject areas being researched. First, there will be a general description of supply chain management and its applications in the construction industry. After which supply chain financing and its models will be presented. Following this the theory of blockchain technology, and its associated technology smart contracts, and its applications in supply chain financing and supply chain management. Lastly, the applications of the technologies in the construction supply chain.

2.1 Supply Chain Management

Supply chain management (SCM) is the term for efficiently manage and coordinate the physical flow as well as the flow of information and financial transactions, to minimize system wide costs while still meeting customers demanding requirements. A supply chain consists of several vertical disintegrated actors, and involves multiple activities, both upstream and downstream (*Simchi-Levi & Kaminsky, 2008; Le May et al., 2017; Chen & Paulraj, 2007*). A traditional manufacturing supply chain is illustrated in Fig. 2-1. However, the globalization of supply chains has made the management and control more difficult since the chains become longer and more complex. This has led to the challenge of efficiently coordinating the aforementioned actors and activities (*Chen & Paulraj, 2007*). To efficiently manage the supply chain, current developments have been towards integrating all involved actors in the supply chain, instead of the previous silo mentality. In addition, traditional supply chains, or linear supply chains, are outdated and have associated disadvantages, such as information sharing between members or a transparent supply chain for customers. Instead, to overcome these challenges, a circular supply chain using a digital transformation could enhance the overall performance of a supply chain (*Casado-Vara et al., 2018; Loop, 2017*). This is possible due to the vast amount of accessible information and new emerging technologies (*Masteika & Čepinskis, 2015*). Casado-Vara et al. (2018) describes a circular supply chain as decentralized and where information is shared across the entire supply chain.

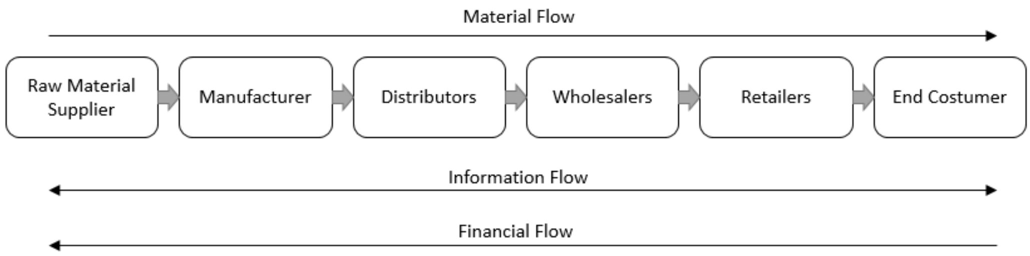


Figure 2-1: Traditional manufacturer supply chain. Adapted from Saberi et al. (2018).

2.1.1 Digital Supply Chain

Büyüközkan and Göçer (2018) define a digital supply chain (DSC) as a way to leverage new innovative technologies to create smart and efficient processes. It is not referring to whether goods or services within a supply chain are digital or not, it is about how the processes is managed with the emerging innovative technologies, such as Internet of Things (IoT), cloud computing, blockchain technology or/and smart contracts. The blockchain technology is seen as one of the emerging technologies and back bone of the new DSC. Thanks to its intrinsic characteristics it can provide; immutability, transparency and traceability and hence easing some of the discussed global supply chain problems (*Saberi et al., 2018; Perboli et al., 2018*). These characteristics are more extensively described in section 2.3 Blockchain Technology.

2.1.2 Supply Chain Management within the Construction Industry

A Construction Supply Chain (CSC) differ from other industries supply chain in terms of its processes, structure, flow of information and cash. Liu et al. (2017) defines CSC as a chain that links raw material, suppliers, contractors and its operational decisions regarding inventory stock, procurement, prefabrication and construction. In contrast to a normal process-based supply chain, CSC is by its nature project-based and a network between various projects and several firms (*Behera et al., 2015; Liu et al., 2017; Segerstedt & Olofsson, 2010*). Moreover, a CSC focusses more on the planning and coordination of materials to the construction site (*Irizarry et al., 2013*). Behera et al. (2015) identifies various linkages of construction projects and the network visualized in Fig. 2-2 represents the underlying structure of the construction industry.

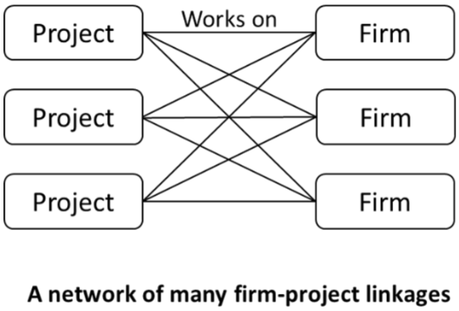


Figure 2-2: Construction project network (Behera et al., 2015)

The majority of projects are unique within construction. (*Sears et al., 2015*). Many researchers agree that CSCs is complex due to its underlying structure and processes, and therefore its characteristics entails an inherent uncertainty throughout the entire supply chain (*Lui et al., 2017; Sears et al., 2015; Segerstedt & Olofsson, 2010*).

There are several different actors involved in a CSC and depending the unique project, involved actors may differ. The following actors are generally involved in a project; a client or owner which order a project, architects and engineers, the main contractor which takes the responsibility to perform and complete the construction according to the client's objectives, subcontractors and lastly suppliers of raw material (*Benton & McHenry, 2010*). Besides these actors there are also external forces such as local government and landowners. This leads to a different supply chain in comparison to a manufacturing supply chain. However, this study focusses on the relationship and flow between main contractor, subcontractors and suppliers of raw material, which is illustrated in Fig. 3-2.

Both the characteristics of a CSC and involved actors differ from a manufacturing supply chain. In a manufacturing supply chain, value is added to the material flow through various activities. Starting from raw material supplier, going through several stages in the chain and finally end up at the final consumer (*Johnston et al., 2013*). In a CSC, the flow is instead converging to the construction site where raw material is assembled and processed, value-adding activities, to final object *(Segerstedt & Olofsson, 2010*).

The high number of involved actors leads to a fragmented CSC where the construction company performs a lesser extent of the jobs themselves, increasing the number of contractors used. In comparison to a process-based supply chain where the actors are relatively fixed, a project-based could involve new actors for each new project. This leads to most of the relationships being temporary and on a short-term basis. This influences the procurement process which is characterized by competitive bidding. (*Behera et al., 2015; Benton & McHenry, 2010*) Another consequence is that contractual relationships are characterized by mistrust which eventually leads to higher project costs. A significant share of the costs are due to inappropriate risk allocations in contracts. (*Zaghloul & Hartman, 2003*)

The construction industry is further fragmented due to the unstandardized platforms that make integration between platforms difficult. Moreover, one of the reasons for the industry´s poor productivity is the lack of digitization, resulting in insufficient information sharing where actors have a different view of transpired events. The main reason for this is that the industry, still relies on paper to manage their supply chain processes. The lack of digital processes and flows makes it difficult for companies to analyze data, retrieve previous data in situations where disagreements appear, risk management in contract and the manual paper-based administration is time consuming. However, the industry is starting to shift towards more digitized processes and new methods to share information. (*McKinsey & Company, 2016*)

Information Management in Construction Supply Chains

As the construction industry has reshaped in terms of number of actors, the traditional master builder no longer exists, and main contractors therefore have a new role as an information manager that coordinates activities in the supply chain. The large number of stakeholders makes it more difficult to identify goals and objectives related to time, cost and quality as there is a correlation between project complexity and total time and cost. (*Lundesjö, 2015*) Fig. 2-3 and 2-4 illustrates the differences between the traditional and modern contractual structures within a CSC. Arrows shows contractual relationships and broken lines non-contractual relationships. As can be seen, in comparison to the traditional and more simplified, the modern structure has higher complexity and a more chaotic and risky relationship.

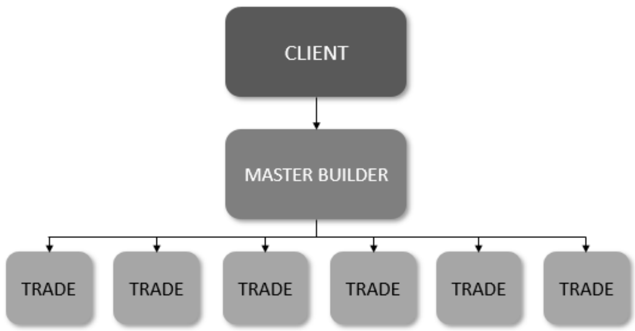


Figure 2-3: Traditional contractual structure (Lundesjö, 2015).

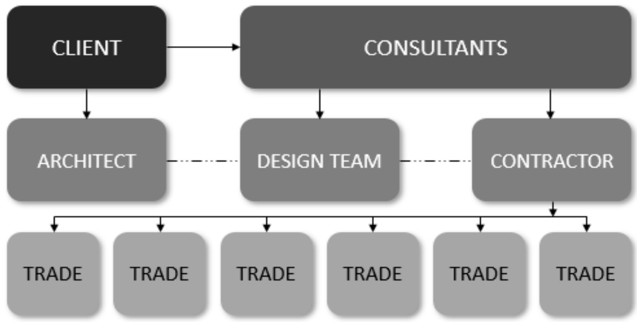


Figure 2-4: Modern contractual structure (Lundesjö, 2015).

Due to the complexity, Lundesjö (2015) emphasizes the importance of information sharing and a common understanding for a construction project to become effective. The challenge lies in both ensuring that all actors have the correct information while simultaneously making sure to avoid information being re-created or re-entered several times during a project life cycle. However, as Fig. 2-5 illustrates, the information exchange between actors in a CSC has the potential to be chaotic and the modern relationship structure somewhat hinder the flows of information and makes information distribution difficult.

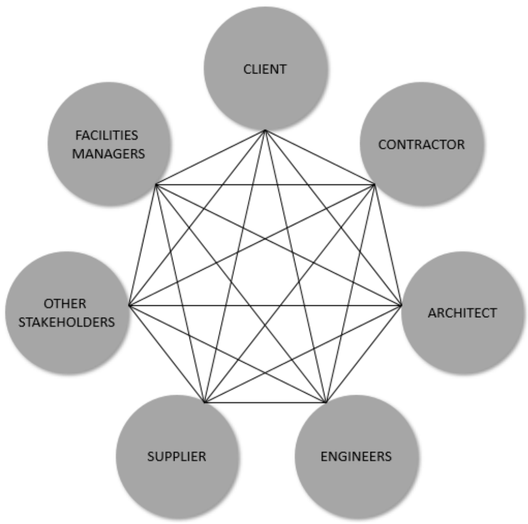


Figure 2-5: Information exchange in a CSC (Lundesjö, 2015).

As a response to the challenges mentioned, there has been an increased interest in the usage of the technology Building Information Modelling (BIM). In the past, the industry has relied on 2D (blueprints) and 3D (Computer Aided Design (CAD)) but now is BIM the standard. The advantages of BIM is highlighted in the definition by the EU BIM Task Group who define the tool as *"essentially value creating collaboration through the entire life-cycle of an asset, underpinned by the creation, collation and exchange of shared 3D models and intelligent, structured data attached to them."*(*EU BIM Task Group, 2017*) Basically, BIM uses 3D models and a common data environment to share information across the entire supply chain and allowing AEC (architecture, engineering, construction) to work from a single source of information (*CDBB, n.d.*). The BIM technology is intelligent and can store data which means if any element is changed, BIM software updates the 3D model, so it visualizes that change. The stored data is referred to as an "information model" which can be used in every stage of a building's life cycle; from inception, operation and later on renovations. Hence, the gathered information is not only stored but one can also take actions based on the information and thereby make the constructions more efficient and enhance collaboration between AEC´s. (Lorek, 2018) However, Turk and Klinc (2017) address and pinpoint some legal issues surrounding the BIM technology that need to be overcome for an industry adoption. As BIM is the management of information it can be used in cases where disputes and litigation arise. For example, it could be disputed regarding who is responsible for the securing the correctness of the data or who has liability for changes or errors made in BIM. (*Turk & Klinc, 2017*)

2.2 Supply Chain Financing

2.2.1 What is Supply Chain Financing

Tate, Bals and Ellram (2019) define the main purpose of supply chain financing (SCF) as a method of reducing capital costs by improving and interlinking the relationship between actors in the supply chain and advancing financing activities in the supply chain. SCF is a financial instrument method, usually an application, that uses technology to optimize working capital and manage the liquidity embedded in the supply chain via collaboration between; buyers, suppliers and financial institutions.

The overall objective of SCF is to improve financial performance and cash flow, additionally passing these advantages both upstream and downstream in the supply chain (*Caniato et al., 2016*). This is usually why SCF is referred to as a win-win-win solution. When referring to improving the financial performance and cash flow in the supply chain the usual KPI is the cash-conversion-cycle (CCC) also referred to as cash-to-cash cycle (C2C). As defined earlier, C2C is a value that reflects the days until cash outflow has turned into cash inflow. There are numerous different variations of SCF instruments and applications, however, the most prevalent and synonymous with SCF is reverse factoring. The other methods that exist are dynamic discounting, inventory financing and purchase order financing. These instruments will be explained in more detail below. (*Tate, Bals & Ellram, 2019; Kleemann, 2018*)

Reverse Factoring

Reverse factoring is when a buyer, together with a financier, provides a preferable credit rating to a supplier during a set payment period. This becomes increasingly beneficial to the partners if the difference between the buyers and suppliers credit rating is greater. (*Tate, Bals & Ellram, 2019*)

Consequently, the cost of borrowing for the supplier will be reduced and the cost of procurement for the buyer will also be reduced (*Wuttke, Blome & Henke, 2013).*

The simplest form of reverse factoring is the usage of a SCF platform connected to a financial institution, usually an intermediary such as a bank. These platforms are tailored to be suitable for the industry but by far the most common form is represented in Fig. 2-6. (*Fowler & Schofer, 2017; Tate, Bals & Ellram, 2019*)

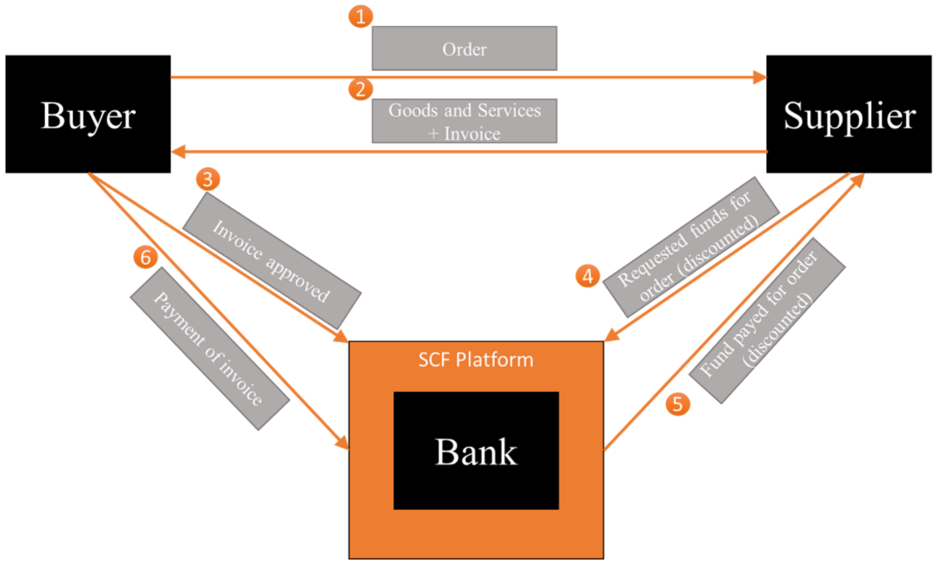


Figure 2-6: Reverse factoring. Adapted from Fowler and Schofer (2017).

The process illustrated in Fig. 2-6 above works as follows; (1) the buyer will order goods from the supplier, and (2) the supplier will send their invoice to the buyer. (3) The invoice will be approved and sent to the SCF platform, accepting that the invoice is correct and is approved for payment. Since the invoice has not reached maturity the buyer is not required to pay for the goods. However, (4) the supplier can still request the money from the SCF platform and get the funds sent to them before the invoice expiration, at a discount (5). This discount difference is what creates the incentive for the bank, (6) since the buyer will pay the invoice at its expiration date in full and the bank controlling the SCF will make a profit equal to the invoice payment from the buyer minus the discounted amount paid out to the supplier. (*Fowler & Schofer, 2017; Kagan, 2019; Tate, Bals & Ellram, 2019*)

There are three main advantages of reverse factoring identified by Tate, Bals and Ellram (2019); reduced cost of debt and higher liquidity for the supplier, stronger relationships between banks and smaller actors creating a more reliable credit history and finally the buyers are able to improve their negotiations with their suppliers.

Dynamic Discounting

Dynamic discounting is very similar to reverse factoring. It is a technology-based system, SCF platform, where the suppliers can choose when they wish to get paid and in return the buyer receives a discount on what they need to pay for the invoice. Dynamic discounting sets specific parameters for being paid, for example; if the supplier wishes to liquidate their invoice before 30 days there will be an 18 percent discount on the invoice. All of this is handled on an invoice by invoice basis via a platform which the parties agree upon. The main advantage of dynamic discounting is that the suppliers can liquidate assets in an easier and faster manner if needed. (*Tate, Bals & Ellram, 2019)*

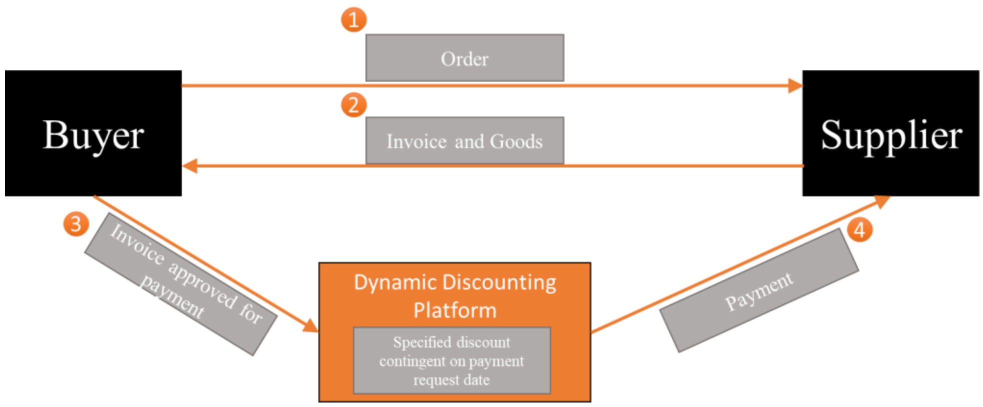


Figure 2-7: Dynamic discounting. Adapted from Tate, Bals and Ellram (2019).

Dynamic discounting is illustrated in Fig. 2-7. The illustration shows a process that would work as follows; (1) the buyer places an order with the supplier who then (2) sends the goods and the respective invoice. (3) The invoice is then approved on a dynamic discounting platform where payment terms are stated, an example being if the supplier wishes to get payed 15 days earlier then there is a discount of ten percent that the buyer can reduce the invoice with. (4) This payment step can occur at any time specified in the payment terms within the dynamic discounting platform.

Inventory Financing

Inventory financing is the ability to gain a line of credit or a short-term loan, from a financial institution, that uses the company's inventory as collateral. This is especially useful when a supplier needs to pay their suppliers within a short time frame and they need to be able to finance their operations until their inventory is sold. (*Tate, Bals & Ellram, 2019)*

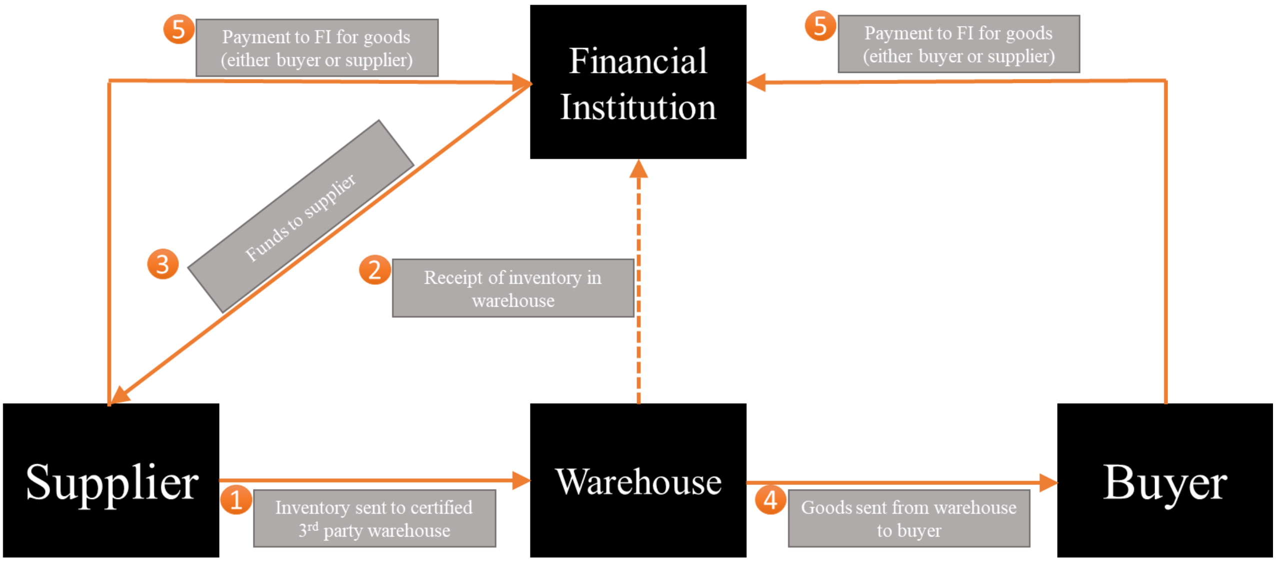


Figure 2-8: Inventory financing. Adapted from UNECE (2012).

Inventory financing is, as illustrated in Fig. 2-8 above, a simplification of what it may look like. The process flow is as follows; (1) the supplier places inventory into a warehouse, a trusted third party certifies the inventory and (2) sends a receipt to the financial institution, usually a bank. After the collateral has been registered at the bank (3) the funds are sent to the supplier who can finance their operations until their inventory is sold. Then production of goods can resume and the (4) goods are sent to the buyer. After this, (5) either the supplier or the buyer pays the financial institute, depending on the financial flow agreed upon at the conception of the deal. (*UNECE, 2012*; *Tate, Bals & Ellram, 2019)*

Purchase Order Financing

Purchase order financing is a short-term funding solution, suitable for business that lack cash flow to accept and complete customer orders. A company's supplier will in advance, once a purchase order is verified, receive capital from the purchasing order financing entity and thereby be able to manufacture and deliver the goods to the buyer or customer. One advantage with this solution is that it allows companies to become more flexible and be able to scale up/down rapidly. Moreover, companies are able to accept larger orders than otherwise might not be possible without this funding solution. (*Tate, Bals & Ellram, 2019)*

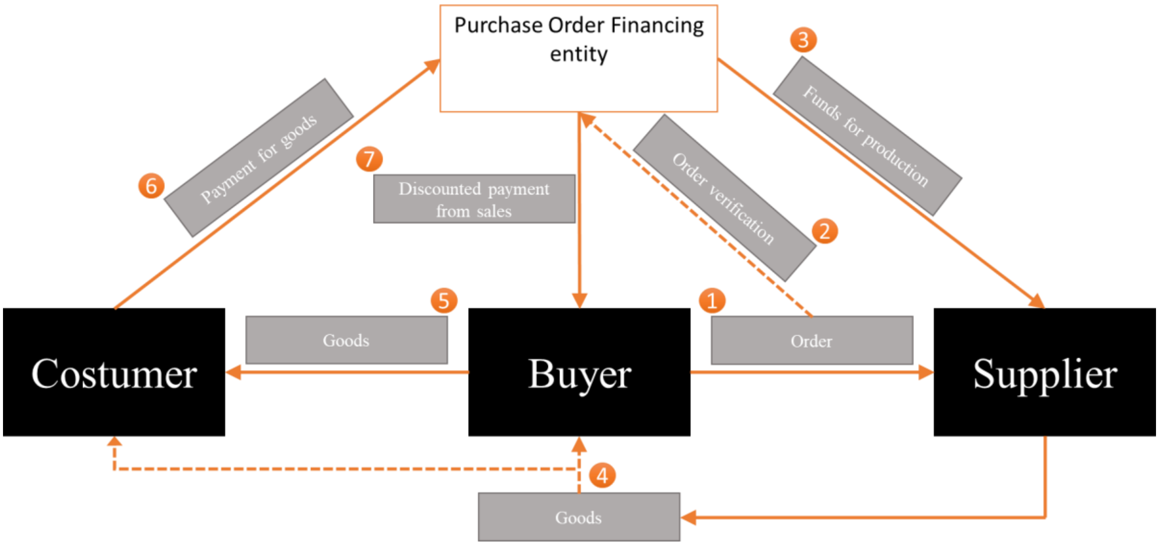


Figure 2-9: Purchase order financing. Adapted from Tate, Bals & Ellram (2019).

In Fig 2-9, an example of a purchase order financing process is illustrated. (1) The buyer, who has liquidity issues and is unable to pay for the order still places an order with the supplier. (2) This order is verified and sent to the purchase order financing entity who (3) pays to produce the order. (4) After the goods are produced, supplier sends the goods to the buyer or the end customer who the buyer is aimed to supply, there is no set process for how this should work. If the goods are sent to the buyer, then (5) the goods are sent via them to the costumer. (6) The customer pays for the goods by paying the purchase order financing entity and they in turn (7) pay the buyer, but they keep a percentage and only pay a discounted amount to the buyer.

2.2.2 Advantages and Disadvantages with Supply Chain Financing

There are both advantages and disadvantages to the SCF solutions of today. The main advantages of a SCF system are that suppliers can lower their products prices since they are able to reduce their loan costs due to the reduced loan rate. This works by the different methods mentioned previously. The bigger the difference in credit ratings the more improved the cost reductions become. Separate to this, there is also the advantage of improved administrative efficiency, stronger relationships and flexibility. (*Kleemann, 2018; Liebl, Hartmann & Feisel 2016*)

The biggest issue for actors today when implementing a SCF solutions is the digitization process. For a SCF system to work optimally the actors need to all be connected and integrated with each other and with the SCF platform. A SCF solution is only efficient if actors in the supply chain all agree on the solution. (*Caniato et al., 2016)* Additional studies have also show that there is a lack of a common vision and goal among companies when implementing a SCF solution. This lack of common vision and goal will ultimately affect the usefulness and level of adoption of the SCF platform. Furthermore, the lack of knowledge within SCF systems creates friction in the system and effects its overall effectiveness. The current systems also require a certain amount of manual inputs to be used which potentially lessens the usefulness of the system as it becomes time consuming. (*More, 2013*)

2.2.3 Technology and Future of Supply Chain Financing

There is a new and emerging trend within financing called *fintech* which essentially is using technology to delivery financial solutions. This refers to, among other technologies, the application of blockchain technology to improve financial transactions. Blockchain technology is a promising fintech solution, especially in combination with smart contracts to reduce manual administration within SCF. Blockchain technology has the potential to revolutionize financial institutes and in turn increase efficiency in SCF as well as SCM. (*Tate, Bals & Ellram, 2019)* Blockchain technology and smart contracts will be further covered in the following sections 2.3 respectively 2.4. and its implications for SCF as well as SCM.

2.3 Blockchain Technology

Firstly, it is important to mention that there exist different configurations of the Blockchain technology, either permission-less or permissioned (*Gupta, 2017*). These vary from each other in terms of level of decentralization, scalability and how the network reaches consensus. The blockchain version that Nakamoto introduced is what the researchers and experts consider to be the original and pure version of the technology. This version is built using the permission-less principle which means that there is no limitations or restrictions regarding interactions with the blockchain and all information is visible for all actors in the network. This version is called *public blockchain* and has mechanisms to give incentives and encourage more participants to contribute and interact with the network. Other configurations are *private blockchain* and *consortium blockchain.* (*Morabito, 2017; Andoni et al., 2019*) These are more extensively described in section 2.3.3.

2.3.1 Blockchain Architecture

The blockchain technology is described as a peer-to-peer network where assets are shared and stored in a distributed ledger and thereby eliminating the need of intermediates, such as banks (*Nakamoto, 2008*). Assets could be both tangible (car, raw material) or intangible (patents, copyrights, intellectual property), and in turn effect the blockchain architecture (*Gupta, 2018*). Unlike a centralized and traditional system with one single owner, the infrastructure is owned by all network participants. Each connected computer is called *nodes*, which are equally responsible for the shared database, also referred to a peer-to-peer replication. The peer-to-peer replication can be described as every participant acting as both a publisher and subscriber and the ledger becomes updated trough this method each time a transaction occurs. Each node on the network holds a complete copy of the entire ledger, from first block (genesis block) to the most recent block. *(Andoni et al, 2017; Gupta, 2018; Hancock & Vaizey, 2016*)

The blockchain technology is a digital data structure and a complete ledger of all historical transactions, creating the "one source of truth". Transactions are aggregated into blocks which are added in a chronological order. In addition to storing transactions, a block also consists of a hash value of the previous block (parent block), a timestamp of when the block was created, a public key signed using its respective private key to secure and validate the user and a cryptographic nonce. Blocks can include more information than this, Fig. 2-10 is only a simplification. (*Laurence, 2017; Andoni et. al. 2019*)

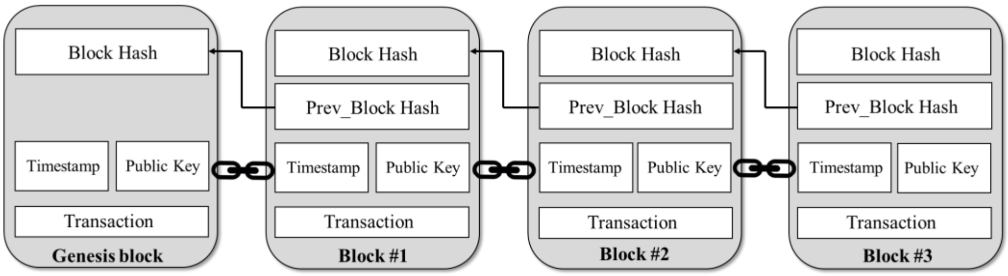


Figure 2-10: Blockchain structure. Adapted from Hong et. al. (2017) and Nofer et. al. (2017).

A hash value can be described as a digital fingerprint and since it is based on previous hash value, illustrated in Fig. 2-10, it creates the linkage that chains the blocks together, hence the name Blockchain. A hash value is created on all mentioned parameters a block contains. By linking blocks in this format, each resulting hash of the previous block represent the entire blockchain since all hashed data of the previous block is hashed into one hash. Thus, forming a chain of records that determines the sequencing order of blocks added to the blockchain. Hash functions are mathematical algorithms that take the input and transform it into a fixed output, illustrated in Fig. 2-11. The most commonly used cryptographic algorithm is Secure Hash Algorithm-256 (SHA-256), which output always consist of a combination of 64 digits and letters. (*Andoni et al, 2019; Nofer et al, 2017; Bauman et al, 2016*) As can be observed in Fig. 2-11, regardless the length of input the output will always be a unique and fixed string. This makes it easier to store longer and larger transactions.

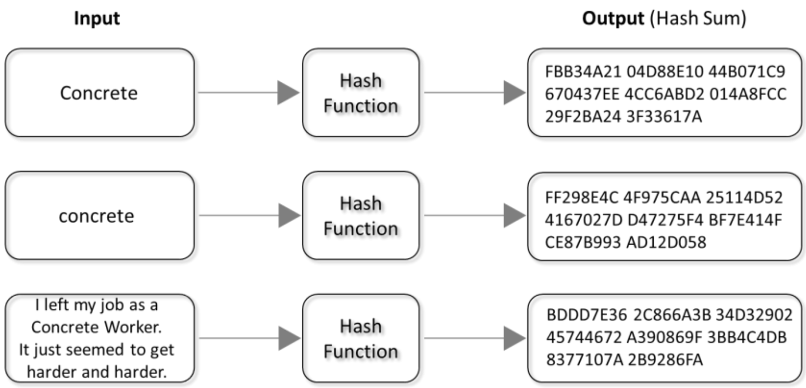


Figure 2-11: SHA-256. Own model, hashes generated in Python[1].

A blockchain, in the traditional sense of being permission-less and distributed is characterized by the following features; decentralization, immutability, anonymity and auditability (*Andoni et al., 2019; Zheng et al., 2018; Morabito, 2017*).

Decentralization means that transactions in the network can be performed between any node without the need of a central trusted actor (e.g. banks). Anyone could therefore participate in the consensus process and consequently the level of power is decentralized among the participants instead of a centralized authority. (*Zheng et al., 2018; Morabito, 2017*)

Immutability refers to the process where all transaction needs to be confirmed, recorded and distributed into blocks in the network. In addition, all blocks need to be validated by other nodes to be added to the blockchain. This makes it nearly impossible to tamper. (*Andoni et al., 2019*)

Anonymity means that it is possible for users to avoid expose their identity. Each user joins a network with a generated address, which is possible to generate multiple times, and therefore could none of the

[1] Python: the programming language

other actors know the sender's actual identity. Thus, participants are considered to be pseudo-anonymous. (*Zheng et al., 2018*)
Auditability or traceability is another useful feature of the blockchain technology. Since transactions in each block is validated and confirmed with a timestamp and chained to each other it allows users to trace a transaction to previous transaction. Therefore, it improves the traceability and transparency of the data recorded in the blockchain. (*Andoni et al., 2019*)

2.3.2 How the Blockchain Technology Works

The blockchain technology is based on *consensus*, meaning the process of establish agreements among the mistrusted participants of a blockchain network through cryptographic codes (*Andoni et al., 2019; Dhillon et al., 2017*). The network is maintained by all nodes and where each node holds a complete register of all the transactions recorded into the blockchain. The nodes that validating transactions as a part of the shared ledger and secure the network is referred to as full nodes or miners. Basically, anyone could act as a full node and create consensus, however, due to its high level of difficulty and required computer power, miners are rewarded for validating and generating the cryptographic codes. When the block is added and permanently stored on the blockchain, finality is reached. Fig. 2-12 illustrates an example how the process of a transaction and agreements are reached and finally a block is "chained".

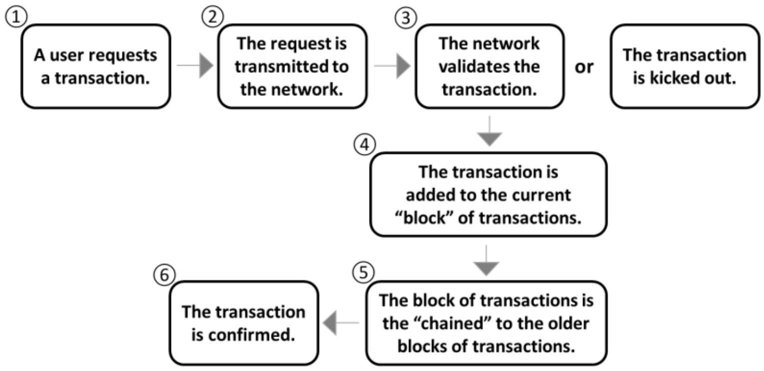


Figure 2-12: How blockchain works (Laurence, 2017).

Gupta (2018) states that the consensus mechanism varies from blockchain to blockchain. However, a consensus commonly includes following: Proof of Stake, meaning that in order to be able to validate transactions, full nodes must hold a minimum percentage of the network´s total value. In addition, a majority of the full nodes must validate the transaction, referred as Multi-signature. Lastly, Practical Bzyantine Fault Tolerance (PBFT) which is an algorithm which purpose is to solve disputes among network participants when records of transactions are not corresponding to others in the set.

The blockchain technology's ethos is to facilitate transactions where there is a lack of trust among participants as well as increased security from network attacks. The degree of trust that a network has, or the expected threat, will determine the most suitable type of consensus algorithm. The consensus algorithm that one chooses will depend on the business context and industry requirements (*Gupta, 2018*). Therefore, there are different degree of consensus mechanisms. The most frequently used consensus method on a public blockchain is Proof of Work, which is a strong consensus algorithm to handle the high degree of mistrust and threat (*Morabito, 2017*). The block that will be added to the chain on a permanent basis is the block that requires most computational power (*Andoni et al., 2019*).

A strong and secure consensus is useful for public networks; however, it is not particularly suitable consensus algorithm for a business where there is no need for anonymity and there exist some degree of trust among the participants. This due to the considerable large amount of computational power and electricity it consumes, making it an expensive process to reach consensus. Consequently, on the other end of the spectrum, a blockchain with known actors can use a simpler and faster consensus algorithm. (*Bauman et al., 2016; Morabito, 2017*)

2.3.3 Different Blockchain Configurations

Since Nakatomo´s first introduction of the technology (Blockchain 1.0), various other configurations of blockchains (Blockchain 2.0 and 3.0) with different characteristics have been developed. Besides the original public permission-less blockchain, other blockchains have emerged that are considered to be permissioned, meaning that there are restrictions regarding who is allowed to participate in the network and limitations to access the shared ledger. Participants needs an invitation or must be validated by either the actor who started the network or fulfill the entry-rules set by the latter. Hence, these permissioned blockchains have participants that are in charge and responsible for the blockchain. This could either be by a single entity, called *private blockchain,* or a hybrid version of the previous two, so-called *consortium blockchain.* (*Laurence 2017; Bauman et al., 2016; Zheng et al., 2018*). In addition to mentioned configuration, there are infinite version of them since the technology and blockchains are programmable (*Maxwell & Salmon, 2017*). However, the three most common are illustrated in Fig. 2-13, - public, consortium and private blockchains.

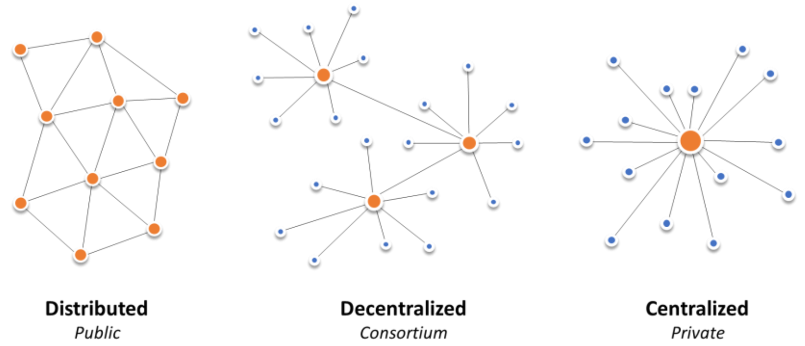


Figure 2-13: Different blockchain configurations. Adapted from Business Blockchain (n.d.).

The blockchain technology has various areas where it could add value and change how we manage supply chains today (*Kamble et al., 2018*). Depending on context and the requirements of the blockchain, each type of the three mentioned blockchain configurations has its advantages and disadvantages depending on the purpose of use. According to Dresher (2017), there are two trade-offs to consider when determining the most suitable blockchain; transparency versus privacy and security versus speed. The core concept of the technology is to use an open and shared ledger be able to verify transactions and ownership of assets through a decentralized and transparent network. The ownership is determined by reviewing records of transactions which can be compared to a public ledger since the register is available for all participants. (*Andoni et al., 2019*)

The second trade-off relates to the time and effort it takes to secure the blockchain and make it almost impossible to tamper versus the speed and scalability that is preferable for some areas of use, e.g. commercial applications. Securing the transaction history refers to the process where hash-puzzles/algorithms are solved to chain the new block to its previous parent block. As the blockchain increases in length and users, it will require more computer power and electricity. This process makes it also time-consuming and reduce the speed at which new transactions can be registered into a block. (*Dresher, 2017; Andoni et al., 2019*) As an example, Bitcoin can process seven transactions per second, adding a new block every ten minutes, in comparison to a VISA´s credit card 2000 transactions per second in average (*Croman et al., 2016; Swan, 2017*). In addition, blocks in a public blockchain are limited to 1MB in size. However, these limitations with public blockchain help ensure a decentralized network which is its advantage and provide its robustness. Larger blocks would make it even more difficult for full nodes to mine blocks and hence push out small actors (*Laurence, 2017*).

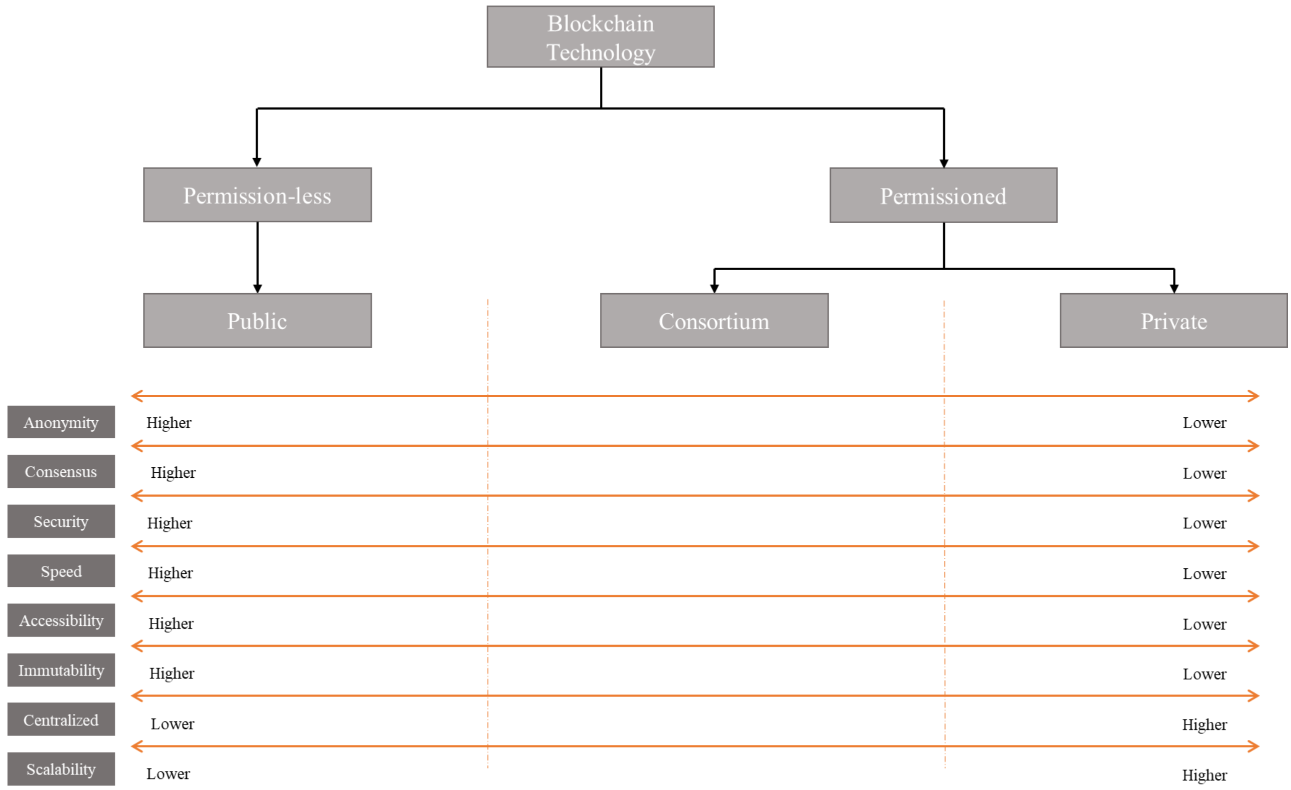


Figure 2-14: Comparison between different blockchain configurations. Own model based on the literature.

As discussed earlier, the core principle of the blockchain technology is creating a decentralized peer-to-peer network with a shared and distributed database where users can be anonymous. Furthermore, consensus is reached through all participants verifying the transactions to prevent tampering and hence eliminate the need for intermediates and a central authority. However, as can be seen in Fig. 2-14, these principles are not the case for consortium and private blockchains. Thus, it raises a question whether these blockchain configurations should be considered as a blockchain technology or only a database with additional features such as hashing and a semi-shared ledger.

2.3.4 Challenges with Blockchain Technology

The blockchain technology has the potential to disrupt and provide several benefits. However, the underlying principles governing the blockchain development, and in combination with the immaturity, leads to several challenges that need to be overcome to create mass adoption. Firstly, one of the technology's major advantages; its immutability, is also a major technological challenge. It is almost impossible to amend or withdraw transactions and thereby updating blocks that have been chained into a blockchain (*Flori, 2017*).

Moreover, there is a need for common fundamental rules within the network since businesses and organizations have different policies. As blockchain developers try to leverage the technology´s capabilities it leads to an increased variety of different blockchains solutions. Therefore, many blockchains operates in their own ecosystem. The idea behind blockchain is a distributed network which means that different blockchain needs to interact and integrate with each other. The ability to share information across different blockchains is referred to *interoperability* (*Lu, 2018*). Morabito

(2017) argue that, to overcome the latter, organizations within the same industry needs to set common standards when developing their blockchains.

Furthermore, there is also the issue regarding change management when attempting to implement any new technology. The implementation is more about standardization of data and set a common language within the network. Additionally, related to change management, there is a lack of understanding of the technology and its acceptance. (*Morabito, 2017*) The technology is relatively complex and difficult to understand without sufficient knowledge, thereby, the use and widely social acceptance is hard to reach (*Drescher, 2017*).

One of the major contributions with the traditional blockchain technology is to establish trust between two unknown parties to such extent that transactions can be performed with security and on an open and decentralized network. However, if the input of data into the blockchain is not self-generated within the blockchain system, such as with Bitcoin, the aspect of trust itself and the “one source of truth” could be challenged. This due to if any data can be entered and recorded into the blockchain system, e.g. through scanning a QR-code, the reliability could be questioned by other participants. However, the usage of a multi-signature could reduce intentionally false data that is being recorded onto the blockchain. Moreover, having a third party as validator negates the usefulness of the technology since this can be achieved without the blockchain technology. If the trust aspect in the blockchain erodes via the insertion of non-validated data, one might as well use a standard database. The issue and challenge will be securing the integrity of the data in without the need to an intermediary for validation. Consequently, the trustworthiness of a blockchain, where the data is not self-generated, could arguably be just as high as reliable the input data is. (*Andoni et al., 2019; Saberi et al., 2018; Lewis, 2016; Apte & Petrovsky, 2016*)

Additionally, blockchains that are not public, i.e. private and consortium, could also have the aspect of trust eroded as the only validators will be the participants allowed into the blockchain network. Thereby, it is not a truly decentralized system, rather a semi- decentralized hashing database. If participants team up and make sure they control more than 51 percent of the computational power and thereby represent the longest chain, they have the possibility to rewrite all historical transactions (*Andoni et al., 2019; Descher, 2017*).

2.4 Smart Contracts

2.4.1 How Simple Contracts Work

To be able to compare a smart contract to a simple contract one needs to be aware of what constitutes a simple contract and how it works. The visualization in Fig. 2-15 is a simplification of a how a simple contract works between actors within a supply chain. A contract, in this case a simple contract, is a contractual agreement between two parties which stipulates certain obligations between them which is enforceable by law. The contract needs to include four key elements: offer, acceptance, consideration and intent to create legal relations. (*Thomason Reuters, 2019; Arizona.edu, n.d.*)

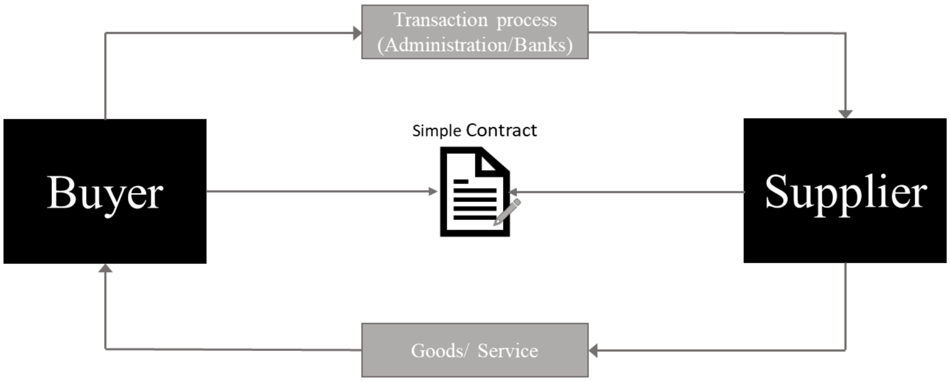


Figure 2-15: Simple Contract. Own model.

In Fig. 2-15, the scenario would be the following; the buyer and supplier negotiate a contract which is signed by each party, the contract will include all the terms that apply within its given scope. For example, a contract stipulating that a certain amount of slag, raw material in construction, will be delivered to the buyer for an agreed upon price. (*Arizona.edu, n.d.*) Then after each party has agreed and signed to the contract, the supplier will send their goods or provide the service to the buyer. If this goods or service upholds to the contractual obligations a transaction process, usually involving internal administration costs as well as an external bank intermediary, will take place from the buyer to the supplier. (*LawTeacher, 2018*)

The cost associated with simple contracts

While the contract stipulates a legally binding promise of goods and services for a fixed price there will often emerge disputes between the signatories. One example would be that the buyer in this case refuses to pay for the goods and services or they are unable to agree on one source of truth. Any dispute surrounding the contract will inevitably lead to costly legal proceedings where litigation cost and other costs will arise. Also leading to potential loses, decreased reputation and mistrust. (*Vatiero, 2018; Shavell, 1980*)

The reality of the contracting process is that it is filled with uncertainty, risk and asymmetric information and fraught with mistrust among actors which lead to higher expenses (*Salazar et al., 1994*). These expenses are not necessarily isolated to the occurrence of a dispute but can manifest themselves in the negotiation process. Mistrust between actors in the construction industry have shown to greatly increase the final production cost. The prevalence of mistrust leads to the addition of higher risk premiums when formulating and negotiating contracts that increase the bottom line. (*Zaghloul & Hartman, 2003*) To mitigate these trust issues and circumvent the transaction costs companies can leverage the blockchain technology, specifically the smart contract technology *(Hofmann et al., 2018).*

2.4.2 How Smart Contracts Work

Smart contracts are a part of the blockchain technology with the first smart contracts created by Nick Szabo in 1994, the blockchain most synonymous with smart contracts is the Ethereum blockchain smart contracts. (*Wall & Malm, 2006*) Smart contracts is a technology that was pioneered on the blockchain and is seen as a blockchain technology derivative. A smart contract is only a contract which is written as code to alleviate the shortcomings of simple contracts and increase the automation of transaction. However, for the most part, smart contracts are exclusively associated with blockchain technology. There are also smart contracts, or automated contracts, that act outside the blockchain that have existed for some time. In the case of blockchain technology, a smart contract is coded and stored into the blockchain and different actors can agree to the contract and engage with it using their public and private keys. Those smart contracts that are written on the blockchain are advantageous as they gain all the previously mentioned benefits that the blockchain technology provides. (*Blockgeeks, n.d.; BlockchainHub, n.d.*)

These smart contracts are built similarly to “if” statements within coding languages such as Python and JavaScript, fundamentally employing the ‘if-this-then-that’ logic (*Morabito, 2017*). Essentially, the trigger to execute the smart contract can be anything and the resulting effect as well. However, the smart contract can only be triggered by information on the blockchain. Hence, the information must first be recorded on the blockchain and that in turn executes the smart contract. In a simple example, a company set’s up the following smart contract: if the RFID (Radio Frequency Identification) tracker on the goods are registered in the port of entry, the RFID tracker will send a verification to the blockchain and in turn the smart contract and the transaction will be executed which sends the funds to the supplier. (*Lanko, Vatin & Kaklauskas, 2018; Law, 2017; Blockchainhub, n.d.*)

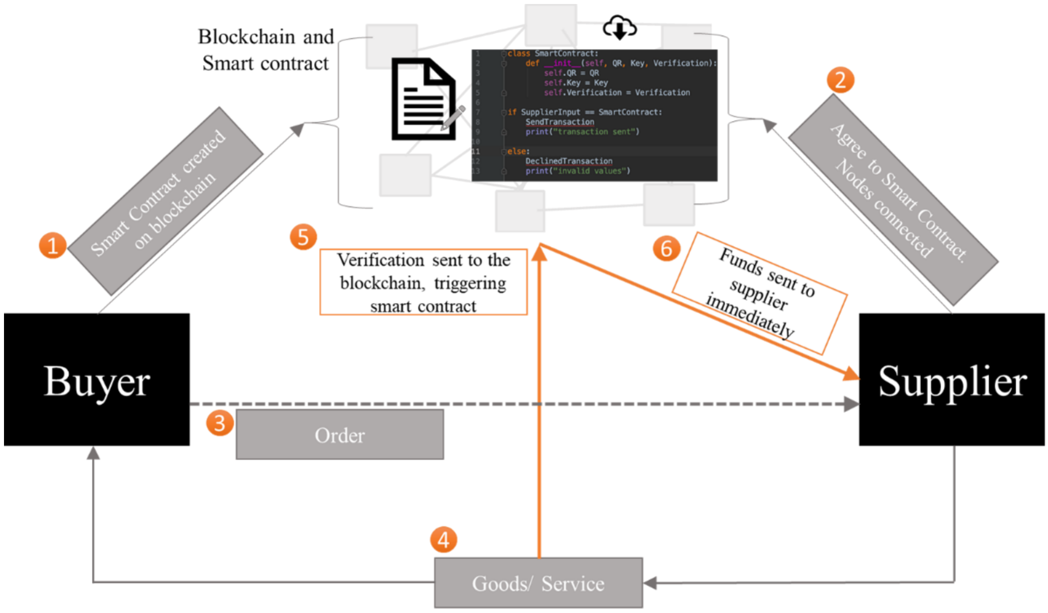


Figure 2-16: Smart contracts. Adopted from Blockchainhub (n.d.)

In Fig. 2-16 an illustration is given of a blockchain smart contract solution in relation to a buyer and supplier relationship. In more technical terms the above illustration shows two nodes (the buyer and the supplier) that are party to a blockchain solution, i.e. an open ledger. There is also the need to specify which blockchain is appropriate. Either private, public or consortium which depends on the use case. On the blockchain, (1) a smart contract has been created and (2) agreed upon by both parties using their private keys, this smart contract includes all the contractual requirements and the “if-this-then-that” logic required to trigger a transaction. This logic can be contractual terms such as pricing and method of verification. (3) The buyer orders goods from the supplier who then (4) sends the goods to the buyer after production. (5) It is important that there is some way to send the needed input data to the blockchain, for instance using an IoT device, in a secure and tamper proof way. This data is feed into the blockchain which triggers the smart contract and (6) executes the transaction. There needs to be a clear agreement that the data in is true and fair, one way of doing this is having a third party validating the data. (*Law, 2017*) Using third party validation is however controversial as previously mentioned by Andoni et al. (2019). There is a need to specify what the resulting action of the code will be when the contractual obligations are upheld, and the logic fulfilled, likewise there needs to be logic governing what happens if these are not fulfilled. (*Casado-Vara et al., 2018; BlockchainHub, n.d.; Hofmann, Strewe & Bosia, 2017*)

All information within the smart contract and the resulting transactions are stored on the blockchain, any actors (nodes) connected to this shared ledger has the ability to see these transactions. This results in greater traceability with the ability to back track transactions among parties as well as improve the information asymmetry between actors. This information symmetry ultimately influencing the trust between actors in a positive way. These automatic transactions will allow for contracts to be set between companies or individuals that may not create a business deal due to trust issues. This decrease in mistrust will lead to the reduction of risk premiums and reduction of the bottom line cost of projects. Furthermore, it relieves the need for other actors in the process such as banks processing transactions that in turn generating costs. (*BlockIDE, 2018; dApp Builder team, 2018*)

The reasoning behind using smart contracts in combination with blockchain is that they become immutable, versatile and can automate processes. The immutability derives from the underlying technology of the blockchain technology so if they are not on the blockchain this aspect will inevitably be compromised. The versatility comes from the ability to change, reuse and adapt the code in the smart contract depending on one's needs. Finally, the automation comes from the way in which the code is written that is the 'if-this-then-that' logic which does not require administration if all the requirements have been fulfilled as this will trigger the transaction ultimately improving efficiency. (*Bartoletti & Pompianu, 2017; Hofmann, Strewe & Bosia, 2017*)

2.4.3 Smart Contracts in Supply Chain Financing

The amount of research on the application of smart contracts within SCF is very limited and tends to be restricted to the financial markets, such as securities in the stock market, and not with respect to physical goods. Tate, Bals and Ellrams (2019) identify that blockchain technology and in turn smart contracts could create great benefits for the fintech industry and in turn the SCF sector.

As described in previous section, SCF is ultimately about optimizing cash flow, costs and creating a win-win-win situation within the supply chain. The areas in which blockchain can enhance the SCF process are the following; validation, authentication, transparency, visibility and speed. With the use of blockchain technology within the SCF the need for intermediaries, such as banks, have the potential of become redundant. (*Ifeanyi, 2018*) One proposed way of working with smart contracts and SCF was presented by Fiser (2018) and depicted in Fig. 2-17. This specific proposal is built on the Ethereum blockchain where a smart contract is created and how this would affect the SCF.

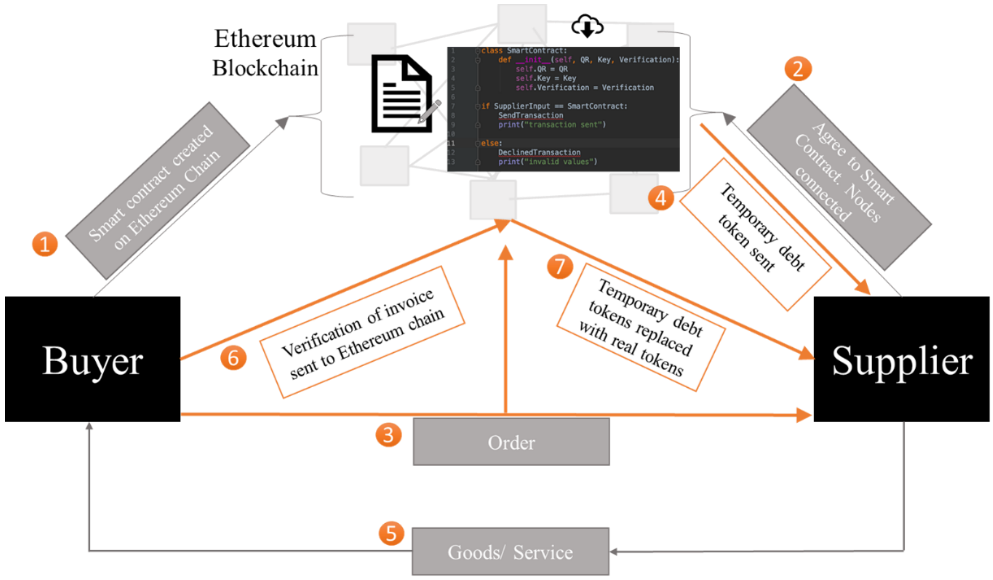


Figure 2-17: Supply chain financing with blockchain smart contracts. Adapted from Fiser (2018).

Essentially, this will work as follows; (1) the buyer will create the smart contract on the Ethereum blockchain after which (2) the supplier will agree to the terms using their private key. The smart contract will include all the terms and conditions that will be required to be fulfilled for a payment to occur. After the supplier has accepted the terms and conditions of the contract the (3) the buyer will send an order request and (4) supplier will receive a temporary token[2], this essentially become a debt bond which the supplier holds. These tokens can be used as currency with other actors on the blockchain as it guaranties the holder to be paid by the buyer, irrespective of who the holder is. This means that the cash flow of the supplier and buyer essentially becomes unchanged and the supplier is able to use the debt tokens to finance the production of the goods. (5) The goods are then sent to the buyer who verifies the delivery and the invoice in their internal administration. (6) This information is sent to the smart contract which in turns (7) execute the transaction and replaces the holder of the "debt" tokens with the real tokens. (*Fiser, 2018*) This is similar to the aforementioned methods in SCF section however with the distinct lack of a financial intermediary.

2.4.4 Challenges for Smart Contracts

Smart contracts have the potential to heavily influence both the construction industry as well as the SCF sector. However, there are several aspects surrounding smart contracts that needs to be resolved. Gronbaek (2016) identifies the following areas as problems that smart contracts will need to contend with; level of transparency and privacy, the law surrounding smart contracts, flexibility concerns, consumer regulation and the link to the physical world. This specific section will be focusing on the legal challenges as many other challenges have already been discussed in previous sections

The precedent for smart contracts in the legal area are very scarce and to the authors knowledge have not been contended in a court of law as the writing of this thesis. Traditionally, the laws that apply to contracts is the private international law, the specific law applied being dependent either on the country where the companies operate, or the law specified in the contract. For international contracts there exist separate regulations, specifically the Rome I regulations are used within the European Union. The Rome I law, Article 3, states that they may bring their contractual case to any legal body they wish, being stipulated in the contract and this would potentially apply in smart contracts. However, this law applies to contractual obligations as stated by law and since smart contracts are only software the Rome I is not applicable. Another issue is if the applicable law has not been defined, then per Rome I Article 4, a choice of law rules and escape clause will enact often resulting in *"…lead to application of the law of the habitual residence of the party required to effect the characteristic"* - Rühl (2019). This article means that the smart contracts law will abide by the countries law where the seller or service provider resides. As Rome I law is not dependent on the specific area where the contract was created the law is suitable but has not been applied. (*Rühl, 2019*)

Smart contracts and blockchain technology have shown great promises in providing advantages to the SCF process. However, before this will become a reality there are several areas of contention before this becomes feasible. Some of these challenges have been identified; create paperless transactions, data privacy and increased participation among actors in the chain. Despite these shortcomings blockchain technology has been identified as a missing link in the SCF process. (*Meijer, 2016*).

The amount of uncertainty in smart contracts and the surrounding legal framework should be

[2] Token is a representation of any asset on the blockchain.

cautioned. Some ways to mitigate the uncertainty have been proposed by the scholars within the law field. These include; combining code and text (a hybrid code), clearly defined variables and code as to minimize uncertainty, come to consensus on what to do when the code cannot be executed, allocate risk in other locations in event of errors in code, and specification of the governing law in event of conflict. (*Levi & Lipton, 2018*) Due to these concerns there are now legal engineers that work on create smart contracts that work on optimizing the code for smart contracts and shape the future legal framework for smart contracts. (*Goldenfein & Leiter, 2018*)

2.5 Blockchain & Smart Contracts in Construction Supply Chains

As mentioned earlier, the blockchain technology has the potential to improve how companies manage supply chains and make them more efficient. It could provide reliability, traceability as well as ensuring correct information and thereby facilitate the flow of both information and material throughout the supply chain in an automated way when it is combined with e.g. IoT devices (*Saberi et al., 2019; Kamble et al., 2018*). It also brings five benefits when it comes to determining following variables about a product; *what* it is, *how* it is (quality), *how* much (quantity), *where* it is and *who* owns it at the moment. Information related to these variables is then recorded onto the blockchain, from the raw material to the end sale. (*Saberi et al., 2019*)

The construction industry involves many different actors and there is need for close co-operation between all of these actors. The construction industry has been slow to adapt to technological advancements but blockchain has several promising applications areas, specifically the application of adding smart contracts to it (*Fox, 2016*). Currently, the application of blockchain, and smart contracts, have not gained traction within the construction industry. The industry and actors lack confidence in its ability to enact change as well as the knowledge about the technology in the industry is low (*Mason & Escott, 2018)*. However, the research is scarce in the area of blockchain in construction but the research that does exist indicates that there is potential. The implementation of smart contracts will allow actors to more easily cooperate and projects can be more easily divided up without manual administration. Furthermore, there is the automatic settling and clearing of trades between actors. (*Turk & Klinc, 2017; Kakavand, Sevres & Chilton, 2016; Hughes, 2017)*

One study that has tackled blockchain technology in the construction industry, specifically the ready-mixed concrete (RMC) industry, is a study by Lanko, Vain and Kaklauskas (2018). In their study they investigated the use of RFID technology together with blockchain technology, including the potentials of smart contracts, to improve the transportation of ready-mix concrete. These improvements were increased efficiency in the supply chain, improved trust among actors and the potential for increased automation of the transportation of ready-mix concrete. Lanko, Vain and Kaklauskas (2018) also go on to say that in the case of a global blockchain technology will increased transparency and increase the trust between actors. This is contingent on a global blockchain which they themselves call “idealistic” in today's concrete industry. Furthermore, they say that a globalized decentralized system, i.e. global blockchain, will significantly increase; efficiency in the supply chain, remove unnecessary links and reduce the negative impact of a humans influence in the supply chain. The conclude by stating that and RFID and blockchain technology, together with smart contracts, will increase automation, reduce losses from human influence, reduced misinformation and eliminate the trust issues present in the supply chain. This effect being seen both upstream and downstream in the supply chain. (*Lanko, Vatin & Kaklauskas, 2018*)

Another study that investigated smart contracts within the construction industry in the British market was Mason and Escott´s (2018) study. They identified that for there to be any viability in mass adoption of smart contracts and blockchain technology there needs to be the presence of knowledge about the technology as well as consensus on its usefulness. Their study showed that there is both very low levels of knowledge surrounding the technology within construction firms. Furthermore, there is a low confidence among the firms that they interviewed that smart contracts can be implemented in the construction industry. Mason and Escott (2018) concluded that there is a need for a maturity in the technology to become useful. Additionally, Mason´s (2017) study identified nine parameters that need to be overcome for the application of smart contracts within construction to become viable to. The most important parameters were the following; clear definition, identify the dissatisfactory areas within the construction industry and develop a common strategy for the implementation of the technology.

3. Methodology

This chapter will motivate and discuss the chosen methodology in this thesis. It will start by presenting the research strategy and research design. After which, the case company will be presented. Thereafter, the data collection is presented and the analysis method. Lastly, the research quality and criticism are presented.

3.1 Research Strategy

To be able to investigate the potentials of smart contracts and blockchain technology within the construction supply chain (CSC) a case study was conducted in collaboration with Thomas Betong AB, the company's suppliers and buyers. Interviews were also conducted with experts from following fields; blockchain, smart contract, law and supply chain financing (SCF). The method that was chosen was a partially mixed method, specifically a qualitative method with an embedded quantitative method. This method provides flexibility and due to the lack of real-world applications and scarcity of academic articles the method becomes appropriate for this thesis.

This is echoed by Bryman and Bell (2015) where they argue that within fields that are unexplored and where there is a lack of knowledge a qualitative method is suitable. Although this thesis uses a mixed method, the primary method is a qualitative method hence this statement is still applicable. Furthermore, Bryman and Bell (2015) states the importance of discussing and motivating the decision for each of the methods of the mixed methods design, highlighting the reasoning for each method and the role it plays. In this case study the quantitative method was primarily used, in combination with certain qualitative responses, to answer **RQ1** *What is the current state of knowledge surrounding blockchain technology and smart contracts within the construction supply chain and what is the sentiment and perceived readiness for implementing such a solution?* , while the qualitative method was primarily used, in combination with the quantitative results, to answer **RQ2** *Can smart contracts, in combination with blockchain technology, be used to increase efficiency in supply chain management and supply chain financing within the construction supply chain? If so, how?* and **RQ3** *How would a blockchain smart contracts solution be designed to be suitable for a construction supply chain?*

As previously mentioned, the chosen mixed method design is embedded case study design where there is greater emphasis on the qualitative method than that of the quantitative method. The functionality of the quantitative method is to bridge some of the gaps that are present in the qualitative methods. The quantitative results will be used primarily to gain an understanding of; the level of knowledge of the subject and the potential improvement areas in construction industry. The quantitative results were used to answer RQ1 and RQ2 to allow for a broader and more generalizable result from a wider range of industry professionals. The qualitative part, on the other hand, will allow for a deeper understanding and analysis of the issues and potential improvements by investigating the problem on a more fundamental and practical level. The qualitative methods provide a richer and more detailed picture of people feelings and thoughts on the chosen topic. The mixed methods approach shares many of the same issues with the qualitative method. These issues involve the inability to generalize the results but by adding the quantitative method there is an increased ability of generalization in the results. Note, the embedded quantitative method does not automatically imply greater generalization, it only provides the potential. (*Bryman & Bell, 2015*)

There are three different types of research approaches; inductive, deductive and abductive. Inductive is when observations and tests are conducted to identify any patterns in the data and eventually arrive at a theory. Deductive approach is when one starts at a theory, develops a hypothesis and then tests these hypotheses on observations or test to finally reach a confirmation or rejection of the stated hypothesis. Finally, the abductive approach reasoning sets to address the weaknesses of the previous two mentioned approaches. The abductive approach tries to explain a certain effect by finding the best explanation, using either quantitative or qualitative methods. Considering the exploratory nature of the subject that is being studied and the number of unknowns on the outset of this thesis an abductive research method is suitable and was used. The abductive research method allows the authors to apply the deductive nature of investigating previous literature and theories to gain an understanding of the subject before commencing on the collection of empirical materials. Furthermore, the approach becomes relevant due to the meager amount of research within the chosen field. (*Patel & Davidsson, 2011*)

Within epistemological there are two elements that need to be considered; positivism and hermeneutics. Each being the counter opposite of each other. Positivism has its roots in the natural sciences where there is a truth that can be tested. Positivism aims to take some fundamental truth, such as gravity, and test this principle through the scientific method and observations ultimately reaching a rejection or acceptance of a hypothesis. Hermeneutic, being positivism opposite counter theory, is the scientific approach of attempting to understand a subject by studying, observing and interpreting a certain phenomenon allowing for subjective views on a subject. This study will be more directed towards a hermeneutic approach. (*Patel & Davidsson, 2011*)

3.2 Research Design

As mentioned previously, the chosen method for this thesis is a case study research design. As Yin (2018) states, this method is appropriate when exploring a research questions that focuses on the *how* or *why* aspect of a field, which this study does. Furthermore, a case study design is especially relevant when one wants to investigate the in-depth complexities of a subject while retaining a real-world perspective. Since the purpose is to attain insights into real-world application of smart contracts and blockchain technology within the construction industry one can clearly see the relevance of the chosen research design. (*Yin, 2018*)

Yin (2018) also mentions that case studies are relevant when there is no or little control over events and when it involves contemporary events. This study also wants to investigate several aspects that are unknown due to how recent the technologies and the scarce amount of research available adding to the unknowns and lack of controllability of the research. Furthermore, the biggest issue and challenges when conducting a case study is that there is very little to no ability to generalize the results.

The most important aspects when conducting a case study are; research question, the proposition, the case, the linkage between data and the proposition and the criteria for interpreting the findings (*Yin, 2018*). The research question, as previously stated, is relevant for a case study as it aims to investigate the *how* aspect of smart contract and blockchain technology. The proposition stated in the introduction shows that there is a reason for investigating these technologies within the construction industry as it has potentials to be disruptive and provide potential improvements. The authors have also identified a case company, Thomas Betong AB, to investigate the aspect of smart contracts and blockchain within the construction industry. The linkage between the proposition and the data will be achieved by interviewing relevant actors in the supply chain, using Thomas Betong AB as a starting point and then speaking to the company's suppliers and buyers. Also interviewing the aforementioned experts. These relevant actors will be interviewed to gain an understanding for how the supply chain works, where the weaknesses are as well as the potential of smart contracts and blockchain technology. Furthermore, these actors will be crucial when evaluating a potential implementation and use cases for the technology. Finally, several big construction companies will be sent a questionnaire to gage the knowledge and shortcomings in the industry. These results will then be analyzed and interpreted in the following chapters of this thesis, being careful as to not generalize or over extrapolate the results. Yin (2018) also states that it is important in a case study to present the theory in a clear way while also representing conflicting theories. This has been done in chapter 2. Theoretical Framework.

The case study is classified as single case embedded approach; however, it can also be argued that it is a multiple case study since several actors in the supply chain is investigated. This thesis is therefore hard to classify as one type of case study and instead lays on a spectrum. Something akin to a single case multi embedded approach. (*Yin, 2018*)

3.3 The Case Company: Thomas Betong AB

The chosen case company for this case study is a concrete production company called Thomas Betong AB. The company is one of Sweden's biggest concrete specialist and their customers include some of the biggest actors on the Swedish market; Skanska, Peab, NCC, Züblin and JM. Thomas Betong AB has existed since 1955 and is the Swedish subsidiary to the parent company Thomas Concrete Group, with locations in Germany, Poland and the southern United States. The company Thomas Betong AB has in total 39 production facilities, where 36 of those produce ready mix concrete and the other three produce precast concrete. (*Thomas Betong, 2019a*) Ready mix concrete is in its simplest form a combination of; water, cement and aggregate (rocks, sand or gravel) which when it dries it becomes hard. The precast concrete on the other hand is when concrete is formed into a mold, for example a ready wall, which is delivered completed to the construction area. This thesis will only be investigating the supply chain relating to ready-mixed concrete (RMC) and not the precast concrete. (*Thomas Betong, 2019b*)

The reason for choosing Thomas Betong AB was two-fold. The primary reason is that concrete is a very integral part of the construction industry, and it can hence be argued that investigating the concrete industry will allow the authors to answer and partially extrapolate the results on the construction industry more broadly. This is further supported by Sears et. al (2015) who defined the concrete industry as a sub-classification within the construction industry. Furthermore, Gagg (2014) highlights the prevalence of concrete in construction industry stating that concrete is the second most consumed material on Earth and is used twice as much as all other building materials combined. However, this study does not argue that all supply chains in construction are identical to that of concrete but instead that they plausible share many similar issues.

The second reason for choosing the case company was that one of the authors of this thesis works part time for the company. This had the possibility to allow for an increased likelihood of engagement and responses from actors and increasing the amount of empirical material.

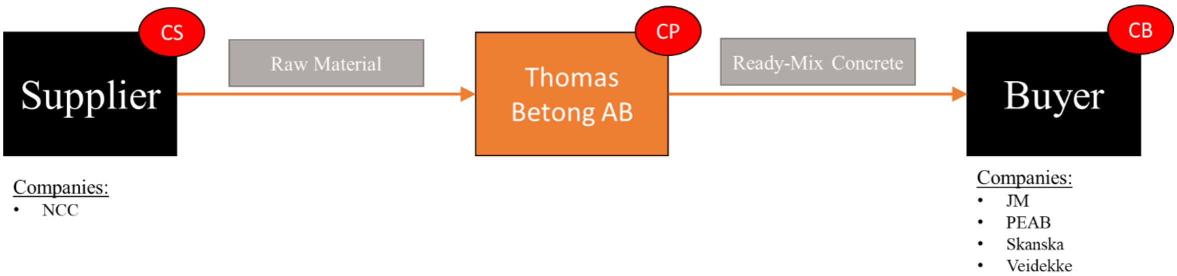


Figure 3-1: Companies involved in the case study. Own model

The case study, while focused on Thomas Betong AB, also includes many of the biggest construction companies in Sweden. These actors and their relation to the case company can be found in Fig. 3-1. The coding CS, CP and CB refers to the following; CS- Concrete raw material supplier, CP- Concrete producer, CB- Concrete buyer. This will be explained in more detail later in this chapter. The supplier the authors choose to look at was NCC, specifically their raw material department, as they are the biggest raw material supplier to Thomas Betong AB and massive in the Swedish construction industry. The chosen buyers where; JM, PEAB, Skanska and Veidekke. These companies make up the majority of the Swedish construction industry, about 63 percent of turnover according to the latest statistics from Sveriges Byggindustrier (2016). When including NCC it covers approximately 69 percent of turnover in the Swedish construction industry. While our case company is specifically focus on the concrete industry the surrounding companies interviewed make up a significant portion of the construction industry and hence represent a significant influence. The ability to interview all these key companies in the Swedish construction industry will allow the authors to gain a comprehensive construction industry picture.

3.4 Data Collection

The data collection process is crucial for any research project and the used methods for this study was both primary and secondary data collection. These two methods will be further elaborated and described in the sections below in terms of processes and motivation of the different selections.

3.4.1 Secondary Data Collection

Before determining the exact focus and scope of the thesis, a broad literature review about blockchain and smart contracts was made to find potential research gaps and interesting topics that needed further research. After which a purpose and research question was formulated followed by a systematic literature review.

Bryman and Bell (2015) describe systematic literature review as a method that allows for a thorough and comprehensive review of the literature since it is performed in an organized and predetermined way. There are numerous ways of conducting a systematic literature review, in this thesis the following approach was chosen; a systematic investigation and thorough examination of existing literature published on established databases. The relevant literature was then gathered into a separate database where the title, weblink and a shorter summary of the article was stored as to achieve a birds-eye-view of the collected material. The experts that were interviewed for this thesis were also asked to provide interesting articles or other sources since the available material was sparse. An iterative approach was also applied when conducting the literature review as new insights from experts and industry leaders provided additional understanding for the subject forcing us to jump between the literature review and the empirical material.

Due to the novelty of most of the topics included in the theoretical framework, several different databases were used to ensure that enough relevant articles were found. The utilized databases were chosen based on their quality of content, reputation and field of expertise. The following search engines, and their respective databases were used; Google Scholar and University of Gothenburg search engine on the university library website. In addition to this, a few books and websites were used as a complement for those areas and topics the academic articles did not cover. However, the aim was to prioritize academic articles and especially peer-reviewed articles.

Systematic Literature Review

The systematic literature review of each topic; blockchain, smart contracts, SCF and the construction SCM was performed in a similar fashion with slight variations in certain areas. The keywords that were used when searching for the specific topics can be found in Appendix A. Articles were initially assessed on their heading and abstract after which the authors examined the articles using the inclusion and exclusion criteria set up prior to the investigation. These criteria's will be presented under each sub category below. One general exclusion criterion was that sources that were not written in Swedish or English were excluded due to the language barriers of the authors.

Supply Chain Management

The systematic literature review of Supply Chain Management (SCM) was conducted by searching for general descriptions of traditional supply chains followed by how the emerging digital supply chains (DSC), specifically blockchain technology, potentially will transform activities. Lastly, on a deeper level, how construction supply chains (CSC) tend to be set up and its main characteristics.

The main inclusion criteria were to include articles that were peer-reviewed or books by established publishers. However, one exception was made for a consulting reports published by one of the most respected consultant firms in the world, the reason being the relevance of the report. Hence, one can argue that the quality of the information is high. The exclusion criteria were any articles that did not uphold the inclusion criteria.

Supply Chain Financing

The systematic literature review of SCF was performed by first identifying a general definition of SCF and then investigating the different financial instruments that can be used. After which these instruments were evaluated on their advantages and disadvantages. To gain an overarching connection to the area of blockchain and smart contracts an investigation was conducted to see how these technologies can be used to influence SCF.

The goal was to use peer-reviewed articles, however, due to the lack of articles investigating every instrument forced the authors to find other sources of information. The new source of information was a book released during the writing of this thesis in 2019 that became the main source of information for this subchapter. Additionally, other articles were used as compliments to identify advantages and disadvantages of the different instruments. A consulting report was also used similar to the SCM section. The inclusion and exclusion criteria were similar to the aforementioned in SCM.

Blockchain & Smart Contracts

The first inclusion criteria for articles about blockchain technology were the following topics; general information about the technology and its architecture and how it works, different configurations and challenges. The topics for smart contracts were; general description of the technology and its characteristics, smart contracts in the construction industry and SCF as well as the legal concerns. As previously mentioned, the aim was to only use peer-reviewed articles to the greatest extent possible. This proved to be challenging when researching these topics. Additionally, this study has focused mainly on articles that are published from year 2014 an on. The reasoning behind this was that after this date Blockchain 2.0 was introduced which created a platform that allowed for programmable transaction, allowing it to be more tailored to other areas. Consequently, the immature of the technologies and the recency of articles published meant that most areas have not been discussed or tackled in the academic literature yet. To circumvent this issue the authors used a wide range of sources, not limited to peer-reviewed articles. These sources were more critically reviewed, and assurances were made by investigating and making sure several different sources agreed on each of the statements.

Due to the scarce existing literature, there were very few exclusion criteria for articles about blockchain technology and smart contracts. Even if an article mainly focused on technical aspects and specific programming aspects of the technologies, some parts of the article where still considered to be useful in order to understand the underlying concepts and usefulness behind the technologies. However, the aim was to focus on information relevant for the research question and exclude information that focus on other industries.

3.4.2 Primary Data Collection

This case study used primarily interviews as the source for primary data. As a complement to the latter, an observation was conducted to understand the integral flows within the chosen field. Interviews are commonly used sources of a case study as it allows one to gain greater insight into the related topics and facilitates the ability to answer the *how* and *why* of the research questions. Moreover, case study interviews tend to be less rigid and semi-structured. The interviews are open conversations where the interviewer works as a guide leading the interviewed into thinking about certain relevant topics. The authors tried to keep the interviews relatively short as to keep the conversation focused on the topic at hand, keeping the interviews <1 hour. (*Yin, 2018*) For this reason a semi-structured interview approach was used.

Another type of case study interview is a structured questionnaire and is the embedded part of the used mixed method and produces the quantitative data for this thesis (*Yin, 2018*). The questionnaire constitutes the primary data to answer the first research question; *what* the current state of knowledge is within the field of blockchain and smart contracts. When identifying the latter, and hence *what*, a structured questionnaire is an appropriate method for answering this (*Yin, 2018*).

Semi-structured Interviews

The primary data for the qualitative part consists of semi-structured interviews with blockchain smart contract experts, a SCF expert and a law expert with focus on automated contracts. In addition, interviews were conducted with companies, and different departments, within the construction industry. Quantitative interview approach in research tends to be very structured leading to one specific answer that can usually be quantified, leading to a higher validity and reliability. On the other end of the spectrum, qualitative studies tend to be more unstructured since the aim is to gain a deeper level of understanding for certain phenomenon's and to be able to understand interviewees own perspective and thoughts.

An unstructured interview guide may only contain one single question which the respondent then freely can respond, followed by follow-up questions asked by the interviewers when it seems fitting. A hybrid between these mentioned approaches is a so-called semi-structured approach. An advantage with semi-structured interviews, in comparison to unstructured and structured, is that the approach allows for a greater flexibility when it comes to which order questions are asked and its possibilities to ask to follow up questions for clarification and further specifications when needed. Interview guides were created in advance insuring that the authors covered the relevant topics. Furthermore, questions that are not a part of the interview guide may still be asked depending on how the interview progresses. (*Bryman & Bell, 2015*) This interview approach was considered as the most appropriate to answer the qualitative research questions due to the exploratory and abductive approach of the study. In addition, it is beneficial to let new information and insights come to light during the interviews since blockchain and smart contracts are relatively unexplored subjects. However, some structure during the interview was required to be able to collect relevant data and perform a thematic analysis. (*Bryman & Bell, 2015*)

Both authors of this case study were present during all interviews. Bryman and Bell (2015) discuss the advantage of having more than one interviewer present since it creates two different roles during the interview. One is the "passive" interviewer, this person takes extensive notes assess the overall development of the interview and make sure that all topics were covered. The "passive" interviewer, however, can intervene at any point where they feel that a comment needs to be developed further or a question needs to take another direction. The "active" interview asks the questions that are in the interview guide and guides the interviewed through the process trying to extract as much information as possible. Moreover, Bryman and Bell (2015) further explain how the atmosphere could change by using multiple interviewer. It opens for discussions between several people rather than an exchange between two people. One author took the "active" role and the other the "passive" role as it was evaluated to be the most advantageous approach given the novelty of the topics in the interview guides.

The interviews were conducted either via face-to-face, Skype or email; depending on the location of the person being interviewed and the available time constraints. The intention and the ambition were at the outset to conduct every interview face-to-face. However, barriers in terms of too long distances led to the usage of Skype interviews. Those that were unable to speak through Skype were requested to share their knowledge via email. It could be considered somewhat disadvantageous to conduct interviews via Skype since one is unable to observe any nonverbal cues and the conversation tends be tenuous due to poor connection and inability to speak simultaneously. However, the authors do not believe this will have a substantial effect on the results as the questions, for the most part, do not analyze the interviewees feelings surrounding a specific subject.

Interview Guide

In total, seven different interview guides were created; one for each specific department; Sales, Finance, IT and Procurement, one for blockchain smart contract experts, one for a law/ automated contracts expert and one for the SCF expert. All these can be found in Appendix B. Each interview guide was based on a literature review about the construction industry, blockchain technology, smart contracts and SCF. The majority of the blockchain and smart contract experts were conducted first which allowed the authors to gain new insights and knowledge within this unexplored field. This led to a re-construction of the interview guides for each department where new topics were added which was not discussed in the literature. In addition, a few follow up questions were asked via email to actors in the construction industry on these new discovered areas. This parallel approach when constructing the interview guides is what Bryman and Bell (2015) refers to as an iterative approach, meaning that the processes proceeded in tandem, repeatedly referring to each other. The reason for choosing an iterative approach when constructing the interview guides were due to the novelty of the technologies and the scarce of existing literature. Moreover, it increased the probability that the majority of the relevant topics were covered, even in the cases where the academic literature had not yet published articles covering the aspects.

For all interview guides, questions were formulated as neutral as possible to avoid influencing respondent to answer in a certain way. Moreover, the interview guides for the different departments were divided into two parts; one focusing on operations and processes related to the department and the other part focusing on blockchain technology and smart contracts. Before the second part, the authors presented a short PowerPoint presentation (Appendix C) about blockchain and smart contracts to give the respondent an overall understanding of how the technology works. This allowed the respondents to discuss the potential pros and cons of the technology. Consequently, this may also have affected the respondents answers with respect to part two. The argument against doing this is that the respondents are affected by the presentation and skew the results. However, the authors decided that due to the low level of knowledge assumed from the outset of the thesis a presentation was suitable to give the respondents the ability to evaluate the technology and form a discussion around the technological implications in the industry.

Structured Questionnaire

The questionnaire (Appendix E) consists of 25 questions and statements in total and is based on the same literature review and inputs from experts as the interview guides. It was constructed in Google Forms and thereafter sent out via email (Appendix D) with a link attached. All questions and statements were carefully created to be as neutral as possible and not giving the respondent any hint of desired answer. The main purpose of the questionnaire is to investigate the current state knowledge within blockchain and to identify improvement areas within the CSC. Bryman and Bell (2015) discusses the importance of clear information for the respondent, therefore, each statement has a shorter description to clarify what the question and/or statement is about. These explanations were especially important for questions about blockchain and smart contracts as the level of knowledge, according to the literature, is low. Since the respondents are unlikely to contact the authors for clarification the need to reduce confusion and misunderstanding is paramount as to be able to collect data that fairly reflects the real-world.

A Likert scale has been used with an even range to avoid neutral answers. In addition, to avoid receiving answers where the respondent might not have sufficient knowledge surrounding the topic, an “Insufficient knowledge” option was available for the majority of the questions and statements. This option was available due to the wide range of competence, profession and departments within the chosen sample. If the individual did not possess the required knowledge to be able to answer the question, then they should not skew the results by answering without the full extent of the knowledge.

Selection of Respondents - Interviews

Bryman and Bell (2015) discuss how big the sample size should be and argue that when respondents answer, and thoughts reappear several times one has reached saturation. This is something the authors of this thesis has aimed to achieve and stopped conducting more interviews with actors from the construction industry and experts when saturation was considered to be identified by the authors.

Construction Industry

As the purpose of the study was to examine the potentials of blockchain and smart contracts within the CSC, it was important to select respondents from different tiers of a supply chain. A wider range of respondents would allow for a more comprehensive understanding of the processes and form different perspectives. For instance, only using the sales departments perspective would not be enough to be able to draw conclusions about an entire supply chain. Additionally, respondents have been chosen based on their knowledge and competence about processes related to contracts and supply chain activities such as; procurement of raw material, sales of goods, IT and financial activities. This was simply done by interviewing each department responsible for each step.

Complementary to using Thomas Betong AB as the primary case company, the study also investigated the company's customers and suppliers. These are located one tier up or one tier down from Thomas Betong AB in the supply chain. The relations to Thomas Betong AB and the companies that were interviewed are illustrated in Fig. 3-2.

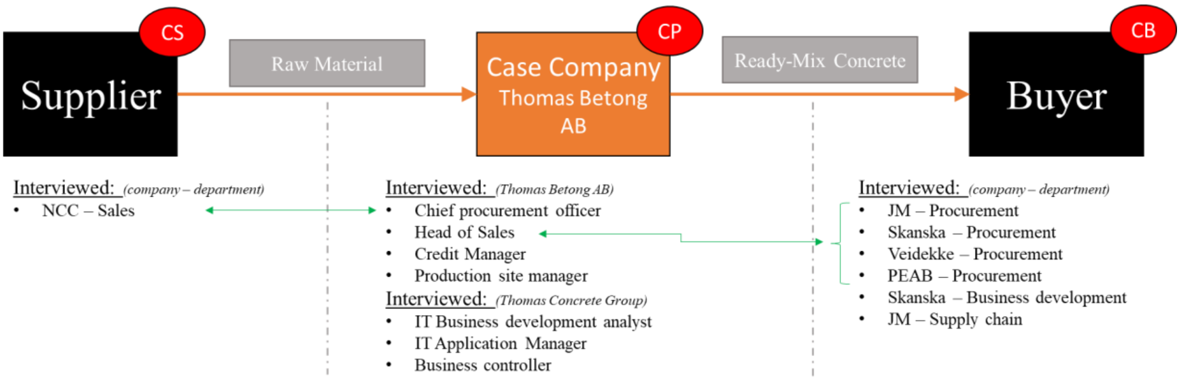


Figure 3-2: Scope of the case study. Own model.

For the initial step in the supply chain the authors interviewed NCC[3], specifically their raw material department, one of the biggest raw material suppliers on the market. There is no other actor before NCC in the supply chain as the company excavates the rocks from the ground and delivery it directly to Thomas Betong AB. To get their perspective the authors choose to interview the sales department, the department working the closest to the case company in many regards.

The next step in the supply chain is Thomas Betong AB and its parent company Thomas Concrete Group. Within Thomas Betong AB the authors interviewed the Finance department to gain an insight into the financial workings of the company. Furthermore, the Head of Sales and Chief Procurement Officer were interviewed. By interviewing these two actors in the supply chain one can contrast that with what their primary contacts in the supply chain think and contrast this to gain insight if there is a common goal. The connection being that the Sales department at Thomas Betong AB has contact with the Procurement department of the buyers and the Procurement department of Thomas Betong AB has contact with Sales at NCC. These relationships are illustrated by the green arrows in Fig 3-2.

[3] NCC is the abbreviation for NCC Industry AB

Additionally, there was an observation, led by the production site manager, at one of Thomas Betong AB's biggest production facilities. This allowed for insights into how concrete is produced and the supply chain in each production facility as well as how quality is controlled and reported. It also allowed the authors to investigate the level of digitization of the processes. This study also conducted interviews within the parent company, Thomas Concrete Group, since the IT department is controlled and operates under the parent company. The IT perspective was considered to be crucial to gain insight into the technical challenges when implementing a new IT solution, like blockchain and smart contracts, as well as understanding the current digital maturity in the supply chain. Additionally, a Business controller at the parent company level was interviewed to gather information about transaction costs and financial challenges facing the entire company.

As mentioned previously, interviews were also conducted with employees from following customers; JM[4], PEAB[5], Skanska[6] and Veidekke[7]. These companies constitute a significant part of the construction industry and their perspective is vital when investigating our chosen research questions. Additionally, the authors wanted to identify how these companies supply chains works and what aspects were the most important. The reason for interviewing the Supply chain manager at JM and the Business developer at Skanska was to gain insights into current developing projects and to investigate if these developments aligned with blockchain and smart contract technology.

A list of the different actors that were interviewed and their roles are presented in Table 3-1 below. Also presented in the table is the company they work for, the duration of the interview, how the interview was conducted and the language in which it was conducted.

Table 3-1: List of Interviewed, Construction Industry.

CONSTRUCTION INDUSTRY					
Title	**Referred to as**	**Company / Department**	**Date / Duration**	**Interview**	**Language**
Head of Sales	CS-1	NCC	2019-03-13 46 min	Skype	Swedish
Business Controller	CP-1	Thomas Betong AB	2019-03-04 41 min	Face-to-face	Swedish
Chief Procurement Officer	CP-2	Thomas Betong AB	2019-03-04 42 min	Face-to-face	Swedish
Credit Manager	CP-3	Thomas Betong AB	2019-03-04 39 min	Face-to-face	Swedish
Head of Sales	CP-4	Thomas Betong AB	2019-03-11 51 min	Face-to-face	Swedish
Business Analyst Developer	CP-5	Thomas Concrete Group	2019-03-12 34 min	Face-to-face	Swedish
Production Site Manager	CP-6	Thomas Betong AB	2019-03-12 37 min	Face-to-face*	Swedish
IT Application Manager	CP-7	Thomas Concrete Group	2019-03-21 31 min	Face-to-face	Swedish
Chief Procurement Officer	CB-1	PEAB	2019-03-01 42 min	Face-to-face	Swedish
Business Developer	CB-2	Skanska	2019-03-08 54 min	Skype	Swedish
Supply Chain Manager	CB-3	JM	2019-03-13 53min	Skype	Swedish
Regional Purchasing Manager	CB-4	Skanska	2019-04-02 61 min	Face-to-face	Swedish
Project Manager/Purchaser	CB-5	Veidekke	2019-03-18 44 min	Skype	Swedish

** Observation, not recorded*

[4] JM is the abbreviation for JM AB
[5] PEAB is the abbreviation for PEAB AB
[6] Skanska is the abbreviation for Skanska Fastigheter AB and Skanska Fastigheter Hus Region Göteborg
[7] Veidekke is the abbreviation for Veidekke Entreprenad AB

Furthermore, each actor has been given a reference code under "Referred to as", this will be the notation used in the empirical findings later in the thesis. The coding is done methodically to allow the reader to easily understand what stakeholders are being referred to in the empirical analysis. The "C" in the beginning of the coding stands for an actor in the CSC. The following "S", "P" or "B" depends on the relation to the case company. "S" are raw material suppliers, "P" is the case company or concrete producer and "B" is the buyer of the concrete i.e. the construction companies.

Experts

Firstly, an expert is a person who is very knowledgeable within a specific field or skillful in a particular area. To gain a nuanced portrait of the topic, both academic and business experts with knowledge about blockchain and smart contracts were selected. These different experts were expected to have different viewpoints on the technology due to different incentives and experience. Certain experts were also interviewed for their specific knowledge within blockchain and smart contract. One example is the blockchain consultant and entrepreneur EBSB-4, see Table 3-2, that was interviewed specifically to answer RQ3 due to this individual's experience within blockchain architecture. While the interviews with blockchain experts were conducted the authors noticed a distinct lack of legal knowledge and hence ELS-1 was interviewed. This individual is a retired lawyer who currently works with automated contracts. Moreover, a SCF expert was interviewed, ESCFA-1 in Table 3-2, to gain insights into the potentials of blockchain and smart contracts within SCF. The authors coded the "Referred to as" category for the experts using a similar logic to that of the construction industry. The first letter "E" refers to the person being an expert. The following letters being either; "BS"- expert within blockchain and smart contracts, "LS"- being an expert within law and smart contracts and finally "SCF" for supply chain financing expert. The final letter in the coding will either be; "A" for academic or "B" for business, referring to the domain in which the individual works.

Table 3-2: List of Interviewed, Experts.

EXPERTS						
Field	**Referred to as**	**Title / Experience**	**Company**	**Date / Duration**	**Interview**	**Language**
Blockchain & Smart Contracts, Academic	EBSA-1	*Blockchain Expert*	RISE Victoria	2019-02-19	E-Mail	English
Blockchain & Smart Contracts, Academic	EBSA-2	*PhD. Associate Senior Lecturer* and Director of University of Gothenburg Blockchain Lab, Guest	University of Gothenburg	2019-02-25 42 min	Skype	English
Blockchain & Smart Contracts, Business	EBSB-1	*Cognitive solution team*	IBM France	2019-02-25	E-Mail	English
Blockchain & Smart Contracts, Business	EBSB-2	*Logistics & technology lead*	BlockLab	2019-02-26 45 min	Skype	English
Blockchain & Smart Contracts, Business	EBSB-3	*Director,* Head of Blockchain	PwC Sverige	2019-03-06 46 min	Skype	Swedish
Blockchain & Smart Contracts, Business	EBSB-4	*Blockchain Consultant & Entreprenur*, Co-funder Swedish Blockchain Association	Alten Group & Swedish Blockchain Association	2019-03-06 34 min	Face-to-face	English
Lawyer & Smart Contracts, Business	ELS-1	*Legal Technologist & Lawyer*, Founder & CEO	Precisely - Automating Contracts	2019-03-21 97 min	Face-to-face	Swedish
Supply Chain Financing, Academic	ESCFA-1	*PhD. Senior Lecturer* at the department of Business Administation, Director Business IT Lab	University of Gothenburg	2019-02-18	E-Mail	English

Selection of Respondents - Questionnaire

The main purpose of the questionnaire was to identify, and to some extent increase the generalizability, the current state of knowledge surrounding the technologies and identify shortcomings within the construction industry. Therefore, the aim was to have a sample consisting of multitude of different companies, within our case study scope. The questionnaire was sent out to 20 selected employees at Thomas Betong AB and Thomas Concrete Group based on their position. However, when selecting respondents from the construction industry the selection was highly randomized as authors had limited insight into the chosen companies' organization. Based on costumer details from Thomas Betong AB´s customer database, an email (Appendix D) was sent out to 184 employees with titles that are associated with; procurement, logistics, planning/ calculation, project management and site manager. The authors were able to deduce from prior knowledge and literature review that individuals associated with these titles are an integral part of the CSC and relevant actors to answer the questionnaire. Based on these criteria the customer database was scraped, filtered for these criteria and sent the aforementioned email. The resulting email list consisted of actors from the following companies; Skanska, NCC, JM, Züblin[8], Tuve Bygg[9] and Veidekke. There is some overlap between the companies used in the questionnaire and the interviews, however, there was no overlap in specific individuals. The reasoning behind sending the questionnaire to 184 individuals is attributed to an issue discussed by Bryman and Bell (2015). They point out that when sending out a questionnaire one may receive a low percentage of replies. In total, 26 respondents answered the questionnaire. The sample size is considered acceptable for a cautious and low level of generalization, even if a low percentage of the respondents answered.

3.5 Data Analysis

To conduct the data analysis for this research the authors used a thematic analysis, one of the most common tools of analysis for qualitative studies (*Bryman & Bell, 2015*). To accomplish this all the interviews were first transcribed and coded into different themes by both the authors. The coding was divided into the main areas that were identified in the literature and reflected in the interview guides. After the authors had coded the interviews separately the results were compared and discussed after which a consensus was reached producing a single coded document consistent of the empirical findings. This method ensured that bias was reduced, and a more accurate representation of the findings was presented. These empirical findings can be found in chapter 4. The empirical findings were also divided into three main areas, each of the areas aiming to be the primary source of information for answering each research question. The answers to the questionnaire was embedded in the empirical findings under the relevant sections.

First a framework of analysis was created to help answer RQ3. The analysis that was conducted consisted of the actors evaluating the empirical findings and connecting them to the theoretical framework. Furthermore, the responses from the industry professionals was compared and contrasted, adding a cross question analysis in the questionnaire responses. Lastly, the industry interviews were connected to the experts within blockchain and smart contracts to find similarities and potential application areas. This was then also evaluated using the framework for analysis which was created beforehand. The data analysis is explained in more detail under subchapter 5.1 Framework for Analysis.

3.6 Research Quality

The quality of a research is dependent on two important factors; *validity* and *reliability*. Especially for a case study method since its validity and reliability is contentious in the field of research. To determine

[8] Züblin is the abbreviation for Züblin Scandinavia AB
[9] Tuve Bygg is the abbreviation for Tuve Bygg AB

the quality of obtained data, there are usually four design tests to assess the previously mentioned factors; *construct validity*, *internal* and *external validity,* and *reliability.* (*Riege, 2003; Bryman & Bell, 2015)* How these tests and techniques are used for establishing validity and reliability, specifically for a case study, will be elaborated and discussed further.

3.6.1 Validity

Validity refers to the quality of the conclusion, more precisely to the degree of which a research instrument accurately measures what it intends to measure (*Bryman & Bell, 2015*). This section will describe how this study has tried to achieve validity in our conclusion by going through following types of validity; construct, internal and external.

Construct Validity
The case study method is about understanding a real-life phenomenon on a holistic perspective but also on a deeper level. This is done via explanations and interpretations of the data collected from practitioners' experiences. Consequently, a case study is often perceived as a more subjective method than other qualitative research methodologies. The reason for this is that researchers tend to have a close and direct personal contact with the organizations and the people one is researching (*Riege, 2003; Bryman & Bell, 2015*). Therefore, the following paragraph will present the authors efforts in avoiding subjectivity during data collection and data processing, to enhance construct validity. These techniques, described below, are suggested by Riege (2003).

Firstly, questions for the semi-structured interviews were thoroughly created so they were as neutral as possible in the sense that they were not giving the respondent any hint and lead them into a desired answer. This reduces the subjectivity and increase the validity of the empirical material since respondent could answer the questions without being influenced or persuaded in a certain direction. In addition, the questions were constructed, to the greatest extent, in a way where respondents were asked for empirical facts about the past, the now, or the future. This allows for answers closely related to the reality and avoiding respondents giving answers from a subjective dreamworld. One weakness of this study´s construct validity is the use of the aforementioned presentation in part two of the department interviews. However, as argued, it is believed that this will allow the respondents the ability to evaluate the technology on a deeper level due to a preconceived notion of general lack of understanding.

Internal Validity
Internal validity for a case study refers to designing an internally valid research process by establish identified phenomenon's in a credible way. It is about identifying generative mechanisms, rather than highlight major patterns, and draw conclusions based on real-life experiences. Hence, it is about causality, and how well drawn conclusions can be derived from the empirical findings. (*Riege, 2003; Bryman & Bell, 201*5)

One technique, suggested by Bryman and Bell (2015), to increase the credibility of the study is to store notes, transcriptions and selection of respondents in order to allow the authors to repeatedly assess the empirical material and thereby track back the conclusions.

External Validity
External validity refers to the analytical generalization and to what extent it is possible to generalize particular findings to a broader perspective or in another context. This is often a challenge in qualitative

studies due to the small sample size and hence a question arises if it is possible to generalize the conclusions to an entire industry (*Riege, 2013; Bryman & Bell, 2015*).

In order to increase the generalizability of the results to the construction industry a questionnaire was constructed. This makes it easier to achieve some reasonable and more generalizable conclusion of the current state of knowledge within the construction industry about the technologies. Moreover, for the for the qualitative parts it is important to define the scope and boundaries of our case study, Riege (2013) argue that it will facilitate the analytical generalization of the research.

3.6.2 Reliability and Replicability

Reliability refers to the repeatability of the operations of the study. It focuses on describing and presenting the used methodology and to what extent another researcher is able to replicate the study to find similar findings and results. Hence, increase the replicability of the study. To achieve reliability and replicability is a challenge for a case study since people are not static measurements. In addition, even if one could describe operations so others can precisely repeat each step, results may still differ. (*Riege, 2003; Bryman & Bell, 2015*) However, the quantitative method for this study are relatively easy to replicate as the questionnaire can be found in Appendix E and the selection process of respondent is also presented.

In order to overcome the aforementioned challenges, and ensuring the reliability and thus replicability, this research has used techniques suggested by Riege (2003) and Yin (2018). Firstly, this research has developed and used a case study protocol, containing all procedures and steps taken which have resulted in our conclusion and gives an overview of the case study. Secondly, after collected all empirical data, a case database was constructed where data was organized to facilitate the data analysis. Thirdly, interviews, excluded those via email, were recorded by using either a tape recorder or the record function provided by Skype. Lastly, Reige (2003) state that the reliability increases if the research is based on peer reviewed sources. However, the blockchain and the smart contract technology are emerging technologies and therefore are current scientific research within the fields of blockchain and smart contracts scarce. Consequently, there are limited peer-reviewed articles published as of the writing of this thesis. Nevertheless, strong effort has been made when conducting the literature review to make sure we include the existing, and relevant, peer-reviewed articles. Since they are emerging technologies, one could argue that interpretation, understanding and application areas constantly changes and therefore could non-peer-reviewed sources be a sufficient complement. However, the majority of these sources has been cited in academic articles.

3.7 Concluding Remarks and Criticism

Parallel to writing the thesis, the authors used Python code to create a consortium blockchain prototype to gain a deeper understanding for the technology and the technical limitations. The aspects learned during this process helped evaluating potential real-world applications and suggested architecture.

The strength of the chosen method is that an iterative approach allows for deeper and more comprehensive research of the chosen field. The authors have also chosen to investigate companies that make up a significant part of the construction industry leading to increased representable results, similar to the real-world.

The methods that has been chosen has its weaknesses as well. Case studies, in general, have very low generalizability which the authors attempted to improve using an embedded approach. Furthermore, one of the authors works at the company which may influence the interviews in certain ways when speaking to customers and buyers. The case also does not tackle small actors in the construction industry and instead focuses on the bigger actors. While this is positive as it becomes representative in terms of turnover there is still the issue that there are plenty of small entrepreneurs in construction that have not been targeted.

4. Empirical Findings

This chapter will initially present an overview of the construction, specifically the concrete supply chain. After this, each section will be divided into the respective empirical findings to answer each research question. 4.2 will primarily be used to answer RQ1, 4.3 for RQ2 and 4.4 for RQ3 respectively.

4.1 Construction and Concrete Supply Chain

4.1.1 Overall Supply Chain

An overview of the entire supply chain for the concrete production cycle is presented in Fig. 4-1 and is based on all the construction industry interviews. The different steps will be explained below and in more details in section 4.1.2 and 4.1.3.

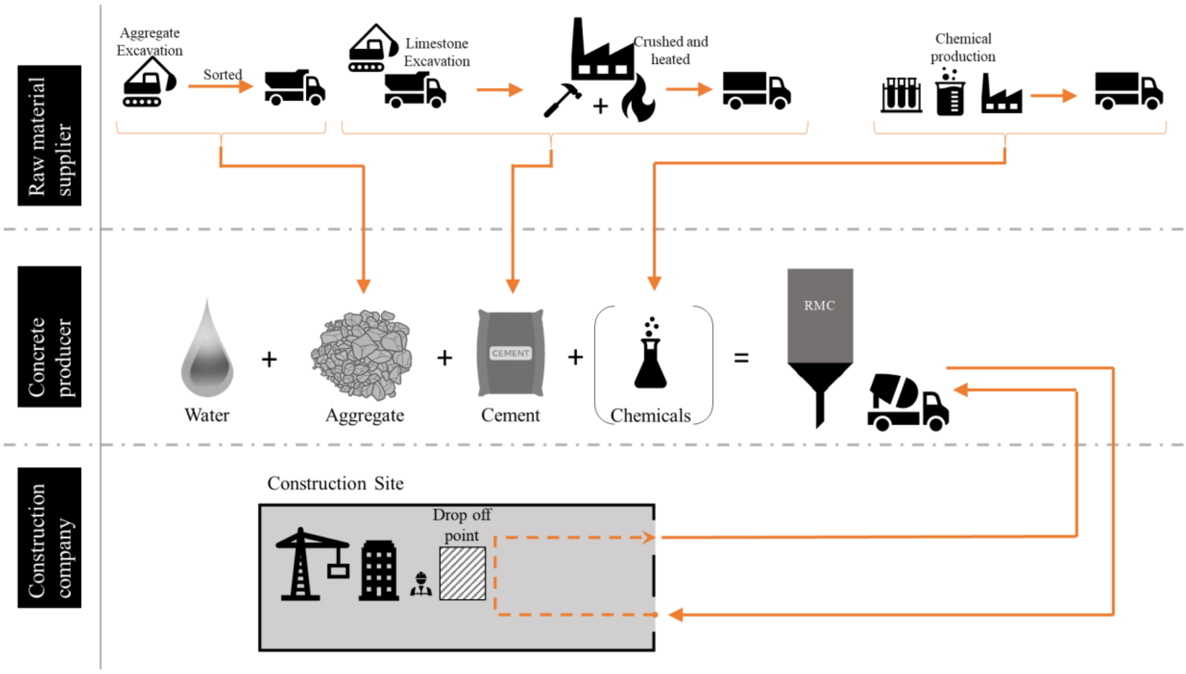


Figure 4-1: Concrete supply chain. Own model.

According to Head of Sales at NCC (CS-1), the supplier of the aggregate will buy a segment of land and excavate the material from the ground. This material will be separated to different sizes of material. After which the wanted size of aggregate will be sent to the concrete producer.

The Production Site Manager at Thomas Betong AB (CP-6) specified the different elements included in the production concrete (water, aggregate, cement and chemicals), each being delivered to the production facility. Water is supplied by the connecting water line and aggregate is filled into aggregate silos. The cement, being a pulverized fine dust, is stored in separate silo and the chemicals are stored in smaller barrels. The concrete is then mixed, in accordance to the recipe the customer wishes, in a big mixer which is filled using automated systems from a control room. These recipes consist of different amounts of the aforementioned raw materials. The ready-mixed concrete (RMC) is then filled into a concrete mix truck and transported to the construction site.

The construction companies that were interviewed had very similar methods for receiving the concrete. The Head of Sales at Thomas Betong AB (CP-4) described it as follows; the concrete truck arrives at the construction site where there is a responsible individual for receiving the concrete. The concrete is then checked to make sure that the quality is consistent with the order and is thereafter poured into a form. After that, the concrete mixer truck returns to the production facility.

4.1.2 Supply of Raw Material

Fig 4-2 illustrates a detailed description of the supply of raw material from the raw material supplier, specifically aggregate in this case, to the concrete producer. This information was provided by the Chief Procurement Officer at Thomas Betong AB (CP-2), CS-1 and CP-6 which was then used to create the figure.

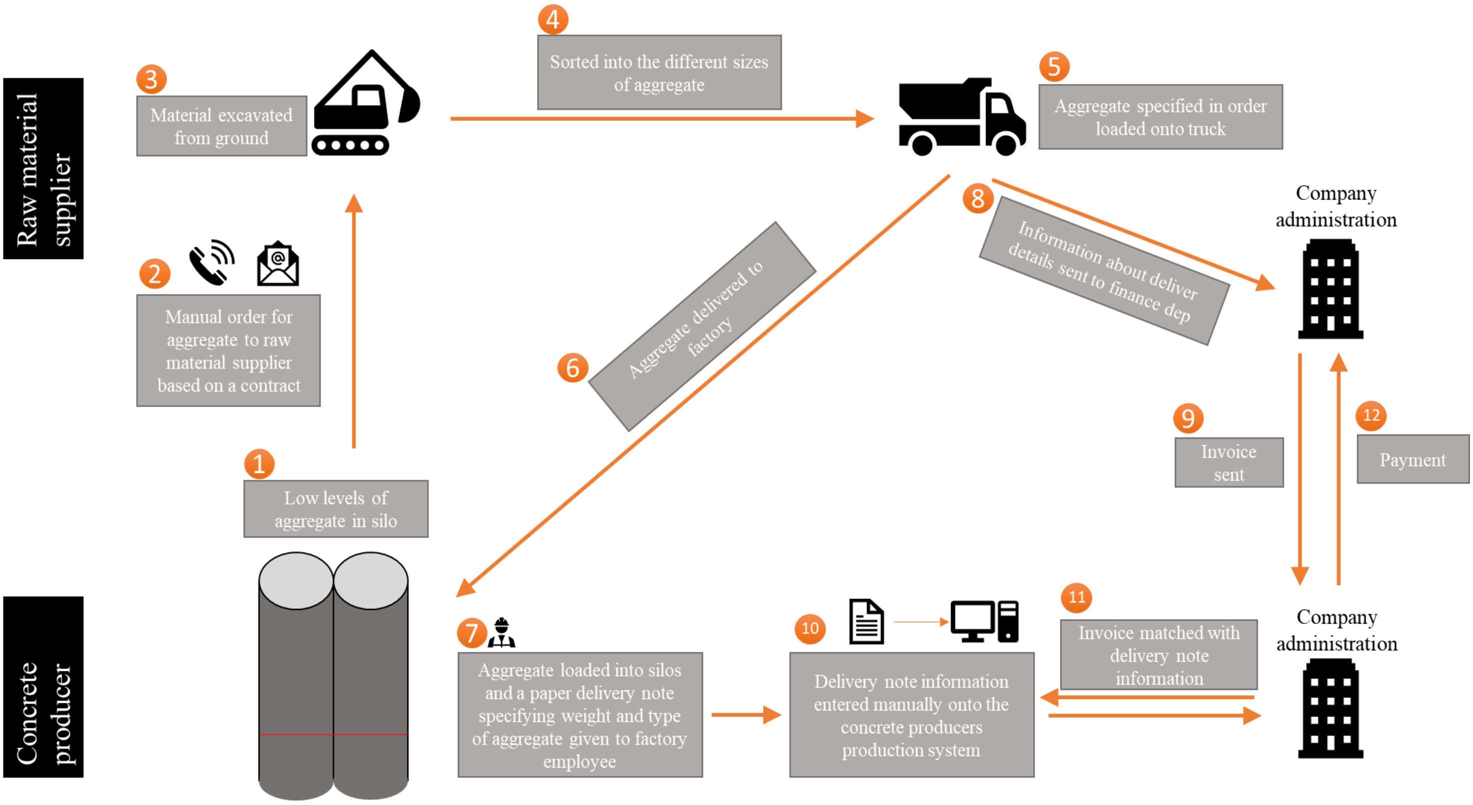


Figure 4-2: Supply of raw material for RMC production. Own model.

Before the supply chain itself starts, the procurement officer will create a multiple purchase agreement which the concrete production facility will base its orders on. This process is further specified in 4.3.1. First step (1) in the supply chain is that the sensors in the silos at the concrete production facility indicate low stock level. (2) Employee at the production facility will then manually send an order to the aggregate supplier, via email or a phone call, where they will specify the size of the aggregate needed. The raw material supplier will confirm the order and (3) excavate the material or take the material from pre-excavated piles of raw material. (4) If the material is excavated, it is then sorted into the different sizes and (5) the wanted order size is loaded onto a truck and (6) the aggregate is sent to the concrete production facility. (7) The aggregate is then loaded into the silos and a paper delivery note is given to the concrete production site employees. (8) The raw material supplier informs their administration that a delivery has been completed where they will (9) create and send an invoice specifying the quality (size) and weight of the delivered material. (10) The concrete production employees will then manually enter the delivery note information into an internal system which is connected to the concrete producer's administrative department. This delivery note information should include the same information as the invoice and the (11) administration at the concrete company will match the information from the facility with the invoice. This information will be matched partially automatically and manually depending on the quality of the information inputted to the internal system.

When all information has been matched, a payment will occur, and the stock levels will be updated in the accounting system.

CP-2 and CP-6 both mentioned that there is a visual control of the raw material, but there are very few manual controls that are conducted on the incoming material. There are very seldom problems with the deliveries according to both CP-2 and CP-6. Furthermore, CS-1 also mentioned that quality controls or quality disputes do not occur often due to the customers buying the raw material have a lot of faith in the quality certification of the raw material suppliers.

4.1.3 Supply of Ready-Mixed Concrete

To get an insight into how the supply of RMC to the construction site is handled there was a consolidation of the information from the Credit Manager at Thomas Betong AB (CP-3), Business Controller (CP-1), IT Application Manager at Thomas Concrete Group (CP-7), CP-4, CP-6 and all the customers (CB-1-5). The result from this information is illustrated in Fig. 4-4.

RMC is a tailor-made concrete that is produced in a factory based on specific recipes depending on the purpose and use case of the concrete. These recipes consist of a specified amount of water, cement, aggregate and any additional chemicals depending on the circumstances of the construction project. One example of a commonly used chemical is retarder. Retarder allows the concrete to be transported for longer distances since when retarder is added the curing time, i.e. hardening time, is increased allowing for an increased distance from production facility to construction site.

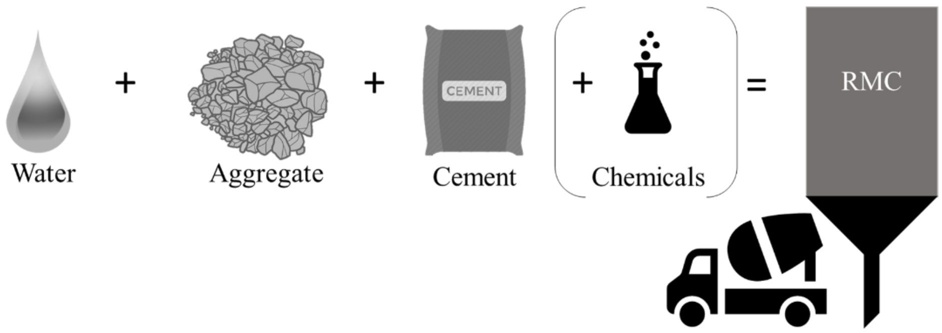


Figure 4-3: Ingredients in RMC. Based on observation and interview with Production Site Manager (CP-6)

This recipe will be a specific combination of water, aggregate, cement and chemicals, as can be seen in Fig. 4-3.

Before the supply of RMC occurs, there is a planning phase and a contracting phase. The planning phase starts with the construction company who has received or taken on a project. During the planning phase architects, engineers and other relevant actors plan the project, this includes consultation with concrete production companies. Here they decide on the appropriate quality depending on the use case and recipe that will be needed for the project, this recipe will usually be tested in a lab. These recipes are extremely varied, the case company investigated has for example over 1200 different recipes in their portfolio. The more common concrete recipe is usually part of a standard contract and a multiple purchase agreement which the customer will use while specific recipes may require specific contracts.

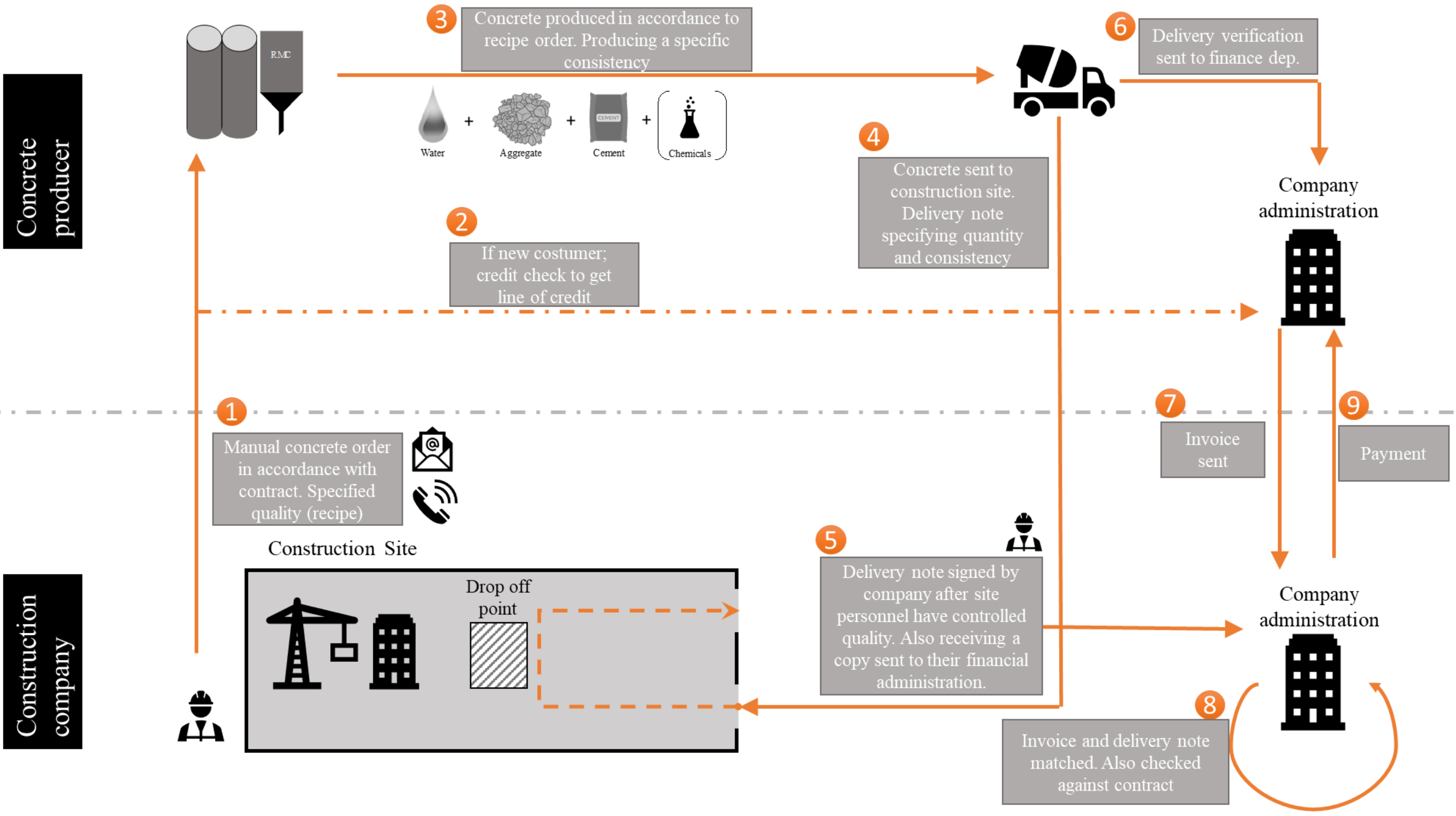


Figure 4-4: Supply of RMC to construction site. Own model.

After planning is completed as well as contracts and all the governmental documentation are signed, there will be a construction site set up. During the construction site project there will early on be a demand for concrete. Responsible for procurement at the construction site will (1) place a manual order for concrete specifying the recipe they wish to order which will then be checked against the buyers existing contracts. If it is a small costumer or a one-time-order there will be a standard contract and pricing used. (2) If the customer is a new customer there will be a credit worthiness report constructed either allowing for a line of credit or denying it. The production facility will then be given permission to (3) produce the concrete with accordance to the recipe.

This is produced in the facility and then poured into a concrete mixer truck. (4) The truck then drives to the construction site with the concrete. (5) When the truck arrives at the construction site the person responsible for receiving the concrete will control the quality of the concrete, record this in a log (usually paper) and sign the paper delivery note, also receiving a copy. (6) The signed paper delivery note will be brought back to the production facility, entered into a system manually and this verification will be sent to the financial department. (7) This will then be used to create an invoice, specifying weight, quality, delivery time etc. which will be sent to the construction company. (8) The information on the invoice will be matched to the delivery note and the signed contract, either automatically, semi automatically or manually. (9) After the invoice has been approved payment will be sent to the concrete producer.

4.2 Current State of Knowledge in Blockchain and Smart Contracts and Readiness

4.2.1 Previous Knowledge

All the interviews with industry professionals indicated that there was either none or very limited knowledge surrounding blockchain and smart contract technology. The limited knowledge tended to be based on word of mouth or blockchain news. In Fig. 4-5 and 4-6 below, one can observe a similar result where the majority of respondent had little or no understanding of blockchain technology and smart contracts.

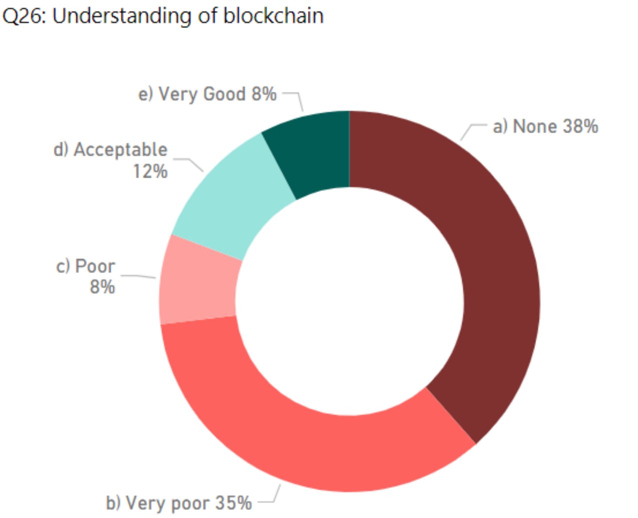


Figure 4-5: Q26: Understanding of blockchain. Based on questionnaire.

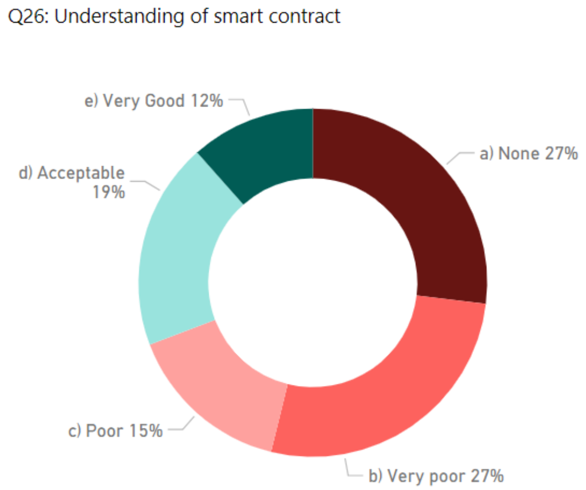


Figure 4-6: Q26: Understanding of smart contracts. Based on questionnaire.

This limited knowledge was also exhibited in other questions in the questionnaire, producing a result where two out of the 26 respondents had previously worked with blockchain technology and three out of 26 respondents with smart contracts. Interestingly, those that had sufficient knowledge of smart contracts agreed, to different extents, that smart contracts are something that the construction industry should strive to implement, illustrated in Fig. 4-7[10].

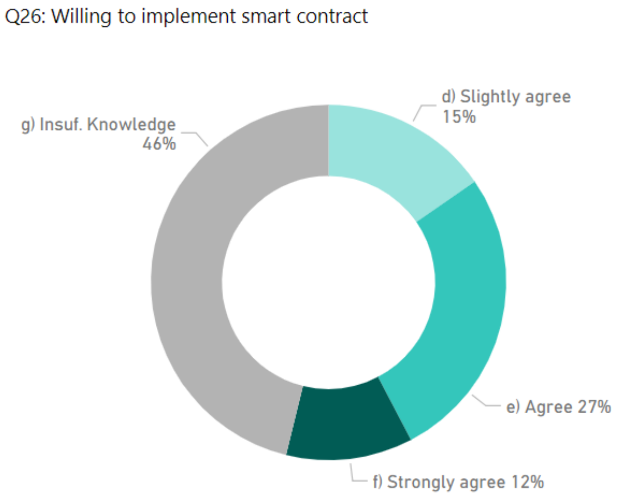


Figure 4-7: Q26: Willing to implement smart contract. Based on questionnaire.

[10] Insuf. Knowledge is the abbreviation for Insufficient Knowledge

4.2.2 Industry Readiness and Sentiment

The actors interviewed were also asked if they believed that smart contract and blockchain technology is suitable for implementation in the concrete supply chain and in turn construction industry. The Chief Procurement Officer at PEAB (CB-1) spoke about the need for a different form of culture, a much greater digital backbone in the business for the technology to be adopted.

“I don't believe that we are mature enough for this sort of technology. Contracts are to rigid in comparison to how the business actually work [...] It’s all about the level of digitization. Both the physical digitalization as well as the mental digitalization needs to be present and the industry just isn't. Period!” - CB-1

This was further supported by the Regional Purchasing Manager at Skanska (CB-4) who explained that the industry is very conservative, however, CB-4 was personally interested in testing the new technology. The other construction company actors; Business Developer at Skanska (CB-2), Supply Chain Manager at JM (CB-3) and Project Manager/ Purchaser at Veidekke (CB-5) all had similar concerns about the low digitization in the industry. However, there was a clear willingness among the actors to increase automation and digitalization the supply chain. Never the less, all actors expressed the need for a use case before being comfortable with investing into a potential implementation.

The concrete producers shared many of the same concerns as the construction companies. CP-4 states that there is still an inadequate digital maturity in the industry that it just does not seem feasible at the moment. However, the Business Analyst Developer at Thomas Concrete Group (CP-5) talked about the implementation issues not being due to the low understanding of the technology. CP-5 did not believe that the issue lies in the industry being immature and a low level of digitalization. She continued to claim that the next generational shift in the industry will bring with it a lot of changes, primarily the need for digitization changes. Additionally, CP-7 also echoed the immaturity of the technology being an issue, adding that a use case would be needed to evaluate the real-world implications. CP-7 also believes that being the first mover is unwise, one should stay ahead but not the leader and take the brunt of the development costs. CP-7 can see the technology possibly being implemented in five to ten years but the industry needs to be focused on implementing simpler digitization processes first. Moreover, he believes there is greater challenges with the aspect of change management rather than implement the technology itself.

While discussing the potentials of the technology several of the individuals expressed concerns about the technology. The concerns in the industry are very spread due to the limited knowledge surrounding blockchain and smart contracts. CB-1 mentioned that smart contracts are locked and rigid while the construction industry is very unpredictable and requires a lot of flexibility.

However, not everyone agreed. The concrete producers (*CP-4, CP-5 & CP-7*) all thought that there is a possibility to code every scenario and outcome, but it will take time to develop and it is important to consider all the variables. The issue is defining the parameters and how to measure them, i.e. finding the ”one source of truth” and which input should trigger what action. The construction industry actors CB-4 and CB-3 also agreed that the variables should be able to be defined and it should be able to be coded. This was further irritated by the concrete raw material supplier CS-1.

All the actors interviewed had legal concerns regarding smart contracts as they currently have no legal footing. CP-4 stating that being the first is always a risk and that the company's board of directors would have to take the decision. CB-2 stated that the company would always need some form of jurisdiction or legal precedent for the company to allow the usage of smart contracts. CP-2 saying that this would require a physical contract that governs the legal aspects of the contract while the smart contract only handle the transaction automation since the smart contract cannot hold in a court of law.

"There will need to be some precedent before we test anything." - *CS-1*

There was no one, neither in the concrete producers, raw material suppliers or construction companies that were particularly comfortable with the usage of a cryptocurrency.

"I do not see cryptocurrency being used in this industry, at least not at the moment." - *CP3*

4.3 Smart Contracts and Blockchain in Construction Supply Chains

4.3.1 Contracts and Procurement in Construction

CB-1 describe that more or less every construction project is unique, and this has an effect on the types of contracts used in the construction industry. The ratio between multiple purchase agreements and

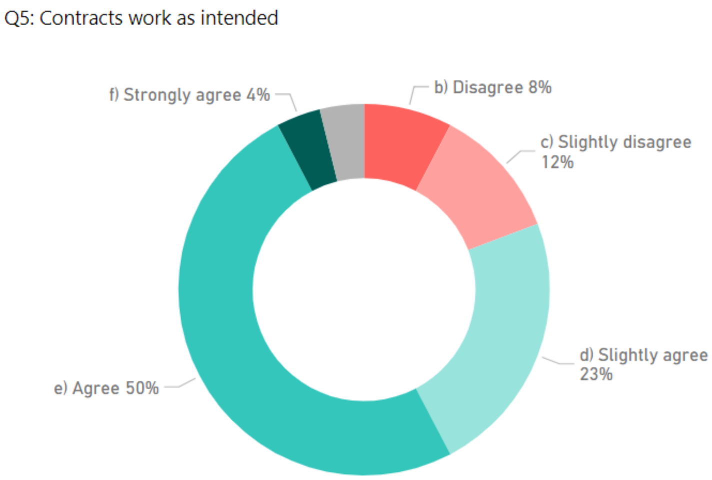


Figure 4-9: Q5: Contracts work as intended. Based on questionnaire.

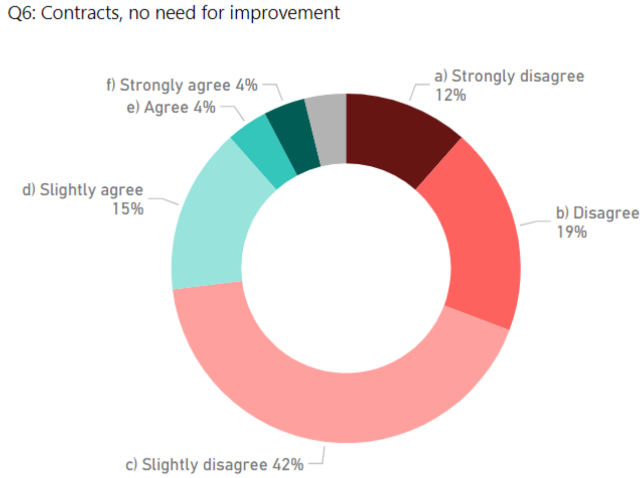


Figure 4-8: Q6: Contracts, no need for improvement. Based on questionnaire.

project unique agreements was similar among all the interviewed companies. Project unique agreements are the most prevalent consisting of, on average, 70 percent while multi purchase agreements represents the remaining 30 percent. However, as the multiple purchase agreements are more beneficial in terms of price and do not require a new negotiation every time, all companies, both construction and concrete, aim to use them as much as possible. Moreover, these types of contracts are usually used for products such as standard doors and other standard products. Based on the multiple purchase agreements, employees at the construction site place the suborder (*CB-1, CP-2 & CB-3*). According to the answers in the questionnaire, 77 percent agreed to different degrees that current contracts works as intended, see Fig. 4-8. Additionally, with regards to how secure contracts are in terms of securing the interest of both parties involved, 77 percent agree upon that current used contracts are sufficiently secure.

However, 73 percent feels that there is room for improvement within current contracts, illustrated in

Fig. 4-9. The suggested improvements are; easier handling, potential additions and modifications should be handled in a more standardized way and finally the legal jargon should be more understandable. Furthermore, one respondent highlighted following:

"It is important with clear contract conditions that are easily understood by both parts. Simpler contracts but not on the expanse of higher cost. At the same time, it is important that these contracts can be easily followed in a business system." - Questionnaire respondent

CP-4 point out that they create 3500-4000 projects annually and CS-1 explain that after the offer, there are usually no modification and therefore the offer ends up becoming the contract. One reason for the wide range of used contracts is described in the quote below.

"Every project is unique; each architect wants to put their touch on the building/construction."
- CB-4

Even though the majority of the contracts are project unique, CB-3, CB-5 and CP-2 explained that the industry standard agreements (ABM 07) are always applied or attached when creating a new contract. CP-2 further discuss how these are beneficial for the buyer but that he has ambitions to exclude specific paragraphs in these mentioned standards to make the risk more evenly shared. Moreover, CP-2 describe that he thinks it will become easier to standardize contracts since the market is moving towards bigger and fewer actors, thereby allowing for industry-wide contracts.

CB-1 and CB-4 both described a generalized contracting process for the construction industry that works as follows; Set specification → Gather offers from several subcontractors → Calculation process and selection → Contract calculation → Production calculation. The questionnaire showed that 85 percent of respondents agreed, to different extents (4% strongly agree, 58% agree and 23% slightly agree), that the current process works well. Moreover, CB-1 was the only respondent that mentioned that some of their subcontractors have the possibility to sign contracts via their mobile phone.

CB-4 further explained that several people within the company are involved in this process, such as; project manager, category manager, production manager and calculation. In addition, there is an architect and the customer. CB-4 and CB-2 further explain how their contracting process has shifted towards what they refer to as "partnering" where the client, architect and the master builder together are onboard at an early stage, around two to three years before the construction starts. The purpose of cooperating from the beginning is to eliminate problems that tends to occur later on in the project and to create long lasting relations. This is done through meetings, delivery planning and information sharing. The goal is, when partnering is at is best, to share knowledge, expertise and all relevant information about a common project. However, CB-2 emphasize, that a prerequisite for a partnering relationship is that the involved actors needs to have relatively high degree of trust to each other. This since partnering opens up for deception and one can take advantage of the available information being shared.

Issues and Risks

The result from the questionnaire shows that companies in the CSC relatively often fails to fulfill their obligations in the contract, as can be seen in Fig. 4-10.

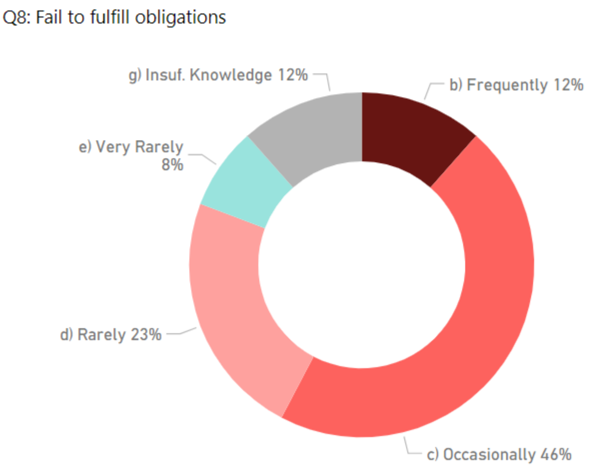


Figure 4-10: Q8: Fail to fulfill obligations. Based on questionnaire

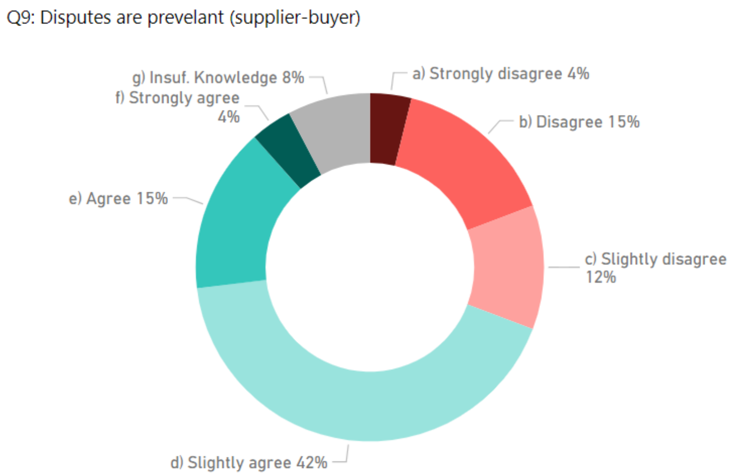


Figure 4-11: Q9: Dispute prevalence (supplier-buyer). Based on questionnaire.

Moreover, the result indicates that disputes between buyer and supplier are common since 61 percent agreed to different degrees, as can be seen in Fig. 4-11. CP-4 echoed this sentiment describing that the construction industry is unique, and disputes are much more common when compared to other industries. CB-4 and CB-3 agrees and describes that when a dispute arises, for example when there is a delayed delivery, there is no convenient control process in place to determine who is right or who is wrong. Furthermore, the costs for breach of contract tend not to cover the actual cost of the breach, one example being delays. In contrast to all of this, CP-2 feels that disputes are not particularly prevalent.

The answers from the questionnaire also indicates that a dispute between two parties often leads to additional costs. 88 percent of the respondents agreed to different degrees, which can be observed in Fig. 4-12.

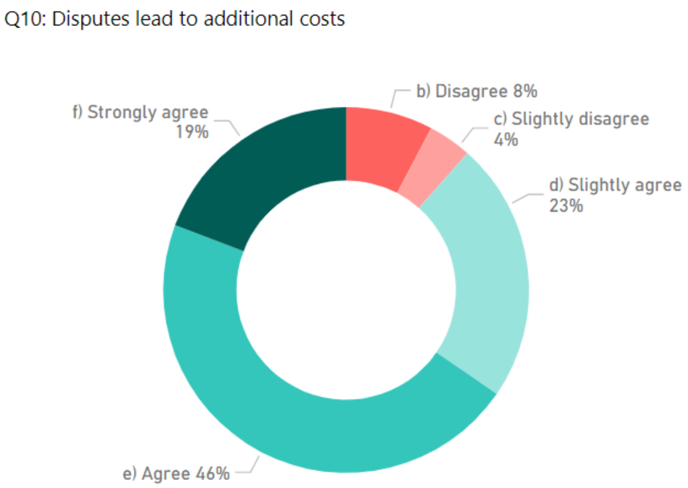


Figure 4-12: Q10: Disputes lead to additional costs. Based on questionnaire.

When asked about the main risks and issues in the contracting process both CB-1 and CB-4 emphasized the challenge of including all the requirements and the issues involved with risk attribution; i.e. who takes the risk, the company or another actor. In addition, both specified the importance of identifying the documentation that represents the truth. What is meant by this is one needs to rank the documentation on which is the primary source of trust, either; the contract, the project descriptions or the blueprints.

Additionally, there seems to be very few issues related to forgery or fraud within the contracting process as 69 percent of the respondents in the questionnaire disagreed with the statement. Moreover, the result from the questionnaire indicates that the ability to enforce contracts works adequately within the industry since 81 percent agree upon this. Both CB-1, CP-1, CP-4 and CS-1 share the same opinion that contracts are very rarely modified after agreement. In the cases where there is a need for an update it is regarding prices and this occur once a year. This corresponds to the questionnaire where 27 percent agree to different degrees (8% strongly agree, 4% agree and 15% slightly agree) to the statement that contracts are often altered after being agreed upon.

4.3.2 Current Traceability Capabilities

When actors in the construction industry were asked how well traceability of transactions, not limited to financial transactions, were handled CB-1 mentioned that they primarily keep track of actors one tier down in their supply chain. As can be observed in Fig. 4-13, the majority, 61 percent, believe that there is an adequate goods tracking within the construction companies and the concrete production companies. In the case of concrete producers, they evaluate the quality to make sure it is correct and keep manual documentation of this for historical references. CB-1 further communicated that there is more emphasis and importance surrounding suppliers upholding appropriate working conditions. For example, CB-1 stated; a supplier from China who uses child labor is never allowed to delivery raw material to the construction projects.

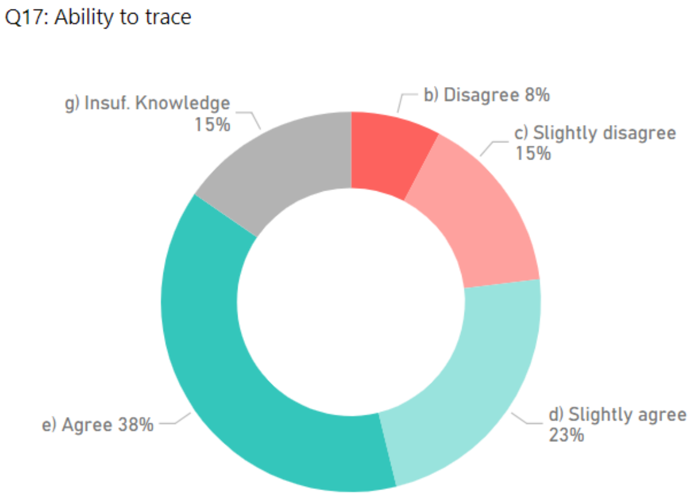


Figure 4-13: Q17: Ability to trace. Based on questionnaire.

CB-3 expressed that the company had recently decided that all their construction projects are going to be "Svanen" certified, indicating that the construction project has meet certain environmental guidelines. This was also echoed by CP-2 and CB-2, stated that traceability itself is not really an issue for the purchaser of concrete, instead the importance lies in the certificate the company possesses. The most important certificate that the concrete producer will require and validate when choosing suppliers is the different ISO certifications. These certifications are especially important for construction companies whose client is the state in Sweden. The state has very strict regulations with regards to certifications and accreditations on construction companies and in turn their suppliers.

To receive certifications, the company is required to have an extensive log book of all the materials while undergoing construction and all the suppliers need to uphold the environmental standards as well. To ensure this, the company does extensive checks and audits on their suppliers. This is very costly and time consuming, but the company believes that building environmentally consciously is necessary for the future of construction. Hence, the importance of upholding these certifications is the primary concern. However, partial tracking is still conducted by using manual log books and computer systems where the company registers when the product was produced, the quality and where the goods were delivered. (*CP-4, CB-2, CP-2*) CB-3 also concluded that they are working on a solution for the suppliers to scan the goods throughout the supply chain and to finally scan at arrival which will then trigger a payment. This will allow the tracking of goods from point A to B and transaction automation.

CB-4 stated that the company does extensive evaluations of new potential entrepreneurs that want to work on or supply to a construction project. These entrepreneurs need to send in information such as; certifications, financial information etc. This information is then verified for authenticity and checked to make sure it complies with their standards. This, however, requires a lot of resources from the company and there is always a risk of manipulation. (CB-4)

With regards to the procurement of raw material for production, CP-2 mentions that the customers are primarily concerned with the source of the material. Specifically, assurances that the raw material is taken from the same source each time and thereby ensuring that the quality of the concrete is consistent. CP-2 also stated that there is an increased demand from buyers that the raw materials comply with newer and more stringent environmental standards. Therefore, the procurement department is developing a system where one can easily backtrack raw material locations.

4.3.3 Trust

CB-1 stated that there is a relatively high degree of trust between them and the entrepreneurs involved in the construction projects, including the suppliers. Further adding that the company conducts tests on a sample of their entrepreneurs and suppliers with the help of third parties. CB-3 went on to state that having a good history with suppliers is what generates trust. They both went on to say that there tends to be trust between construction companies, the entrepreneurs and suppliers. However, if there is a rocky past with regards to quality or other concerns then the construction company will evaluate them more carefully (*CB-1*, *CB-3*). The questionnaire also show indication that there is trust between the actors in the supply chain, as can be seen in Fig. 5-13 and Fig. 5-14, both with regards to trust of suppliers as well as trust of buyers. The question about trust in suppliers indicated that 65 percent do not think that there is a lack of trust, while for the buyers that number was 62 percent.

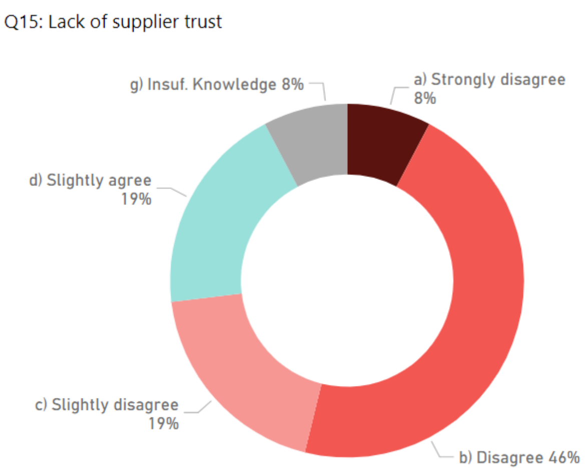


Figure 4-14: Q15: Lack of supplier trust. Based on questionnaire.

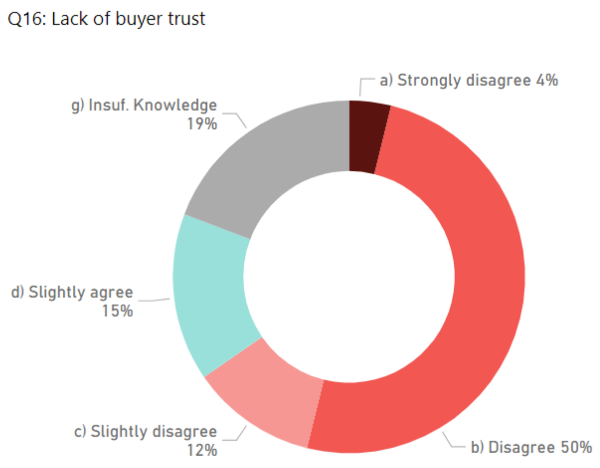


Figure 4-15: Q16: Lack of buyer trust. Based on questionnaire.

CP-2 states that the trust between the suppliers of raw material is all based on historical president, he estimates that the they trust around 70 percent of the suppliers. CP-4 also indicates that the history plays a significant role in the degree of trust, estimating that from a sales perspective, that they are trusted by 60-80 percent of customers, i.e. construction companies. CP-4 also points out that there is a fine line between earning money and earning too much money, buyers will feel cheated if the company is too profitable and creating the perception of inflated pricing.

CB-4 also pointed out that trust is not generated immediately and automatically, instead the trust between the construction company and its suppliers and entrepreneurs is built up over time. CB-4 went on to say that the company conducts initial audits of new suppliers and entrepreneurs which in turn sets the groundwork for the trust relationship that will be built over time. CB-2 echoed this, saying that the trust and relationship between the company and its suppliers is generally good but it goes up and down depending on the historical events. The company prefers to work with a fewer number of actors that they trust, sometimes testing new suppliers or entrepreneurs to build new potential relationships. (CB-4, CB-2)

CS-1 indicated that the business is very local. The excavation sites tend to be located close to the buyers and this proximity usually leads to a close collaboration and trust between the two actors.

"There is quite a lot of trust until something goes wrong, at that point there is no trust, there is an evaluation based on historical data to make sure it is consistent over time." - CP-2

From a financial department standpoint, CP-3 states that the initial test is to make sure that the buyer has the necessary financial precedent to allow for a line of credit to be issued. However, it is not always that clear cut in construction as these values are notoriously volatile, meaning that the information fluctuates massively and there needs to be a clear dialog with the sales department when evaluating potential credit levels. Sales will usually have some relationship or initial trust which will weigh into the decision process around the level of credit that should be issued.

4.3.4 Level of Digitization

Current Level of Digitalization

During the interviews there was an overwhelming sentiment that the construction industry, including the concrete stakeholders, were behind the curve with regards to digitalization. All the interviews conducted mentioned a very low level of digital maturity in the industry. CP-7 describe that there is definite room for improvement but that they currently have certain digital tools to interact with customers. However, this interaction is very basic, allowing the customer to request certain reports from a BI solution. CB-5 and CP-7 both mentioned that they are constantly working on digitization projects but that they tend to fade out.

"There is currently a lot to do here but we haven't come particularly far yet [...] every day there is an increased awareness around technology and digitization and the company board has placed clear indications that we need to increase digitization in the company." - CP-7

CP-2 mentioned that there is a lot of diversity within the customer base, from small privately-owned companies to big multinational enterprises. Continuing to state that these different customers have massively contrasting incentives and abilities to invest into IT solutions, hence the solutions must be suitable for all the customers. CP-2 further mentioned that smaller companies usually are more resistant to change. However, as mentioned, there is a trend towards bigger and fewer companies which CP-2 think will facilitate the digital transformation in the industry.

CP-1 and CS-1 both described the construction industry as conservative and fearful of new technologies, also stating that no one wants to be the first mover. CP-4 went on to explain that due to how the industry is set up the incentives for streamlining and investing in digital developments is low, specifying that many actors charge on an hourly basis meaning that automation will impact the bottom line at the company.

"The construction industry is not ready yet, people do not want to reduce the number of hours they can bill. Everyone builds their profit around charging as many hours as possible, there is no incentive for the actors to reduce the number of hours since this is the source of revenue." - CP-4

However, it is clear that the industry is moving in a more digitized direction embracing new technology. CB-2 explained that the company has GPS in their trucks and QR codes on windows that can be scanned when a delivery is made. Furthermore, CP-7 explained that they are currently uses IoT in their concrete mix trucks in United States which means that they become a mini concrete factory that automatically mixes the concrete to ensure the quality that arrives at the construction site is correct. These IoT devices as described by CP-7 can upload concrete quality data as well as location data to a cloud database.

CB-5, CB-2 and CP-7 describe today´s process of handling delivery notes as very manual which results in 95 percent of them not being signed. All the interviewed actors from the construction industry indicated that having digital signatures on delivery notes would be preferable to today's process. CB-5 went on to highlighting that relieving the need for physical documentation of paper delivery notes would create benefits for both administration as well as the construction personnel.

"I believe that everyone would appreciate greater digitalization." - CB-5

CP-7 mentioned that, when changing to the new ERP system later this year, there is a goal of 90 percent of all delivery notes should be digital and there will be a phone application where it will be possible to sign them. However, CB-1 further discuss the challenges of automating processes for unique products that are not greatly standardized and does not have a frequent flow. For these types of products, he believes that the complexity will outweigh the benefits of certain investment.

Information Sharing

As can be seen in Fig. 4-16, the majority (62%) believes that a shared and open ledger between two parties is something beneficial. This sentiment was shared among the respondents that were interviewed, some however worried about too much information sharing. All the interviewed actors were prepared to share information, at least between parties, however not in an open network. CS-1 explained that if the company is transparent in its processes then the company will see positive returns in the form of increased trust and a common goal of profitability. Notably, the companies who used "partnering" contracts were also the companies who were prepared to share the most information on an open platform with several actors, the restrictions being that only key actors have access. Moreover, CB-4 discuss how excess information sharing in their map file system could be something negative where for instance company Y upload information that is not relevant to company X. Too much information makes it uncontrollable.

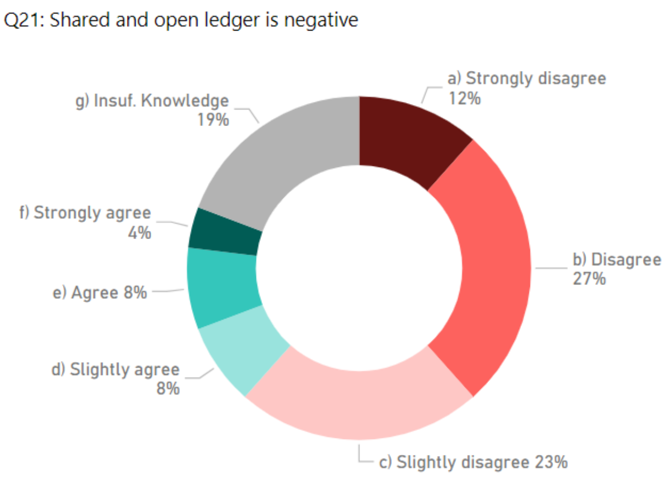


Figure 4-16: Q21: Shared and open ledger. Based on questionnaire.

The type of information all the interviewed said they wanted to restrict are aspects such as pricing, as this can be used by competitors to gain a competitive advantage. It can also be used against the company during contract negotiations as well. However, not all actors saw issue with the volume of products being shared. CB-2 explained that volume is not a problem since most companies have a good overview of the market and competitors can easily calculate this.

"You do not want to show someone else what you have, but still see what others have."- CP-1

CP-4 pointed out that actors are prepared to share information to different extents depending on where in the organization you are. CP-4 went on to explain that on the construction site, everyone wants to be as transparent as possible, while the higher up in the organization one moves the more limited the amount of information sharing becomes. There is also a move towards increased information sharing in the industry. CP-5 explained how customers and suppliers want to share more information and have access to more information to analyze their own data to create an advantageous organization. There is also increased requirements surrounding communication, more actors want increased order automation and validation instead of being forced to do manual orders via customer service.

"There is a clear interest among customers to see more [...] this includes the suppliers, it would be great if we had sensors in the silos that told us when the cement was at critical levels and an order is sent immediately. This is not complicated it is just that we are not there yet."- CP-7

Both CB-1, CB-2, CB-3 and CB-5 explain that they use the BIM technology to different degrees and CB-1 and CB-3 further highlighted the time it has taken for the construction industry to adopt this technology and utilize its full potential. Nevertheless, they consider the technology as the future when it comes to information sharing.

4.3.5 Blockchain & Smart Contracts within Construction Supply Chain

PhD. Associate Senior Lecturer (EBSA-2), Cognitive solution team at IBM (EBSB-1) and The Logistics and technology lead at Blocklab (EBSB-2) sees the potential for blockchain and smart contracts to improve supply chains by digitizing the chain and facilitate tracking the asset from point A to B. However, Blockchain Expert at RISE (EBSA-1), EBSA-2, EBSB-2, the Director and Head of blockchain at PwC (EBSB-3) and the Blockchain Consultant and Entrepreneur from Swedish Blockchain Association (EBSB-4) point out several challenges that need to be overcome before being able to use blockchain and smart contracts in supply chains that involve physical goods. EBSB-3 explained that physical goods are not digital in its nature which means one needs to rely on some sort of digital footprint in the asset you want to track. EBSA-1 takes it a step further and states that the technologies are very poorly suited for tracking flows where it needs to be a link between the physical world and the digital word. Consequently, all blockchain experts emphasize the importance to secure the input data into the blockchain but also the challenges to achieve this in a secure and realistic way.

"If you put information that is corrupted into the blockchain then the blockchain is corrupted." - EBSB-4

Surrounding Technologies

EBSB-2 and EBSA-2 discuss how IoT devices can work as a source of input data but also how to ensure that the data has a proof of identity. EBSB-4 also discuss how the usage of a method which automatically feeds the data into the blockchain, without any manual involvement, could create a link between the two worlds. However, adding that, it is about ensuring that the IoT device produce the true outcome, the “single source of truth”, and making sure that no one has tampered with it. EBSA-2 argue that there needs to be a trusted third party, as well as several various sources, that can verify the “single source of truth”. Further explaining how industries with low digitalization will face problems feeding enough data into the blockchain to make it reliable.

“It does not matter what you put there but how you put it there.” - EBSB-4

EBSB-3 describe how the technologies; IoT, Artificial Intelligence and Blockchain are interrelated and creates value together. For example, having smart contracts that learns and update itself through Artificial Intelligence.

“IoT feels, AI learns, Blockchain remembers.” - EBSB-3

However, EBSA-1 argue that there needs to exist some extent of trust when the data is not self-generated, and if that is the case there is no need for the blockchain technology.

“If you trust the data input, then you do not need a blockchain. If you do not trust the data input, a blockchain will not help.” - EBSA-1

Both EBSA-1, EBSB-3 and EBSB-4 agreed upon that blockchain technology and smart contract, at its current state, only works when the data that it relies on is self-referencing and completely digital, as the case with cryptocurrencies.

4.3.6 Current Supply Chain Financing Solutions

Current State

When investigating the use of SCF methods there were no actors that used any methods or instruments discussed by Tate, Bals and Elram (2019) (*CB-1, CB-4, CP-5, CB-2, CP-2 & CP-3*). Furthermore, no such solution was being worked on by the companies, to the best of the respondent’s knowledge. However, the respondents did see SCF as something interesting for the construction industry and something that could be beneficial. CP-3 mentioned that, as a concrete production company, the financial process is still significantly manual. CB 1-4 all said that the financial process is still very paper based and poorly digitized.

Transaction Automation

CB-4 describe that there is no or minimal automatic matching of delivery notes to the received invoices. The process is a very manual process. This was also repeated to a certain extent by CB-1. The issue, as CB-3, CP-3 and CP-5 states, is that the delivery notes are signed by hand at the construction site and the invoice goes into the administration system. Delivery notes and invoice information needs to match in the ends. This matching is done either manually or semi automatically. The invoices are controlled five different times and despite this there is about four percent invoices that are incorrect. There are currently ideas to improve this automation process according to CB-3 by using QR codes and scanners to automatically trigger transactions. CP-5 also states that there is a majority interest in automating processes and eliminating unnecessary steps. Further adding that a few systems have been partially automated but due to a low digitization culture usually leads to human influence being required. CB-5 states that everything is manual and that there is a wish to move towards a more digitized system. CB-2 also concluded that there is limited automation in the transaction process, further stating that these traditional methods often lead to errors.

Intermediaries and Payment

CP-4 stated that there are over 60-70 percent of invoices that are paid with a significant delay, leading to costs throughout the supply chain. Additionally, CP-3 states that these payment delays are also partly due to poor administration at smaller customers and outdated invoicing leading to lost invoices. This is further supported by the result from the questionnaire where there is a strong agreement surrounding the excessive time used administrating transactions, as can be seen in Fig. 4-17, around the time being spent administrating transactions being too much. However, the sentiment surrounding administration costs are also split very widely in two direction as seen in Fig. 4-18.

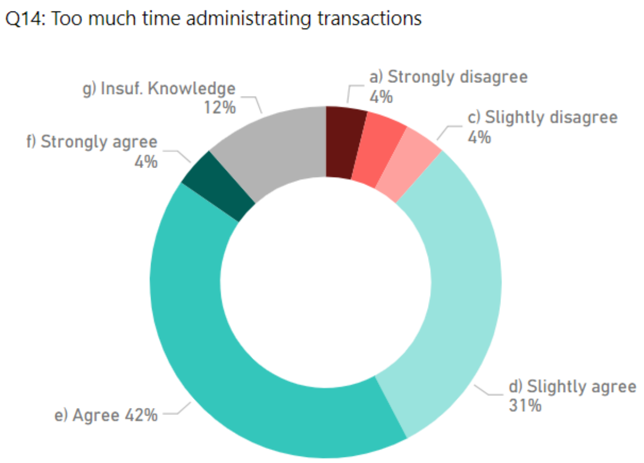


Figure 4-17: Q14: Too much time administrating transactions. Based on questionnaire.

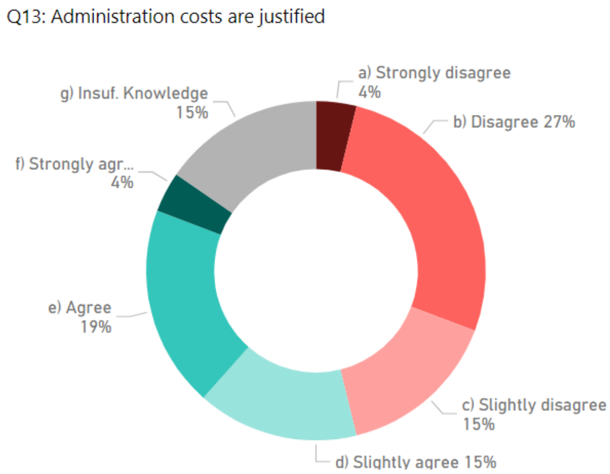


Figure 4-18: Q13: Administration costs are justified. Based on questionnaire.

With regards to intermediaries, CP-3 states that there is a definite need for the bank as an intermediary as they provide a lot of security in transactions, but they are also in need of improvements with regards to speed as the transactions takes long time to register in the system. In contrast, questionnaire respondents seem to be somewhat content with the transaction speed, illustrated in Fig. 4-19. However, they were somewhat split on the necessity of having intermediaries, such as banks, in the transaction process, as can be seen in Fig. 4-20.

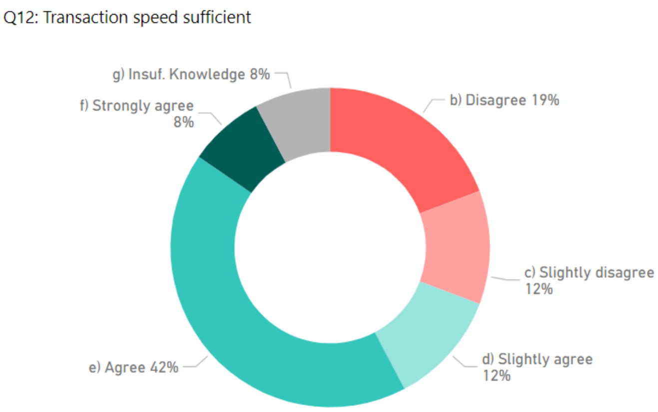


Figure 4-19: Q12: Transaction speed sufficient. Based on questionnaire.

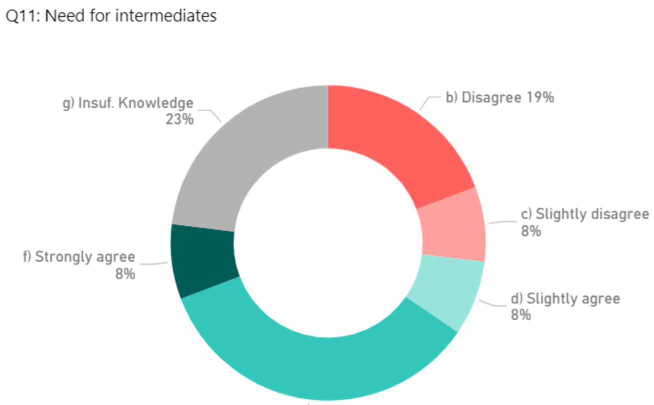


Figure 4-20: Q11: Need for intermediates. Based on questionnaire.

The transaction costs with banks are approximately around 1,50 SEK per transaction, this however was only the cost the bank charged and did not include any administration or other costs. As CB-1 states, banks are not only for the administration of transactions but also essential in regards financing the supply chain in the form of loans. CS-1 and CP-2 both regarded the aspect of removing banks as intermediaries as something positive.

4.3.7 Blockchain & Smart Contracts within Supply Chain Financing

Phd. Senior Lecturer (ESCFA-1) define supply chain financing (SCF) as the financial flow of the supply chain and the various applications to make this flow more efficient, especially by increasing the visibility which allow firms to reduce variability. He further explain that the blockchain and smart contract technology has the potential to (i) increase the visibility in the supplier network, beyond first tier supplier, as payments could be traced through digital platforms, (ii) improve the cash-to-cash cycle as it allows for faster administration and (iii) improved security if the blockchain technology can ensure that the data provided in the smart contract are tamper proof and correct at all times. EBSB-2 discuss how financial transaction could be automated and one can eliminate manual labor, e.g. manual signatures, and extensive paperwork that is used today. In addition, EBSB-2 reflects upon how it could become easier to issue better lines of credits if it is possible to validated and back track the data in the supply chain. Furthermore, ESCFA-1 discuss that there are other techniques that could provide similar benefits as he mentioned but that the blockchain technology is the current frontrunner.

"There are of course other techniques that promises the same thing but the blockchain solutions are to my best awareness the frontrunner at the moment." - ESCFA-1

Moreover, ESCFA-1 consider smart contracts as a complement to current SCF instruments (reverse factoring, dynamic discounting etc.) and how it could be linked to Know Your Customer (KYC) processes to verifying the identity and mitigate frauds. ESCFA-1 also highlights the importance of all members using a similar IT-infrastructure. To be able to achieve this he adds that establishing the SCF solution on a private or consortium blockchain would likely be the best alternative.

"Standardization is going to be key – making sure that there are industry standards applicable to existing ERP-systems etc." - ESCFA-1

ESCFA-1 also added that to take advantage of the blockchain technology it most likely needs to be linked to surrounding technologies, such as IoT, to capture the entire benefits provided by smart contracts. Moreover, as the quote above state, the flexibility of existing ERP-systems will be an important factor according to ESCFA-1.

ESCFA-1 believes that intermediates, e.g. banks, will still play an important role when it comes to SCF. However, their role will change as new technologies emerge and focus will be more on providing platforms and needed SCF-infrastructure or provide excellent customer experience. He adds that banks traditional service margins will shrink, and they will be forced to adapt to the new landscape. Furthermore, ESCFA-1 emphasize that there needs to be a trusted third party ensuring that the technologies are working.

"We are still going to need trusted validators that ensures that the blockchain is working, that the code is correct etc." - ESCFA-1

4.3.8 Potentials of Blockchain and Smart Contracts

There is a big divide surrounding the main potentials of blockchain and smart contracts. Some believe that it can solve many different issues while some see it as specifically a cryptocurrency instrument. EBSA-1 stated that he sees no potential so far for blockchain and smart contracts on a physical goods supply chain. Further adding that there are problems with scaling decentralized system, creating consensus and having the social infrastructure for it. EBSA-1 went on to say that with the current state of knowledge surrounding the technology, one cannot know if the problems are hard or impossible to solve. EBSA-2 says that the biggest potentials for blockchain and smart contracts is the possibility of having a permission-less transaction process where the hurdles to participate in the market are minimal.

EBSB-1 is convinced that there is huge potential when using smart contracts to increase automation and digitalization of transaction ecosystems for supply chains. EBSB-3 stated that they are currently working on blockchain technology solutions within the construction industry but added that there are other issues that the industry needs to tackle first.

The Legal technologist and Lawyer (ELS-1) thinks that the greatest potential for blockchain and smart contracts within construction is the interaction between the construction industry and governmental agencies. Going on to state that blockchain and smart contracts can help and increase the trust and immutability of these processes.

"There is a very strong case in investigating the interaction between the construction industry and government and the potential benefits of blockchain [...] Smart contract can disrupt the traditional supply chain." - ELS-1

4.3.9 Risks Associated with Blockchain & Smart Contracts

EBSB-4 talked about the blockchain technology being very complicated. Further adding that most people in the space are either developers or tech people. EBSB-4 pinpointed that there needs to be a focus on the application and User Interface (UI) perspective to facilitate the adoption of the technology. He goes on to say that the advanced concepts are making people afraid to develop solutions using the technology and there needs to be a simplification; the people using the solution do not need to know how the underlying concept and technology works, it only needs to solve the problem.

"UI applications are super bad in today's blockchain solutions […] No one is an expert in this domain, things change very rapidly." - EBSB-4

EBSB-1 shares many of the same concerns with the optimistic blockchain experts which is that there needs to be enough digitization so that one can support the input data to the blockchain, i.e. "one source of truth".

EBSB-2 thinks that the biggest risk with the blockchain technology is that people do not understand what it is, thinking that it can solve all the problems in the world. He continues to say that the research that exists does not state how successful they have been with implementing the solutions, the research being very opaque about what people can do with it and its main benefits.

"There is very little research done in terms of practical applications." - EBSB-2

EBSB-2 also goes on to speaking about smart contracts not being contracts further adding that they are not particularly smart. EBSB-2 goes on to say that smart contracts are still insufficient in a legal perspective. Further adding that the smart contracts are only as good as the programmer; one must consider every loophole and scenario that exists. He also states that one should focus on supply chains that are simple and easily distilled into its different aspects to be able to use a smart contract solution. However, using them as a legal contract is not something he believes is possible today. However, using smart contracts as only a form of transaction automation can be worthwhile if the single source of truth can be identified and agreed upon.

EBSB-3, similar to EBSB-2, thinks that one of the greatest risks is that people think that it is the solution to everything. The product may just become a glorified database which there are other superior and simpler solutions for. Furthermore, EBSB-3 says that smart contracts are not actually smart specifying that the people that create them do not understand the consequences of the contracts and have inadequately considered the legal aspects. The people that create these contracts also do not understand the accounting and financial implications, adding further issues. Automation transaction is beneficial but there needs to be an overarching understanding of the processes for a smart contract solution to be successful. Continuing to say that there needs to be some form of standardization and simplification of the chain and processes to work.

EBSA-2 stated that the biggest risk is the immaturity of the technology, specifically the consortium and private blockchains. Stating that the immaturity lies around the technology since the blockchain can be built in many ways. EBSA-2 also articulated that there is a trade-off between performance and privacy. He went on to say that there are also governance concerns and legal concerns with the technology that needs to be figured out. Furthermore, EBSA-2 mentioned that there needs to be an understanding of how a business will go from their current systems to a blockchain system and asking why before.

"Blockchain is a design window and within that window there is a number of different types of blockchain solutions." - EBSA-2

EBSA-2, similar to EBSB-2, says that there is a need of more use cases and applications to understand what one can do with the technology. Further stating that there is a slow movement towards technology maturity where one can see more use cases down the road. EBSA-2 went on to saying that there are very poorly optimized smart contract solutions with a lot of performance related issues today. He also said that he has concerns about the high costs associated with smart contracts. EBSA-2 noted that smart contracts have a very complex syntax and script, making coding complex and filled with issues. Further adding that the contracts do not know what to do if the code itself has not taken a scenario into account. EBSA-2 also showed concerns regarding interoperability of smart contracts and blockchain.

ELS-1 discussed the aspect of "one source of truth" which usually comes down to IoT devices and its ability to feed information to the blockchain. However, he showed concerns regarding IoT device tampering and pointing to the fact that if the device can be tampered with in any way then the blockchain smart contract solution will become corrupted as the input data is corrupted.

4.3.10 Legal Challenges for Blockchain & Smart Contracts

One of the greatest concerns during the industry interviews were the legal concerns surrounding smart contracts. EBSB-3 stated that the regulation side and the legal industry has had a hard time keeping up with technology but has seen an increased rise of interest among lawyers, specifically surrounding smart contracts. These legal concerns were also shared by EBSA-1 and EBSA-2. EBSA-1 stating that the lawyers need to understand the blockchain and smart contract technology to be able updating the governing laws surrounding them before there is market acceptance.

ELS-1, a retired lawyer with experience in automated contracts, was interviewed to gain deeper insights into the legal concerns. He started off by stating that the law profession is not ready yet, pointing the fact that corporate lawyers are very resistant to these types of changes, especially contractual changes. ELS-1 also pointed to the need to secure the input data before the legal profession will feel comfortable as corrupted input data will inevitably lead to extensive legal issues later down the road. It is incredibly important that the liability falls on the responsible party to become legally viable. Furthermore, ELS-1 states that the combination of technology and legal concerns leads to very few companies wanting to become the first mover and thereby impeding the development of blockchain and smart contracts. It is hard to create legal precedent without development. ELS-1 also pointed out the potentials of the blockchain and smart contracts to influence the governmental interactions between construction companies and governmental agencies. He mentioned that due to the strict regulations that the State poses on construction companies during government projects one could use blockchain to ensure that the documentation is legitimate. This could be validated by third parties' actors such as ISO certifiers or others to reduce manipulation and tampering. ELS-1 believes that change can be pushed onto the industry from governmental agencies and thereby facilitate the legal adoption.

"The compliance perspective is very interesting within the construction industry." - ELS-1

ELS-1 goes on to say that from a legal perspective it is also important to identify who owns the data, in a public blockchain this is clear since everyone owns it but from a consortium and private blockchain this becomes more complex. He goes on to ask; does the builder of the blockchain platform own the data or who owns the data? ELS-1 adds that this aspect must be settled, also adding that the owner of the platform can act as a gatekeeper.

ELS-1 also states that legal preceding is seldom clear cut, associating liability to a specific party is complex. He goes on to say that it can be difficult, especially in construction, where the vast number of actors involved in a construction project increasing the complexity when defining who did what wrong. ELS-1 adding that this complexity will be multiplied when attempting to code it into an automated contract such as a smart contract.

"Who is in the wrong, who is liable?"- ELS-1

ELS-1 goes on to say that there needs to be a standardized way of working, creating interoperability between systems. Further adding that lawyers need to understand the smart contracts for them to become viable, there needs to be a logical way of moving from natural language to control language, i.e. code. ELS-1 recommends a simplified control language, this is a code that the lawyers can understand but underlying it is a more complex code that is versatile and programmable. Also adding that for this to become viable it would require extensive documentation that allows for the lawyers to interpret it and use it in a court of law.

“Natural language needs to be translated into control language […] there are not a lot of people that are programmers and lawyers simultaneously.”- ELS-1

4.4 Designing an Appropriate Blockchain & Smart Contract Solution

4.4.1 Configurations

Private, Consortium, Public Permissioned or Public Permission-less

EBSA-1 stated that private and consortium blockchains do not make much sense. Further adding that consulting firms or businesses that sell the idea might disagree but that is because it is a source of revenue. He continues to say that consortium blockchain are only distributed and decentralized databases with access management rights that are controlled centrally. This is nothing new and has been around for decades. EBSA-1 also adds that the none public blockchains rely on an institution and incentive mechanisms that are not within the data structure.

“There is no such thing as a private blockchain and it makes absolutely no sense conceptually.” - EBSA-1

This is was also echoed by EBSB-4 who said that private blockchains, and in extension consortium blockchains do not make much sense and that they do not add up with the ideology of the blockchain. ESBS-4 continuous to say that it is essentially a distributed database which already exists today without blockchain. EBSB-4 championed the use of public permissioned blockchains. He went on to state that using public permissioned blockchains is preferable when you need public verifiability but still want certain restrictions pertaining to the smart contracts. However, adding that public permissioned blockchains mean that the information will be able to be seen and extracted by everyone. EBSB-4 also mentions that a public permissioned governed blockchain allows for faster transactions speeds while still having high security.

“In my opinion private blockchains don´t make much sense.” - EBSB-4

EBSB-2 stated that for a supply chain most solutions will probably be a consortium solution, however, using a public blockchain as a notary would also be feasible. Specifically pointing out that there will be cross industry initiatives that will be running on consortium blockchains. EBSB-2 had similar statements about private blockchains as EBSA-1 and EBSB-4, however, he was more focused on whatever solution does the job, either being consortium or public, stating that as long as it fits the business and solves a problem.

“I do not believe in private blockchains, that is nonsense, it is a centralized database.” - EBSB-2

EBSA-2 does not think that the idea of private and consortium blockchain are a disruptive idea. Stating that there are already distributed databases today and it is nothing unique. However, adding that people who call a consortium blockchain a distributed database is unjustified, and he argues that then you are missing out on some of the interesting characteristics of the technology. It is not the immutability of the databases that is interesting since this already exists today, but it is more interesting in the tokenization of physical goods and the ability to create immutable smart contracts.

EBSB-3 had a sentiment that was unique among the respondents and summarized well in the quote below. However, also adding that the market does need to decide on a definition of what blockchain is eventually to reduce confusion.

"I don't care if it is a private or consortium blockchain, there is too much debating around this. As long as the solution solves the problem it is fine."- EBSB-3

Trust Instrument

"Blockchains do not have much to do with trust [...] I don´t think it is a trust technology" - EBSA-2

EBSA-2 shared his thoughts on the aspect of blockchain technology being a trust instrument. He brought to light that if people think that technologically generated trust will be able to trump traditional forms (e.g. trust in institutions) of trust just does not hold water. EBSA-2 goes on to say that you cannot call an instrument a trust instrument if every other week something happens that breaks this statement. He referred to the example where people have lost millions of dollars because they lost their private key, or someone died. The theory behind it being a trust instrument does not hold up to reality. Further arguing that people that call it a trust instrument is doing the technology a disservice.

4.4.2 Developer Recommendations

EBSB-4 stated during the interview that a new Blockchain 3.0, specifically one referred to as EOS.io[11], is available and is one of the most widely used blockchains on the market. Adding that it opens the possibility to have a public blockchain that is still permissioned. Furthermore, he states that the ability to develop smart contracts on the EOS platform is superior to that of for example Ethereum since it is more versatile, and the smart contracts can be modified and do not have to be scrapped when they become obsolete. Furthermore, the consensus algorithm is built on a delegated proof of stake combined with BFT.

"There is a fine line between security and efficiency in the blockchain." - EBSB-4

EBSB-4 mentioned that secure transactions require a lot of computing power and will decrease the transaction speed, leading to a trade-off that needs to be made. He goes on to say that one can also use so-called "block producer" which produces blocks, acting similar to a notary in the verification of signatures. He then adds that this information can then be called using API's[12] to an internal system at the company or governmental agency. EBSB-4 states that these "block producers" work similarly to a democracy where users vote on who should produce the blocks depending on what the block producers promises to provide, essentially a campaign. The top 20 block producers, those with the most tokens, will then be tasked to mining the blocks. He concludes with the fact that EOS.io blockchain is exactly this type of system and adding that it is one of the most widely used blockchains.

[11] EOS.io is a Blockchain 3.0 solution
[12] API is a function that allows one to access information from other sources such as databases, operating systems or other applications.

EBSB-4, similar to many other, mentions the importance of securing the input data and removing manipulation and creating the “one source of truth”. EBSB-4 is unsure about the application of specifically EOS.io on physical goods supply chain but does mention that IoT devices can be used to send information to the blockchain which the blockchain can then use to communicate with the smart contract. He also adds that EOS.io has a multi index table that works similar to any SQL[13] server where it is possible to call the data that has been posted. Further stating that using this form of blockchain solution allows for minimal infrastructure to be constructed at the company and hence the company can focus on making appropriate API's that call the data from the blockchain. He also stated that the tokens required for transactions become an asset in the company and EOS.io does not charge anything per transaction. EBSB-4 ended it by saying that it all comes down to the architecture and the organization; one needs to choose a blockchain smart contract solution that works for the business and one needs to be adaptive to change due to how rapidly things change within blockchain. EBSB-4 also emphasized the importance of making a proper and user-friendly UI where the end users do not need to know it is made on the blockchain or not.

“Don't make them super complicated, make them user friendly [...] You don't have to show that you are actually using blockchain because no one really cares.” - *EBSB-4*

EBSB-2 states that public blockchains are the most interesting and viable solutions when implementing a blockchain solution. He adds that one way of working with the public blockchains is by using them as a notary which is similar to what EBSB-4 states where you have “block producers” producing the blocks and maintaining the blockchain infrastructure. However, if one wants to use a consortium blockchain the most efficient method of consensus would be Proof of Authority based on multiple oracles according to EBSB-2.

ELS-1 states that when developing the code, it needs to be understandable for lawyers, specifically smart contracts. He adds that one can circumvent this by using a natural language contract, preferably a digital contract where each underlying clause would be codable logic programed that controls and automate transactions. ELS-1 discussed the possibility of a contract being signed in natural language while at the same time the parties are also agreeing to an underlying code which then automates transactions.

Interoperability

One of the key aspects brought up during the interviews was the concept of interoperability. Interoperability being how the blockchains communicate with each other. EBSA-2 showed a lot of concern with today's blockchain solutions within the supply chain since not everyone is using the same blockchain solutions and architecture. Further adding that since there is no way for them to speak to each other there will need to be some form of interoperability to make them feasible solutions. EBSA-2 also stating that preferably it needs to be built by everyone for everyone and there needs to be some form of standardization.

EBSB-2 goes on to say that the best way to solve interoperability would be if everyone used a public blockchain or a form of notary as then the code would work the same for all actors. Adding that another solution could be that there will be intermediary actors that will create the interoperability for each blockchain and how it should communicate with each other. EBSB-4 emphasized heavily on the use

[13] SQL is a programming language that one can use to use to export data from a database.

of EOS.io and since it is the most favored blockchain it will be able to have interoperability among many different solutions. However, adding that, the interoperability between EOS.io and other blockchains still need to be solved and may be solved using notaries.

Smart Contracts Outside the Blockchain

EBSB-4 says that a smart contract solution excluding the blockchain technology is possible and that it already exists in certain industries. However, adding that, smart contracts that are built on only one centralized database have the issue of trust. This was echoed by EBSB-2 also pointing out that there is no way for someone to verify the transactions instead you only see the result.

4.4.3 Mass Adoption

According to EBSB-1, the blockchain technology is mature enough but the problem lays in determining, depending on network and context, the most suitable business model. EBSB-2 mentioned that the technology is already at a mass adoption stage referring to Hyperledger and how it opened for programmable blockchains and hence be used for companies. However, EBSB-2 believes it will take a couple of years before it reaches another level of potential with the integration of IoT devices etc.

EBSA-1 and EBSA-2 are more skeptical and they do not consider the technology as mature at this point, pointing out that misleading definitions cause confusion in the market. EBSA-2 further analyzed that if he as a programmer does not understand the system, how will other feel comfortable with the technology and get them to work. There needs to be a wide acceptance of a type of system where there needs to be a “killer” application that is suitable for everyone. EBSB-3 believes that the general level of digital maturity needs to be higher for a mass adoption as well as a cloud-based infrastructure. Finally, EBSB-4 states that for mass adoption to take place there needs to be a user-friendly UI (User Interface) that everyone can understand.

“These definitions are a massive problem for blockchains where smart contracts being incorrectly named for example”. - EBSA-2

5. Analysis

Following chapter will be analyzing the empirical findings, identifying connections between the findings, experts and industry professionals. First a framework for analysis is presented as to evaluate the appropriate configuration in RQ3. After this, the analysis is done on the state of knowledge and readiness followed by its potential applications in the industry supply chain. Lastly, there are potential blockchain smart contract solutions presented.

5.1 Framework for Analysis

5.1.1 Analysis of Knowledge and Readiness

The first aspect of the analysis, and the first research question, will be investigating the level of knowledge of blockchain technology as well as smart contract technology within the construction industry. The analysis will be primarily using the quantitative results from the questionnaire while also looking for cross relationships between the different questions and statements to attempt to explain the results. Furthermore, this will be put in relation to the interviewees responses as well as the expert's knowledge to identify the level of knowledge and readiness within the construction industry.

5.1.2 Analysis of Blockchain & Smart Contracts on SCM and SCF

The second research question was aimed to investigate blockchain and smart contracts and its potential effects on supply chain management (SCM) and supply chain financing (SCF) within construction. This analysis will primarily focus on bridging the identified problems that are present within the construction industry and using the information obtained from the experts to examine if the applications blockchain and smart contract can lead to potential benefits. To achieve this, the analysis has been split into two elements. The first element was evaluating SCM in the following areas; contracts, trust, information sharing and digitalization to finally evaluate blockchain and smart contracts to improve these aspects. The second element was to evaluate SCF in the following areas; transaction automation and intermediaries to help identify how blockchain and smart contracts could help to improve these aspects. To evaluate these two elements the authors looked at the empirical findings from the industry interviews and consolidated this with the expert interviews to evaluate the potential benefits of the blockchain and smart contract technology. These were then also cross checked in relation to the literature to gain insight into potential discrepancies or relationships between the theory and reality. As a further helping aspect the questionnaire results were used to help bolster the industry interviews answers and add to the generalizability.

5.1.3 Analysis of an Appropriate Blockchain

To analyze the final research question, the authors wanted to evaluate the appropriate configuration for a blockchain smart contract solution to be implemented within the Construction Supply Chain (CSC) as well as a governmental agency construction procurement. To evaluate this the authors constructed a decision tree, illustrated in Fig. 5-1. This decision tree is based on the decision tree created by Wagenaarm (2018) but is modified using the theoretical framework as well as expert interviews to be applied on a physical supply chain.

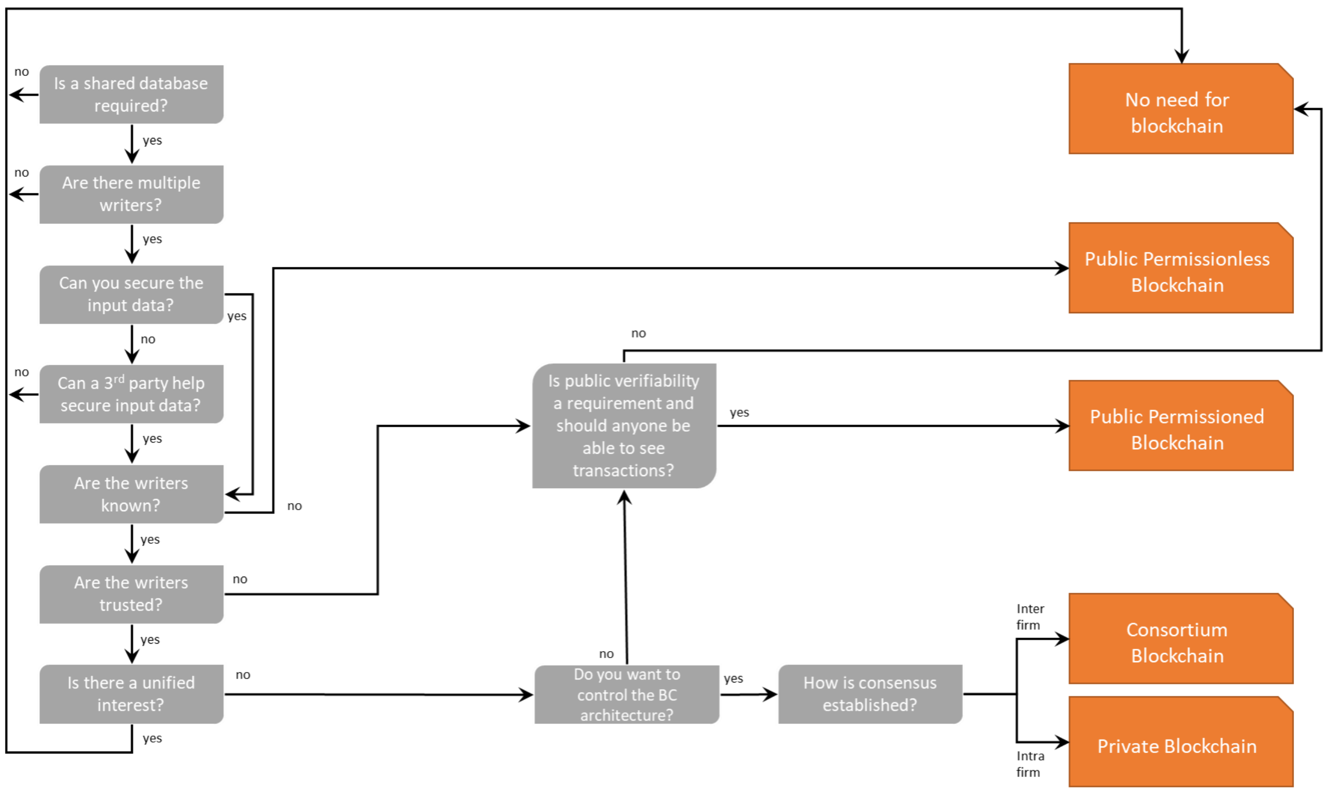


Figure 5-1: Blockchain decision tree for a physical supply chain. Adopted from Wagenaarm (2018).

Applying the decision tree above, the authors will recommend a potential blockchain solution based on the expert interviews as well as the requirements established by the industry interviews. The resulting decision will be split into two different application areas, one being construction and one being the governmental side. While the step called "Can a 3rd party help secure input data?" does conflict with what Andoni et al. (2019) and what EBSA-1 states the authors still decided to include this due to the empirical findings from other experts such as ELS-1, EBSB-4 and EBSA-2. Note that this decision tree excludes certain aspects that are inherent to blockchain which would make the decision tree much to elaborate and complex to become usable.

5.2 Current State of Knowledge in Blockchain & Smart Contracts and Readiness

This subchapter will analyze the first research question; *What is the current state of knowledge surrounding blockchain technology and smart contracts within the construction supply chain and what is the sentiment and perceived readiness for implementing such a solution?*

5.2.1 State of Knowledge

As the result from the questionnaire showed, only two out of the 26 had previously worked with blockchain technology and three out of 26 had previously worked with smart contracts. Furthermore, none of interviewed industry actors had any experience within blockchain technology and smart contracts. This was no surprise as blockchain technology is still seen as a high-tech solution while the digitization within the construction industry is low as described by Klark et al. (2017), McKinsey & Company (2016) and Mason and Escott (2018). This low digitization was also apparent during the interviews as all the respondents pointed to the low digitalization of the construction industry. Furthermore, the experts all indicated that very few true blockchain smart contract solutions have been implemented in SCM.

The questionnaire also aimed to gain insight into the respondents understanding of blockchain technology and smart contracts. A majority (69%) answered that they either had no, poor or very poor understanding of smart contracts. The authors were surprised that 31 percent had either acceptable or good understanding of smart contracts. Connected to this there was a majority (81%) who claims to have no, poor or very poor knowledge of blockchain technology and a smaller part (19%) who had either good or acceptable knowledge. The authors expected that the answers to these two questions would be identical as smart contracts are unanimous with blockchain technology. One can believe that this difference is due to the nuanced discrepancies between a smart contract and an automated contract leading to potential confusion among respondents. Drescher (2017) also discusses the complexities of understanding the blockchain and smart contract technology due to a lack of sufficient knowledge.

This disconnect is not uncommon within the field of blockchain technology as the field is filled with unclear definitions. Maxwell and Salmon (2017) state that there are infinite versions of blockchain technology due to the programmability of the technology. Consequently, these unclear definitions were also apparent in the answers from the blockchain smart contract experts who had limited consensus on definitions of different aspects of the blockchain technology. The concept of automated contracts is nothing new and has existed for some time as brought up by EBSB-2 and EBSB-4, also pointing to smart contracts usually being more towards transaction automation than smart contracting. EBSB-2 also pointed to automated contracts and smart contracts being identical. Hence, one could argue that the disconnect between the two aforementioned questions is due to poor consensus within the field and as EBSB-3 points out the industry needs to state a clear definition and to reduce confusion. There needs to be a clear differentiating characteristic defined between the two.

Further confusion is also potentially created due to the ever-changing nature of blockchain technology. EBSB-4 states that the technology changes on a weekly basis with new ideas and applications constantly being introduced. Due to this it is not surprising that there is the potential for confusion when respondents answer these types of questions in a questionnaire. These findings surrounding understanding of smart contracts and blockchain technology within construction was similar to the findings of Mason and Escott (2018). The confusion surrounding the technology was also very apparent in the answer given by EBSA-2 who said that if he as a programmer does not understand the technology then how will others be comfortable and use the technology.

5.2.2 Sentiment and Perceived Readiness

While the previous knowledge and understanding of smart contract and blockchain technology was low there was still a slight majority (54%) who believed that a blockchain smart contract solution is something that the construction industry should strive to implement. Further analysis showed that when looking into these respondents, the 54 percent, one can see in Fig. 5-2, how they answered surrounding implementation and understanding of smart contract. In this figure one can observe that even though the majority of those respondents that had no, poor or very poor knowledge still unanimously wanted to implement a smart contract solution to different degrees.

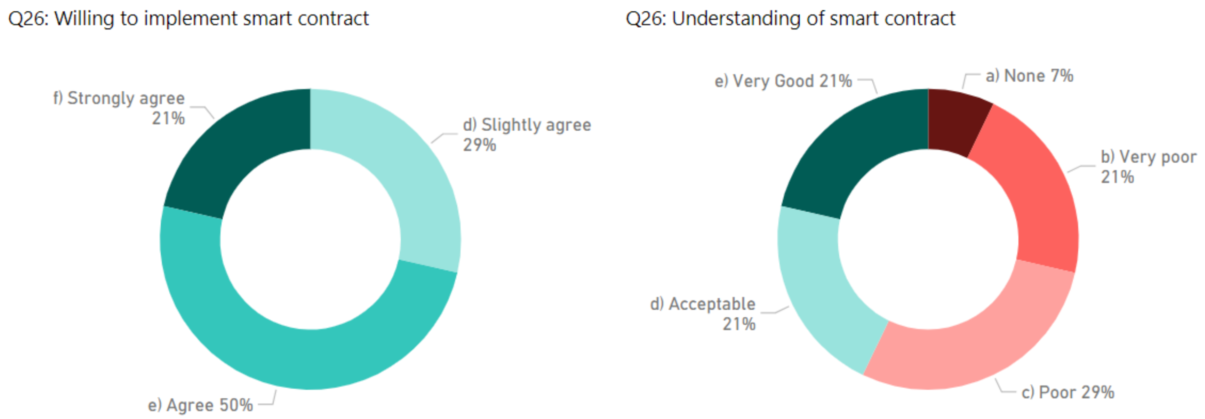


Figure 5-2: Implementation willingness / Understanding smart contracts. Based on questionnaire.

The authors believe that actors answered this way due to the willingness to increase digitalization, information sharing and automation in the construction industry. The importance of information sharing on efficiency was something clearly emphasized by Lundesjö (2015), which may be the reason why the industry is interested in increased information sharing. The three aspects; increase digitalization, information sharing, and automation were all aspects that the construction industry respondents showed great interest in. However, the interview respondents added further analysis, showing concerns about the current level of digitization adding that this will put additional restrictions on potential implementations. This willingness to implement smart contracts, identified in the interviews as well as the questionnaire, stood in great contrast to the findings of Mason and Escott (2018) who found the opposite in the UK construction industry. The difference can potentially be due to the market where the Swedish construction industry may be pushing towards more digitization or the fact that this study only sampled the biggest companies in the Swedish construction industry.

Despite there being a majority interest in implementing a blockchain smart contract solution, it also brings to light many concerns. CB-1, CB-4 CB-2 and CB-5 all said that the construction industry is not quite ready for this type of technology due to the low digitalization still present in the construction industry. This sentiment was also shared by CP-4 and CP-7, however, CP-5 was somewhat more positive to the digital maturity of the industry. There were also concerns raised surrounding the ability to code every scenario into a smart contract, the legal applications of smart contract and the use of cryptocurrency. Given the responses one can argue that there is a low readiness to implement a blockchain smart contract solution at this point in time.

The biggest issues for the construction industry to overcome before a blockchain smart contract implementation is clearly the level of digitalization. This primarily refers to creating a complete digital supply chain (DSC) with less manual and physical labor requirements as described by Büyüközkan and Göçer (2018), an issue clearly brought to light by CB-1 as well. One will also need to be able to create an immutable tokenization of physical goods, as described by Saberi et al. (2018) and Perboli et al. (2018), which requires an advanced DSC. This aspect of tokenization or digital fingerprint for physical goods is an issue that all the experts also drew great attention to. Another aspect that needs to be tackled before readiness can be created is the ability to code every scenario into the smart contract. As EBSB-2 describes, one needs to be able to distill the process, preferably choosing a simple supply chain. Finally, the legal aspect needs to be solved as ELS-1 states, this will require the code to become more user friendly and understandable before the legal profession can embrace it. This legal aspect was something shared by CS-1 who said that the legalities must be sorted out before implementation is possible. These sentiments are also brought up by Morabito (2017) and Drescher (2017) who states that the technology needs to be more widely understood and standardized before one will see the ability for mass adoption and market readiness.

Additionally, CP-1 and CS-1 both described the construction industry in general as very conservative and resistant to change, especially complex technical changes. This was further discussed by Mason and Escott (2018). However, this statement becomes somewhat counter intuitive due to the aforementioned positivity towards implementing a smart contract solution. The authors believe that there is a change emerging with regards to construction and IT development which was further supported by CP-5 and CP-7 who have positive outlooks on the future technological changes in the construction industry. Further supported by McKinsey & Company (2016).

Finally, one additional aspect that could hinder the readiness for implementing a blockchain smart contract solution is the current culture in the industry. Morabito (2017) stated the importance of change management when implementing a blockchain solution, indicating that it is not only the digitization that needs to be improved. As CP-4 stated, the industry has poor incentives for optimizing their operations since a significant portion of billable hours are generated from extensive manual labor. As Büyüközkan and Göçer (2018) states increased technological innovation creates smarter and more efficient processes. If these more efficient processes could reduce the earning capabilities of the company then the incentive to implement them is low. It should however be stated that the authors believe that the increased efficiency could lead to increased profitability for construction industry as it could improve C2C cycles as talked about by Chain (2018) and improve the competitive advantage, reduce costs and attract more competent personnel as O’Brien (n.d.) states.

Concluding remarks: Current State of Knowledge and Readiness
With regards to knowledge, sentiment and readiness for implementing a blockchain smart contract solution within construction the authors believe that the construction industry is not currently in a place to do so. Even though the knowledge is low there is still a positive sentiment towards the technology possibly indicating a future potential.

5.3 Smart Contract & Blockchain in the Construction Supply Chain

This subchapter will analyze the second research question; *Can smart contracts, in combination with blockchain technology, be used to increase efficiency in supply chain management and supply chain financing within the construction supply chain? If so, how?*

5.3.1 Supply Chain Management

Simchi-Levi & Kaminsky (2008), Le May et al. (2017) and Chen & Paulraj (2007) define SCM as a method for minimizing system wide costs in order to manage the flows more efficient. By making the supply chain more digital, one can leverage new technologies such as blockchain and smart contracts which Saberi et al. (2018) and Perboli et al. (2018) argue will improve supply chains. Both the answers from interview respondents and the literature (*Casado-Vara 2018; Loop, 2017*) are coherent and indicating that the low level of efficiency is due to the vast amount of manual labor and the silo mentality which hinder the information sharing across the supply chain. Therefore, this section will analyze how and if blockchain and smart contracts have the potential to increase the efficiency in the construction industry. Furthermore, some of the deficiencies surrounding the blockchain and smart contracts will be brought up to light.

Contracts and Procurement: Potentials and Risk of Blockchain & Smart Contracts

Behera et al. (2015), Liu et al. (2017) and Segerstedt & Olofsson (2010) all characterize construction projects as highly unique projects when compared to other industries. This was also reflected in the empirical findings where all the industry professionals echoed the sentiment of unique projects, further adding that this requires contracts to be unique. This means that the majority of the contracts are project unique agreements, where new agreements are created for each project. Due to the unique nature of construction, CB-1, EBSB-2 and EBSB-3 states that a blockchain smart contract solution will probably be easier to implement for a product that is standardized to some extent, as the products that have multiple purchase agreements. Taking this into account one can argue that initial implementations should be applied to products that have easily distilled processes and minimal variables to manage, a sentiment brought up by CB-1. On the other hand, industry standard agreements and the trend towards bigger and fewer actors might help facilitate the transition for more industry-wide contracts according to CP-2. This will create increased standardization and thus lay the groundwork for a potential blockchain smart contract solution.

Even though the questionnaire indicates that the contracts that are currently used are secure enough, work as intended and where the contracts process is satisfying, a majority feels that there is room for improvements. One major identified issue is the low percentage that fulfill their obligations in the contracts within the construction industry. A plausible result of the latter is the high degree of disputes that is present in CSC in comparison to other industries, according to CP-4 and the questionnaire. The empirical finding also shows that disputes tend to lead to additional costs, where one reason is the lack of a convenient control process to determine who is right or who is wrong as described by CB-3. The latter also corresponds to Vatiero (2018) and Shavell´s (1980) statement where disputes inevitably leads to higher costs. This is also supported by what one can observe in Fig. 5-3 where the majority of respondents who believes that companies often fail to fulfill obligations also agree upon that disputes are prevalent.

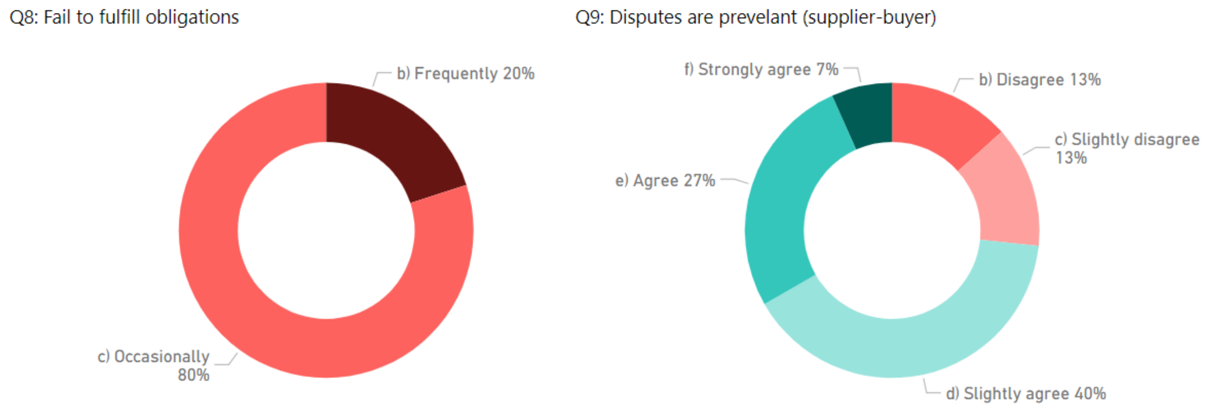


Figure 5-3: Not fulfilled obligations / Disputes (buyer-supplier). Based on questionnaire.

Since a smart contract is based on the 'if-this-then-that' logic it has the potential, in combination with blockchain, to force parties of the contract to fulfill what is stated in the contract (*Morabito, 2017*). Also, since the blockchain stores all historical transaction in an immutable way, the "single source of truth", it would be possible identify the five dimensions of a product, discussed by Saberi et al. (2019); *what* it is, *how* it is (quality), *how* much (quantity), *where* it is and *who* the owner is and hence determine who is liable if a dispute occurs. It could therefore reduce the additional costs related to disputes. All the respondents indicated a clear interest in implementing transaction automation in their processes. Smart contracts can trigger this transaction automation, depending on how the contract is built as described by EBSB-4 and discussed by Hofmann, Strewe and Bosia (2017). Hence, when the smart contracts obligations have been fulfilled a payment can then be triggered. The process of transaction automation is covered later in the analysis.

However, the issue and concerns regarding the legality and the ability to enforce a smart contract is still present. This was one of the greatest concerns highlighted during the industry interviews and no one was particularly willing to implement smart contracts without legal precedents. This lack of legal precedent was also highlighted by Rühl (2019). Based on what the experts stated, one can argue that it will take some time for the legal industry to develop regulations around smart contracts. Similar to the construction industry, the legal profession is also resistant to changes which has resulted in poor knowledge about the technologies. As a result, there is no common language between the natural language[14] and control language[15] which ELS-1 and Levi and Lipton (2018) believes needs to be in place to solve the legal concerns. ELS-1 also mention that it could be difficult sometimes to code liability clauses as defining the liable party is usually complex. This could be especially difficult for the construction industry where products are not particularly standardized, e.g. products such as concrete as it is a perishable product. Consequently, it will plausible take some time until the legal industry is mature enough and hence until the construction industry feel comfortable to implement smart contracts. However, Goldenfein and Leiter (2018) states that there are legal engineers working on a legal framework for smart contracts which could potentially facilitate the adoption of the technology. Furthermore, ELS-1 stated that there is a growing interest within the legal field and new emerging technologies such as smart contracts.

Moreover, as both CB-1 and CB-4 highlighted, there is an inappropriate risk allocation when it comes to who shall bear the risk. This is also something Zaghloul and Hartman (2003) discussed and how it is one of the major reasons to higher project costs. This is nothing smart contracts can solve as the code needs to specify who is liable for what. However, if it is possible to increase the degree of trust with IoT devices connected to blockchain for example, it would according to Zaghloul and Hartman (2003) and CP-3 reduce risk premiums and where the customer could get a higher line of credit.

Traceability: Potentials and Risk of Blockchain & Smart Contracts

The questionnaire indicates that there is an adequate ability to track goods in CSC. However, in contrast, both CB-3 and CP-2 point out a future desire to be able to track goods from point A to B in a more convenient way by scanning the goods throughout the supply chain and adding transaction automation capability. There is also a need to be able to trace either goods or actors in their supply chain in order to uphold their code of conduct or meet environmental standards and thereby receive certificates (*CB-1-4 & CP-2*). Furthermore, these companies conduct extensive audits on their suppliers to ensure that they meet and comply with required standards. These procedures (track-and-trace and conduct audits) in today's CSC requires extensive manual administration which, according to CB-3 and CB-4, leads to high costs and a lot of resources.

Some experts (*EBSA-2, EBSB-1 & EBSB-2*) see the potential of blockchain and smart contracts to increase the efficiency by facilitating the tracking of goods from point A to B. In addition, the immutable feature blockchain provides makes it perfectly suited to track and record transaction since it makes it nearly impossible to tamper according to Andoni et al. (2019). Concurrently, the complex relationship structure of CSC, illustrated both by Behere et al. (2015) and Lundsjö (2015), causes

[14] Natural language – the language that consists of normal letters and words.
[15] Control language – the syntax or language in which code is written

uncertainties across the entire supply chain. Both the literature and empirical findings shows that the complexity also leads to additional time and costs to finalize a project or when conducting audits etc. The blockchain technology could provide a more transparent supply chain which could mitigate the complexity and hence reduce the additional costs and time, a sentiment shared by Saberi et al. (2018) and Perboli et al. (2018). It would not be necessary to, firstly, manage processes manually and, secondly, facilitate the track and trace of suppliers and goods to receive required certificates. Thus, making the CSC more efficient.

However, as discussed by many of the experts and in the literature, there needs to be a link between the physical world and the digital world, i.e. secure input data. One study by Lanko, Vatin and Kaklauskas (2018) proposed using RFID technology to create this link between the data and the blockchain. If an immutable link cannot be created in a trusted way, i.e. through IoT devices, the blockchain and smart contract technology is very poorly suited for tracking physical goods. Consequently, the challenge lies in finding a solution for securing the input data as to make it tamper proof. If the input data is corrupted, the blockchain and smart contract itself will be corrupted and hence the feature of immutability, trust and tracking makes no sense. ELS-1 also agreed that there needs to be a way to secure the input data for the legal profession to gain traction in the legal field, otherwise it could lead to legal issues where determining the liability is crucial. EBSA-2 discuss how the usage of a third party could be a solution, which hence will require some degree of trust, making it a trusted third party which actors can rely on. ELS-1 also recommended using a trusted third part in the form of a government agency. However, the use of a third party is contentious as Andoni et al. (2019) states that if one needs an intermediary then blockchain is the wrong solution.

Nevertheless, the low level of digitalization in CSC could hinder the usage of a blockchain smart contract solution when it comes to traceability, a concern that Morabito (2017) raises as well. There must be surrounding technologies that feeds the blockchain with enough data, otherwise it will not be possible to track and trace, an aspect heavily emphasized by all the blockchain and smart contract experts. However, as described by CP-7 and CB-2, they are starting to use surrounding technologies which has the possibility to feed a blockchain with data. This implies that the industry is moving in the right direction to be able to feed the blockchain with data.

To conclude, there are other technologies that needs to be in place before, such as IoT devices, that can feed the blockchain and smart contracts with data in a secure and tamper proof way. This is something that CP-7 also highlighted, where the prioritization needs to be on simpler digitization processes due to the low digital maturity. Before mentioned challenges and issues are solved, it would be difficult to increase the traceability and thus the efficiency with a blockchain smart contract solution within a CSC given its current state.

Trust: Potentials and Risk of Blockchain & Smart Contracts

Zaghloul and Hartman (2003) argue that CSC and its relationships is characterized by mistrust due to its structure and high number of involved actors. This is conflicting when compared to the empirical findings (*Figure 4-14 & 4-15; CB-2, CB-3, CS-1, CB-2 & CB-4*) which indicated that there is a relatively high degree of trust among known actors. However, CB-1, CB-3, CP-3, CP-2 and CP-4 pointed out that trust is nothing that is generated immediately and automatically, instead it is something that is built up over time and thus based on the history. Therefore, when contracting new suppliers or until something goes wrong with current suppliers, there will be an evaluation or an initial test to examine the financial status. This indicates that there is a lower degree of trust among unknown actors.

In contrast to the literature (*Behera et al., 2015; Benton & McHenry, 2010*) which state that most of the relationships is temporary and on a short-term basis, the empirical findings imply that this is not the case. One identified trend is the shift to what CB-2 and CB-4 refers to as "partnering" where the aim is to work with few actors that they trust to develop a deeper relationship over a longer period. CS-1 confirmed that there exists trust among actors since the business tends to be very local.

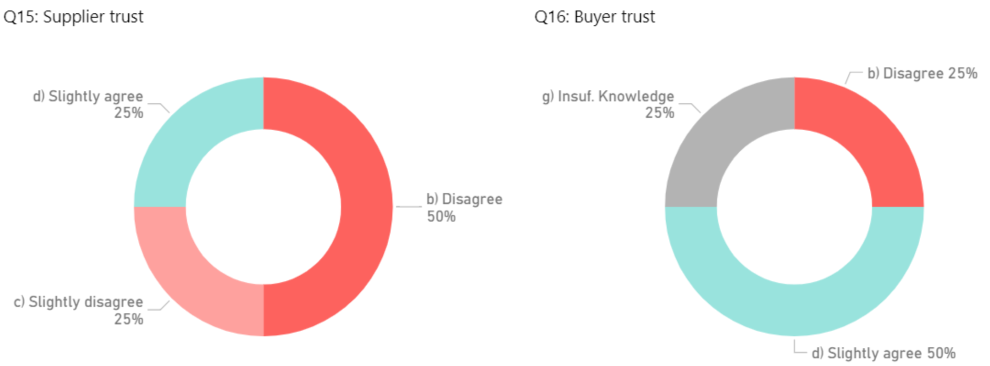


Figure 5-4: Forgery / Lack of trust (buyer and supplier). Based on questionnaire.

In Fig. 5-4 one can observe what those who believed forgery was common to a certain extent answered with regards to the trust for the supplier and buyers. A contributing factor for the degree of trust might be the low level of forgery and fraud, according to the questionnaire, in the CSC. Notably, as can be seen in Fig. 5-4, forgery or fraud does no directly lead to higher mistrust in the construction industry among the companies and their suppliers and buyers. Instead, stated by CB-1 and CB-3, the mistrust is generated via other means such as suppliers not acting according to plan leading to issues such as delay. However, the authors are not stating that forgery does not create mistrust, only that forgery does not seem to be the biggest contributing factor.

As discussed in previous section is how blockchain smart contracts can establish trust between two parties. The literature (*Andoni et al., 2019; Saberi et al., 2018; Lewis, 2016; Apte & Petrovsky, 2016*) consider the ability to establish trust as one of the major contributions of the blockchain technology. ELS-1 also mention how the technologies can increase trust of interaction with governmental agencies. Correspondingly to the experts, the literature also highlights the issue with seeing blockchain as a trust instrument if the data is not self-generated, which is not the case with physical goods or certifications. EBSA-1 argue that if there is trust among actors, there is no need for a blockchain and one might just use a standard database instead.

As there already exist some degree of trust between known actors of a CSC, at least according to the empirical findings of this study, there is no need for a blockchain solution according to previous discussion. However, EBSA-2 argue that blockchain is not only an instrument for establishing trust but should also be seen as an instrument that can provide other features such as immutable smart contracts or the tokenization of physical goods. This argument and features will be further discussed in the section about information sharing and BIM.

An interesting aspect of the existing degree of trust is that it could allow the known actors to trust IoT devices output and thus the data feed onto the blockchain. As Lanko, Vain and Kaklauskas (2018) suggested is the usage of multi-signatures which plausible will reduce intentionally false information and eliminate some trust issues. This study did not investigate if actors would trust the output from IoT devices which is an interest question to examine further. However, this would not be appropriate for actors (e.g. new actors) where there is a lack of trust, or how Zaghloul and Hartman (2003) define the industry, due to the inability to secure input data at the moment. Even though it might increase the degree of trust if unknown actors feel that IoT devices are more trustworthy than the party (e.g. buyer or supplier).

Digitalization and information sharing: Potentials and Risk of Blockchain & Smart Contracts
Due to the structure of a CSC, Lundesjö (2015) emphasizes that it is crucial that there is a common understanding and ensuring that all actors have the same and correct information for a construction project to become effective. The complexity of a CSC creates what can be described as a peer-to-peer network of information sharing, as illustrated in Fig. 2-5. However, highlighted by (CP-7) and McKinsey & Company (2016), there is a lack of a truly integrated platform that is synced between the actors of a CSC. Current interaction with customer is on a very basic level where limited information is shared and sometimes still require manual handling. However, McKinsey & Company (2016) state that the construction industry has changed its mindset and started to embrace new digitized processes and methods to share information. This is also confirmed by CP-5 who explained that there is a growing interest across CSC to share more information in a digitized way to avoid manual handling. Moreover, there is a desire to gather data which can be analyzed for trends. The inability to analyze information that is not digitized is one of the reasons McKinsey & Company (2016) points out as one of the consequences of the poor productivity within the industry. Blockchain could, as can be observed in a Fig. 5-5, work as a digital tool where uploaded information becomes the "single source of truth". This allow actors to have the same view of the reality which Lunesjö (2015) argued are one of the most important factors for a construction project to become effective. It hence also has the possibility to reduce non-value adding activities such as re-enter or re-create information several times during a project life cycle.

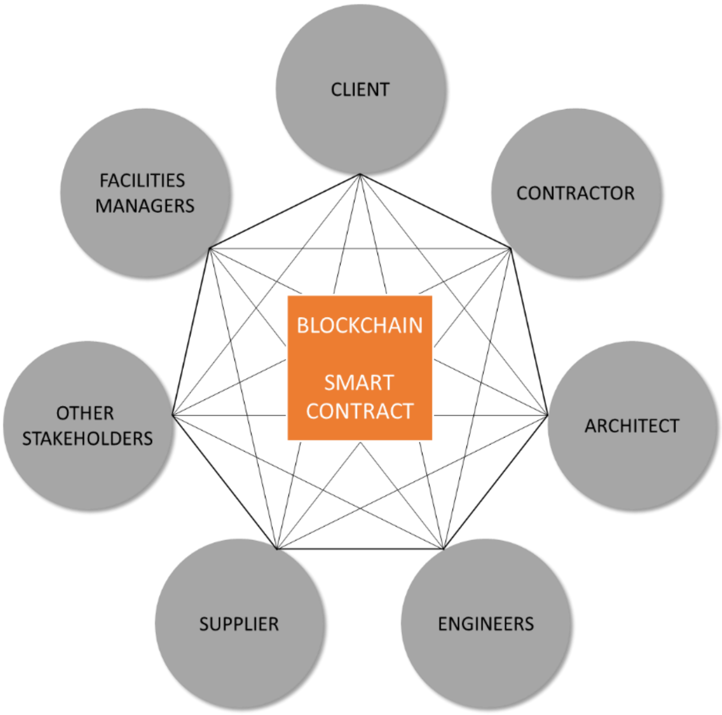


Figure 5-5: Information exchange in a CSC with blockchain. Adopted from Lundesjö (2015).

Today's actors in the construction industry use BIM technology to share information related to a construction project, a tool which the empirical findings found was adequate. Also, the trend towards "partnering", where actors share information and form long term relationships, among different actors in the construction industry indicates this. However, the industry is not utilizing the full potential of the BIM technology yet. As Turk and Klinc (2017) argue, there are some weaknesses with the BIM technology that needs to be solved to achieve industry adoption. Currently, when uploading data to the BIM, there are no function to track who did what and when or who changed the information. The features of the blockchain technology has the potential to overcome mentioned issues. As EBSA-2 argued, the blockchain technology is more than creating a trustworthy infrastructure. Thus, it is not about creating trust among the peer-to-peer relationships since, as discussed, it is not possible to secure the input data. However, the benefits blockchain could provide to BIM is that since every transaction is created and marked with the actor's public key using the actors private key thereby making it possible to manage information on who did what and when. This is the aspect that Andoni et al. (2019) refers to as auditability within blockchain technology. This is something that is important from a legal point of view according to ELS-1. Moreover, it will not be possible to tamper with the data once it is uploaded. Hence, it provides an immutable record of transactions which could be the basis for any disputes and legal issues that might occur. Important to note, the blockchain smart contract solution would not replace the BIM technology. The authors believe instead that the blockchain technology will work as the database for the information. Thereby negating the interoperability aspect, as discussed by Lu (2018) and all the blockchain experts, as well as making sure that all the data is immutable and potential forgery can easily be back tracked. This would help alleviate concerns discussed by Turk and Klinc (2017).

Moreover, CB-2 and CB-4 discuss "partnering" further where actors at an early stage should share information, knowledge and expertise etc. This collaboration has the potential to increase efficiency as described by Lorek (2018). However, there is a concern of trust and where other parties could take benefit of the information being shared. This is also the case if one would use a blockchain solution since the information is there and available at all time for all of those who has access to the ledger. Therefore, blockchain would not be able to solve the trust issue related to "partnering". However, those who agreed to different degrees that sharing information on an open ledger is something bad does not seem to be due to the lack of trust to the supplier or buyer, as illustrated in Fig. 5-6. This figure illustrates the individuals who believes that an open ledger is something negative and their respective answers regarding trust.

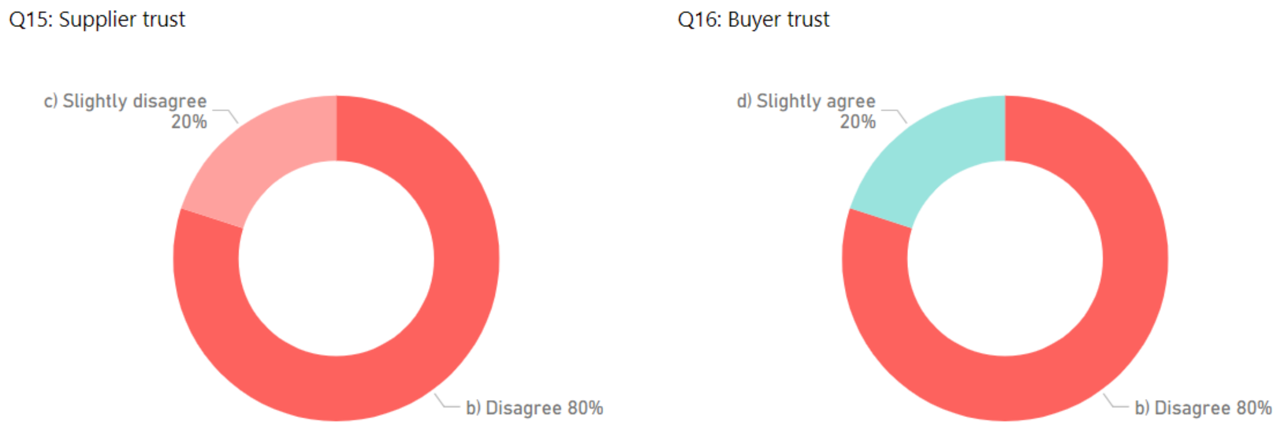


Figure 5-6: Open ledger / Lack of trust (buyer/supplier). Based on questionnaire.

One major paper-based information sharing processes is the handling of delivery notes where all interviewed actors from the construction industry only could see benefits with a digital delivery note. As described in the flows of raw material and RMC (subchapter 4.1.2 and 4.1.3) it is a very manual process which require a lot of human involvement. Additionally, since the delivery note is manually entered into the system it allows for human errors and complicates the matching process with the invoice. As Lundesjö (2015) highlights, the challenge lies in avoiding that information is re-created or re-entered several times during a project's life-cycle. This is what is happening with a manual paper-based process. However, a blockchain smart contract solution cannot solve this alone, but digital delivery notes uploaded onto the blockchain might increase the efficiency in terms of significant acceleration of workflow where activities related to delivery notes can be performed in automatic or semi-automatic modes, thus reduce the number of employees involved in the process.

Concluding Remarks: using Blockchain & Smart Contracts in Supply Chain Managment
Blockchain and smart contracts seem to have the potential to improve the efficiency CSC. This will however require that the paper-based processes that are prevalent today are replaced with more automated and digitalized processes. Also, by facilitate the flow of information through an integrated platform, e.g. BIM, which would allow actors to have a common perspective of the reality. Moreover, it could reduce the number of disputes and hence the additional costs related to it. The immutability blockchain provides also allows for traceability of both transaction but also follow the goods from point A to B. The authors are however not saying that blockchain is the only solution to this and other technologies may be more suitable implementations to gain this desired effect.

Furthermore, there is the concern of securing the input data and the legal aspects surrounding smart contracts that needs to be solved before blockchain and smart contracts can truly be utilized. Until then, there could be a discussion if a blockchain smart contract solution would be the most appropriate solution to improve the efficiency in the construction industry at the moment or if the focus should be to automate and digitize transactions in other ways.

5.3.2 Supply Chain Financing

Currently none of the SCF solutions that Tate, Bals and Elram (2019) identified are being used in the construction industry. This was clear as raw material suppliers, concrete producers and construction companies all stated that they do not use these types of financial instruments. However, as Tate, Bals and Elram (2019) states, a SCF solution is any application that improves the financial performance of the supply chain. This performance improvement was something which all interviewees were interested in, more specifically the aspect of contract automation, which can arguable be seen as a form och SCF depending on how the functionality of the smart contract is build. One example of this was proposed by Blockchainhub (n.d.) in Fig. 2-16.

However, none of the industry professionals expressed any interest in using a Reverse factoring system, one of the most common forms of SCF as identified by Klemann (2018). The actors also did not mention issues surrounding financing in the form of loans which is one of the primary selling point of reverse factors as mentioned by Wuttke, Blome and Henke (2013). However, the authors did not expect to gain any information surrounding financing issues due to the sensitive nature of the subject. Additionally, the firms that were interviewed were all massive firms were the financing does not tend to be an issue. Furthermore, the construction industry showed no indication of implementing a Dynamic discounting system, Inventory financing or Purchase order financing. The reason that the industry has not implemented this type of instruments is most likely due to the conservative nature of the business and the low technological development as mentioned by almost every interview respondent.

Furthermore, Tate, Bals and Ellram (2019) state that blockchain technology and smart contracts can revolutionize SCF and increase the efficiency. ESCFA-1 agrees with this, adding that the technology can help increase visibility, further improve C2C cycle via faster administration and ensure tamper proof transactions. EBSB-2 also stated that the primary advantage of smart contracts on the blockchain is the use of automating the transactions, also allowing for better lines of credit due to a more complete transaction history being tracked in an immutable fashion on the blockchain.

The smart contract and blockchain technology are more of a complement to the current SCF systems as discussed by Tate, Bals and Ellram (2019), this was also pointed out by ESCFA-1. The aspect of incorporating blockchain with inventory financing and dynamic discounting is a fascinating prospect. Dynamic discounting would be built into the smart contract, thereby allowing for both automated transactions as well as the ability to extract the transaction at an earlier date with a discount. This type of logic can easily be coded into a smart contract due to the simple logic. Furthermore, the banks can provide better inventory financing as the goods have been tokenized and are stored on an immutable blockchain, thereby resembling an inventory financing system. However, as previously stated, there is an issue with securing the input data and ensuring that the tokenized assets are correct, something that most of the blockchain experts were concerned about and uncertain on how to handle.

ESCFA-1 further presented the issue of using similar IT-infrastructure and the need for the blockchain and smart contracts to work with existing ERP systems. This is the aspect of interoperability as pointed out by almost all the experts. The aspect of handling the inner interoperability, communication with the existing ERP system and blockchain, will have to be handled by a combination of API's and SQL servers, i.e. sending information automatically to the blockchain as described by EBSB-4. Further, the interoperability across the supply chain will be solved by using the same blockchain solutions as pointed out by EBSB-4. Moreover, there is a need for a combined effort when developing it for the industry. The concern surrounding interoperability is also brought to light by Lu (2018) and Morabito (2017), stressing that there needs to be some form of way for the different blockchains to communicate. The authors believe that the companies that are considering implementing such a solution should attempt to gather all the actors and make sure that there is a standardization and consensus on what should be developed and on what platform to ensure interoperability.

Transaction Automation: Potentials and Risk of Blockchain & Smart Contracts

There was an apparent need and a want for transaction automation within the construction industry as indicated by all the respondents. Furthermore, there is a problem with transaction speed as CP-4 stated that 60-70 percent of invoices are paid late and CP-3 echoed this saying that outdated systems and slow administration leads to long C2C cycles. However, the current state of automation and technology level is very low within the construction industry which can prove to become a hindrance when developing such a solution.

This trend was also present in the industry questionnaire. In Fig. 4-19 one can see that a significant minority believed that transaction speed is something that should be increased and in Fig. 4-18 that the time spend administrating transactions was too high. A cross relationship analysis of the respondents who answered that the cost of administration was not justified also answered that the time spent administering transactions was too high, as can be seen in Fig. 5-7. Concurrently, the relationship indicates that the costs are primarily associated with time spent on administration, however the authors are not definitely stating a direct correlation or causation between the two effects.

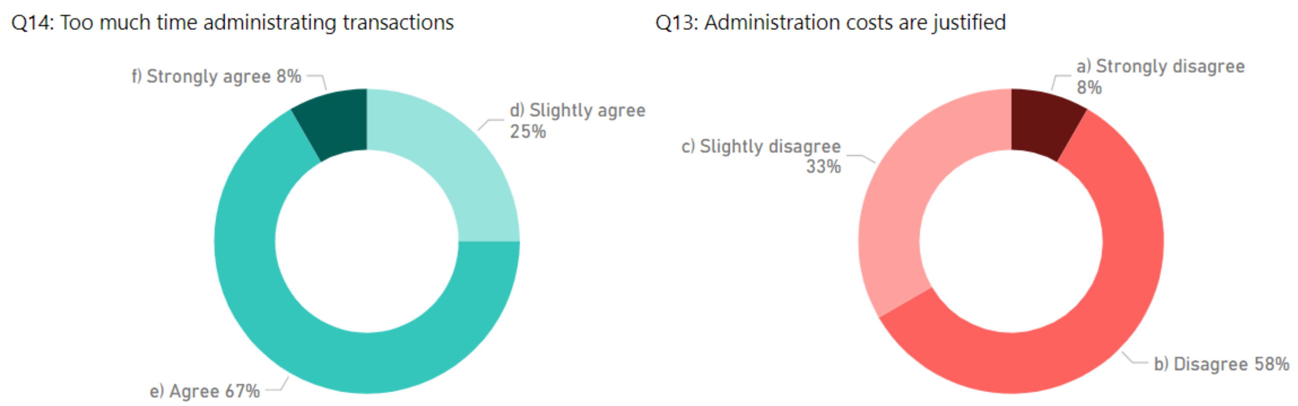


Figure 5-7: Time administrating / Administrating costs. Based on questionnaire.

Some of the SCF advantages are increased administrative efficiency, stronger relationships and flexibility in the system, as identified by Klemman (2018) as well as Liebl, Hartman and Feisel (2016). In contrast to this Caniato et al. (2016) stated that SCF is only as efficient as the actors are with working with the system and as More (2013) states the SCF system will only work if there is a common goal among actors. It is clear from all the interviews and questionnaires that there is a common goal of increasing the efficiency within the supply chain as well as increasing the administrative efficiency, thereby the sentiment of SCF lines up with the wishes of the actors in the supply chain. This common goal for automation is key for the industry to adapt an automated transaction system or a SCF system.

The authors believe that a blockchain and smart contract system can be useful for the transaction automation as does several of the blockchain and smart contract experts, including the SCF expert. This is also echoed in the literature where Fox (2016) and Tate, Bals and Ellram (2019) believes that smart contracts, with blockchain technology, will help to revolutionize the construction industry. Further, Lank, Vain and Kaklauskas (2018) showed that these technologies can be used to greatly increasing the efficiency in the supply chain. However, the authors of this thesis also see several issues with the low digitization, primarily the need for paperless transactions, for example, no more paper deliver notes. This is also echoed by Meijer's (2016), stating that there needs to be much more digitization for a blockchain smart contract solution to be feasible to implement. As Mason and Escott (2018) states, there is a lack of confidence in the construction industry and a lack of skill to implement smart contracts.

Intermediaries and Payment: Potentials and Risk of Blockchain & Smart Contracts

The concept of intermediaries within blockchain and smart contracts technology is one that is highly contentious. The majority of articles such as Ifeanyi (2018), Meijer (2016), Law (2017) and Casado-Vara (2018) all believe that the blockchain and smart contract technology will remove the necessity for intermediaries, specifically banks. However, the authors of this thesis believe that this is only the case within the world of cryptocurrencies and not within the aspects of physical goods, at least not at the current state of IoT devices in the construction industry. ESCFA-1 states that he believes that intermediaries will still be needed, and the technology will only be a complement to smart contracts and blockchain technology. Not everyone agrees with this, as Ifeanyi (2018) says that the technology has the potential to make intermediaries redundant. As previously mentioned, a physical good blockchain will possibly require a third party securing the input data to the blockchain, supported by the blockchain experts. This sentiment however is not shared by Andoni et al. (2019).

Primarily, ESCFA-1 argue that smart contracts and blockchain will not become a technology that removes intermediaries such as banks, instead it becomes a complement. This sentiment was agreed upon by many of the blockchain experts such as ESBA-2, EBSB-1 and EBSB-2. In contrast to this, several of the people interviewed, including the questionnaire, showed that there was a willingness to remove the banks from the transaction process. However, as CB-1 stated the banks are not only necessary for the transaction process but they are also crucial for the financing of the supply chain. Banks are crucial in the loan financing of investment, a source of investment which will be lost if one wishes to cut the banks of completely. Hence, it is not reasonable to believe that it is feasible to exclude intermediaries within the a blockchain smart contract solution within a SCF construction solution.

If one also wishes to cut out the banks completely, actors will need to start using cryptocurrency on the blockchain which none of the actors interviewed were prepared to do. Furthermore, a quick cost analysis showed that a business who moved over to an EOS.io application would be spending no money on transactions as they are free while the bank charge a transaction cost of approximately 1,50 SEK per transaction. However, the authors believe that this cost is of such an insignificant amount that this argument does not merit removing the bank intermediaries and the additional value that add to the industry, at least not for the case company which was studied. Also note that this transaction cost is a very rough estimate and excludes many operational costs that would increase the overall cost per transcation.

Concluding Remarks: using Blockchain & Smart Contracts in SCF
At current stage, the authors do not believe that a blockchain smart contract solution will help the construction industry to improve their SCF or implement a SCF method. The reasoning being the low digital maturity and the prevalent use of manual administration, one example being paper delivery notes. However, the authors still believe that blockchain and smart contracts has the potential be able to provide great benefits to SCF solutions. This change will most likely first be implemented by banks who have a better technology backbone as supported by Klark et al. (2017).

This means that the banks have a much better opportunity to implement such a solution which the construction industry can then take advantage of as they are customers to the banks. The construction industry should investigate the possibility of first implementing a traditional SCF methods to improve financial flows. However, this is outside the scope of this thesis and conclusions will not be made on this as this would still need to be investigated.

5.4 Designing an Appropriate Blockchain Smart Contracts Solution

This subchapter will analyze the third research question; *How would a blockchain smart contracts solution be designed to be suitable for a construction supply chain?*

Firstly, in 5.4.1, the most suitable blockchain configuration for a CSC will be analyzed as well as the most suitable for a network including governmental agencies. Secondly, in 5.4.2, on a more technical level, some development recommendations when designing a blockchain smart contract solution for these two scenarios will be discussed and how a potential implementation could take place.

5.4.1 Configurations

The blockchain literature is almost exclusively focused on the following three types of configurations: public, consortium or private. Each of these are characterized by their chosen architecture and distribution method. When selecting an appropriate configuration one can clearly state that there is no need for a private blockchain in the construction industry, or any industry for that matter, as all the blockchain experts interviewed agreed unanimously that the concept of a private blockchain is nonsensical since it simply becomes a database. The interviews also showed that actors in the CSC are unwilling to share their transaction information with everyone which means that a public permission-less blockchain is not an option either. This since the configuration allows anyone to join the blockchain and interact with it.

This leaves only two options left, either the consortium blockchain or a public permissioned blockchain. These two options both can be selective about who is allowed to interact with the blockchain, however, at different extents. The consortium blockchain allows the company to be completely selective about who has access to the blockchain including the information that is allowed to be seen and who can validate transactions. However, in a public permissioned blockchain everyone can see the information on the blockchain, but restrictions are set on the interaction with smart contracts.

According to EBSA-2 and EBSB-4, the more interesting case is when you have a public blockchain as it is truer to the true ethos of what a blockchain is. However, EBSB-1 believes that a consortium blockchain, such as Hyperledger, is the stronger candidate due to its architecture versatility. EBSB-2 has similar thoughts, however, not restricted to Hyperledger and is open to public blockchain solutions as well within SCM. EBSB-3, however, believes that the configuration that solves the problem despite the configuration is the right method. Due to this split in the expert's opinion it becomes hard to pinpoint which is the better alternative. However, when considering the aspects of the industry actors who are unwilling to share information open with everyone one can conclude that the only alternative left is the consortium blockchain for the construction industry. To clarify the only blockchain alternative is a consortium blockchain but it is not the only alternative on the market, another database may provide a similar solution as described by all the blockchain smart contract experts.

CB-5 described that the process when tendering for government jobs needs to be open, transparent and requires several certifications. Since the transactions need to be visible and have certain clear defined certifications that are required before tendering one possible implementation is public permissioned blockchain. This will create a transparent process with high security and lower the possibility of manipulation. These two different configurations for the two different industries will be developed further below.

Construction Industry Configuration

The most suitable blockchain configuration for the CSC is possibly a consortium blockchain. This due to the fact that the industry actors that were interviewed (*CB-1, CB-4, CP-4 & CP-5*) clearly stated that they were open for sharing information among actors. However, sharing should be restricted to the relevant actors, that is the people involved in the construction or in the supply chain and not competitors. The consortium solution is the only blockchain that allows for this form of blockchain, further supported by EBSB-4, EBSA-2, EBSB-3, EBSB-2, Laurence (2017), Bauman et al (2016) and Zheng et al. (2018). This form of consortium blockchain also allows for the use of automated transactions, using smart contracts, without having to use cryptocurrencies. This is very important as many actors showed concerns around the use of cryptocurrencies. This will, as described by ESCF-1, require the collaboration with intermediaries such as banks to accept the transaction data from the smart contract. However, as described by CP-7 and CP-3, if the files are in a standard format this is not an issue. Since it is a consortium blockchain, EBSB-2 stated that the most effective form of consensus is the use of Delegate Proof of Stake using multiple oracles. Due to this form of consensus and the use of a closed consortium system it would mitigate the issues with slow transactions speeds which was discussed by Andoni et al. (2019). However, this simplicity does infect the security as described by Drescher (2017) and there can be a risk of a 51 percent attack as described by Andoni et a. (2019). An important part, pointed out by EBSB-4, is to collaborate across the supply chain when developing the blockchain. This will also help ensure that everyone uses the same blockchain and hence one will remove the issues with interoperability as discussed by the blockchain experts as well as by Lu (2018). The process of determining the most suitable blockchain configuration is illustrated in Fig. 5-8, as indicated by the red lines. To reaffirm the previous statement, the authors of this thesis are assuming that input data can be secured as to create a representation of the usage of the decision tree.

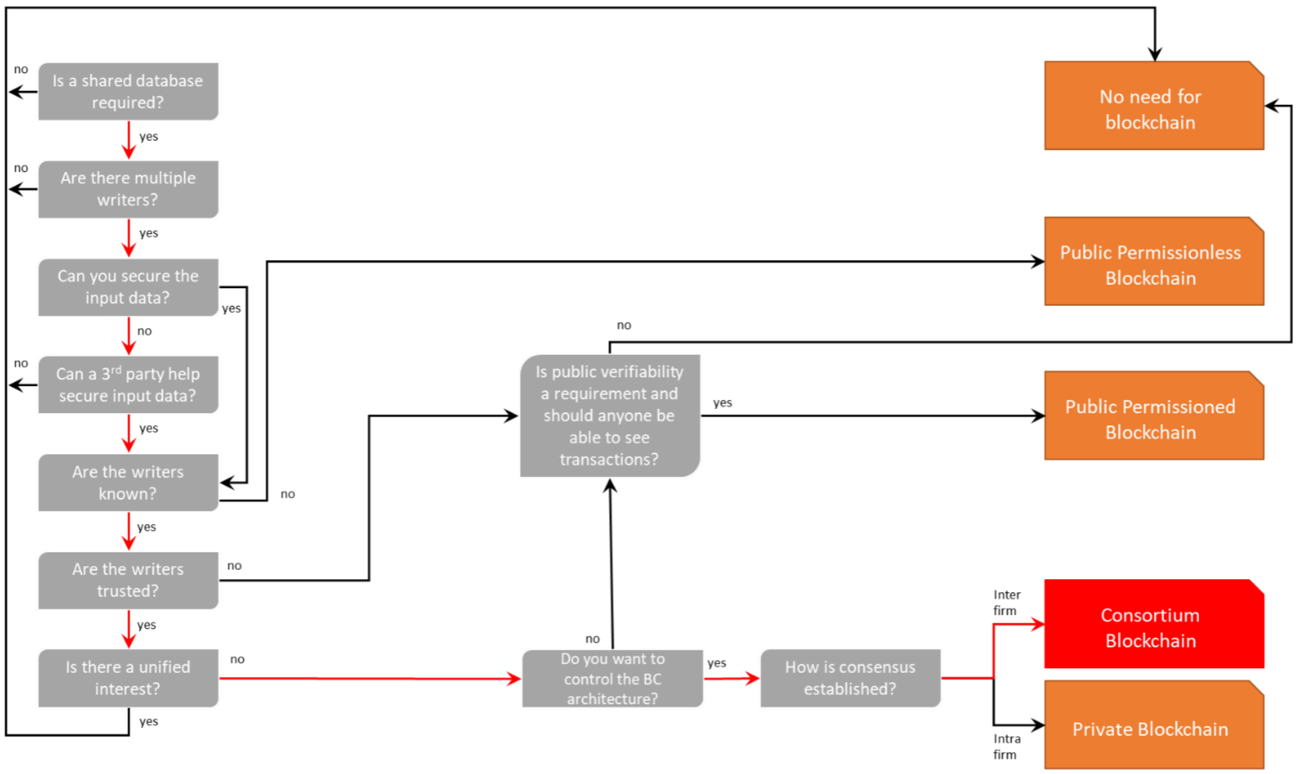


Figure 5-8: Path of selecting the most suitable blockchain for the construction industry.

Governmental Agencies Construction Procurement

With regards to a network including governmental agencies, the most appropriate configuration is the public permissioned blockchain using a governed platform. The process of determining this is illustrated in Fig. 5-9, as indicated by the red lines. One of the reasons for this is due to the fact that the blockchain is not developed or controlled by one node which means that the issues surrounding gatekeeping and building a consortium blockchain is circumvented (*ELS-1, EBSB-4*). Secondly, everything is publicly verified which means that the feature of security is added, which will be important for the overall trust in the system (*Drescher, 2017*). Andoni et al. (2019) states that public blockchains, due to the high security, have slow transactions speed. However, in the recommended system the transactions are fast while still being secure due to the public verifiability being a governed system which is more efficient as described by EBSB-4. According to EOS.io website, the public permissioned blockchain recommended by EBSB-4, is able to perform 3,996 transactions per second while in comparison as Swan (2017) and Croman (2016) state that Visa can only do 2000 transactions per second. Furthermore, with the use of a public blockchain there is no risk of a 51 percent attack on the blockchain as described by Andoni et al (2019), thereby increasing the security even more than a consortium blockchain. Therefore, the trade-off between security and speed is not as much of an issue as previous blockchains, a trade-off previously required as identified by Drescher (2017).

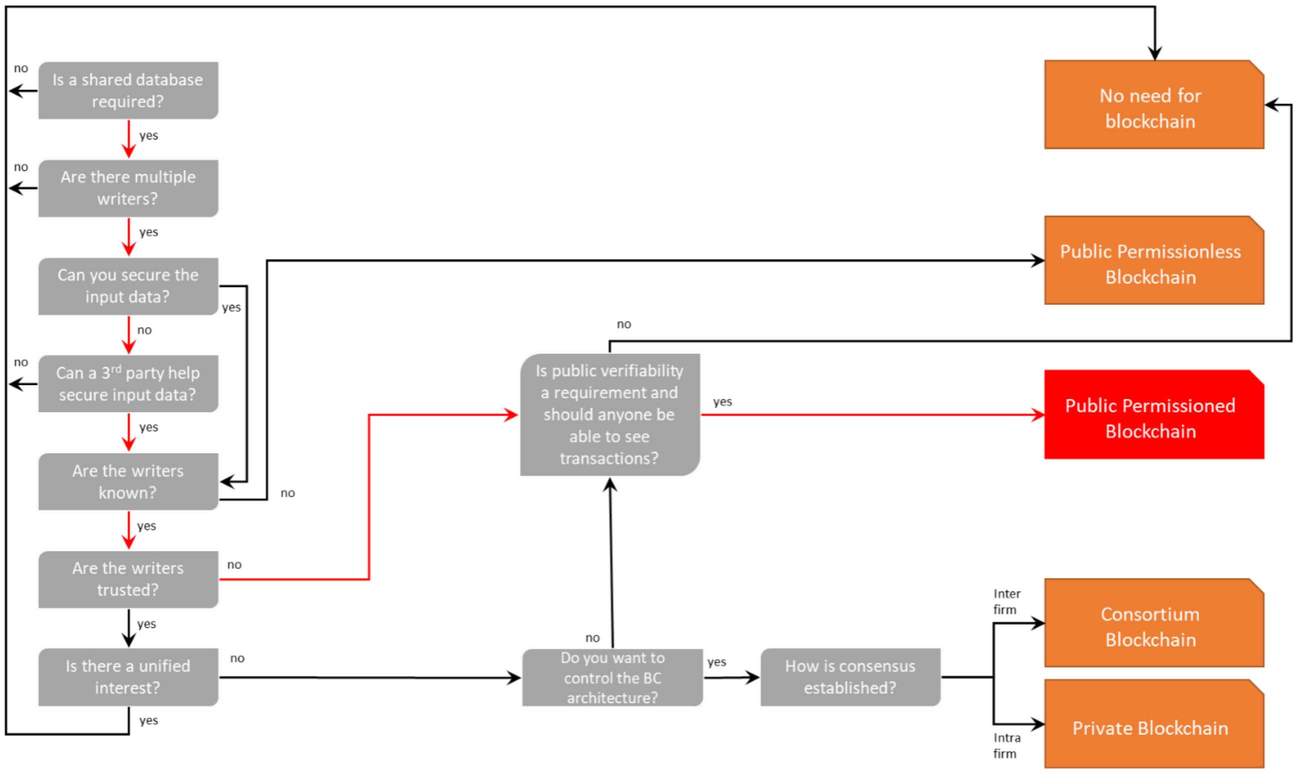


Figure 5-9: Path of determining the most suitable blockchain for governmental agencies.

One of the biggest challenges for blockchain technology is the aspect of interoperability as mentioned by Lu (2018) as well as EBSA-2, ELS-1 and EBSB-4. However, EBSB-4 states that if all the systems are running on one public permissioned blockchain then the interoperability issue is negated. So, if each actor wishes, they can customize their own front end that communicates with the public permissioned blockchain which is then converted into the standard format that all other permissioned to see the information. Further, EBSB-4 states that the underlying data is stored in a multi index table, essentially a big excel sheet, or SQL database which means that one can call using API's any information that one would need to retrieve allowing for public openness. Furthermore, EBSB-4 states that any information can be stored on the public permissioned blockchain. However, one of the remaining issuesb with this form of solution is that the data that is stored in a public blockchain cannot be modified after it has been registered. This becomes a big issue when it comes to the tokenization of physical goods. One needs to be able to secure the input data as specified by Andoni et al. (2019), Saberi et al. (2018), Lewis (2016) and Apte & Petrovsky (2016). This was further stressed by all the blockchain smart contract experts, law expert and SCF expert as this is incredibly difficult to accomplish. As discussed with many of the experts, the use of IoT devices is the best alternative but as specified by ELS-1, EBSA-2, EBSB-2 and EBSB-4, IoT devices can be manipulated and hence negating the usefulness.

Concluding Remarks: Configurations

Due to this massive issue of securing the input data the authors do not believe the implementation of a blockchain smart contracts solution at the moment for the construction industry, or any physical goods for that matter. The previously mentioned low level of digitalization in the industry creates even greater issues in creating a trusted and "one source of truth" for the physical goods. This means that the data will always be under the threat of being tampered with and negate the point of storing it on the blockchain as it unable to be changed, something also highlighted by Flori (2017). Corrupted input data means corrupted blockchain. The authors do however recommend the construction industry into working towards better digitization that can allow for increase automated transactions, not necessarily smart contracts, but instead a normal contract that stipulates some form of transaction automation possible through a third party. The use of a trusted third party is something which ESCFA-1 also emphasized in saying that any SCF platform would still require this to be feasible. However, for the sake of future guidance the next subchapter 5.4.2 will give a brief overview of what the development and architecture could potentially look like in a future concrete supply chain or a governmental agency working with construction procurement.

However, it is important to note that certain theoretical framework may not be relevant anymore as the technology changes very quickly. This was something that EBSB-4 also mentioned, stating that the blockchain technology changes so rapidly that a lot of the assumptions and limitations quickly become obsolete. One example is the trade-off in Fig. 2-14 which no longer has such clear divides between the different configurations.

5.4.2 Development

The following subchapter is going to describe how a blockchain smart contracts can potentially be used in two different settings. One being the concrete supply chain, the case companies specific supply chain, and the other being a potential governmental agency governing the construction industry. These sections are potential solutions that are based on the information collected during construction industry and expert interviews as well as the observation.

The Concrete Supply Chain

This section will consider how a blockchain smart contract solution could resemble within a concrete supply chain. As previously mentioned, the authors will be taking a hypothetical situation, however not unreasonable, based on the respondents interviews as well as the experts to exemplify this. This example will primarily be concerned with what a blockchain smart contract solution could look like using the current projects being worked on at the case company and restricted to the production and delivery of RMC.

As has been previously stated, the industry professionals that were interviewed mentioned that sharing information is something that they are positive about implementing. CS-1 specifically stating that it would have positive returns. However, as several respondents also mentioned (*CB-1, CB-4, CP-4 & CP-5*) that they only want to share certain information with certain actors and not have completely open books with everyone. As previously mentioned, this makes the consortium blockchain the most viable. This is further supported by EBSB-1, EBSB-2, EBSB-4 and EBSB-3 who believe that a consortium blockchain is the only solution for companies that want to use a blockchain and not share information on a public ledger. The most important part as stated by EBSB-4 is to create a blockchain by everyone for everyone.

Some of the most important aspects for the blockchain solution will be the ability to have automatic transactions, via smart contracts, and the ability to secure the input data and finally the ability to back track transactions. The ability to automate the transactions will require the bank intermediaries to be connected to the blockchain solution, something that ESCFA-1 states is still essential for a blockchain solution smart contract solution who wishes use current SCF methods and established currencies. The reason for this is because this blockchain will not be using any form of currency only a tokenization of physical assets and transaction. Furthermore, as previously stated, the companies still wish to trade using established non-cryptocurrencies, so the execution of transactions will still need to go via the bank.

With regards to smart contracts, many of the industry actors stated was that they would not be comfortable with using smart contracts as a legal document due to its inability to be used in the court of law. Hence, as ELS-1 mentioned one can have a digital contract that is written in normal language which is enforceable by law, but the contract also refers to the code which the smart contract is written. Each signatory to the digital contract will be accepting the transaction automation of the smart contract code.

The aspect of input data for the concrete supply chain could be handled by the technology mentioned by CP-7 and CP-5 where the concrete trucks are being fitted with technology that controls the quality of the concrete during transportation and uploading the consistency of the concrete to the cloud. This information will be intercepted and feed into the blockchain and thereby become an immutable source of data verifying the quality of the concrete delivered. Furthermore, this system allows for real time location tracking which is also sent to the blockchain. Thereby taking care of the concerns raised by the blockchains experts, and ELS-1, surrounding the input data. Also adding the functionality of the digital signature of delivery notes as was currently being worked on as stated by CP-7. This also helps to cover the five product dimensions as discussed by Saberi et al. (2019).

Finally, the backtracking will come from the digital signatures on the blockchain associated with the input data of the material. For example, each concrete mixer trucks consistency and location tracker will be given a specific identity on the blockchain. Using this identity one can backtrack and control what the quality was of the delivery and where the truck came from using its location tracking and thereby one can go back and see if the issue was in the raw material used. Since the concrete is mixed using a computer system as described by CP-6 one can upload this information and thereby backtrack the raw material used.

With regards to the actual design one will also be required to create a UI (User Interface) that works via API communication with the blockchain as to make sure users adapt to the new technology and lessens the change management required. This is something that EBSB-4 focused heavily on, making the UI simple to use. Gupta (2018) states that the consensus algorithm will need to be adjusted depending on the business context where blockchain is being implemented. EBSB-2 states that with regards to consensus, Proof of Authority based on multiple oracles is the most suitable in the case of CSC. This is where you choose only a few stakeholders that have the authority to validate transactions, possibly using third party validator as described by EBSB-4.

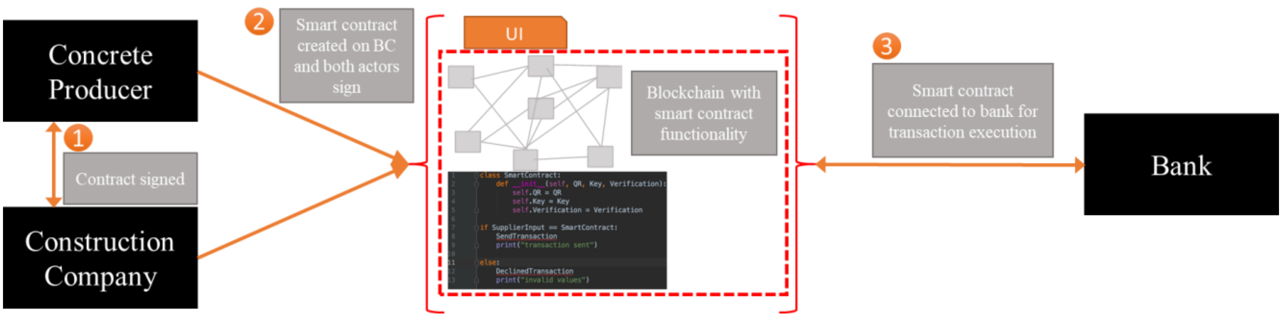


Figure 5-10: Blockchain smart contract set-up. Own model.

In Fig. 5-10, one can see how the process would be conducted before any transactions take place. First the platform blockchain will need to be built, also adding a simple user-friendly UI with which the parties can easily interact with, as stated by EBSB-4. It is important that all the actors are involved in the design process as to facilitate trust, as EBSA-2 states it is not a trust instrument just because it is blockchain technology. (1) The parties will sign a normal contract that can be used in court, either digital or physical. This contract will stipulate all the usual ABM-07 requirements, and any other contractual terms, as stated by all the interview respondents as well as specify that all transactions will be controlled by the smart contract on the blockchain. (2) The two parties will register their nodes on the blockchain and sign the smart contract using their private key and (3) their banks will also have to connect their transaction systems to allow for automated transactions. The UI will require to have added functionality as to be useful. One example of this functionality is the ability to place orders that automatically check the contract specifications. Furthermore, allowing the bank to connect to the system would allow one to add functionality that allows for a SCF solution akin to dynamic discounting. The way to do this would be to add a caveat to the code where the concrete producer will first be paid 30 days after delivery, however, with the option to request the transaction at and earlier date for a discount.

The RMC supply chain will also be required to interact with the blockchain, how this will work is represented in Fig. 5-11. It is a reconstruction of Fig. 4-4 and uses the empirical findings to create an amicable solution that coheres to all the industry professional requirements.

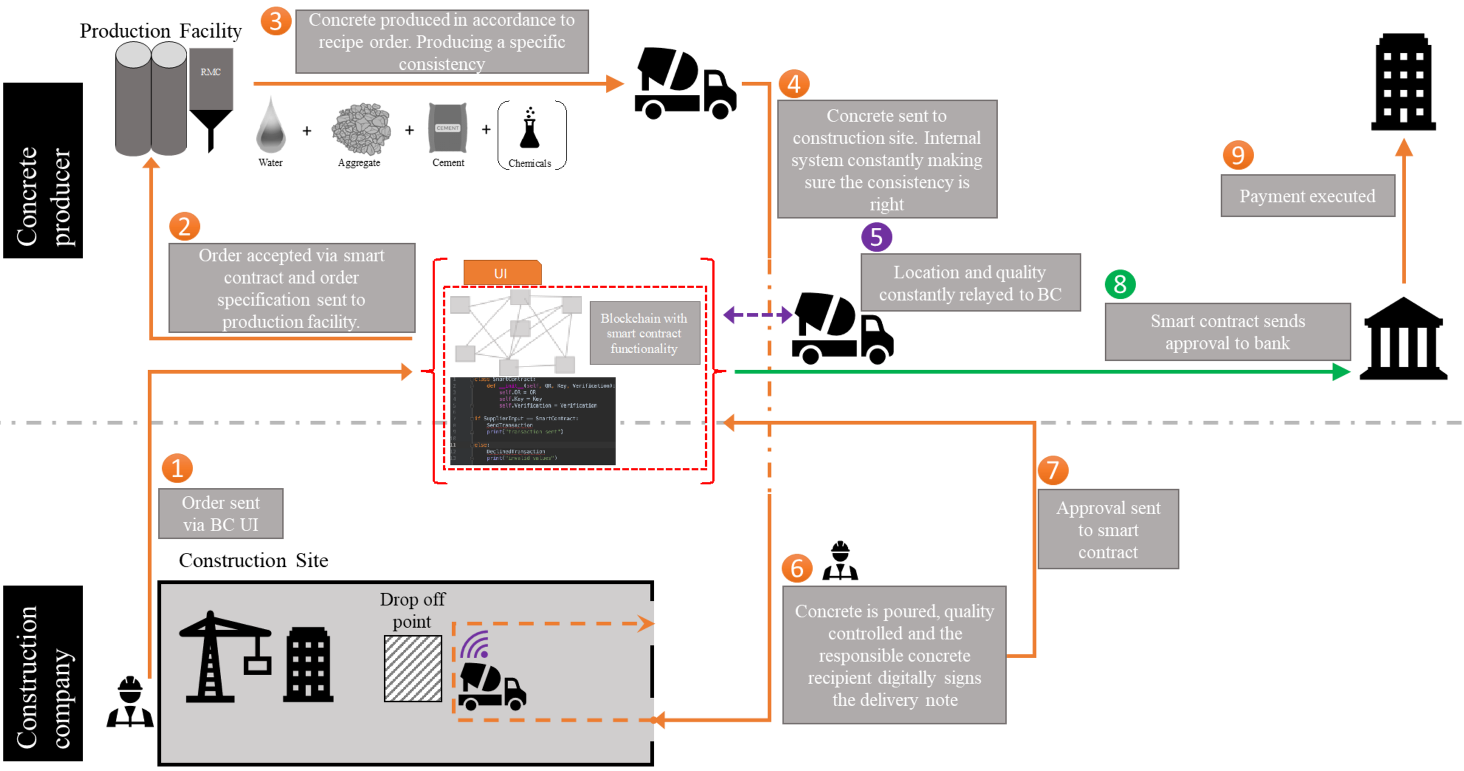


Figure 5-11: RMC supply chain using blockchain smart contract solution. Own model.

The process would work as follows; (1) The construction company that wishes to order something does so via the UI that is connected to the smart contract blockchain system. The order will be matched to the existing contracts and if there is an existing contract for that type of order (2) the smart contract will tell the production facility to produce the concrete according to the specifications. (4) The concrete is loaded into a concrete mixer truck that has the aforementioned system that tracks the consistency and the location of the truck. (5) During the trip to the construction site the concrete mix truck is constantly pinging the blockchain feeding it with information about the consistency, quality and place. The system will also make adjustments to the recipe to make sure that the concrete is the appropriate quality when arriving at the construction site. (6) The person responsible for receiving the concrete will, as always, perform a visual inspection, and sign the delivery note using the aforementioned app. (7) This will then be sent to the smart contract as a confirmation of delivery and quality which will then (8) send this confirmation to the bank showing the verifications and in turn (9) the payment will be executed according to the code.

Concluding Remarks: Concrete Supply Chain

This consortium blockchain solutions with smart contracts is nothing unique per say and could be solved using other technologies. As EBSB-4 states - a consortium solution is nothing unique and there are other solutions on the market that allow for an immutable shared database and the ability to have automatic transactions. However, as EBSA-2 states the blockchain technology should not be limited to whether or not it is unique instead for the interesting aspects it can provide for a company; including tokenization of physical goods and the use of smart contracts and automated contracts.

It does however still solve a problem, which EBSB-3 stated as long as it solves the problem it is fine. The problems this solution solves is the decreased administration and increased automation across the supply chain, both aspects that all the respondents in the questionnaire as well as the interviews were highly interested in implementing. This consortium blockchain also solves the problem surrounding information sharing with relevant parties, as none of the actors interviewed wanted to have completely open books. It will also require other technologies such as the apps and the concrete mixer truck system, however, these solutions are currently being tested and not an unreasonable assumption to make.

Having a contract that refers to the smart contract code also negates the issues surrounding the contract not being able to be enforceable by law as stated by ELS-1. With regards to coding the scenarios, CP-7 has already stated that this should not be an issue and something that is feasible within the delivery of concrete, especially with these new systems. Finally, there is the need for change management when choosing to make this form of change something that is stressed by Morabito (2017) and CP-7. As all the actors have stated, the industry is conservative, and these types of changes will take time to implement which increases the importance of a simple and user-friendly UI.

To conclude this recommendation is only one type of system, the amount of programmability is endless as explained by Maxwell and Salmon (2017). It is important, as EBSB-4 stated, to be flexible and adjust to changes quickly as things change very rapidly within the field of blockchain.

Governmental Agency Construction Procurement

In this scenario the authors will be evaluating the situation that ELS-1 stated could be the most feasible and interesting use case. In this section the authors will evaluate the use of a blockchain smart contract solution on a governmental agency who procures for construction projects.

When tendering for a government project there is a need for several documentation to be submitted and all certifications and qualifications need to be thoroughly controlled, according to CB-5. For the sake of this example, the authors will use the governmental agency "Trafikverket", the Swedish Transport Administration. The agency that in part stands for the construction of the public roads. Trafikverket's procurement process is presented in Fig. 5-12.

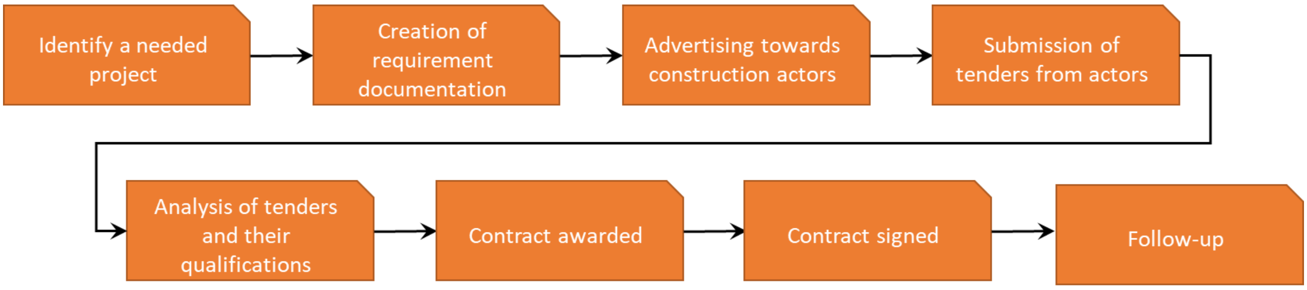


Figure 5-12: Trafikverket's procurement process. (Trafikverket, 2019).

Initially, there is some need, i.e. a production project. Thereafter, a specific contract is documented specifying what is going to be needed, the requirements on the tenderers, subject of procurement and how these tenders will be evaluated. They then advertise this information and tenders can be submitted. After this, tenders are analyzed and qualified which then leads to the awarding of the contract and the signing of the contract. Then the contracts are monitored and continuously followed up during the contract period.

The most feasible starting point is a public permissioned blockchain such as EOS.io that allows for highly programmable smart contracts and that allows for permissioned transactions, as recommended by EBSB-4. The first step would be for the smart contract to be published on the EOS.io blockchain where all the specifications for receiving the contract is specified. EBSB-4 describes how programable the smart contracts are to any specifications. As these requirements are set, Trafikverket can then specify the required certificates for receiving the contracts. For example, this could be that the supplier must have an ISO certification suitable for the project and a registered and approved financial statement registered with the Swedish authority "Bolagsverket". This type of certification immutability is something that ELS-1 found very fascinating and a suitable use case for the blockchain in the construction industry.

The requirement for these suppliers would then be that their company must have their certificates signed on the blockchain by these governmental agencies to be able to sign the contract that Trafikverket has published on the blockchain. If these authentications are not present, then they cannot sign the government smart contract and hence they will be unable to partake in the tendering for the construction project. Since all this is published on the blockchain all the actors are able to partake in the information that has led to the decision. Thereby, creating a more open process that minimizes the corruption, something that is an issue according to ELS-1. As this Blockchain 3.0 is automatic, it is possible to code in the contract that allows for the automatic rewarding of the construction contract. An exemplification of how this would potentially work is illustrated in the Fig. 5-13.

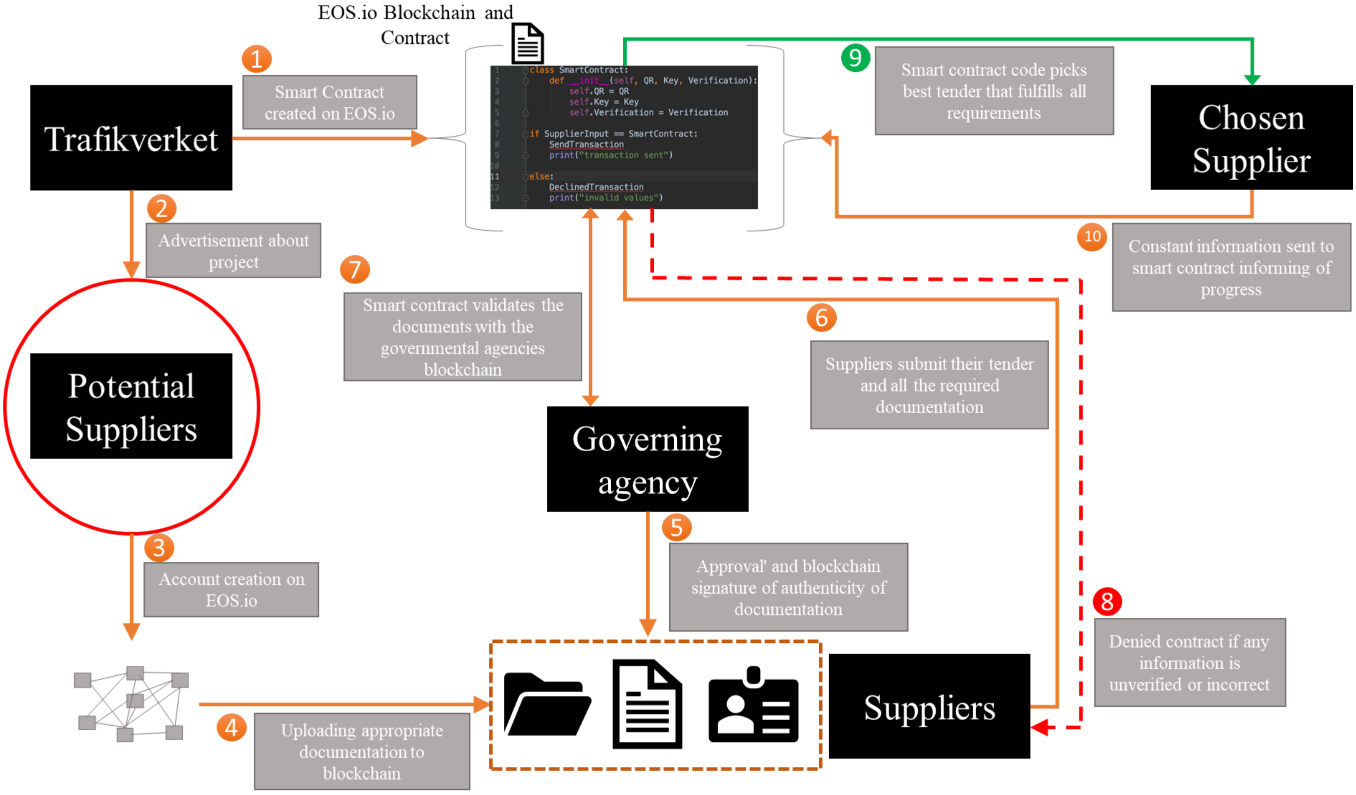


Figure 5-13: Governmental agency using blockchain smart contracts. Own model.

As CB-5 stated, the procurement process for the state, and thus Trafikverket, is very demanding and requires a lot of documentation which inevitably takes a long time for Trafikverket to process. What Trafikverket does is then (1) post the contract that specifies the needs and the requirements of the tenders that which to take part on the EOS.io blockchain. This contract will have requirements such as the different certifications, e.g. ISO, to be signed and verified by the governing bodies respective blockchain accounts on the blockchain and additional requirements. This is then (2) advertised to the potential suppliers on the market who are told to (3) create a blockchain account and register their business and (4) upload any necessary documentation. These documents are then (5) approved by the agencies that are required to approve them. With their approval the documents are given a digital hash that verifies that they have been approved. The suppliers that wish to attend will (6) send their documentations to the EOS.io smart contract that will then (7) verify the documentation against the governmental agency blockchain. (8) If the documentation is falsified or not approved, the supplier will be unable to be awarded the contract. (9) If all the information is correct and the tender is the best a supplier will be chosen. This choice can be automatic, however, evaluating the actual value of the tenders themselves will still require a certain amount of human interaction. Then the supplier, as with the normal contracts, will have to (10) constantly be sending information about the progress to the smart contract to show that they are keeping their contractual obligations. This can also be verified by a third party if need be.

Concluding Remarks: Governmental Agency Construction Procurement

As ELS-1 stated, the most interesting use case for blockchain is in terms of a governmental agency by using it to reduce corruption and increase security in the procurement process. To do this, the most feasible solution is as mentioned the public permissioned blockchain as described by EBSB-4. This allows for a situation where the process can be seen by everyone but only those that are eligible can interact with the contract. Since all government processes have to be open in Sweden, having every part of the procurement process stored on a public blockchain will allow everyone to access these public documents and vet the process.

The most complicated part here as described by ELS-1 will be coding every scenario into the contract. The coding of requiring the documents to be signed by the controlling agency is relatively easy as all they need to do is have a dedicated blockchain account with which they sign the documents. However, the difficult part will be the evaluation of the tenders, i.e. evaluating if the tender is serious and able to be conducted by the company submitting it. This will undoubtedly still require manual administration; however, the control documentation can be automated and since everything is stored even the manual evaluation everyone will have access to it. The final aspect, exclusive to EOS.io, is the ability to alter contracts after they have been signed with the consent of both parties as described by EBSB-4. This helps to solve the issues that other blockchains have where one needs to scrap the contract when it needs to be changed as described by Hofmann, Strewe and Bosia (2017). There also needs to be a discussion around the legality of the smart contract as described by ELS-1, most likely requiring a physical contract connected to the smart contract.

The governmental agency recommendation, similar to the concrete supply chain recommendation, is only a simplified example and can be modified to the desired outcome. Due to the previously mentioned fast changes that occur in the blockchain space one will need to evaluate this type of solution when one has decided to implement it taking potential changes into account. Furthermore, this thesis was unable to speak to any actors from Trafikverket and their specific point of view on this technology is not considered.

6. Conclusion

This chapter will be concluding the study and clearly answer each research question. The question is first repeated and then answered below. Lastly, recommendations for future research is presented.

6.1 Research Question 1

What is the current state of knowledge surrounding blockchain technology and smart contracts within the construction supply chain and what is the sentiment and perceived readiness for implementing such a solution?

The purpose of the first research question was to evaluate the level of knowledge surrounding blockchain technology and smart contracts within the construction industry. Furthermore, the research question was aimed to gage the sentiment surrounding the technology within the construction industry as well as the perceived readiness of the industry among actors. Firstly, the knowledge surrounding the blockchain and smart contract technology was unsurprisingly very low in the construction industry.

However, the sentiment surrounding the potential implementation was surprisingly positive. A majority of the interviewed showed great interest in the technology, specifically the smart contracts and its ability to automate transactions, a trend also present in the questionnaire. Finally, the perceived readiness was low among the individuals interviewed indicated that the low level of digitization was the primary concern. Another concern was that the industry is very conservative, and the amount of change management required is too high at its current state. Furthermore, the legal concerns surrounding smart contracts is still a significant hinderance to any company considering developing a blockchain smart contract solution.

Interestingly, outside the scope of the question, the authors found a great discrepancy in the literature and among the experts surrounding what constitutes a blockchain. This clearly shows the immaturity of the technology and the need to some form of consensus surrounding applications and use cases.

6.2 Research Question 2

Can smart contracts, in combination with blockchain technology, be used to increase efficiency in supply chain management and supply chain financing within the construction supply chain? If so, how?

At the current state of the construction industry, the authors do not believe that blockchain and smart contract technology can be used to increase efficiency in supply chain management or supply chain financing. The primary reason seems to be the low level of digital maturity in the industry. However, due to many respondents indicating on-going digitization projects that are underway and a clear change in how the construction industry operates the authors also believe that there is a place for a blockchain smart contract solution, or similar solution, in the future. The authors also identified a strong opportunity in incorporating blockchain technology together with BIM technology that are becoming more prevalent in the construction industry. Furthermore, the strong willingness for information sharing among all the actors show a strong groundwork for an industry to use a blockchain solution. However, the industry should not implement on the sole basis of trust as the current trust in the industry is relatively high and something that the authors believe will not significantly be improve with blockchain smart contract technology.

Another potential area of implementation is the usage of blockchain smart contracts for transaction automation. The construction industry showed great interested in having transaction automation and is definitely something the industry should strive for. The authors, however, believe that developing a blockchain technology for this is too complex and using an automated transaction service via ERP systems or a classic SCF system via a bank is more feasible at the current state.

While the blockchain technology and the smart contract technology could lead to increased efficiency, the low level of digitization does not make it feasible. Furthermore, the authors believe that there are other areas of digitalization that the construction industry should be focused on first before considering a blockchain smart contract solution. For a blockchain smart contract solution to be considered the construction industry must first be able to secure the input data. To summaries, at current stage, blockchain smart contracts do not seem to be the new rebar in the construction industry.

6.3 Research Question 3

How would a blockchain smart contracts solution be designed to be suitable for a construction supply chain?

The authors primarily investigated the use of blockchain smart contract solution on the concrete supply chain and not every construction supply chain. Therefore, the authors recommend that when implementing blockchain smart contract solution on specifically a concrete supply chain a consortium solution is the most suitable. However, the authors also believe that this would likely be the case for other construction supply chains as the sentiment was very similar. One would need to make changes to the proposed design in Fig. 5-11 with regards to the material and the processes adhering to these materials.

Furthermore, the empirical findings created an eye-opening insight into the potentials for a public permissioned blockchain for governmental agencies involved in construction procurement. Unfortunately, this was outside the initial scope leading to limited data, hence no conclusions will be made on this, however the authors believe that this is an interesting case nonetheless and one that should be investigated further.

6.4 Future research

There is plenty of research that still needs to be conducted within the field of blockchain and smart contracts which was obvious when speaking to the blockchain smart contract experts and the law expert. This thesis initially attempted to gain perspective on real life implementation and develop a blockchain prototype in Python but was unable to do this due to time constraints. Hence, more research still needs to be conducted on the real-world application of blockchain and smart contracts. Furthermore, research needs to indicate and describe the successfulness of the implementation in terms of identify the actual efficiency increases of using the technology, if there are any at all.

There also needs to be further research surrounding the different configurations of blockchain attempting to establish a certain level of consensus on the use cases and definitions in the industry. The lack of consensus surrounding the different blockchains and their usefulness could create confusions which potentially could have an impact on both the understanding of the technology as well as the implementation.

One of the most pressing issues surrounding smart contracts is the legality of them. Research should be conducted within the legal field to create an understanding for what the legal profession would need to accept such a solution. This thesis investigated this very briefly but there needs to be a more detailed description so that there may be a possibility to influence the legal profession to adapt the technology. The authors also believe that another interesting area of investigation will be the potential legal implications of companies using consortium blockchains and competition authority's perspective on this.

Furthermore, a consortium blockchain involving several major actors within an industry could raise the question of forming a cartel. During this thesis the authors were in contact with the Swedish Competition Authority to further discuss this scenario, however it was only on an initial stage and therefore something that needs to be investigated further.

Another interesting aspect to examine further is the potential blockchain and smart contracts has to improve construction supply chains from a sustainability perspective as the industry plays a huge role when it comes to producing greenhouse gas emissions.

The last interesting further research opportunity would be the application of the blockchain technology and smart contracts within a controlling governmental agency. This was only something this thesis mentioned briefly and became an afterthought to some extent, hence detailed research into this application area would be very interesting.

7. References

Andoni, M. Robu, V. Flynn, D. Abram, S. Greach, D. Jenkins, D. McCallum, & P. Peacock, A. (2019). 'Blockchain technology in the energy sector: A systematic review of challenges and opportunities'. *Renewable and Sustainable Energy Reviews*, Vol. 100, p. 143-174.

Apte, S. & Petrovsky, N. (2016). 'Will blockchain technology revolutionize excipient supply chain management?', *Journal of Excipients and Food Chemicals*, Vol. 7, no.3.

Arizona.edu (n.d.). *The Contracting Process*, Arizona. EDU Research Gateway Negotiation and Acceptance, viewed: 03-03-2019, <https://rgw.arizona.edu/administration/negotiation-and-acceptance/contracting-process>

Bartoletti, M. & Pumpianu, L. (2017). 'An Empirical Analysis of Smart Contracts: Platforms, Applications, and Design Patterns', *International Conference on Financial Cryptography and Data Security*, Vol. 10323, pp. 494-509.

Bauman, D. Lindblom, P. & Olsson, C. (2016). 'Blockchain: Decentralized trust.', *Näringspolitiskt forum #15*, Entreprenörskapsforum, Örebro Universitet, pp. 1-114.

Blockchainhub (n.d.). *Smart Contracts*, BlockchainHub, viewed: 05-03-2019. <https://blockchainhub.net/smart-contracts/>

Blockchain Business (n.d.). *Blockchain Fundamentals*, Business Blockchain HQ, viewed: 11-03-2019, <https://businessblockchainhq.com/blockchain-fundamentals/>

Blockgeeks (n.d.). *What are Smart Contracts: The Blockchain Technology That Will Replace Lawyers*, Block Geeks, viewed: 10-02-2019, <https://blockgeeks.com/guides/smart-contracts/>

BlockIDE (2018). *Smart Contract Automation - The Mantra for New Age Businesses*, Medium, viewed: 11-03-2019, <https://medium.com/@blockide/smart-contract-automation-the-mantra-for-new-age-businesses-4221f79e6ef1>

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

Caniato, F. Gelsomino, L. Perego, A. & Ronchi, S. (2016). 'Does finance solve the supply chain financing problem?', *Supply Chain Management: An International Journal*, Vol. 21, Issue 5, pp.534-549.

Casado-Vara, R., González-Briones, A., Prieto, J. & Corchado, J. (2018). 'Smart Contract for Monitoring and Control of Logistics Activities: Pharmaceutical Utilities Case Study.' *Advances in Intelligent Systems and Computing*, pp.509-517.

Casey, M. & Wong, P. (2017). *Global Supply Chains Are About to Get Better, Thanks to Blockchain*, Havard Business Review, viewed: 11-03-2019, <https://hbr.org/2017/03/global-supply-chains-are-about-to-get-better-thanks-to-blockchain >

Cdbb (n.d.). *Building Information Modelling*, cdbb Centre for Digital Built Britain, viewed: 23-03-2019, <https://www.cdbb.cam.ac.uk/BIMLevels>.

Chia, S. (2018). *When will the construction industry embrace digital transformation?,* UK Construction Media, viewed: 13-03-2019 <https://www.ukconstructionmedia.co.uk/features/construction-digital-transformation/>.

Croman, K. Decker, C. Eyal, I. Gencer, A. Juels, A. Kosba, A. Miller, A. Saxena, P. Shi, E. Sirer, E. Song, D. & Wattenhofer, R. (2016). 'On scaling decentralized blockchains', *International Conference on Financial Cryptography and Data Security*, pp 106-125.

dApp Builder team (2018). Will Smart Contracts Revolutionise Traditional Contracts, Medium, viewed: 10-04-2019 <https://medium.com/ethereum-dapp-builder/will-smart-contracts-revolutionise-traditional-contracts-5833543c903e>

Drescher, D. (2017). *Blockchain Basics: A Non-Technical Introduction in 25 Steps*, Apress, Berkeley California.

Entech. (2018). *4 Reasons Construction Industry Technology is Still Behind the Curve*, Entech, viewed: 2019-02-15, <https://entechus.com/4-reasons-construction-industry-technology-is-still-behind-the-curve>

EU BIM Task Group (2017). *Handbook for introduction of Building Information Modelling by the European Public Sector*, EU BIM Task Group, viewed: 2019-03-16, <http://www.eubim.eu/wp-content/uploads/2017/07/EUBIM_Handbook_Web_Optimized-1.pdf>.

Fiser, S. (2018). *Supply Chain Finance Reimagined on the Blockchain*, Medium, viewed: 2019-03-18, <https://medium.com/bluebear-tech/supply-chain-finance-reimagined-on-the-blockchain-417d857e1791>.

Flori, J-P. (2017). 'The security and insecurity of blockchains and smart contracts', *Blockchains and smart contracts; The technology of trust? Réalités Industrielles*, viewed: 2019-03-25 <http://www.annales.org/ri/2017/english/RI17_22Flori.pdf>

Fowler, J. & Schofer, J. (2017). *Understanding Supply Chain Finance*, PWC, viewed: 2019-01-25, <https://www.pwc.com.au/publications/pdf/supply-chain-finance-jul17.pdf>

Fox, S. (2016). *Why construction needs smart contracts*, NBS, viewed: 2019-02-05, <https://www.thenbs.com/knowledge/why-construction-needs-smart-contracts>

Goldenfein, J. & Letier, A. (2018). 'Legal Engineering on the Blockchain: 'Smart Contracts' as Legal Conduct', *Law and Critique*, Vol. 29, Issue 2, pp. 141-149.

Gronbaek, M. (2016). *Blockchain 2.0, smart contracts and challenges*, Bird & Bird, viewed: 2019-03-01, <https://www.twobirds.com/en/news/articles/2016/uk/blockchain-2-0--smart-contracts-and-challenges>.

Gupta, M. (2018). *Blockchain For Dummies*, John Wiley & Sons, Inc., Hoboken (NJ).

Hancock, M. & Vaizey, E. (2016). *Distributed Ledger Technology: beyond block chain*, Government Office of Science, viewed: 2019-03-08, <https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/492972/gs-16-1-distributed-ledger-technology.pdf>

Hofmann, E., Strewe, M. Sarkis, J. & Bosia, N. (2018). 'Supply Chain Financing and Blockchain Technology the Case of Reverse Securitisation', *International Journal of Production Research*, Vol. 57, Issue 7, pp. 2117-2135.

Holland FinTech. (2017). *Financial technology in the construction business*, Holland Fintech, viewed: 2019-03-25, <https://hollandfintech.com/2017/04/financial-technology-construction-business/>.

Hong, Z., Wang, Z., Cai, W. & Leung, V. (2017). 'Blockchain-Empowered Fair Computational Resource Sharing System in the D2D Network', *MDPI: Future Internet*, Vol 9, pp 85-106.

Hughes, D. (2017). *The Impact of Blockchain Technology on the Construction Industry*, Medium, viewed: 2019-03-15, <https://medium.com/the-basics-of-blockchain/the-impact-of-blockchain-technology-on-the-construction-industry-85ab78c4aba6>

Hukkinen, J. Mattila, J. Somlander, K. Seppäla & T. Goodden, T. (2019). "Skimping on Gas - Reducing Ethereum Transaction Costs in a Blockchain Electricity Market Application*", Hawaii International Conference on System Science*, pp. 6875-6884

Hyperledger. (n.d.). *Hyperledger*, Hyperledger: The Linux Foundation Project, viewed: 2019-03-19, <https://www.hyperledger.org/>.

Hyperledger Fabric. (n.d.). *Hyperledger Fabric.* Hyperledger: The Linux Foundation Project, viewed: 2019-03-19, <https://www.hyperledger.org/projects/fabric>.

Ifeanyi, O. (2018). *Blockchain Technology and its Potentials to Accelerate Supply Chain Financing (SCF)*, Medium, viewed: 2019-04-01, <https://medium.com/datadriveninvestor/blockchain-technology-and-its-potentials-to-accelerate-supply-chain-finance-scf-c48c357f2c12>.

Irizzary, J. Karan, E. & Jalaei, F. (2013). 'Integrating BIM and GIS to improve the visual monitoring of construction supply chain management*', Automation in Construction*, Vol. 31, pp. 241-254.

Johnston, L. Gamon, J. Wolge, K. Yoder, J. Freeland, A. Wozniak, C. Zombro, D. & Newcorner, N. (2013). *Supply Chain Management: Concepts, Methodologies, Tools, and Applications Volume 1,* Business Science Reference, United States of America.

Kagan, J. (2019). *Supply Chain Finance*. Investopedia, viewed: 2019-04-16 <https://www.investopedia.com/terms/s/supply-chain-finance.asp>

Kakavand, H. Sevres N. & Chilton, B. (2017). *The Blockchain Revolution: An Analysis of Regulation and Technology Related to Distributed Ledger Technologies*, SSRN, viewed: 2019-03-05, <https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2849251>.

Kamble, S. Angappa, G. & Arha, H. (2018). 'Understanding the Blockchain technology adoption in supply chains-Indian context', *International Journal of Production Research*, Vol. 57, Issue 7, pp. 2009-2033.

Kark, K. Brown, C. & Shaikh, A. (2017). *Technology budgets: From value preservation to value creation,* Deloitte Insights, viewed: 2019-03-02, <https://www2.deloitte.com/insights/us/en/focus/cio-insider-business-insights/technology-investments-value-creation.html>.

Kleemann, K. (2018). 'Theory of Supply Chain Finance: Its Implementation and an Organization's Benefits', Double Degree, Saimaa University of Applied Sciences, Finland, <https://www.theseus.fi/bitstream/handle/10024/142768/Kleemann_Thesis_2018.pdf?sequence=1>.

Lanko, A. Vatin, N. & Kaklauskas, A. (2018). 'Application of RFID combined with blockchain technology in logistics of construction materials', *MATEC Web Conf.,* Vol. 170, Issue 03032.

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

Law, A (2017). 'Smart contracts and their application in supply chain management' MIT Thesis, Massachusetts Institute of Technology, Massachusetts, <https://dspace.mit.edu/handle/1721.1/114082>.

LawTeacher (2018). *A simple contract*, LawTeacher The Law Essay Professional, viewed: 2019-03-16, <https://www.lawteacher.net/free-law-essays/contract-law/a-simple-contract.php>.

Levi, S. & Lipton, A. (2018). *An Introduction to Smart Contracts and Their Potential and Inherent Limitations,* Harvard Law School Forum on Corporate Governance and Financial Regulation, viewed: 2019-04-01, <https://corpgov.law.harvard.edu/2018/05/26/an-introduction-to-smart-contracts-and-their-potential-and-inherent-limitations/>.

Lewis, A. (2016). *Confused by blockchain? Revolution vs Evolution,* Bits on Blocks, viewed: 2019-01-20, <https://bitsonblocks.net/2016/05/09/confused-by-blockchains-revolution-vs-evolution/>

Liebl, J. Hartmann, E. & Feisel, E. (2016). 'Reverse factoring in the supply chain: objectives, antecedents and implementation barriers', *International Journal of Physical Distribution & Logistics Managemen*t, Vol. 46 Issue: 4, pp.393-413.

Lorek, S. (2018). *What is BIM (Building Information Modeling)*, Constructible, viewed: 2019-04-20, <https://constructible.trimble.com/construction-industry/what-is-bim-building-information-modeling>.

Loop, P. (2017). *Blockchain: The Next Evolution of Supply Chains,* Industry Week, viewed: 2019-03-12,<https://www.industryweek.com/supply-chain/blockchain-next-evolution-supply-chains>.

Lundesjö, G. (2015). *Supply chain management and logistics in construction: delivering tomorrow's built environment*, Kogan Page, London.

Löfgren, I. & Gylltoft, K. (2001). 'In-Situ Cast Concrete Building', *Nordic Concrete Research,* viewed: 2019-04-07, <http://publications.lib.chalmers.se/records/fulltext/9232/local_9232.pdf>.

Marks, M. (2017), *Construction: The next great tech transformation,* McKinsey & Company, viewed: 2019-03-09, <https://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/construction-the-next-great-tech-transformation>

Mason, J. (2017). 'Intelligent Contracts and the Construction Industry', *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction,* Vol. 9, Issue 3.

Mason, J. & Escott, E. (2018). *Smart Contracts in Construction: Views and Perceptions of Stakeholders*, University of the West of England, viewed: 2019-03-22, <http://eprints.uwe.ac.uk/35123/3/FIGrevised.pdf>.

Masteika, I. & Čepinskis, J. (2015). 'Dynamic Capabilities in Supply Chain Management', *Procedia - Social and Behavioral Sciences,* Vol. 213, pp. 830-835.

Maxwell, W. & Salmon, J. (2017). *A guide to blockchain and data collection,* Hogan Lovells, viewed: 2019-04-21, <https://www.hlengage.com/_uploads/downloads/5425GuidetoblockchainV9FORWEB.pdf>.

McKinsey & Company. (2016). *Imagining construction's digital future,* McKinsey & Company, viewed: 2019-02-30, <https://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/imagining-constructions-digital-future-infographic>.

Meijer, C. (2016). *Blockchain and Supply Chain Finance: the missing link!*, FinExtra, viewed: 2019-04-08, <https://www.finextra.com/blogposting/14049/blockchain-and-supply-chain-finance-the-missing-link>

Morabito, V. (2017). *Business Innovation Through Blockchain: the B^3 perspective,* Springer International Publishing AG, Switzerland.

More, D. (2013). 'Challenges of supply chain finance: A detailed study and a hierarchical model based on the experiences of an Indian firm', *Business Process Management Journal*, Vol. 19 Issue: 4, pp.624-647.

Nakamoto, S. (2008). *Bitcoin: A peer-to-peer electronic cash system,* Bitcoin, viewed: 2019-03-15, <https://bitcoin.org/bitcoin.pdf?>.

Nofer, M. Gomber, P. Hinz, O. & Schiereck, D. (2017), 'Blockchain', *Business & Information Systems Engineering*, Vol. 59, Issue 3, pp. 183-187.

O'Brien, C. (n.d.). *What's the Cost of Not Going Digital For a Business?,* Digital Marketing Institute, viewed: 2019-03-20 <https://digitalmarketinginstitute.com/en-eu/blog/what-is-the-cost-of-not-going-digital-for-a-business>.

Patel, R. & Davidson, B. (2011). *Forskningsmetodikens grunder: att planera, genomföra och rapportera en undersökning,* 4 Edition, Studentlitteratur, Lund.

Penzes, B. (2018). *Digital Transformation of High Productivity,* Institution of Civil Engineers, viewed: 2019-02-14, <https://www.ice.org.uk/ICEDevelopmentWebPortal/media/Documents/News/Blog/Blockchain-technology-in-Construction-2018-12-17.pdf>.

Quist, N. (2017). *5 trender som förändrar byggindustrin i grunden*, BIMobject, viewed: 2019-02-03, <https://www.bimobject.com/sv/news/articles/5-trends-of-disruption-that-will-change-the-industry-of-construction->.

Rosman, M. (2018). *Futurism: Everyone is a Tech Company Nowadays*, Revelx, viewed: 2019-04-05, <https://www.revelx.co/blog/everyone-is-a-tech-company/>.

Rühl, G. (2019). *The Law Applicable to Smart Contracts, or Much Ado about Nothing?* University of Oxford Faculty of Law, viewed: 2019-01-30, <https://www.law.ox.ac.uk/business-law-blog/blog/2019/01/law-applicable-smart-contracts-or-much-ado-about-nothing>.

Saberi, S. Kouhizadeh, M. Sarkis, J. & Shen, L. (2018). 'Blockchain technology and its relationships to sustainable supply chain management', *International Journal of Production Research*, Vol. 57, Issue 7, pp. 2117-2135.

Salazar, G. Serrambana, V. Denny, T. & Farrel, T. (1994). 'The Cost-Trust Relationship in the Construction Industry', *Construction Institute*, viewed: 2019-03-16, <https://www.construction-institute.org/resources/knowledgebase/knowledge-areas/project-organization-communication/topics/rt-024/pubs/sd-100#>.

Seifert, R. & D. Seifert. (2011). 'Financing the Chain', *International Commerce Review*, Vol. 10, Issue 1, pp. 32-44.

Shavell, S. (1980). 'Damage Measure for Breach of Contract', *The Bell Journal of Economics*, Vol. 11, Issue 2, pp. 466-490.

Sveriges Byggindustrier (2016). *30 största byggföretagen efter omsättning i Sverige 2016,* Sveriges Bygg Industrier, viewed: 2019-02-27, <https://www.sverigesbyggindustrier.se/UserFiles/Files/BI_Analys/30_storsta_byggforetagen_i_sverige_2016.pdf>.

Swan, M. (2015). *Blockchain: Blueprint for a new economy,* First edition, O'Reilly Media, Sebastopol.

Swan, M. (2017). 'Anticipating the Economic Benefits of Blockchain*', Technology Innovation Management Review*, Vol 7, pp. 6-13.

Tate, W. Bals, L. & Ellram, L. (2019). *Supply chain finance: risk management, resilience and supplier management*, Kogan Page Ltd, London.

Tapscott, D. & Tapscott, A. (2017). *How Blockchain Will Change Organizations*, MIT Sloan Management Review, viewed: 2019-02-18, <https://sloanreview.mit.edu/article/how-blockchain-will-change-organizations/>.

Thomas Betong (2019a). *Historik*, Thomas Betong, viewed: 2019-04-08, <http://thomasbetong.se/om-foeretaget/thomas-betongs-historik>.

Thomas Betong (2019b). *Om Betong*, Thomas Betong, viewed: 2019-04-08, <http://thomasbetong.se/vart-erbjudande/om-betong>.

Thomson Reuters (2019). *Practical law: Contract,* Thomason Reuters Practical Law, viewed: 2019-03-08, <https://uk.practicallaw.thomsonreuters.com/4-107-6271?transitionType=Default&contextData=(sc.Default)&firstPage=true&comp=pluk&bhcp=1>.

Trafikverket (2019). *How We Procure,* Trafikverket Swedish Transport Administration, viewed: 2019-04-01, <https://www.trafikverket.se/en/startpage/suppliers/Procurement/How-we-procure/>.

Turk, Z. & Klinc, R. (2017). 'Potentials of Blockchain Technology for Construction Management', *Procedia Engineering,* Vol. 196, pp. 638-645.

Tönnissen, S. & Teuteberg, F. (2018). 'Using Blockchain Technology for Business Processes in Purchasing − Concept and Case Study-Based Evidence', *International Conference on Business Information System,* pp. 253-264.

UNEC (n.d). *Share of constriction in GDP*, United Nations Economics Commission for Europe, viewed: 2019-02-25, <https://w3.unece.org/PXWeb/en/Charts?IndicatorCode=8&CountryCode=442>.

UNECE (2012). *Inventory Finance,* Trade Facilitation Implementation Guide United Nations, viewed: 2019-04-17, <http://tfig.unece.org/contents/inventory-finance.htm>.

Vatiero, M. (2018). *Smart Contracts and Transaction Costs*, University of Oxford Faculty of Law, viewed: 2019-02-18, <https://www.law.ox.ac.uk/business-law-blog/blog/2018/10/smart-contracts-and-transaction-costs>.

Wagenaarm (2018). *Blockchain Decision Tree,* Steemit Beta, viewed: 2019-03-27, <https://steemit.com/blockchain/@wagenaarm/blockchain-decision-tree>

Wall, E. & Malm, G. (2016). 'Using Blockchain Technology and Smart Contracts to Create a Distributed Securities Depository', Department of Electrical and Information Technology Lund University, Lund.

Weber, I. Lu, Q. Tran, A. Deshmukh, A. Gorski, M. & Strazds, M. (2019). 'A Platform Architecture for Multi-Tenant Blockchain-Based Systems' *International Conference on Software Architecture, Hamburg Germany.* <https://publications.csiro.au/rpr/pub?list=SEA&pid=csiro:EP189764&expert=false&sb=RECENT&n=19&rpp=25&page=1&tr=226792&dr=all&q=>

Wuttke, D. Blome, C & Henke, M. (2013). 'Focusing the financial flow of supply chains: An empirical investigation of financial supply chain management', *International Journal of Production Economics,* Vol. 145, Issue 2, pp. 773-789.

Yin, R. (2018). *Case Study Research and Applications,* 6th edition, SAGE Publications Inc., New York.

Zaghloul, R. & Hartman, F. (2003). 'Construction contracts: the cost of mistrust', *International Journal of Project Management,* Vol. 21, Issue 6, pp. 419-424.

Zheng, Z. Xie, S. Dai, H-N. Chen, X. & Wang, H. (2018). 'Blockchain challenges and opportunities: a survey', *International. Journal Web and Grid Services*, Vol. 14, No. 4, pp.352–375

Appendix

Appendix A: Keywords for Literature Review

Supply Chain Management

Supply Chain	+	Management
		Digital
		Construction
		Concrete

Blockchain Technology

Blockchain	+	Supply chain management
		Supply chain
		Technology
		Architecture
		Consensus
		Configuration
		Construction
		Concrete

Supply Chain Financing

Supply Chain Financing	+	Different instruments
		Blockchain
		Smart contracts
		Technology
		Construction
		Advantages/ Disadvantages

Smart Contracts

Smart Contracts	+	Construction
		Automation
		Efficiency
		Blockchain
		Legal
		Challenges

Appendix B: Interview Guides

Interview Guides for Construction Industry

Finance Department

Part 1: Department Questions

1) What is your current position in the company and can we get a brief description about what you do in the company?
    a) What does the company structure look like, how is your department connected to the supply chain?

2) What is your department's and specifically your role in the contracting process? Either within procurement of raw material or in sales.

3) How does this contract process work today, could you describe last time you were involved? Was it a normal process or was it something that was out of the ordinary?
    a) What sort of contracts are primarily used?
        i) Ex. Industry standard contracts, standard form contracts etc.
    b) To what extent is the process manual handled?
        i) How can the process be more standardized/ made digital?
    c) What do you see as some of the issues with the current contracting process? Can you please describe some of the issues you have faced lately?
    d) How prevalent are the following outcomes experienced in the contract process; (1) payment delay (2) trust issues (3) disputes (4) transaction security (5) contract tampering (6) transparency issues (7) high transaction costs, (8) power imbalance.
        i) How are these different issues handled today?

4) Please describe the financial transaction process:
    a) ***Procurement***: how payment of raw material is verified and payed, quality assurance.
        i) Are price disputes something that often occurs? What are the cost associated with verifying quality and correct payment?
    b) ***Sales***: How are goods sold, how are companies valued and receive credit, credit length, payment methods, cancelation fees.
        i) Are credit losses through for ex. bankruptcy common and how are they handled? What costs are associated with controlling for this?

5) What is the average transaction cost for the company i.e. bank fees, administration etc.?
    a) Is this cost a fair price to pay?

6) Does your company currently use any supply chain financing solution and if so how does it work?

Part 2: Blockchain and Smart Contract Technology

7) How familiar are you with blockchain technology?

8) How familiar are you with smart contract technology?
    a) Is the company currently involved in any blockchain/ smart contract solutions or planning to participate in any future projects? Are you aware of any ongoing projects in the construction industry involving blockchain? If yes, please elaborate

9) Blockchain technology uses an open ledger that provides visibility and traceability into everyone's (connected to the blockchain) supply chains. Is that something that concerns the company?

10) Smart Contracts in combination with blockchain technology have the potential of removing intermediaries (Banks etc.) from the transaction process.
    a) How important are these intermediaries for your department? Is this a concern? If yes, why?

11) The blockchain technology aims to increase transparency, immutability, traceability, security, real-time information and speed up the transaction process.
    a) Which advantages do you find interesting for your department? Why?

12) Smart Contracts aim to increase automation, trust and reduce human influence in the contracts process as well as the transaction process.
    a) Are these aspects interesting for your department? Please elaborate why in that case?

13) How concerned are you about the following risks that smart contracts pose after being implemented?
    a) Lack of legal framework, ridged system (inability to alter), open ledger/database, the inability to code and foresee most scenarios, cancelation and changes.

14) Do you believe that there is place for this technology today within the construction business?
    a) To what extent will the market adapt to this new technology?
        i) What actors are required for mass market adoption?
    b) What do you see as the main challenges if your department would implement smart contracts?

IT Department

Part 1: Department Questions

1) What is your current position in the company and can we get a brief description about what you do in the company?
    a) What does the company structure look like, how is your department connected to the supply chain?

2) What is your department's and specifically your role in the contracting process? Either within procurement of raw materials or in sales.

3) Are you involved in any contract negotiations and creation in your work? Either within procurement of raw material or sales. If yes;
    a) What sort of contracts are primarily used?
        i) Ex. Industry standard contracts, standard form contracts etc.
    b) From an IT point of view can the contracts process be standardized/ digitized? What would be the outcome of digitizing and standardizing these contracts?
    c) How prevalent are the following outcomes experienced in the contract process; (1) payment delay (2) trust issues (3) disputes (4) transaction security (5) contract tampering (6) transparency issues (7) high transaction costs, (8) power imbalance.
    d) How are these different issues handled today?

4) Are current IT systems integrated with other suppliers/buyers? ex. sharing inventory, procurement sources, quality verifications.
    a) What are some of the issues with sharing these?

5) Does your company currently use any supply chain financing solution and if so how does it work?

Part 2: Blockchain and Smart Contract Technology

6) How familiar are you with blockchain technology?

7) How familiar are you with smart contract technology?
    a) Is the company currently involved in any blockchain/ smart contract solutions or planning to participate in any future projects? Are you aware of any ongoing projects in the construction industry involving blockchain? If yes, please elaborate

8) What do you see as the biggest technological challenges surrounding blockchain technology from an implementation standpoint? Similarly, the implementation of a smart contract solution?
    a) Do you believe other forms of technology need to be implemented before smart contracts and or a blockchain technology is feasible? Ex. IOT.

9) How concerned are you about the following risks that smart contracts pose after being implemented?
    a) Lack of legal framework, ridged system (inability to alter), open ledger/database, the inability to code and foresee most scenarios, cancelation and changes.

10) Does IT see blockchain and smart contracts as technologies that is worth investing resources into developing?

11) Do you believe that there is place for this technology today within the construction business?
    a) To what extent will the market adapt to this new technology?
        i) What actors are required for mass market adoption?
    b) What do you see as the main challenges if your department would implement smart contracts?

Procurement Department

Part 1: Department Questions

1) What is your current position in the company and can we get a brief description about what you do in the company?
    a) What does the company structure look like, how is your department connected to the supply chain?

2) How does the procurement process of raw material take place today? Please give a short description of the process flow.
    a) How are delivery verification and quality assurance of raw material handled today?
        i) Are there often trust concerns between the company and the raw material suppliers? If yes, please elaborate the issues.
    b) What triggers a payment for goods received?
        i) Is automating the payment terms and conditions something that is realistic? I.e. is the process clear enough to automate.

3) Is it possible to backtrack raw material procurements location of origin and quality assurances in the way you work today? To what extent is it automatized?
    a) Is this aspect important for the company?

4) How does this contract process work today, could you describe last time you were involved? Was it a normal process or was it something that was out of the ordinary?
        i) What sort of contracts are primarily used?
            (1) Ex. Industry standard contracts, standard form contracts etc.
        ii) To what extent is the process manual?
            (1) How can the process be more standardized/ made digital?
            (2) Are contracts usually modified after finalization? If yes, please explain the most common modifications.
    b) What are some of the risks today involved in the procurement process?
    c) What do you see as some of the issues with the current contracting process? Can you please describe some of the issues you have faced lately?
    d) What are the most essential contract requirements? Ex. quality, verification, pricing, contingencies etc.
        i) State some examples of the most important parts you include.
    e) How prevalent are the following outcomes experienced in the contract process; (1) payment delay (2) trust issues (3) disputes (4) transaction security (5) contract tampering (6) transparency issues (7) high transaction costs, (8) power imbalance.
        i) How are these different risks handled today?
    f) What are some of the main areas in which procurement needs an improved contracting process?

5) Does your company currently use any supply chain financing solution and if so how does it work?

Part 2: Blockchain and Smart Contract Technology

6) How familiar are you with blockchain technology?

7) How familiar are you with smart contract technology?

a) Is the company currently involved in any blockchain/ smart contract solutions or planning to participate in any future projects? Are you aware of any ongoing projects in the construction industry involving blockchain? If yes, please elaborate.

8) Blockchain technology uses an open ledger that provides visibility and traceability into everyone's (connected to the blockchain) supply chains. Is that something that concerns the company?

9) Smart contracts in combination with blockchain technology have the potential of removing intermediaries (Banks etc.) from the transaction process.
   a) How important are these intermediaries for your department? Is this a concern? If yes, why?

10) The blockchain technology aims to increase transparency, immutability, traceability, security, real-time information and speed up the transaction process.
   a) Which advantages do you find interesting for your department? Why?

11) Smart contracts aim to increase automation and trust as well as reduce human influence in the contracts process and the transaction process.
   a) Are these aspects interesting for your department? Please elaborate why in that case?

12) How concerned are you about the following risks that smart contracts pose after being implemented?
   a) Lack of legal framework, ridged system (inability to alter), open ledger/database, the inability to code and foresee most scenarios, cancelation and changes.

13) Do you believe that there is place for this technology today within the construction business?
   a) To what extent will the market adapt to this new technology?
      i) What actors are required for mass market adoption?
   b) What do you see as the main challenges if your department would implement smart contracts?

Sales Department

Part 1: Department Questions

2) What is your current position in the company and can we get a brief description about what you do in the company?
   a) What does the company structure look like, how is your department connected to the supply chain?

3) How does the sales process work? Please give a short description of the process flow.
   a) How are delivery verification and quality assurance of deliveries handled today?
      i) Are there often trust concerns between the company and customer? If yes, please elaborate the issues.
   b) What triggers a payment for goods delivered?
      i) Is automating the payment terms and conditions something that is realistic? I.e. is the process clear enough to automate.

4) With today’s sales processes, can you guarantee the quality and origin of the goods to your customers, by for example traceability?
   a) Is this aspect important for the costumer?

5) How does this contract process work today, could you describe last time you were involved? Was it a normal process or was it something that was out of the ordinary?
   a) How does this contract process work today? Please give an example.
      i) What sort of contracts are primarily used?
         (1) Ex. Industry standard contracts, standard form contracts etc.
      ii) To what extent is the process manual handled?
         (1) How can the process be more standardized/ made digital?
         (2) Are contracts usually modified after finalization? If yes, please explain the most common modifications

b) What are some of the risks today involved in the sales process?
c) What do you see as some of the issues with the current contracting process? Can you please describe some of the issues you have faced lately?
d) What are the most essential contract requirements? Ex. quality, verification, pricing, contingencies etc.
   i) State some examples of the most important parts you include.
e) How prevalent are the following outcomes experienced in the contract process; (1) payment delay (2) trust issues (3) disputes (4) transaction security (5) contract tampering (6) transparency issues (7) high transaction costs, (8) power imbalance.
f) How are these different issues handled today?
g) What are some of the main areas in which sales needs an improved contracting process?

6) Does your company currently use any supply chain financing solution and if so how does it work?

Part 2: Blockchain and Smart Contract Technology

7) How familiar are you with blockchain technology?

8) How familiar are you with smart contract technology?
   a) Is the company currently involved in any blockchain/ smart contract solutions or planning to participate in any future projects? Are you aware of any ongoing projects in the construction industry involving blockchain? If yes, please elaborate

9) Blockchain technology uses an open ledger that provides visibility and traceability into everyone's (connected to the blockchain) supply chains. Is that something that concerns the company?

10) Smart contracts in combination with blockchain technology have the potential of removing intermediaries (Banks etc.) from the transaction process.
   a) How important are these intermediaries for your department? Is this a concern? If yes, why?

11) The blockchain technology aims to increase transparency, immutability, traceability, security, real-time information and speed up the transaction process.
   a) Which advantages do you find interesting for your department? Why?

12) Smart Contracts aim to increase automation and trust as well as reduce human influence in the contracts process and the transaction process.
   a) Are these aspects interesting for your department? Please elaborate why in that case?

13) How concerned are you about the following risks that smart contracts pose after being implemented?
   a) Lack of legal framework, ridged system (inability to alter), open ledger/database, the inability to code and foresee most scenarios, cancelation and changes.

14) Do you believe that there is place for this technology today within the construction business?
   a) To what extent will the market adapt to this new technology?
      i) What actors are required for mass market adoption?
   b) What do you see as the main challenges if your department would implement smart contracts?

Follow-up Questions to Construction Industry:

1) Do you use the BIM Technology?
   a. If yes, to what extent?
   b. If not, is this something you plan to implement in the near future?

Interview Guides for Experts

Blockchain and Smart Contracts

1. Could you please briefly describe your current job title and what you do within the field of blockchain? How long experience do you have?

2. What are the limitations and potential risks with the blockchain technology?

3. What are the limitations and potential risks with smart contracts?

4. What are some of the primary legal concerns surrounding smart contracts?

5. What are the main industries you see as potential for blockchain technology and why?
    a. Potentials for supply chains involving physical goods?

6. What are the main industries where you see potential for smart contracts and why?

7. Considering; public, private and consortium blockchain today, which do you see as the most viable option for a smart contract solution for a supply chain and why?
    a. Is a private or a consortium configuration a true blockchain technology solution?
    b. Do you know if there are any open source platforms for creating a private/ consortium blockchain with smart contracts?
    c. What type of consensus algorithm is often used for a consortium configuration?

8. Do you think smart contracts complexity, in terms of the need of coding every outcome into it, out way its usefulness?

9. Are you familiar with supply chain financing? If yes, how will smart contracts affect the future of supply chain financing?

10. How long do you think it will take until the technology is matured enough for mass adoption?
    a. What infrastructure / surrounding technology would you say is the most important for this technology to be feasible?

11. What do you think about the implementation costs related to a blockchain smart contract solution? Are they justified?
    a. What will it take to reduce them?

12. Do smart contracts require the blockchain technology to be feasible? Please elaborate why.

Questions specifically asked to Blockchain Consultant & Entrepreneur (EBSB-4)

1. How would you build a blockchain to track physical goods in a consortium?

2. What is the best way to approach this problem?
    - Do you build mini blockchain for each good produced or all goods between one company to another?

3. What consensus should be used in a consortium blockchain? Is there any point?

4. Can a smart contract solution be build using a hash blockchain, but the rest of the goods tracking is kept separate?

5. In a public permissioned blockchain, is the information visible for everyone?

Supply Chain Financing

1. What do you see as the greatest improvements that smart contracts can bring to SCF?

2. What do you see as the main advantages with smart contracts, in comparison to standard contracts, with respect to cash flow and financing?

3. Do you see any limitations or weaknesses with smart contracts when it comes to supply chain financing?

4. Considering the following type of blockchains; public, private and consortium. Which do you see as the most viable option for a smart contract solution for supply chain management/ financing applications?

5. What are the main challenges for companies to adopt smart contracts within supply chain financing?

6. What industries will smart contracts within supply chain financing be the most useful, is there any specific industry that you believe will benefit the most?

7. What surrounding technology do you see as paramount for smart contracts to be useful within supply chain financing? E.g. IoT etc.

8. Smart contracts will require most scenarios/ outcomes to be coded, is this realistic in supply chain financing?

9. In a world of smart contracts on the blockchain, what will be the future role of banks and their intermediation of transactions?

Lawyer and Smart Contracts

1. Could you please briefly describe your current job title and what is your knowledge within the field of blockchain and smart contracts? How long experience do you have?

2. What are some of the primary legal concerns surrounding blockchain technology?
    a. Multi nodes, which jurisdiction? ROME I regulations?

3. What are some of the primary legal concerns surrounding smart contracts?

4. Do you see the legal system being unwilling to adapt to a smart contract world?

5. Will everything be able to be smart contracts or are we still going to be dependent on “normal” contracts to a great extent?

6. In what kind of areas do you think blockchain can improve the legal industry?

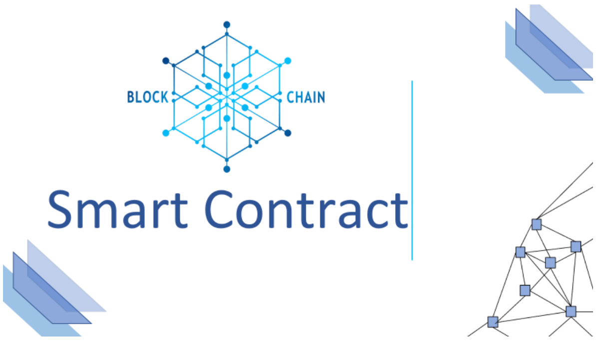
7. If 3-4 biggest companies are in the same consortium blockchain, do you see this being an issue from a competitive perspective? Primarily when thinking about Swedish Competition Authority?

8. How long do you think it will take until the blockchain technology has matured enough for mass adoption, in a law perspective?

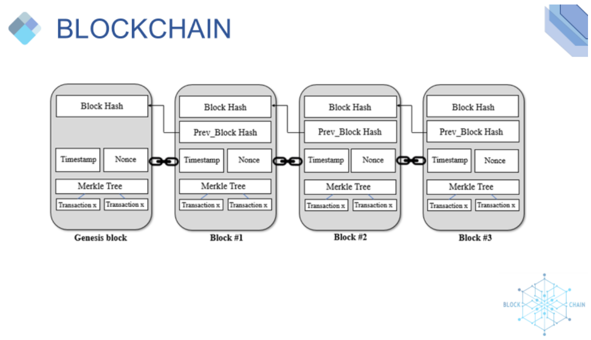
9. How long do you think it will take until the smart contract technology has matured enough for mass adoption, in a law perspective?

Appendix C: PowerPoint Presentation

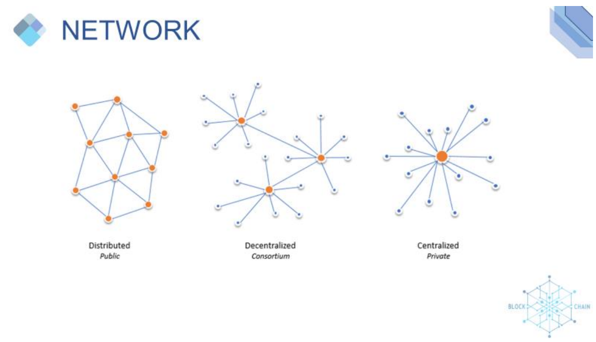
Slide 1:



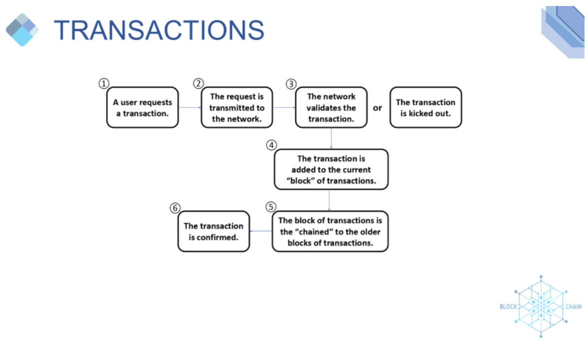
Slide 2:



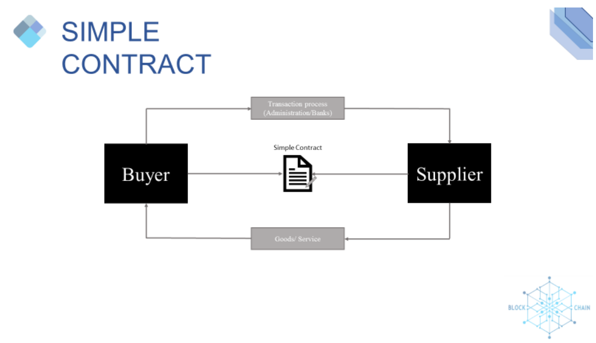
Slide 3:



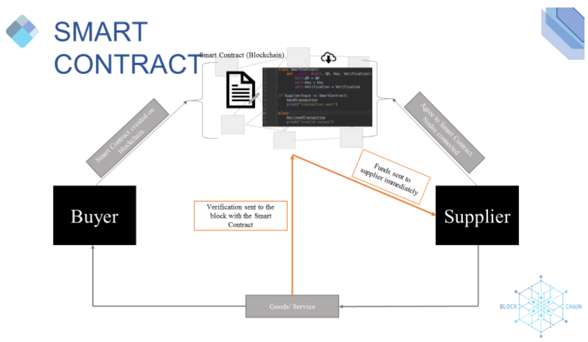
Slide 4:



Slide 5:



Slide 6:



Appendix D: Email Questionnaire

Hello,

Our names are Viktor and Tim and we are two students from the School of Business, Economics and Law at the University of Gothenburg. We are currently writing our thesis about the application of smart contracts and blockchain technology within the construction industry.

We are writing this thesis in collaboration with Thomas Betong AB and now we need your help to gather data about the contracting process within the construction industry. Furthermore, with this questionnaire we aim to identify the current level of knowledge surrounding smart contracts and blockchain.

You will remain anonymous and the data will be used as empirical findings.

The questionnaire is in English and takes approximately 10-15 minutes.

Please find the link below:
https://docs.google.com/forms/d/e/1FAIpQLSdXcpOX4yv1ZhY1q3BHvTAinzXuqQ5Su-iAx2SNx4ctFp5weg/viewform?usp=sf_link

Many thanks in advance and we appreciate that you are taking your time.

We would appreciate if you please could answer 22 March 2019 at latest.

Best regards,

Viktor and Tim

Appendix E: Questionnaire

Important!
"Contracts" in the questionnaire refer to the contracts between your company and supplier of raw material or the buyer of the end product that your company sells. Even though you may not be directly involved in the contracts process of these materials, please attempt to answer to the best of your knowledge.

This survey will be used as empirical evidence in a master thesis on the applications of smart contracts in the construction industry.
The questionnaire will take around 10-15 minutes

---

1. **What is your job title?**

2. **What department do you work for?**
- Finance
- Sales
- Procurement
- IT
- Production
- Other

3. **The current contracts process works well**
- Strongly disagree – Disagree – Slightly disagree – Slightly agree – Agree – Strongly agree
- (Insufficient Knowledge)

4. **The ability to enforce contracts works adequately**
- Strongly disagree – Disagree – Slightly disagree – Slightly agree – Agree – Strongly agree
- (Insufficient Knowledge)

5. **Contracts work as intended**
- Strongly disagree – Disagree – Slightly disagree – Slightly agree – Agree – Strongly agree
- (Insufficient Knowledge)

6. **a) Contracts are in no need for improvement**
- Strongly disagree – Disagree – Slightly disagree – Slightly agree – Agree – Strongly agree
- (Insufficient Knowledge)

   b) If you believe there is room for improvement, please state some of these improvements (you may skip this question if you wish):

7. **Companies in the construction supply chain fail to fulfill their obligations in the contract**
- Very frequently – Frequently – Occasionally – Rarely – Very rarely – Never
- (Insufficient Knowledge)

8. **Disputes between the two parties (buyer-supplier) to a contract are common**
- Strongly disagree – Disagree – Slightly disagree – Slightly agree – Agree – Strongly agree
- (Insufficient Knowledge)

9. **Disputes between two parties (buyer-supplier) often results in additional costs**
   That is in form of administrative costs, legal costs or other additional costs
- Strongly disagree – Disagree – Slightly disagree – Slightly agree – Agree – Strongly agree
- (Insufficient Knowledge)

10. **Intermediates (e.g. banks) are essential for the transaction process**
   That are the banks are seen as an integral part of any transaction to take place, without them transactions would not be viable.
- Strongly disagree – Disagree – Slightly disagree – Slightly agree – Agree – Strongly agree
- (Insufficient Knowledge)

11. **The current transaction speed is sufficient**

This includes the time between delivery and payment. Ex. delivering the concrete and getting paid or delivery of the raw material and paying the supplier

- Strongly disagree – Disagree – Slightly disagree – Slightly agree – Agree – Strongly agree
- (Insufficient Knowledge)

12. Administration costs related to transactions are justified

The amount of cost in form of time, effort and fees are at an acceptable level.

- Strongly disagree – Disagree – Slightly disagree – Slightly agree – Agree – Strongly agree
- (Insufficient Knowledge)

13. The time spend on administrating transaction is too much

- Strongly disagree – Disagree – Slightly disagree – Slightly agree – Agree – Strongly agree
- (Insufficient Knowledge)

14. There is a lack of trust between your company and suppliers

- Strongly disagree – Disagree – Slightly disagree – Slightly agree – Agree – Strongly agree
- (Insufficient Knowledge)

15. There is a lack of trust between your company and buyers

- Strongly disagree – Disagree – Slightly disagree – Slightly agree – Agree – Strongly agree
- (Insufficient Knowledge)

16. The current process allows for the ability to track and trace goods

- Strongly disagree – Disagree – Slightly disagree – Slightly agree – Agree – Strongly agree
- (Insufficient Knowledge)

17. Forgery/ fraud is common within the contracts process (before and after agreement)

Meaning that parties to the contracts commit fraud after agreeing to the contract or before. Example this could be lying about their financial situation.

- Strongly disagree – Disagree – Slightly disagree – Slightly agree – Agree – Strongly agree
- (Insufficient Knowledge)

18. The contracts are often altered after being agreed upon

This is where one of the parties attempt to alter the contract after they have agreed upon and signed the contract.

- Strongly disagree – Disagree – Slightly disagree – Slightly agree – Agree – Strongly agree
- (Insufficient Knowledge)

19. Current contracts are sufficiently secure

The contracts are secure enough that you can trust them to secure the interests of both parties involved.

- Strongly disagree – Disagree – Slightly disagree – Slightly agree – Agree – Strongly agree
- (Insufficient Knowledge)

20. Having a shared and open ledger (data base) between suppliers/ buyers and your company is bad

An open ledger is where select information is shared between everyone that has access to the open ledger. For example, everyone can see how much raw material was purchased from someone but not the price.

21. My understanding of blockchain technology is

- None – Very poor – Poor – Acceptable – Good – Very good

22. I have previously worked with blockchain technology

- Yes
- No

23. My understanding of smart contracts is

- None – Very poor – Poor – Acceptable – Good – Very good

24. I have previously worked with smart contracts

- Yes
- No

25. A blockchain smart contract solution is something that the construction industry should strive to implement

- Strongly disagree – Disagree – Slightly disagree – Slightly agree – Agree – Strongly agree
- (Insufficient Knowledge)