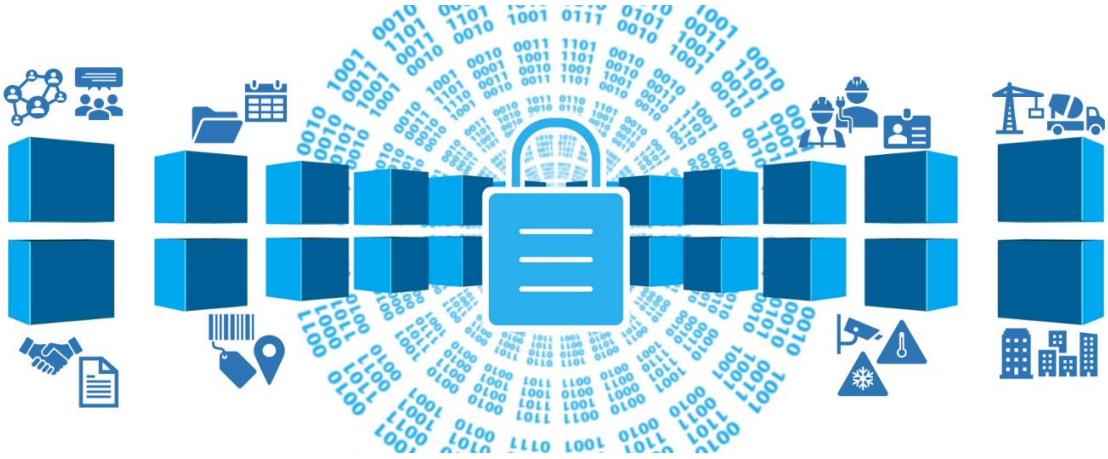
Transaction Cost

- Reduction in the Construction Industry by Embracing Blockchain Technology



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AALBORG UNIVERSITY
STUDENT REPORT

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Synopsis:

This master's thesis researched blockchain technology's possibilities in the construction industry, within a transaction cost framework. The research started with investigating solutions to reduce unnecessary transaction costs, which led to a research of blockchain technology. This led to the problem formulation: *How can blockchain technology benefit the construction industry in relation to reducing the transaction costs?*
The problem formulation was answered through a literature study, two rounds of interviews with first 5 experts within blockchain in construction and second 3 construction professionals, and a conceptual model for using blockchain in the procurement phase. That led to the conclusion that blockchain technology provides high collaboration levels in a trusting environment through transparency, traceability, trust in the system and security.

Abstract

Dette Speciale af kandidatuddannelsen "Management in the Building Industry" (Byggeledelse på dansk) undersøger, emnet transaktionsomkostninger i byggebranchen og hvordan disse kan reduceres ved hjælp af blockchain teknologien.

Dette er gjort gennem, først at lave et litteraturstudie af hvad transaktionsomkostninger er, hvorefter transaktionsomkostningers betydning i byggebranchen bliver klargjort. dette ender ud i en pre-problemformulering:

"Hvad kan reducere de unødvendige transaktionsomkostninger i byggebranchen?"

Denne pre-problemformulering besvares gennem de 4 mulige løsninger: Ikke digitale løsninger, BIM, IoT, Big Data og Machine learning og blockchain technology. En blockchain løsning arbejdes videre med og ender ud i problemformuleringe:

"Hvordan kan blockchain teknologien sænke transaktionsomkostninger i byggebranchen?"

Med problemformuleringen in mente, er der lavet et litteraturstudie, som gennemgår hvordan blockchain teknologien fungerer og hvordan blockchain teknologien kan bruges i byggebranchen. Ud fra litteraturstudiet, formuleres der spørgsmål til 1. runde af interviews som bliver lavet med 5 eksperter inden for BCT i byggebranchen. Svarerne fra 1. interview runde og litteraturstudiet lægger grundlag for spørgsmålene til 2. interviewrunde. I 2. interview runde bliver 3 udviklere spurgt til hvordan BCT kan hjælpe deres arbejde i byggebranchen. Ud fra den viden som er indsamlet er der lavet en koncept model, til hvordan BCT kan implementeres i byggebranchen.

Gennem diskussionen er der fundet frem til, at blockchain teknologien generer bedre samarbejde, i et troværdig miljø gennem transperens, sporbarhed, tillid til systemet samt sikkerhed, som vil give lavere transaktionsomkostninger.

Preface

This Master thesis has been created by Ana Bunic and Casper Gøtze who study "Management in the Building Industry", at Aalborg University. This report has been made in the time span from the 1st of February to the 10th of June.

The thesis group want to thank all the companies who have participated in the research of transaction costs reduction through blockchain technology in the construction industry.

Readers guide
The report utilises the Harvard citation method, and a bibliography can be found in the rear of the report. All tables and figures in this report have been enumerated after the chapter they appear in, along with the number they appear in the chapter. For example, Figure 2 in Chapter 1 will has the name Figure 1.2. If a figure or table does not have a citation, it means it has been produced by the project group.

In order to keep the report in one language, transcriptions of the interviews have been translated from Danish to English. The report utilises abbreviations for terms that are used frequently the list of abbreviations.

Aalborg, June 2020

Ana Bunic and Casper Østergaard Gøtze,

Keywords: Transaction cost, Blockchain technology, Procurement in the construction industry.

List of abbreviations	
TC	Transaction Costs
TCE	Transaction Cost Economics
IoT	Internet of Things
BIM	Building Information Model
DLT	Distributed Ledger Technology
p2p	Peer-to-peer

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CHAPTER

1 Introduction

This chapter introduces the topic and explains the motivation to pursue this topic and its relevance.

1.1 Background and Motivation

This thesis is taking an offset in the project report written in the previous semester, which was concerned with modifying the procurement process in the construction industry with consideration of reducing TCs (Bunic and Gøtze, 2019). The focus was put on the events during projects that precede the contract signing and all the wastefulness in terms of money, time and resources that generate TCs. A share of TCs is necessary and expected to ensure that procurement regulations are followed, fair competition is organised and that the most suitable solution is awarded. However, a motivating factor to this research remains an unnecessary part of TCs, which does not add economic value or quality to the construction project. Considering TCs are the foundation of this research, here follows an overview of literature concerned with aforementioned, both from economics' and the construction industry's perspective.

TC in Economics

A substantial body of knowledge is produced on the subject of TC. The literature is dominated by two leading scholars and Nobel Laureates, Coase and Williamson, who gave explanatory views of TCs (Suematsu et al., 2014). Therefore, the following sections will highlight the basic insights of the two mentioned scholars.

TC theory is one of the theories that are a part of an economic stream called the New Institutional Economics (NIE) (Obińska-Wajda, 2016). The founder of NIE is considered to be economist Ronald Coase with his pioneering paper "The theory of the firm" (1937), as claimed by Obińska-Wajda (2016); Carroll et al. (1999); Rao (2002). Prior to Coase's article, the classical economists thought of markets to be frictionless, having no TCs, where resources are reallocated by *"the invisible hand"* of the market (Suematsu et al., 2014). Coase opposed the classical economists' claims by asking the question of why firms exist at all, when the market is such a perfect mechanism (Suematsu et al., 2014). Later, Coase (2005) clarified that a firm, *"a little planned society"*, could only continue to exist if it performed at a lower cost than would be incurred if it were achieved in the market, and also at a lower cost than it could be performed by another firm. He states that there is friction in the market and that there are costs of using the pricing mechanism – discovering what the relevant prices are, negotiation costs, costs of drafting the contracts, costs of inspections and arrangements for settling disputes. These costs have come to be known as transaction costs (Coase, 2005). Coase (1937) also explains why then all the production is not performed by one big company to avoid TC. To answer, Coase (1937) says, as the company grows, there may be decreasing returns, which means that the costs of organising additional transaction within the firm may rise. Additionally, a production might not be used in a way to yield the greatest value and supply price might rise for the larger firm. With those insights,

Coase gave a view of boundaries of the firm in terms of decisions about whether to produce internally or to outsource (make or buy), based on cost minimization (Rao, 2002). Based on his work, some scholars considered the make-or-buy decision as a focus (Rao, 2002; Shah, 2007) and paradigm problem (Shelanski and Klein, 1995) of TCE. Suematsu et al. (2014) argues that TCE addresses the question of the company to produce internally, vertically integrate or buy from the market.

While Coase started the school of TCE, Williamson extended it and thoroughly studied. Williamson (2007) claims that a transaction happens when a good or service is transferred across a technologically separable interface. According to Suematsu et al. (2014), transaction interfaces are all organisations, processes and systems. The design of these determines the amount of TC incurred. Williamson (2007) compares transaction with a mechanical system and the force of friction. More friction in economic exchange means that misunderstandings and conflicts between exchanging parties occur, which leads to delays and breakdowns. Thus, more friction brings higher TCs. Williamson claims that the total costs of economic activity are the sum of production and transaction costs (Winch, 1995). Given that production is efficiently organised, the question posed is how to keep TC to a minimum (Winch, 1995)? The answer lies in Williamson's concept of TCE. He comprehensively explains that TCs differ relative to the decision of governance type employed. Williamson (1996) supports Coase's observation that firms (hierarchies) and markets are alternative forms to manage the very same transaction, and also allows other different forms of relationships based on collaboration. Williamson (1996) refers to them as *"hybrids"*, while Winch (1995) denotes those as *"network governances"*, and Eccles (1981) uses a term *"quasi-firm".*

Each of the mentioned governance types is preferable in different situations, and the choice is depending on three environmental factors, where each stimulates a specific human behavioural characteristic. Three environmental dimensions are uncertainty, asset specificity and transaction frequency (Winch, 1995). A first dimension, **uncertainty**, Galbraith (1977) defined as a function of difference between the amount of information required for a decision, and the information that is available, as found in Winch (1995). Winch (1995) adds that uncertainty is generated by complexity and/or dynamism. The condition of complexity happens when information is available, but its collection or analysis is either technically impossible in the given time, or would cost more than returns; whereas dynamism denotes an inconstant situation in which present information are poor guides to future events (Winch, 1995). A second dimension is **asset specificity**, which Williamson (2007) marks as the most important for TCE. It is defined as the extent to which the resources required are available from a large number of sources or only a few sources (Winch, 1995). Finally, the last dimension is **transaction frequency**, which refers to whether an input is required on a regular or occasional basis (Winch, 1995).

Above described three contingencies, uncertainty, asset specificity and transaction frequency, encourage three human behaviour factors: bounded rationality, opportunism and learning, respectively. According to Williamson (2007), **bounded rationality** acknowledges limits on cognitive competence, or that a *"organisation man"* has *"less powerful analytical data-processing apparatus".* Put differently, human beings have every intention to make a rational decision, but they are limited in absorbing and analysing all the information that surrounds them. The incidence of asset specificity encourages **opportunism** – the strongest form of self-interest (Williamson, 2007). Opportunism can be observed when holders of scarce assets take advantage of their situation by overcharging, or by using their power to influence the other party in the exchange (Winch, 1995). Williamson (2007) emphasizes that bounded rationality and opportunism are

especially important when combined. Without both, the issues of TCs and governance type would be changed or even disappear. Finally, transaction frequency relates to a factor of **learning**, seeing that spot transactions provide no opportunity to learn about the transacting parties, while repeated transactions allow learning and building a relationship (Winch, 2009).
Figure 1.1 sums up the three dimensions of TC and behavioural factors. It shows that an appropriate governance type is in a three-dimensional space as a function of the three contingency factors (Winch, 2001). Issues and increased TCs are caused only when these factors interact with each other: if uncertainty is close to zero, everything is transparent and known so contracts can be made to prevent opportunism. If asset specificity is close to zero, unforeseen events can be dealt with as they happen.

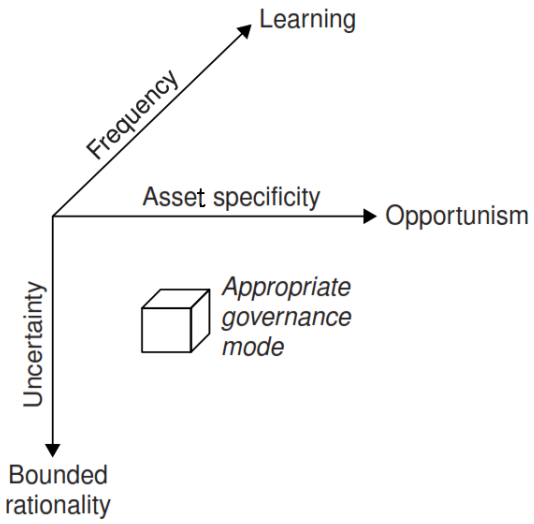

Figure 1.1: The transaction governance level, (Winch, 2001)

Wang (2003) states that despite a voluminous body of knowledge on the subject of TC, there is still no theoretical consensus on the definition of TC. Rao (2002) supports that by saying that TCs are still largely unexplored area of economics. Scholars usually provided a definition that suits their research. They defined TCs by describing what TC are comprised of and in which process they arise. As an example, here follows a list of costs that are included in TC given by Shah (2007), who specifically researched TCs in the construction industry:

- The parties to a transaction finding each other and communicating directly or indirectly;
- The drawing up of agreements and contracts;
- The definition and inspection of goods involved in the transactions;
- The keeping of records;
- Enforcement of the agreements and contracts.

There are many more definitions found in the literature to denote terms *transaction* and *transaction costs.* Ramstad (1996) noticed a difference in Williamson (2007)'s and Commons (1931)'s interpretation of a transaction, where former is focused on the movement of a good or service, and latter on the property rights and ownership. Similar distinction follows in denoting term transaction costs with Pint and Baldwin (1997) on one side, and North (1990) on the other.

For this report, it is deemed not important to list definitions found in the literature. A description that scholars agree on and is generally acceptable, is that TCs are those costs that are not production costs (Hughes et al., 2006; Williamson, 2007; Buitelaar, 2007; Suematsu et al., 2014). As Petersen and Bækkeskov (2015) show with a simple equation, TCs together with production costs summate total cost:

$$\text{Total activity cost} = \text{production cost} + \text{transaction cost}.$$

The most commonly used categorization of TC is given by Williamson (2007) and will be used in this report. He differentiates between *ex-ante* and *ex-post* types of TC, meaning TC before and after the contract signing. Ex-ante are costs of information gathering, drafting contracts, negotiating conditions, decision-making and safeguarding an agreement. Ex-post are the ones incurred while monitoring and enforcing a contract, cost of solving disputes and deviations from the agreement. Ex-ante and ex-post costs are interdependent, meaning that increasing or decreasing one group of costs could influence the other, and vice versa (Rao, 2002).
As it comes to quantifying TCs, yet again, scholars are not agreeing on how to or if it is even possible to measure TC. On one hand, Buitelaar (2007) states that empirical studies are almost impossible as TCs are often hidden, indirect and are not measured in terms of money and man-hours. Additionally, Wallis and North (1986) claim that economic actors do not have the motivation to observe TC as a separate cost, they are concerned with the bottom line. On the other hand, Suematsu et al. (2014) says that universal procedures for measuring, analysing and streamlining TCs could be defined because transaction structures are invariable, despite different production in every sector, company and department.

TC in the Construction Industry

Where there is an economic activity, there are TC, and that goes also for the construction industry. Rajeh et al. (2013) argues that there is a need to better evaluate TCs in construction, given that the procurement decision is highly cost-sensitive. Available literature that deals with the application of TC framework in this industry is limited, but also scattered because of different definitions and many variables that influence TC. TCs in the construction sector are typically associated with the procurement and tendering process, and its consequences. For example, Hughes et al. (2006), who studied TCs in the construction sector, groups TCs in pre-tendering (marketing, selling, pre-qualification rounds), tendering (calculating prices, risk and environmental assessments, health and safety plans, quality plans), and post-tendering work (performance monitoring, enforcement and disputes). That TCs are related to procurement is reassured with interviews from the previous project report, where 8 construction professionals confirmed the fact (Bunic and Gøtze, 2019). The following Table 1.2 sums up costs and activities that might comprise ex-ante and ex-post TC in the construction industry.

EX-ANTE TC	EX-POST TC
Initiation costs • Team selection • Proposal evaluations • Start-up meetings **Preliminary design costs** • Early design documentation • Approvals **Negotiation and contracting costs** • Preparing bidding documentation • Approvals • Commercial negotiations • Drafting contracts • Costs of unsuccessful tenderers **Feasibility study costs** • Evaluating the environmental and financial feasibility • Evaluating the profitability of the project • Information search and assessment **Advice costs** • Technical • Legal • Financial	**Monitoring and control costs** • Ensuring the terms and conditions of the contract are met • Ensuring that parties are upholding their responsibilities under the contract documentation **Dispute resolution costs** • Resolving conflicts • Costs of mediation, arbitration and litigation (lawyers, claim consultants) • Indirect costs of delays and degeneration of working relationships **Implementation costs** • Day-to-day implementation of the contractual obligations • Contract administration • Administering claims and change orders

Figure 1.2: Ex-ante and ex-post TC, extracted from (Jin et al., 2017)

There have been attempts to estimate and measure TCs in the construction industry. However, the results of those studies have shown different figures. The first reason for that is the unclear definition of TC, so the inconsistency in defining TC leads to differences in collecting data and measuring (Li et al., 2014). Secondly, construction procurement is a complex process that offers different options in terms of contracting methods, tendering procedure and price agreement, and in each of these options, the amount od TCs differ. Furthermore, it is important to define whose TCs are being measured (client, contractor, consultant, losing bidders etc.). Finally, as Tah et al. (1994) and Shash (1998) noted, not many companies are willing to participate in these kinds of studies due to the sensitive nature of the information required. A few examples are extracted to point out that the amount of TC that should not be negligible. Bygherre Foreningen (2018) states that 5 consultants together use up to 28% of the contract value in the tender process while bidding for a project. Li et al. (2014) estimated TCs for clients (private and public), and found that average ex-ante TCs are 3.6% of the contract value, and ex-post 6.4%. Hughes et al. (2006) gives a combined estimation from different studies that says that overall TC might vary from 0.5 to 15%.

To depict and summarize important variables that influence TC, Bunic and Gøtze (2019) inspired by Hughes et al. (2006), made a table that shows a conceptual distinction of procurement methods in Denmark (Table 1.1). The idea behind it is to show that by describing a project by

a method of contracting does not sufficiently describe how something is procured and what are TC (Hughes et al., 2006). For example, knowing that Design & Build Contract is used, suggest merely that Contractor is the party responsible for design, coordination and construction. It does not indicate what the amount of TC could be, because the client is unknown, the tendering method and the extent od subcontracting. Thus, when considering TCs, all of the categories shown in Table 1.1 should be taken into consideration.

Table 1.1: Conceptual definitions in procurement, inspired by Hughes et al. (2006)

Category	Examples
Ownership, initiation, funding	Private Client, Public Client, Subsidized Client, Developer
Responsibility for design	Consultant (Architect, Engineer), Turnkey Contractor, In-house design team
Responsibility for management and coordination	Client, Main Contractor, Turnkey Contractor, Lead Consultant (for consulting services)
Tendering procedure	Public tender, Restricted tender with prequalification, Restricted tender without prequalification, Confidential tender, Negotiated procedure, Negotiated procedure without prior announcement, Competitive dialogue, Innovation partnership, Project competition
Amount of subcontracting	0 - 100%

As it was noted earlier, from the point of Coase (1937)'s article, the concept of TC has developed into a branch of theories concerned with the make-or-buy decision (Hughes et al., 2006). Winch (2009) states that the pure market and pure hierarchy have rare application in construction projects, what indicates that collaborative forms (Williamson's hybrids) are preferred over producing entirely in-house or buying of the market. Hughes et al. (2006) remark that in-house production is not feasible in the modern construction industry. On the contrary, many characteristics of the industry are working in favour of subcontracting. Those include the definite period of a project, the wide geographical spread of locations of construction sites, diversity of skills required during projects and uneven requirements and for specific skills (Hughes et al., 2006). However, Hughes et al. (2006) states that multiple layers of subcontracting greatly increase TCs. That is significant, since 80 – 90% of work is outsourced in the construction sector (Hinze and Tracey, 1994; Lingard et al., 1998; Mbachu, 2008; Al-Hammad, 1993). This is why Hughes et al. (2006) draws attention from the make-or-buy decision to the problem of structuring the relationships in the complex network of contracts in the course of a construction project.

As already indicated, not all TC are wasteful (Buitelaar, 2007; Rao, 2002; Suematsu et al., 2014).

A general tendency is to think of TCs as costs that should be reduced. However, unrestrained reduction of TC is not a sustainable course for maximising social welfare and profit in companies (Rao, 2002). Buitelaar (2007) expressed TCs as both means with a purpose and deadweight losses, meaning that TCs bring certain benefits like security and trust in the system, but at a point, they become a waste of time, resources and money. Buitelaar (2007) asks here how to draw the boundary between "good" and "bad" TC and who is to judge? Finally, companies and industries have the ability to reduce TC, but should not aim for eliminating them. Hence, TC management is an issue of resource allocation, and not an issue of maximum reduction of TC.

To summarize, this section extracted the required knowledge of TC framework for this report. TCE can hardly be utilised without looking into Coase's and Williamson's work. Therefore, this section presented Coase's observation of friction in the market, which should be accounted for in the decision whether to produce in-house or to buy in the market. Williamson extended his work and added a social component, saying that uncertainty, specific assets and frequency of transactions influence bounded rationality, opportunistic behaviour and learning, respectively. Important to mention is that these factors have an influence when combined. Taking into account these factors, a decision about the appropriate governance type can be made, which will result in the reduced TCs. However, knowing that this is a theoretical framework, when making a decision, the strategic capabilities of the company should also be considered. When applying TC framework in the modern construction industry and projects, it is observed that complete hierarchical governance is uncommon.

During the previous semester project, interviews were conducted with contractors, developers and consultants to get their view on TC (Bunic and Gøtze, 2019). It was found that individual companies are inadvertently reducing their TCs by favouring networking governance type and working with familiar companies. Approaches to reduce excess TCs were observed and will be revised in Chapter 3. However, a major accumulator of unnecessary TC happens in public procurement. It was discovered that contractors do not get invited to the next project if they fail to submit a bid to the current project. To "stay in the game" contractors make the bid, despite it being overpriced due to heavy outsourcing. These practices add to unneeded TC (Bunic and Gøtze, 2019). Next, an issue was found in a practice that on the first look seems like it could reduce TC. It concerns EU tenders where there is a possibility to avoid tendering on one part of the deal, which is 20% of the contract cost, but a maximum of DKK 500 000. The issue arises when the allowance is spent on an architect, and when developer tenders the project, he cannot select the same architect. That causes the additional issue of copyrights that the first architect owns, and these increase TC (Bunic and Gøtze, 2019). Here mentioned are just some of the issues in public procurement, and higher TCs are expected since the procurement of public projects needs a balance between competition and cooperation (Dorée, 2004). However, having the government as a dominant market player (Dorée, 2004; Barima, 2017), construction procurement is still an issue that needs attention. Having said that, the motivation remained to explore a construction procurement process within the transaction cost framework yet again, only this time on the scale of an industry, and not individual companies.

1.2 Relevance

The relevance of the subject of transaction costs lies in the efficiency of the procurement and tendering processes, and contract management in the industry, given that TCs are closely associated with these procedures.

McKinsey published a report entitled "Reinventing Construction: A Route to Higher Productivity", which claims that the construction sector, as one of the largest in the world economy and contribution of 13% of GDP, is significantly less productive relative to other sectors (McKinsey, 2017). Moreover, the productivity of the sector has been flat for decades (McKinsey, 2015). Therefore, McKinsey (2017) proposed seven routes to fight poor productivity, and three of those are related to the procurement process, which directly points to transaction costs and related activities. Firstly, McKinsey (2017) incentives to **improve procurement and supply-chain management**, given that research showed that poor supply-chain and procurement accounts for 10 – 30% of the cost and time overruns. Setting up relationships and contracts in highly fragmented industry results in transaction costs. To depict high fragmentation and complexity in supply chains, ICE (2018) offers an example of the Crossrail project in London, where more than 700 suppliers were contracted. Since transaction costs are economic losses based on the quality of contract management, the contract framework is influencing the amount of costs. Accordingly, McKinsey (2017) suggests **rewiring the contractual framework** with the claim that misaligned contractual structures are one of the top causes of low productivity. The change should happen by improving tendering practices and ensuring a trusting environment for all parties. Finally, McKinsey (2017) proposes to **reshape regulation and raise transparency**, where are also TCs incurred, given that resources spent on regulation and transparency are TCs. In summary, the McKinsey report is greatly focused on the procurement process and surrounding activities, which generate transaction costs. If seven identified routes to higher productivity are implemented, it is suggested to boost productivity by 50 – 60% (McKinsey, 2017). This claim suggests the importance of addressing the aforementioned issues.

The UK has conducted several studies long before the mentioned McKinsey's report to document the problems of the sector and put in place a program for improvement. Interestingly, those reports repeatedly gave recommendations to increase the efficiency procurement process and tendering practices and to reduce costs. For example, Latham (1994) proposes partnering to establish long-term contracting arrangements and to form registers of approved companies, which both could lower TCs incurred in information search and verification. Additionally, he proposes higher levels of standardisation and speedy dispute resolutions to reduce costly procedures after contract signing. Egan (1998) also criticised tendering practices and proposed long-term relationships instead of competitive tendering. However, Wolstenholme et al. (2009), when they made a review of progress since Egan's report, still pointed out tender processes that destabilise the supply chain, and procurement practices that are becoming more expensive. As a good practice, the Japanese construction industry is mentioned, and key points are transparent procurement, contract and payment processes (Wolstenholme et al., 2009).

Considering the years when these reports were issued, and that procurement processes are still organised inefficiently, resulting in high transaction costs and low productivity of the industry, it was deemed important to observe the construction industry within the transaction cost framework and explore options to alleviate some of the sector's pain points. If a viable option that reduces wasteful transaction costs would be identified, it would bring benefits to the construction companies, clients, tendering authorities and the taxpayers.

CHAPTER

2 Research Methodology

2.1 Project Structure

This project is structured as can be seen in Figure 2.1. The first chapter is the introduction, it starts with the background and motivation where the literature review of transaction costs is presented. Afterwards is explained why this topic is relevant.
The second chapter is the research methodology, where it is explained how the information is gathered and explained the validity and reliability of the research.
The third chapter is where the pre-problem formulation is, it is the question that have to be answered in the fourth chapter.
The fourth chapter is where the answer to the pre-problem formulation is, here are possible solutions to the pre-problem formulation, and is the foundation to the problem formulation.
The fifth chapter is the Problem Formulation, this is made on the basis of the literature review and contains sub-questions to secure the problem formulation is answered.
The sixth chapter is a literature review of blockchain technology, where the important information is put in. It includes studies of blockchain technology in the construction industry.
The seventh chapter is where the interviews with Experts in blockchain technology in the construction industry is presented. It starts with an explanation of each interviewee and the findings of the interviews can be found in this chapter.
The eighth chapter is the interviews with construction professionals. There is an introduction to the interviewees and the findings from the interviews.
The ninth chapter is a proposal to implement blockchain technology into the construction industry.
The tenth chapter is the discussion where the emperical data are compared with the literature.
The eleventh chapter is the conclusion, it is where the problem formulation is answered and the points from the discussion are clarified.

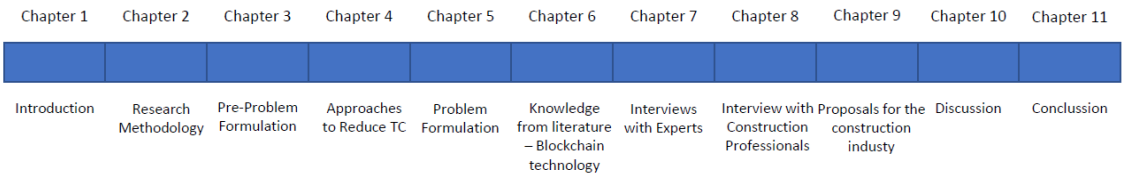

Figure 2.1: The parts in the structure of the project

2.2 Philosophies of Science

Which kind of philosophy of science is used in the project is important to know, because there are different ways of perceiving data, so the reader knows how the thesis group have perceived the data collected in the project. Fuglsang et al. (2014) claim that there are 4 different philosophy of science directions, which are:

- Positivism
- Realism
- Hermeneutics and Pragmatism
- Social constructivism.

Positivism is knowledge acquired through empiri and deduction of theoretical laws. It is a completely objective way of thinking. **Realism** is a direction in philosophy of science that perceives the society as an objective reality that exists even though the human is not aware of it. The philosophy acknowledge that interpretation is necessary to find the circumstances behind the visual reality. **Hermeneutics and Pragmatism** are scientific philosophy direction that seek to break the boundaries between object and subject, which means that human can not be perceived as objects, because they have their own subjective meanings, which can not be done if they are perceived objective. The society is, if one looks at the hermeneutic and pragmatic direction, the connection of materialist and thinking and is about the understanding and interpretation. Within the **Social constructivism** there are no objective reality, but it is the humans' perception of the reality and how their thoughts form the reality. It is said that in social constructivism events are historical changeable, because events have a historically and socially perspective. (Fuglsang et al., 2014)

Because of the subject transaction costs and Blockchain technology in the thesis, the thesis group can not gather the needed data via the worldview of positivism, because through the literature study former studies are perceived of the thesis group. Instead the thesis group have the worldview of hermeneutics and pragmatism, because the thesis group is going through the thesis with the observations from the literature from transaction costs, which gave one perspective of the subject, and afterwards the thesis group read about blockchain technology which gave another perspective on the literature. This also gave the angle to solve the issues with lowering transaction costs by looking into BCT.

Through the process of the project there have been used is the inductive and deductive method, because the thesis group starts with researching transaction cost in the construction industry, the findings from that is used to research Blockchain technology and how it can contribute to reducing the transaction costs in the construction industry, which ended in the problem formulation. This is used to make the interviews and analyse them, where the deductive method is used. The method is shown on figure 2.2.

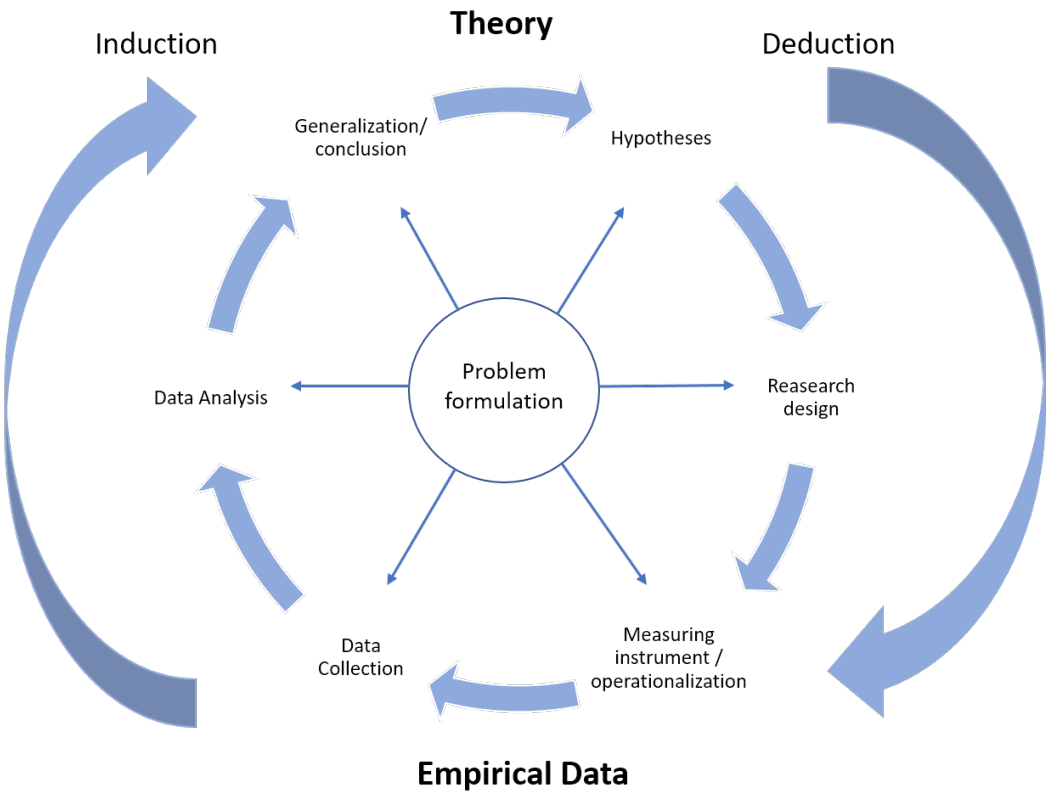

Figure 2.2: Showing how the Inductive and Deductive method works. Inspired by Bohnstedt (2018)

2.3 Research Design

It is important to determine the research design because as Bryman (2016) says is the foundation of the data collection and analysis. It is the way the thesis group secures to analyse the data in a scientific way. Bryman (2016) distinguish between 5 different research designs, which is used in different occasions.

- Experimental design
- Cross sectional design
- Longitudinal design
- Case design
- Comparative design

The experimental design is not selected, because the situation of the project is complex and the variables of the research are not controllable. The cross sectional design is a design where you get a snapshot of a phenomena, this is not chosen either. The longitudinal design is a phenomena observed over a longer period of time. Comparative design is a where two phenomenons are compared by literature. The research design chosen in this project is case design because as Bryman (2016) says, it is a good design when researching one case which using blockchain technology to reduce transaction costs is, because the technology is a case used to reduce the unnecessary transaction costs.

2.4 Method

In the project, there are used different methods to gather the information for the research both primarily and secondary data, the primary data are information gathered by the project group and are gathered trough 8 qualitative interviews, with experts working with BCT in Denmark, a spokesperson from DI (Dansk industri), and developers located in Aalborg. The secondary data are information gathered from the articles and books that are looked through for information of the topic, which is presented in the literature review.

2.4.1 Literature Review

The purpose of making a literature review is as Bryman (2016) says, to make the foundation of the research by knowledge that are already found about the topic. In the literature search the project group have searched on different databases such as ASCE, Web of Science, and Scopus, but Google Scholar is also used. For the part about economics and the foundation of transaction costs have the master group used databases started with searching on the keyword transaction costs in construction, but evolved it into first tendering in construction and afterwards the keyword procurement in construction. There were 931 hits on the different keywords searched, whereas it was sorted by titles which gives 53 relevant articles. The abstract and conclusion were then read to see if they were relevant for the project. It ended up in 51 articles where some of them are found by searching for the primarily source of the information in the articles.

Similar to the economics part about transaction costs have the project group searched the same databases in relation to BCT the key words that are searched are "Blockchain technology", "The intersection between BCT and CI procurement", "The intersection between BCT and CI" because limiting it to procurement gave few results, and "The intersection between BCT and procurement/tendering". From these keywords there were found 62 articles with useful knowledge.

2.4.2 Case Study

This project is done to research how/if BCT can reduce the transaction costs in the construction industry, therefore have the masters group interviewed several parties in the industry, the experts who are trying to make BCT work in the industry, developers and client advisor. The case study is often criticized because it can be hard to generalize (Vaus, 2001). For that reason the project group compare the empirical data to what data that comes from the literature, to make the conclusions more able to be generalized. This is done to increase the validity, because the project group gets a wider view on the same topic, which will increase the correctness of the answer the project group get. It will also increase the reliability, if the answers are similar.

2.4.3 Interview

In this project there are made several interviews to discover more information about blockchain technology in the construction industry and to get concrete answers from construction professionals in Aalborg, on if the blockchain technology can help them in the everyday work life. The interviews are made in respect of the theories made by Kvale (2008) where the seven steps are followed. The seven steps are in Figure 2.3.

Figure 2.3: The seven steps of Kvale (2008)

- By **Thematizing** it is meant the purpose of the research, it is in this part where the topic to be studied is clarified
- **Designing** is the phase of the project where the interview design is made.
- **Interviewing** is the phase where the interviews are held.
- **Transcribing** is where the recorded interviews are putten in to text, in this project the transcription is of every word, that's been said in the interview although when the interviewer says "yes" and other small words to get the conversation flowing is left out.
- **Analyzing** is the phase where the information gathered in the interviews are processed and put into use in the project.
- **Verifying** is the phase where the project group evaluate the interviews results to say if it's reliable and valid.
- **Reporting** is the last phase, it's in this phase where the project group makes their discussion, conclusion, and solution for the project. This is the end product.

Designing

The designing of the interview is made with respect to Chapter 6 on page 27, the design are made with the **Frame of reference** which is the theory or information from literature which is use to make the **Reflections** where there is written what is wanted to get from the answers the interviewee gives. An example of this is in figure 2.1. Bryman (2016) state that there are advantages in using both open and closed questions because the closed questions gives the answers on the same terms as the interviewer, this is done about asking about how BCT can help in tendering phase in different manors, which can be seen in Appendix A on page 79. The open questions are made to get the interviewee to answer on their own terms, this is done with the questions about , because the interviewer ask a general question, and let the interviewee talk about the topic, where after the interviewer asks followup question to secure that the answers to the research are collected, some times the interviewee asked further questions that came to mind while the interview was going. Sometimes the interviewer asked a question that is a clarification to see if the answer was understood properly by the interviewer.

Table 2.1: An example of how the interview questions are made, the whole interview guide is in Appendix A on page 79

Reference	Reflection	Question
What does the theory say	**We would like to know**	**How do we get to know it**
Wüst and Gervais (2018) suggests that permissioned blockchain shares similarities with a traditional database, which naturally brings up the question whether a blockchain is better suited than the database.	We want to know about the extent of usage of BCT in the construction sector.	1. What problems can BC solve in the CI that we can't solve with a traditional database?
		2. How can BCT benefit future projects by learning from the former ones?

After making the analysis of the first 5 interviews with Experts in the field of BCT in the construction industry, there were gathered knowledge to make another interview guide see Appendix B on page 83 to get research how the technology will affect their business, and to hear if it is useful in the industry.

The interview questions are translated to Danish because 5 of the 8 interviews were held in Danish. This was done to get more reliable and valid answers from each of the interviewees, because the danish construction industry mainly works in Danish. The questions are made in a semi-structured manor, because some of the questions are concrete and others are more open ended. The interviewee can always add their consideration to the question and go of topic, but the interviewee controls the interview back to topic to get the answers questions needed for the research.

The interviews were held in person with 1 of the 8 interviews. Most of the interviews were held over Microsoft Teams because of a global pandemic called Covid-19, so for health reasons were they made on distance, this made it a bit harder to get the conversation flowing, and there were some minor stops in what was said during the interviews but the information got through anyway.

Transcribing

The interviews are all recorded and afterwards transcribed approximately verbatim, with respect to what there is said in the recording. The interview also include some start of sentences that were interrupted and reformulated by the interviewee if it made sense. They are included because, although an initial start of a sentence does not make sense in itself and can be omitted in relation to the sentences, that contain information that are valuable for the research. It is transcribed in this manor, because the report are written in English and one of the group members doesn't speak danish, so the understanding of the conversations in the interviews are perceived in the right way.

Analysing

Kvale (2008) states that there are 5 ways of analysing an interview. **Categorization** where the information from the interview are categorized and scales how strong the interviewees opinion are to the topic, **Condensation** where the answers are shortened without excluding the meanings of the answer, **Structuring** is focusing on the stories told by the interviewee, and

try to map the structure and purpose of it, **interpretation** where it is about digging deeper than what the answers indicates by itself by analyzing the answers in a greater context and in relation to a wider frame of reference, the last thing is **Ad hoc** which is a mixed method of the earlier described. This is what the project group are using, because the interviews are categorized in the different categories of the interview questions, and the stories told in the interview are interpreted by the project group with the perspective of the literature review. A tool the masters group used to analyse the interviews is Nvivo, which can be used as a highlighter but digitally. This makes it easier for the masters group to categorize the different parts of the interviews.

Verifying
Throughout this chapter it is shown that the project group made actions to increase the reliability and validity of the interviews. One of those were testing the questions for bias on each other before interviewing. There have been interviewed several experts with different insights in BCT and several professionals in the construction industry, that increases the reliability of the answers that is collected by the project group.

2.5 Reliability and Validity

It is important that the data collected in the project are both reliable and valid, to make sure the research is scientific. Reliability is how accurate the data is every time, in order to hit the same answer whilst validity is about hitting the correct answer the correctness level of the answer. (Bryman, 2016). This report is a broad research which covers a lot of content, there are included information about two different theories. This raises the validity, because the variable are not missing. The interviews that are made, are backed up by the data from the literature review which raises both the reliability and validity. There are made two rounds of interviews to ensure repeatability in the project, where there in the first round with experts were asked about BCT in the construction industry, and that data is used to interview the construction professionals in the second round of interviews about the impact the BCT can make in their work. Because of the two rounds of interviews and the way they are structured, there is a respondent validation.

CHAPTER

3 Pre-Problem Formulation

This chapter will present the initial problem formulation.

As mentioned in Chapter 1, the application of TC theory to the construction industry was studied in the previous semester and on the scale of individual companies (Bunic and Gøtze, 2019). Finding that unnecessary TCs are generally known of, but written off as "part of the job" stimulated motive to keep exploring the subject, though from broader, industry-level perspective. Additionally, given that many well-known published reports reviewed in the introductory chapter, directly or indirectly, put the blame for low productivity in the procurement process, it was deemed significant to study the construction procurement within TC framework. Therefore, the initial problem formulation is phrased as follows:

What can reduce the unnecessary TC for the construction industry?

It is important to distinguish what will be observed under the term "TC". TCs are in the construction industry generally considered as costs generated in the procurement process, but there are still many open interpretations. In this thesis, a term TC encompasses the costs incurred from the decision to build to the contract signing (ex-ante TC) and the consequences of the signed contract (ex-post TC). Additional doubt that might be raised is what exactly are TCs. For example, if the costs incurred in making the drawings are production costs or TC. Thus, all costs that lead to entering into the contractual agreement or give the potential to do so, are TCs.

The next issue is defining what exactly are unnecessary TCs, which leads back to Buitelaar (2007) who asked who is to decide which TCs are non-value adding and which are functional TCs and how to make that decision? The way to explain both of these might be looking into specific activities that incur TCs (shown in Table 1.2) and discuss them. For example, different approvals that need to be obtained before starting the construction phase are in itself made to reduce TCs. Constructing the building is regulated, and with the making of rules, TCs are reducing. This subject is explored in (Buitelaar, 2004) where are considered different property rights and regulation. However, the remaining question is how is the process of obtaining approval organised, less or more efficient. For many other activities, the process could be criticised to incur unneeded TCs. For example, the way of searching for information or drafting contracts. Next, dispute resolution costs could be also marked as non-value adding. While it is acknowledged that disputes arise and need to be solved, a lot of resources is spent in finding where and by whom the mistakes were made. Siebert (2016) deals with global economic issues and states that resources that are needlessly employed for quarrels could be used in production to generate a higher income and improve the standard of living. The same applies to the resolution of disputes in the construction industry.
To finalize, it is difficult to draw a clear line between TCs that are and are not adding value to the project. Perhaps it is useful to think about minimal TCs as maximum process efficiency, as stated

by Buitelaar (2004). A building will be procured either way, the question is how are the processes organised with respect to TCs. Considering lean thinking philosophy, minimal TCs would be generated if all activities that absorb resources but create no value are eliminated (Womack and Jones, 1997).

CHAPTER

4 Approaches to Reduce TC

This chapter will provide answers to a pre-problem formulation.

Through brainstorming sessions and with previous insights and knowledge, possible solutions were listed and discussed. Hereby, these solutions are grouped into Non-digital solutions, BIM, IoT and Blockchain technology, and discussed how they affect the construction industry within TC framework.

4.1 Non-Digital Solutions

First solutions that were considered are "non-digital" because of the awareness that the construction industry is among the least digitised sectors (McKinsey, 2016) and that the companies have limited R&D budgets to spend on digital upgrades, in comparison with companies in other sectors (McKinsey, 2019).

Collaborative working practices

The specific focus here are framework agreements and maintaining established relationships between companies to reduce TCs, as found in Bunic and Gøtze (2019). In the research was found that network is a preferred type of governance in the construction industry. Developers, contractors, subcontractors and consultants work with companies they are familiar with and have an established relationship. Additionally, the projects are also awarded on the account of previous relationship and references. In this way of working, opportunistic behaviour is reduced, more information is shared what reduces uncertainty and enables better decision-making. Ex-ante TCs are reducing because of frequent transactions between parties. Similarly, ex-post TC also have potential to get reduced, especially dispute resolution costs. Although disputes are inevitable in a collaborative working environment, parties that know each other can quickly come to agreement and resolution without the involvement of lawyers or courts. This working practice is in literature termed "the shadow of the future" (Eriksson and Lind, 2016). Eriksson and Lind (2016) state that this is a critical aspect that provides an opportunity to reward cooperative behaviour and punish opportunism. The idea behind it is that a party will not act opportunistically, even if there is a chance to do so, because that would put working on future projects at risk. In line with this, one of the construction professionals interviewed in Bunic and Gøtze (2019) declared: *"There is a lot of karma in this business."* However, this method of procuring projects does not apply to publicly funded projects, where competition is encouraged as a means to avoid monopolies and drive industry growth and innovation (Dorée, 2004). Hughes et al. (2006) claims that ex-ante TC of public projects are higher than those in the private sector, which is evident since specific procedures need to be followed and more stakeholders need to be involved and managed. In the incapacity to cover both public and private projects, and in the fact that the subject of collaborative working in the industry has been scrutinised in the literature, lies the reason that this solution will

not be explored further as a method to reduce TC.
Another collaborative working practice discussed was framework agreements. The idea derived from reading about the strategic partnership named Trust, that is delivering projects in the Copenhagen area and is one of the only ones in Denmark (ByK med TRUST, 2020). A project director of Trust mentions non-value-added TCs associated with the tendering process as one of the challenges that were overcome with entering into the partnership (Thinggard for NTI, 2019). Hughes et al. (2006) also mentions savings in the re-tendering costs, but states that frameworks are known for being very expensive to contract and negotiate agreements in the beginning. Framework agreements are not "one size fits all" solution and are currently used in large scale projects. Because of not covering the "standard" projects that are everyday practice in the industry, this subject will not be further researched.

Acquisitions
Bunic and Gøtze (2019) found that increasingly favoured method of contracting – Turnkey – is "designed" for big players in the market, which leaves small companies out of the game. For that reason, many small engineering and architectural companies have been purchased by bigger companies. This could be done in a way that a smaller company ceases to exist or that it is purchased in a way that its legal structure does not alter. In acquisitions, the big partner is moving some of the production in-house and reducing costs, while a smaller company has a chance to compete. This is a phenomenon that Bleeke and Ernst (1995) noticed in strategic alliances when they result in one of the partners taking over the other. The hierarchical structure reduces TCs in cases of high uncertainties with many information flowing around, and in high asset specificity when the project is exposed to an opportunistic hazard. Since the construction industry is characterised with a high level of outsourcing, acquisitions will not be explored as a means to reduce unnecessary TC.

Certainly, other approaches could reduce unnecessary TC, whether ex-ante or ex-post. These could be, for example, better communication or a different management method. However, no specific method was thought of that would reduce TC on the industry level.

4.2 BIM

Being a current expression of digital innovation in the construction sector (Li et al., 2019a), BIM could not be excluded as one of the possible means to reduce unnecessary TC. BIM is defined as a digital model that integrates many sources and gives an exchange platform where different disciplines collaborate and solve design and construction issues (Shojaei et al., 2019). Considering TC are normally associated with the procurement process, Bunic and Gøtze (2019) interviewed construction professionals about ways BIM is influencing their business in respect to alleviating incurred TCs. Firstly, it was found that professionals still tend to think of BIM as a 3D model used to make a more compelling case to the potential client, and less as a digital model filled with all the required information. Secondly, as the main challenge was mentioned the difficulty to get all BIM tools that are used in a project to work together. Finally, the current reach of BIM is not gaining trust with professionals to use it during tendering and is seen as a waste of resources, especially in regular everyday projects. The original purpose of BIM is to be an information loaded model which would collect all data and enhance collaboration. When this is achieved, decisions could be made on the best set of available information with undisturbed information flows, minimum levels of bounded rationality and biased decisions, which

would ultimately lead to reduced TC (Bunic and Gøtze, 2019). However, this level is not reached yet, especially not in procurement. There are still some barriers that need to be overcome, for example, the problem of gathering information after they had been collected, deficiency of BIM specialists, lack of standards, ownership etc. Hamma-adama and Kouider (2020) share similar opinion and claims that BIM together with other on-going developments in the industry, namely Lean Construction, could improve the construction processes, but the influence on improving supply chain and procurement management is questionable.

4.3 IoT, Big Data And Machine Learning

The International Organisation for Standardization (ISO, 2018) defined IoT as an infrastructure of interconnected entities, people, systems and information resources together with services which processes and reacts to information from the physical world and virtual world. The important aspect is electronic devices (thermometers, video cameras, microphones, heaters etc,) that interact with the physical world. Big data and cloud computing technologies then gather and process information. IoT enabled environment could benefit the industry by obtaining site information, to monitor the statuses of the workers and to execute emergency actions automatically in the event of an emergency (Sawhney et al., 2020).
Big data got its name because it can analyse unstructured data from information systems and use it appropriately. Based on these, it can forecast events important for the construction project. For example, it can collect data regarding weather and traffic, and forecast the possible delays in the construction process.
Machine learning, as a subset of AI, can improve the construction project by helping humans where they are fallible. For example, it can enhance design quality by rapidly identifying mistakes. On top of that, it can learn from data and it can help determine if a particular element of the design is optimal for a specific use.
These three interrelated technologies could cut TC to some extent, especially when paired with BIM. For example, where humans fail short to make the right decision because of bounded rationality, ideally, machine learning could cover that issue. However, it seems that these technologies are still far away in the future when it comes to the construction sector, because of the high complexity of processes. Additionally, TCs depend on levels of opportunism, which is a characteristic of a human to act in self-interest. In that view, it is unclear how machines that learn from historic data and sensors could aid the minimising of TCs.

4.4 Blockchain Technology (BCT)

Blockchain technology is a distributed database that maintains a list of records, for example, transactions or information (Dakhli et al., 2019). Being distributed means that each participant of the network has a copy of the database. Dakhli et al. (2019) uses a simple analogy of application of Google Doc. A participant can view it, add to it, but a major difference is that he cannot change the information that is already there.
The effect of blockchain on reducing TC is certain and already noticed in the very first application of BCT, where Nakamoto (2019) devised a system that allows payments without the need to trust a third party. Trust means paying fees to the third party, in this case, a financial institution, to oversee a transaction. Considering that the basic unit of a blockchain is a single transaction (Treiblmaier, 2018) and that the basic unit of analysis in TCE is the transaction (Davidson et al.,

2016), it suggests an important connection between TCE and BCT. Additionally, Deloitte (2019) states that BC solutions reduce *friction* across organisations and industries, which leads back to Coase (1937)'s attention of *friction* in the market.

Inevitably, the technology will also benefit the construction industry. Institution of Civil Engineers ICE (2018) issued a report, stating that blockchain has arrived and it offers an opportunity for the industry to become more productive and transparent. It provides three main features that blockchain can enable - transparency, traceability and collaboration (Figure 4.1). Interestingly, transparency and collaboration are exactly the buzzwords in reports mentioned in Section 1.2, where the relevance of TC framework in the industry and construction procurement was expressed. Perera et al. (2020) critically analysed the potential of blockchain in the construction sector, and boldly stated that BCT has enormous potential to change the construction procurement process and that one of the best applications will be government procurement systems.

Figure 4.1: Blockchain enabled features for the construction industry, (ICE, 2018)

Deloitte (2018) states that data is quickly becoming the core for future success in the construction industry and that there is an urgent need for companies to devise a framework for collecting the data, to analyse it and provide it to the right people in the right moment. In KPMG (2016)'s survey about exploiting the technology to improve the performance of the construction projects, one respondent claimed that his company is spending 80% of the time collecting data and 20% of the time analysing it, and that technology should flip those percentages. A study made in Box Inc. entitled "The Information Economy: A Study of Five Industries" by (Bouck, 2014), examined collaboration patterns in five industries, among which is the construction industry. Bouck (2014) states that the information is at the centre of today's economy and brings up a new ROI – return on information, as the new measure of success of companies. Return of information considers access to information, how fast it moves and how quickly can it be updated and leveraged to generate value (Bouck, 2014). The visualisation of the results of the study are shown in Figure 4.2 and indicate that construction companies have the highest rate of work shared with outside companies, approximately double of any other analysed industry (Bouck, 2014). These insights are pointing to the direction of BCT as a data management technology that could support and ease communication and information flow in the complex network of the construction sector where the infromation is stored in remote silos, and by that also reduce TCs. In his book, Suematsu et al. (2014) talks about reducing TCs through fixing transaction interfaces, where all organisations, processes and systems are interfaces. Fixing interfaces means fixing ways of transacting. Suematsu et al. (2014) also states that *"Cooperation and collaboration become possible when there are interfaces to unify people's activities."* Although

there is no mention of BCT in the book, it might appear as BCT is exactly the interface that would enable much-needed cooperation in the procurement process. BCT could also work together with technologies explored in Sections 4.2 and 4.3 to further reduce costs. As an underlying, supporting technology, it could alleviate issues that BIM, IoT and Big Data are currently facing. For example, BIM models are constantly revised and modified by participants, which can lead to conflicts later in the project. BCT is able to record information on who did what and when in the model, that information cannot be changed and can serve as a basis for any legal arguments that might arise (Belle, 2017).

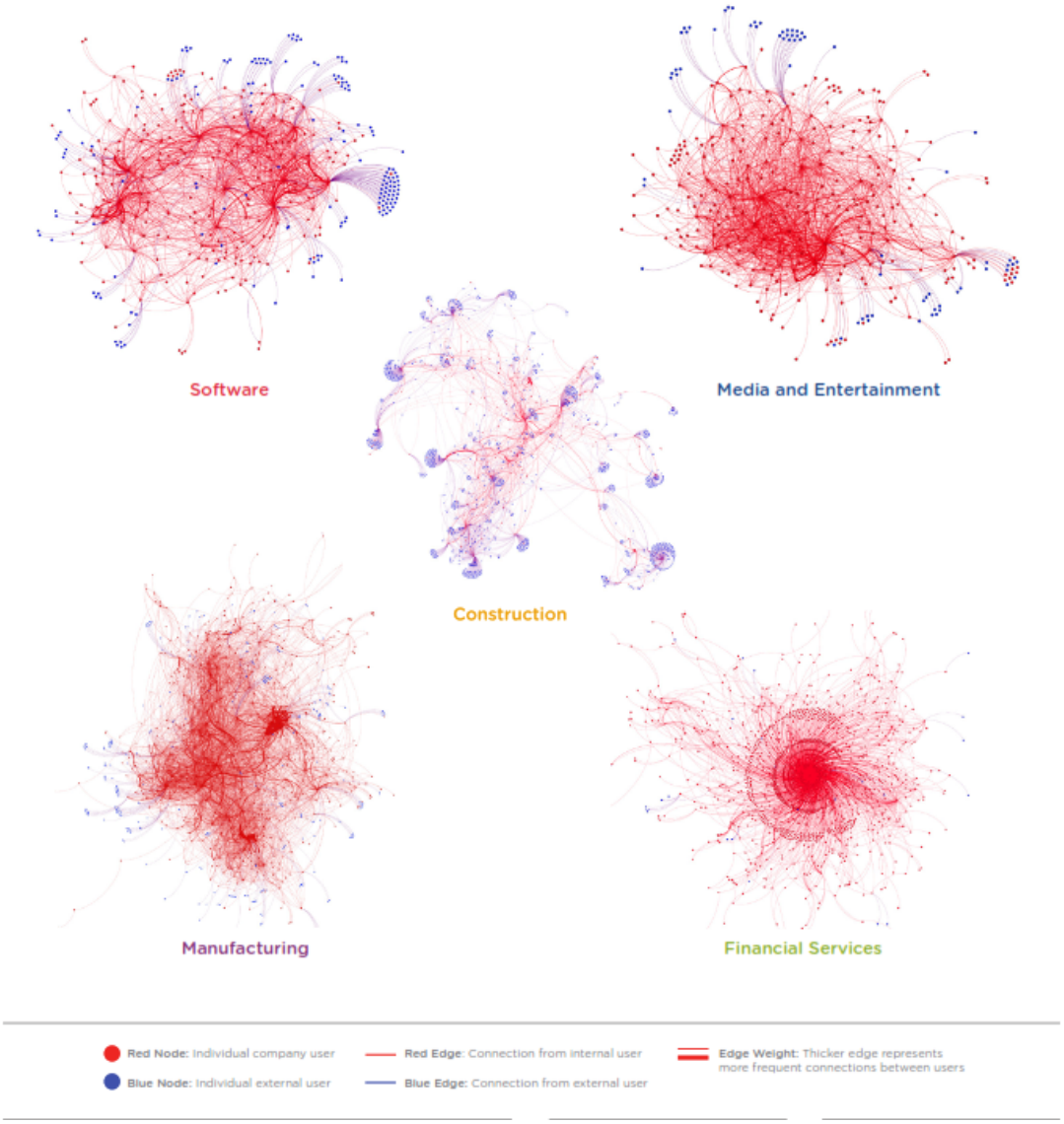

Figure 4.2: A visualisation of collaboration graphs that depict patterns how firms interact with and share their content in each industry. It shows a high level of external collaboration for the company in the construction industry – content must be shared with a wide range of stakeholders during a construction project, (Bouck, 2014)

4.5 Selected Approach

The selection process was based on the preliminary research of the possible approaches to reducing TCs. Considering all the insights presented in this chapter and the nature of the construction industry, as a complex, highly distributed industry with many participants and information flows with different levels of access, **Blockchain Technology** appears to be the most suitable answer to the pre-problem formulation. Given the *distributed* supply chains and *distributed* information in the industry, a *distributed* solution could be a good approach to reduce unnecessary TCs and allow secure communication and information flow between clusters formed in the industry (as seen in Figure 4.2). Furthermore, BCT offers benefits such as traceability, transparency and collaboration that are sought in the construction procurement. As noted in Chapter 1, TC framework is best suited to observe the procurement issues, and Section 4.4 has shown that TCE corresponds well to studying BCT. BCT could also be the technology that BIM and IoT are missing to achieve their full potential.

CHAPTER

5 Problem Formulation

After selecting a solution to the pre-problem question through Chapters 3 and 4, this chapter formulates the exact research question together with sub-questions to direct the research. It also informs about the coverage and limitations of the thesis.

This thesis researches the interconnection of three areas, construction industry, blockchain technology and transaction cost theory, as shown in Figure 5.1. Two aspects and possible confusion points are clarified here. Firstly, the initial concern of the thesis was the construction procurement process with the concept that a tender process is part of the procurement as found in (Bunic and Gøtze, 2019). The definition of procurement process differs, and some scholars include construction and monitoring of performance (Rajeh et al., 2015) in it, while others put awarding the contract as the last activity of the process (Flanagan and Jewell, 2018). Initial research of literature that studies BCT in the industry showed small amounts of publication that is concerned with events in the construction project that take place before contract signing. Some studies mention the application of BCT in the procurement and tendering, but are not clear on the definition of procurement and activities affected by BCT. Furthermore, supply chain management is often blended with procurement management in the literature. For the mentioned reason this research was broadened from the procurement process to the construction industry. Nevertheless, the procurement process and tendering remain an interest so one of the sub-questions is directed towards it.
Secondly, although the research question is extended, the usage of TC framework is steering it to the procurement process, since TCs are usually associated with that phase. In Chapter 3 was clarified that this thesis considers ex-ante TCs as costs incurred in activities that lead or have a potential to lead to contract signing and ex-post TCs as generated in actions that are the outcome of contracts. As it comes to the scope of the research, it is taking a holistic view and observing all types of companies and participants of the construction projects.
Considering the discussion of the possible solutions to the problem of unnecessary TCs showed in Chapter 4 and above-mentioned remarks, the problem formulation reads as follows:

How can blockchain technology benefit the construction industry in relation to reducing the transaction costs?

The problem formulation is complemented with the following sub-questions that will help answer it:

- How can BCT benefit the procurement process?
- What type of TC can be impacted by BCT and how?
- How does BCT affect disputes in the construction industry?
- How can BCT be implemented in the industry?

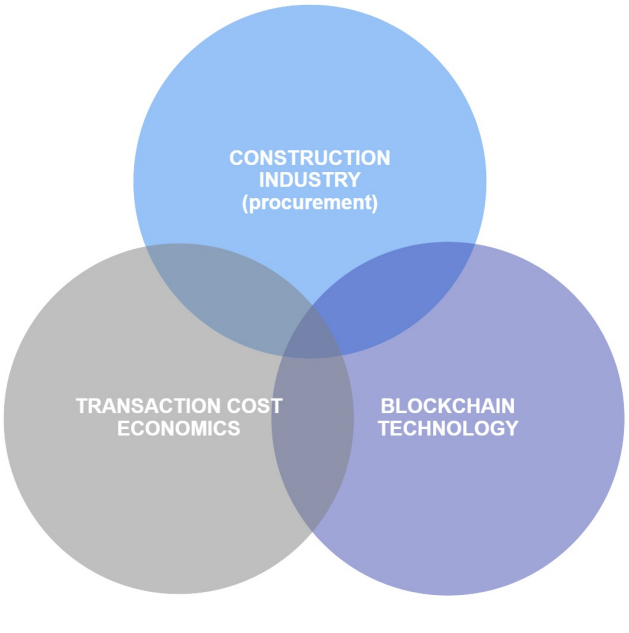

Figure 5.1: Outline of the research focus - a combination of the construction industry, blockchain technology and transaction cost economics.

Limitations

BCT is a technology introduced in 2008. Being a recent innovation, there are no finished use case studies in the construction industry. Therefore, the results of the use cases could not be observed and only the cases in progress could be used. Next, BCT is rooted in computer science and thus comes with some highly technical characteristics. Considering this thesis is primarily concerned with the construction industry, BCT will be explored as a conceptual model that can affect the industry and it will not go into technical details. Despite being a “new” technology, it is greatly studied in literature and there are many publications available. Therefore, only the knowledge that corresponds with data gathered from interviews was extracted. For example, BCT for the construction sector is currently explored for the use among companies, and there is no need for a public blockchain and consensus mechanisms that come with it. In line with that, this thesis is focusing more on private blockchains. Similarly, despite being the first application of BCT, Bitcoin and its operating system will not be examined. Considering data from interviews, after the "Byggeriets Blockchain" Project was selected, all the companies listed as participants in the project were asked for an interview. However, five out of ten accepted the interview. From interviewees, information on three out of eight use cases was collected. Finally, this thesis will not explore quantitively if BCT can mitigate TC. It will explore how and what types of TCs the technology can impact.

CHAPTER

6 Knowledge from Literature - Blockchain Technology

This chapter is organised as follows. First, the origin of BCT together with definitions of the technology is introduced. The key concepts of the technology are presented to enhance understanding of the topic, together with a description of a transaction process that takes place on the blockchain and possibilities to configure the BCT. Second, BCT is observed in TC framework and smart contracts are explained. Next follows an overview of the literature that deals with the use of BCT in the construction sector, with a focus on the procurement process. Finally, the barriers and challenges that BCT needs to overcome to be adopted are presented. Despite being a new technology, BCT is greatly explored in literature. However, this review is made to the extent required for this thesis.

6.1 Fundamentals and Overview

BCT is an innovative technology usually labelled as emerging (Xu et al., 2016) and disruptive (Zhu and Zhou, 2016) technology that will change the business world as is known today (Hoffmeister and Stossberger, 2018). In two years (2016-2018) there has been more than half a million publications and 3.7 million Google search results for blockchain (McKinsey, 2018). Furthermore, the UN and several governments are researching potential uses of blockchain (McKinsey, 2018; Pollock, 2020). Despite high awareness of BCT, Hamma-adama and Kouider (2020) states that the understanding of technology is low.

BCT is commonly associated with cryptocurrency, specifically Bitcoin. Bitcoin was a first practical blockchain application presented in 2008, in a paper entitled: "Bitcoin: A Peer-to-Peer Electronic Cash System" under a pseudonym Satoshi Nakamoto (Nakamoto, 2019). Nakamoto (2019) proposed a system that is *"based on cryptographic proof instead of trust, allowing any two willing parties to transact directly with each other without the need for a trusted third party."* Soon after publishing the paper, the first Bitcoin client was released and for the first time, the value could be transferred between remote, untrusting parties without the need for financial intermediary (Catalini and Gans, 2016). However, Bitcoin is one of two ideas that were proposed. The other one is the technology itself behind Bitcoin – blockchain (Swan, 2015). BCT presented a technical solution to a double-spending problem in this innovative system (Davidson et al., 2016). The significance of blockchain should be observed separately of Bitcoin (Davidson et al., 2016), which is just one, although the most popular application of BCT (Crosby et al., 2016). That is especially so because Bitcoin has been labelled as questionable since it enables a multibillion-dollar global market of anonymous transactions without any control (Crosby et al., 2016). Nevertheless, Crosby et al. (2016) claims that BCT is non-controversial technology which has worked accurately over the years and found application in various sectors.

Through many articles, authors have tried to pinpoint what BCT present and is. Therefore, to avoid a lengthy read and repetition, a definition by a recognised professionals in the blockchain industry is extracted and will be used in this thesis.

"A blockchain is a magic computer that anyone can upload programs to and leave the programs to self-execute, where the current and all previous states of every program are always publicly visible, and which carries a very strong cryptoeconomically secured guarantee that programs running on the chain will continue to execute in exactly the way that the blockchain protocol specifies...Blockchains are not about bringing to the world any one particular ruleset, they're about creating the freedom to create a new mechanism with a new ruleset extremely quickly and pushing it out. They're Lego Mindstorms for building economic and social institutions." (Buterin, 2015)

Buterin (2015) specifically emphasizes that this definition does not use any terms that would point toward a particular use case (for example, financial cases) and it does not mention technical properties of the blockchain. It simply explains what a blockchain does. In addition to the given definition by a founder of blockchain-related company, Figure 6.1 was made to summarize keywords that were repeatedly used in other definitions of BCT.

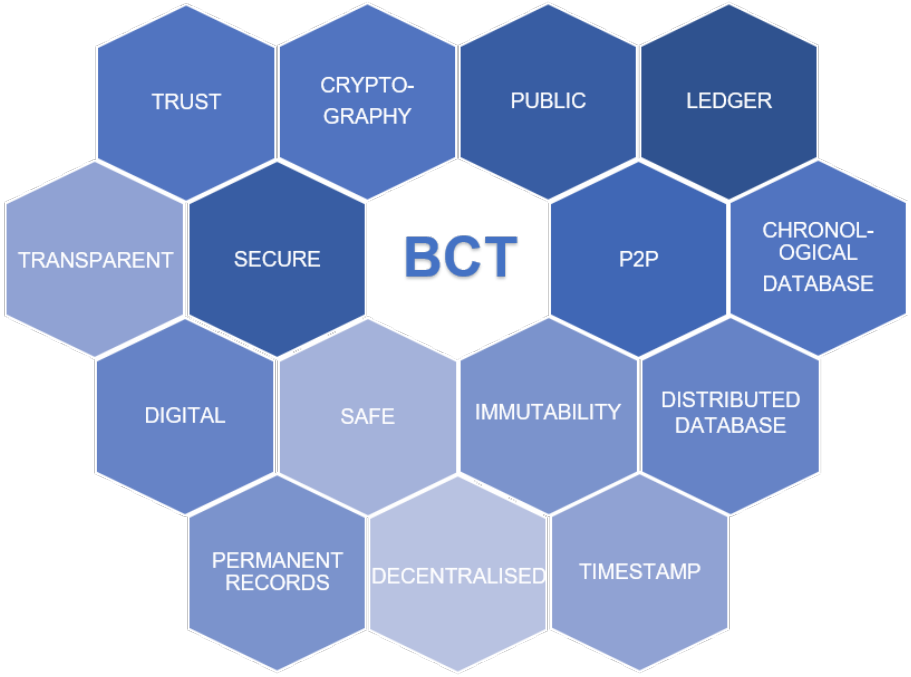

Figure 6.1: Keywords used while defining Blockchain Technology in literature

As indicated in Buterin (2015)'s definition, BCT is not for financial uses only. BCT was invented as a solution to a problem in the design of digital money, but its universality and applicability in other sectors have been quickly discovered (Davidson et al., 2016; Li et al., 2018; Zheng et al., 2018b). Thus, blockchain has the ability to represent ownership in currency, digital content, intellectual property, equity, information, contracts, financial and physical assets (Catalini and Gans, 2016). Its high transparency, resilience, efficiency (Davidson et al., 2016) and ability to track transactions, store information, enforce contracts across a variety of digital assets is what makes BCT a general-purpose technology (Catalini and Gans, 2016).

As any technology, BCT also matures with time. Swan (2015) classified the technology into

three categories: Blockchain 1.0, 2.0 and 3.0. Blockchain 1.0 refers to decentralisation of money and payments (Bitcoin), while 2.0 encompasses wider scope in terms that all financial transactions are performed on the blockchain, with public and private records, digital identities stored on the blockchain (Swan, 2015). Finally, Blockchain 3.0 represents a new paradigm for organising activity with less friction and more efficiency, where all modes of human activity could be coordinated with BCT (Swan, 2015). However, Iansiti and Lakhani (2017) argues that true BCT transformation of business is still far away in the future. Iansiti and Lakhani (2017) continues that the reason for that is BCT not being a "disruptive" technology, that is usually labelled, but a **foundational technology.** As such it has the potential to create new foundations for economic and social systems (Iansiti and Lakhani, 2017).

6.2 Key Concepts

To understand BCT and its possibilities, deeper concepts behind the technology should be explored. Therefore, this section will provide with key principles behind BCT. Next, a simple example of a transaction will be described and ways to configure BCT will be explored.

While BCT is an innovation, it is in fact based on a creative combination of not particularly new concepts, cryptography and game theory (Catalini and Gans, 2016). Aside from mentioned, there are four other important concepts: ledger, peer-to-peer (p2p) network, consensus mechanism and validity rules (Hileman and Rauchs, 2017).

Ledger. Terms blockchain and distributed ledger technology (DLT) has been used interchangeably through literature. However, DLT is a broader term that describes all technologies – including blockchain - that distribute information across multiple sites, countries or institutions (Treiblmaier, 2018). Therefore, BCT is often described as a "ledger". Beck et al. (2019) states that the idea to use the term originates from historic times when ledgers were used to demonstrate the ownership of an asset. Ledgers were updated by a single authority that served as a centre of trust for the people and the king controlled them. When transactions were made between kingdoms, two kings needed to update their records simultaneously (Beck et al., 2019). Blockchain is an alternative to that system. The difference between the two types of record-keeping is depicted in Figure 6.2. As shown, in blockchain, each party has access to the database and its complete history, which means that no single party controls the data (Dobrovnik et al., 2018).

P2P transmission. Knowing that each party has a copy of a ledger, the question of communication between parties is solved by utilisation of the p2p network. Parties or peers or nodes are communicating directly with each other instead through a central node (Dobrovnik et al., 2018). All the nodes are connected on a flat topology without a hierarchy and no peer is superior to others (Perera et al., 2020). Nodes are computers connected on a network, and when a message appears it is sent to any of the nodes, and each node sends it quickly to its neighbour (Navadkar et al., 2018).

Cryptography. Cryptographic techniques are necessary for creating a trustworthy means of identification, authentication, and authorisation and ensuring data security (Drescher, 2017). This method verifies the source of the data and integrity of data is called "a digital signature" (Rutland, 2017). It also ensures that the signer cannot later claim that he did not sign the transaction that was sent. Cryptographic techniques allow the mechanism of sharing data on

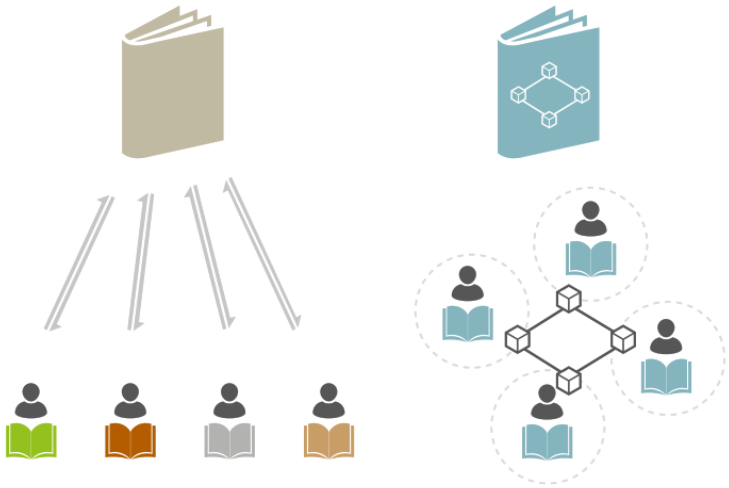

Figure 6.2: Separate record keeping by everyone based on central ledger (left) and record keeping based on Blockchain as a distributed ledger for all participants (right), (ICE, 2018)

the blockchain and the possibility for data to be tamper-proof (ICE, 2018).

Consensus mechanism. A consensus is a synonym for an agreement among separate individuals (Drescher, 2017). The mechanism operates under the assumption that not every party is honest (Hamma-adama and Kouider, 2020). There are many different ways to reach consensus and they usually vary with different uses of blockchains.

Validity rules. These are rules set for the network under which valid transactions are considered (Hamma-adama and Kouider, 2020), because it has to be assured that the data structure contains only valid blocks (Drescher, 2017). These rules are specific to the application of the blockchain.

6.2.1 Configurability

Blockchain can be configured with regards to read and write/commit permissions for the participants and by the ownership of the data infrastructure (McKinsey, 2018). The chosen configuration relates to the security and threat model of the blockchains (Hileman and Rauchs, 2017), which allows meeting needs of various applications of blockchain (Zhu and Zhou, 2016).

Public & Private Blockchains. In public blockchains, anyone can join the network and stay anonymous, while in private all the participants are known (ICE, 2018).The important difference between public and private is that in public, the participants are incentivised to run the network and validate transactions (ICE, 2018). In that manner, they compete to validate transactions and add them to the chain, and the winner is rewarded (the process known as “mining"). According to ICE (2018), in private blockchains, the incentive is not needed since the participants willingly entered the network in order to conduct business. Participants are granted access to the network by the central entity using operating rules for the network (He et al., 2016). This type of blockchain is a fully private system. A type of partly private blockchain is hybrid or consortium system. Here, the consensus mechanism to validate transactions is executed by pre-selected individuals or organisations (e.g. a consortium of financial institutions) (He et al., 2016). Structure of public, private and hybrid blockchain is illustrated in Figure 6.3.

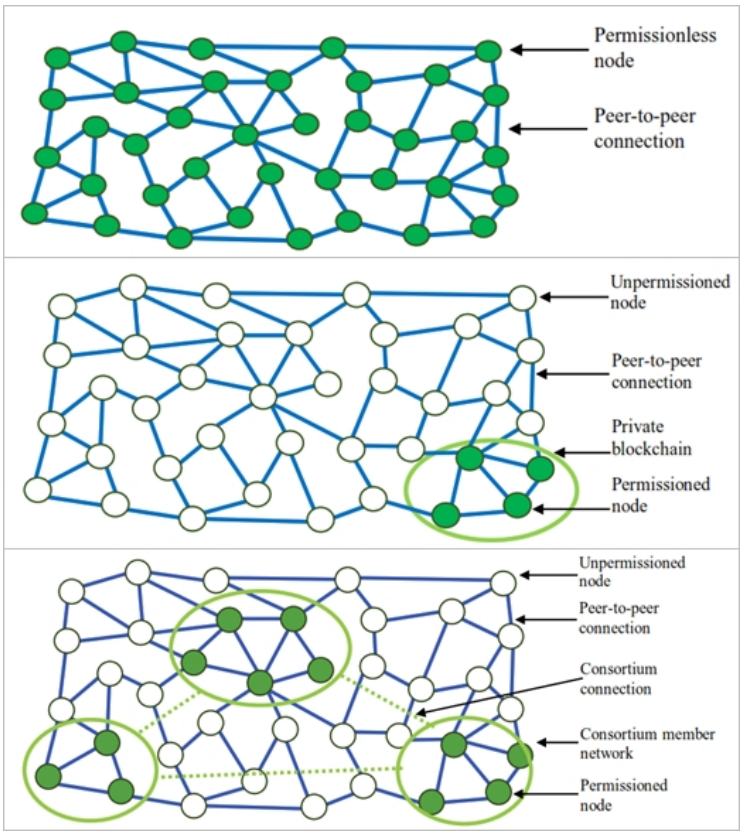

Figure 6.3: From the top: structure of the public, private and hybrid blockchain, (Perera et al., 2020)

Permissioned & Permissionless Blockchains. Synonyms used for these terms are decentralised and centralised blockchains, which indicates who can participate in the network. In decentralised (permissionless) blockchain (e.g. Bitcoin) each participant has the same "permissions" (O'Leary, 2017). In centralised (permissioned) blockchain, a central authority decides to give access to each party to read and/or write on the blockchain (Wüst and Gervais, 2018).

Above described four configurations give four main blockchain types that are shown in Figure 6.4, with their access capabilities. Permission to read, write, commit means that a participant is allowed to see transactions, generate transactions and update the state of the ledger, respectively. Public permissionless blockchains present a potentially hostile environment with unknown actors (Hileman and Rauchs, 2017) because it is completely open to anyone. To prevent dishonest behaviour of the participants, a combination of game theory and cryptography is employed with a reward system (Hileman and Rauchs, 2017). In contrast, in private permissioned blockchains everyone is known and already vetted by a network starter or a set of rules. Participants are held accountable through of-chain legal contracts and agreements (Hileman and Rauchs, 2017). O'Leary (2017) suggests that a public permissioned blockchain would be suitable for government applications, where transactions would be visible to the public, but the government would manage the blockchain. Hyperledger Fabric by the Linux Foundation is an example of an open-source permissioned blockchain solution, while Bitcoin is a public permissionless blockchain (ICE, 2018).

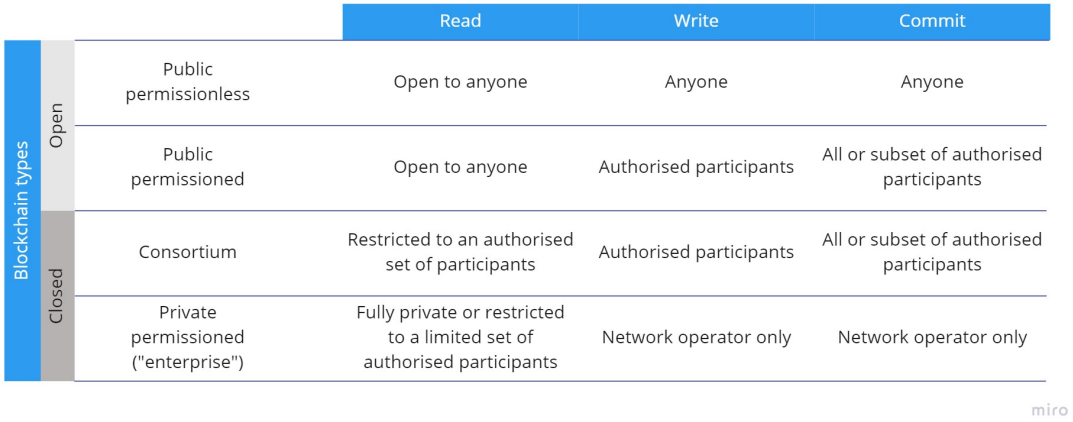

Figure 6.4: Main types of blockchains, where approval to read gives the options of a public and private blockchain, while write/commit approval refers to the option of permissionless and permissioned blockchains, adapted from (Hileman and Rauchs, 2017)

6.2.2 Transaction Process

A typical transaction process made on the blockchain goes through 5 stages shown in Figure 6.5 and described as follows. In stage 1, A initiate transaction to B. A transaction can be a digital payment, agreement, contracts or things that require a recording and verification of their occurrence (Barima, 2017). This transaction is then, in stage 2, broadcast to the whole network and waits for validation. During that phase, it is checked if sender and receiver are appropriate. Mechanisms to validate transactions are numerous and depend on the application of the blockchain. After the network reaches consensus, the transaction information is put in the “block” and becomes immutable (stage 3). The block is included in the chain and the whole network has an updated copy of the ledger (stage 4). This technical structure – a chain of blocks - is where the name *blockchain* originates from (Wüst and Gervais, 2018). Finally, in stage 5, the transaction is finished, and B receives a transferred digital asset. The details of the transaction are not stored (Barima, 2017), but an immutable record of the described transaction, of its origin and the fact that transaction occurred. Immutability of the record is achieved because records are stored in different nodes in the network, so it is nearly impossible to tamper with records (Zheng et al., 2018a). According to Rutland (2017), immutability means that data on the blockchain cannot be changed or modified, not even by a system administrator. However, if the majority of the network agree to change the record, it can be done, so it is more precise to say that immutability is a measure of the difficulty needed to edit data (Rutland, 2017). Therefore, in private networks, changes are possible if all participants agree to modify the data (Li et al., 2019a). An algorithm ensures that all participant have the same version of the ledger (Li et al., 2019a).

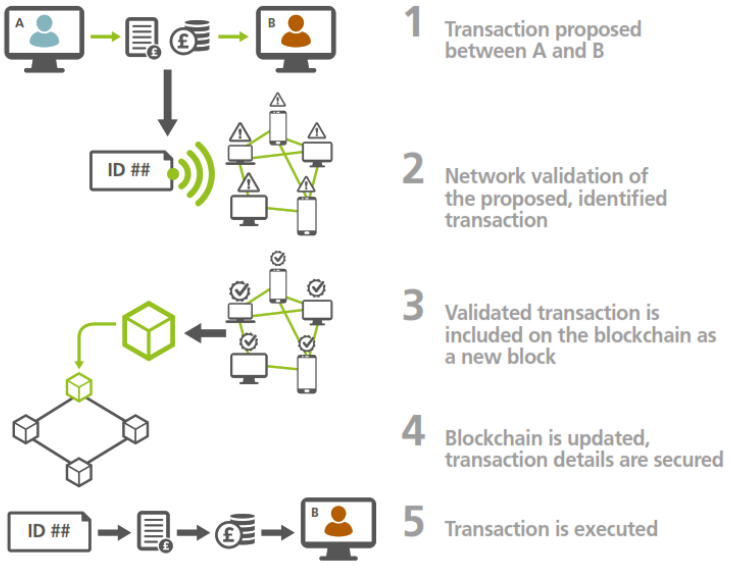

Figure 6.5: Transaction process on the blockchain, (ICE, 2018)

The process of creating a block and adding it to a chain (stage 4 in Figure 6.5) explains the tamperproof nature and security of the blockchain. It is related to specific blockchain architecture. Figure 6.6 illustrates an example of blockchain as a sequence of blocks (Zheng et al., 2018a). Each block is connected to the previous block through a cryptographic reference called *hash* (Zheng et al., 2018a). A hash is produced by encoding the content of the transaction but cannot be used to recreate the original transaction (Treiblmaier, 2018), which provides end-to-end encryption of the system (Dakhli et al., 2019). Through this connection of blocks, a highly resilient record is created because the whole chain has to be altered to modify one block (ICE, 2018).

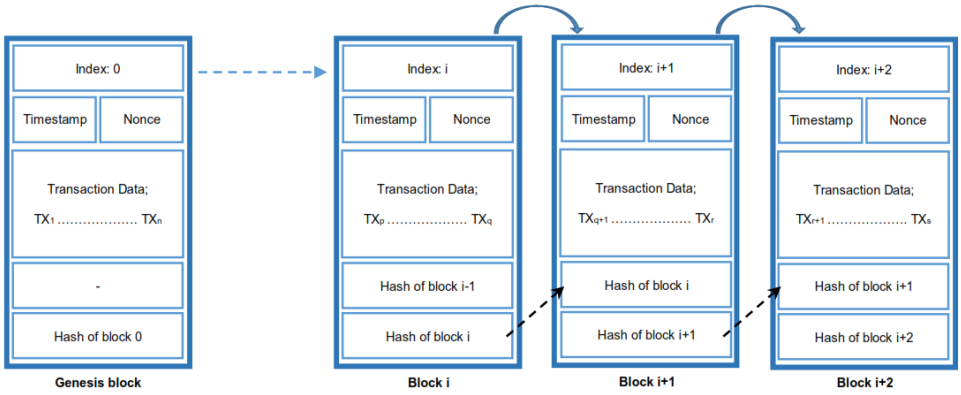

Figure 6.6: An example of a blockchain, where genesis block is the first block in the chain, and a nonce is a unique number assigned to the block, (Perera et al., 2020)

6.3 Implications for TC

Several scholars employed TC framework in researching BCT (Schmidt and Wagner, 2019; Catalini and Gans, 2016; Davidson et al., 2016; Shermin, 2017; Treiblmaier, 2018). There are three perspectives taken in the studies: BCT as a technology that will reduce specific ex-ante TCs, smart contracts that run on the blockchain and are promising reduction of ex-post TC (reviewed later), and finally BCT as a disruptor of today's governance modes.
Schmidt and Wagner (2019) claim that BCT might significantly reduce TCs, specifically search and information cost in terms of buyer/supplier reputation, negotiation and agreement costs because of automated smart contracts and finally, costs of disputes since all the activities were tracked on the blockchain. However, (Davidson et al., 2016) state that negotiation and renegotiation costs will be unaffected by BCT. Catalini and Gans (2016) specified two key transaction costs affected by BCT, verification and networking costs. Verification costs are related to searching for information to make confirmation, while networking costs are in this study costs spent in operating in a marketplace without employing a third party (Catalini and Gans, 2016). The study claims that verification costs will be zero with using BCT, but it acknowledges the friction caused by linking offline and online matters, meaning that not all information is on-chain, but is off-chain in physical world.
Schmidt and Wagner (2019) claim that BCT could cause that the choice of the optimal governance structure changes by limiting opportunism and uncertainty. Opportunistic behaviour could be controlled by eliminating the need for trust by BCT being transparent, secure and immutable (Davidson et al., 2016). Ultimately, BCT could enable more market-oriented governance structures, as there is no need for a trusted relationship anymore (Schmidt and Wagner, 2019). While Schmidt and Wagner (2019) claim that BCT will push governance mode towards the market, Davidson et al. (2016) takes a slightly different stand and modifies Coase (1937)'s question between firms and market, into: *"Why do (might) some transactions occur in blockchains, rather than in firms or markets?"* (Davidson et al., 2016)'s reasoning starts from selecting firms or markets based on TCs in dependence to uncertainty, asset specificity and frequency. Based on these factors, transactions are carried out more efficiently in some governance modes, so TCs determine the efficiency of governance institutions. Considering that, Davidson et al. (2016) denotes blockchain as an institutional or social technology for coordinating people.

6.3.1 Smart Contracts

Smart contracts are denoted as the valuable prospect of blockchain that could eliminate opportunism (Davidson et al., 2016), formalise and enforce agreements between people and institutions by standardising transaction rules (Shermin, 2017). The idea of a smart contract stems from the nineties when Szabo (1996) defined it as:
"The basic idea of smart contracts is that many kinds of contractual clauses can be embedded in the hardware and software we deal with, in such a way as to make a breach of contract expensive for the breacher. A canonical real-life example, which we might consider to be the primitive ancestor of smart contracts, is the humble vending machine. Within a limited amount of potential loss (the amount in the cash register should be less than the cost of breaching the mechanism), the machine takes in coins, and via a simple mechanism, dispense change and product fairly. Smart contracts go beyond the vending machine in proposing to embed contracts in all sorts of property that is valuable and controlled by digital means."

Put simply, a smart contract is a computerized transaction protocol that executes the terms of a contract (Szabo, 1994). Shermin (2017) clarifies that a smart contract checks whether stakeholders in a transaction conform with the conditions that were predefined. These conditions might be payment terms, confidentiality, enforcement etc. (Li et al., 2018). If participants do comply with agreed, the transaction is validated and the payment is released, and if not, it is rejected. BCT has enabled an easier way to register and execute smart contracts (Crosby et al., 2016), and according to He et al. (2016), the contracts can be self-executing and self-enforcing without the need for intermediaries. Potential benefits of using smart contracts include increased speed, efficiency and trust, reduction of transaction costs that derive from opportunism, reducing costs of verification and enforcement (He et al., 2016) and lowering fraud and malicious doings (Li et al., 2018).

Being a relatively new technology, there are some concerns and challenges that come with it. Firstly, Li et al. (2018) mention that immutability of the blockchain could become an issue if the mistakes or vulnerabilities are written into the code of a smart contract due to the lack of legal knowledge or simple human fallibility. Once uploaded to the blockchain, the contract becomes permanent, unchangeable and irrevocable (Li et al., 2018). However, there is some flexibility in modifying uploaded contracts if the consensus of the network is reached to do so. For these reasons, it has been suggested by Boucher (2017) that smart contracts should be used for repetitive deals and not for single complicated contracts. A second challenge is regarding limited flexibility of smart contracts when it comes to accommodating unforeseen events and handling "unknown unknowns" (Shermin, 2017). Coders develop contracts based on the information available at the time of the contracting, and the mentioned issue arises in contracts whose clauses might change in its lifespan. A third challenge is a commonly mentioned blockchain issue, and that is the disconnection of on-chain and off-chain items. Wüst and Gervais (2018) say if that issue of connecting the physical world with virtual in a secure way, smart contracts will become an extremely powerful tool. Finally, since practical smart contracts are new, the issue arises about the extent of their legal bond (Wüst and Gervais, 2018).

6.4 BCT in the Construction Industry

The research efforts concerned with the application of BCT in the construction industry are mainly sorted in two categories, holistic research where the understanding and implementation of BCT is explored and dedicated research which is focused on one of the following areas: implementation of smart contracts, and the interconnection of BCT with IoT and BIM (Kifokeris and Koch, 2019). This section gives an overview of studies of BCT in the construction industry with the focus on the procurement process and influence on TCs and afterwards, research of smart contracts and the interconnection of BCT and other emerging technologies are presented. Finally, barriers to implementation of BCT are reviewed.

6.4.1 General Concept of BCT in the Industry

Wang et al. (2017) notes two main challenges faced by the construction sector, trust issues and supply chain issues. Trust issues are part of everyday construction activities, especially in a cross-disciplinary environment, while supply chain displays issues of transparency (Wang et al., 2017). The complexity of the supply chain is weakening the trust levels and security of pay-

ments, which creates a hostile and conflictual environment (Perera et al., 2020). According to Dakhli et al. (2019), the industry is primarily an industry dominated by social interactions, so the challenge is the search and identification of the right information at the right time in the right place and especially to the right person. By implementing BCT, there is trust, immutability, security and transparency that have the potential to alleviate many of the above-mentioned problems (Perera et al., 2020). Additionally, Dakhli et al. (2019)'s study revealed the potential cost savings with BCT implementation to be 8.3% of the total cost of the housing building construction.

Blockchain Configuration.
O'Leary (2017) argues that public blockchains are not the option to be taken in business settings since anonymous participants run the infrastructure (Hileman and Rauchs, 2017). According to Shojaei et al. (2019), the construction industry is to use private blockchains because of the nature of construction projects and the importance of confidentiality. In private networks, all members are pre-vetted and known, but transactions are secret unless one has permissions to see them (in contrast, in public structures, all transactions are visible and members unknown) (Shojaei et al., 2019). To control issues of competitors pulling business intelligence information off the blockchain, different companies could be allowed to have different "views" (O'Leary, 2017). The interest question is posed by O'Leary (2017): If blockchains that are to be used in corporate settings – private blockchains, generally cloud-based, with central control, and without anonymity or lacking anonymity – is this system still a "blockchain"? If a construction project is run on the private blockchain network, all the stakeholders are members of it and governance is based on the consensus of the stakeholders and collaborative project ecosystem is created (Figure 6.7) (ICE, 2018). Each member has their copy of the ledger with all the interactions recorded. The information can be visible for everyone or private between specific members and transactions are immutable and cryptographically signed, which results in finding specific information a matter of seconds and complexity of project control could be reduced (ICE, 2018). Having many consortia and partnering arrangements in the industry, high collaboration levels in a trusting environment could be reached with blockchain solutions (Perera et al., 2020).

Figure 6.7: Collaborative project ecosystem, (ICE, 2018)

Procurement and Tendering Aided by BCT.
Perera et al. (2020) state that BCT is the first concept since internet and e-procurement that is extending the procurement revolution. Moreover, Mathews et al. (2017) consider the procurement process a strategic issue where savings through TCs and time could be achieved with internet-based technologies. The problems that could be reduced with the use of BCT are explained hereafter. A traditional procurement has developed into a system heavily dependent on contracts with hostile relationships between parties and often with a requirement for a third party to act as an intermediary (Mathews et al., 2017). Another issue mentioned by Mathews et al. (2017) is a need for controlling intellectual property and created data (architect retaining copyright, issuing licences and controlling who did what). Further, construction projects are temporary with short periods of cooperation between a large number of participants, which causes unstable, trustless relationships with lack of transparency and traceability (Ye et al., 2018). Ye et al. (2018) claim these issues lead to low efficiency and productivity. BCT can solve or to an extent reduce mentioned problems by collecting more reliable information in addition to other advantages that BCT brings and enable a reliable, open and competitive market that will reflect positively on the construction procurement (Ye et al., 2018).

It was mentioned earlier that (O'Leary, 2017) proposes a use of private blockchains in the industry, however Perera et al. (2020) claim that in the public procurement process, a public blockchain should be used to maintain transparency and accountability. In line with that Sheer Hardwick et al. (2018) propose a fair and transparent government tendering scheme using blockchain. The proposed process goes through the stages of publishing a tender, bidding period and closing the tender and contract award. The scheme is imagined in that way that the tenders cannot be changed, bids are confidential and cannot be modified, companies do not know which other companies have placed the bid. After the opening of the bids, the selection of the best bid is published and companies that have lost can compare winning bid against the evaluation criteria. Additionally, after the award, the tender can be made public so that citizens can evaluate the whole process. According to Sheer Hardwick et al. (2018), this transparent tendering framework provides collision avoidance, confidentiality, privacy and integrity. This scheme employes private blockchain, but it gives permission to citizens or interested party to evaluate the process of tendering. Di Giuda et al. (2020) support the idea of organising tenders with the help of BCT by storing all tender documentation by the client and bidders on the blockchain. In this way, all the procedures and criteria are available to all participants, and the award criterium is explicit which eliminates possible misdoings.

6.4.2 Smart Contracts

Smart contracts appear to be at the forefront of the application of BCT in the construction industry with the ultimate objective to replace traditional contracts with a new method of technological contracts (Shojaei et al., 2019). Smart contracts are interpreted in the literature as coded computer programs that execute the contract conditions, but also as the logic governing the network that is encoded within itself and relies on peers for verification (Shojaei et al., 2019). In that way, smart contracts are partially automated, as verifications are needed from the members from the blockchain network. Shojaei et al. (2019) give an example of the main contractor who puts in a request for a transaction for the work executed, but only the inspectors inside the network can approve that transaction.
Benefits of smart contract listed and explained through literature are many. The common

agreement is that the application of smart contracts in the construction industry will result in significant cost and time savings, including transaction costs (Wang et al., 2017; Belle, 2017; Shojaei et al., 2019; Mason, 2019). There is an opportunity for reducing TCs of intermediaries, administration of contract documents and costs of cost of disputes, lawyers and courts (San et al., 2019; Shojaei et al., 2019). When a dispute arises, each transaction is recorded, tamper-proof and easily accessible (Shojaei et al., 2019). Further, Wang et al. (2017) states that smart contracts will eliminate the payment and cash-flow issues and protect contractors, subcontractors and suppliers from late payments and insolvency. This could be done with embedded cryptocurrency (Wang et al., 2017; Cardeira, 2015), although Shojaei et al. (2019) claim that cryptocurrencies are not necessary for the use of smart contracts in the industrial applications, but monetary compensations can be executed. As payments will be automated, the whole web of payments will be created where the payment to the main contractor triggers a payment to subcontractors and suppliers (Wang et al., 2017). According to Shojaei (2019), a new type of work breakdown structure would be created, that would help the project participants better understand their responsibilities and liabilities, as well as how other work packages could affect theirs. Uncertainties would be reduced because of predefined outcomes (Shojaei, 2019) and because of thousands of mini contracts where each has clear execution terms. This setup would result in a better holistic view of the project, both before and during execution. In traditional contracts, trust is placed in people, organisations and authorities, who are susceptible to error and corruption (Shojaei et al., 2019). With the use of BCT and smart contracts, the trust will be reshaped and will be based on software codes (Wang et al., 2017). However, Shermin (2017) raised a doubt here, if the handful of software developers that have the know-how of programming smart contract will start to act opportunistically. Shojaei et al. (2019) claim that contracts will be easier to understand than traditional contract language and Mason (2019) that there will not be legal leeway in the interpretation of the contract. In contrast, contracts will be straightforward and unambiguous, as in the example: “If Company A generates a work order, then Company B agrees to do it in return for the fee agreed” (Mason, 2019). This way of contracting will reduce the risk of opportunistic behaviour since the possibility of various interpretations of the contract terms are eliminated and lawyers will not be needed in the extent as they are today. On the other hand, Reuters (2017) states that many common events that happen in a construction project are difficult to capture in a code, for example, force majeure or on-site accidents causing work to stop. ICE (2018) adds that contractual standards like FIDIC, NEC or AB can be implemented to be a part of a smart contract. ICE (2018) gives an example good practise in applying the smart contracts, where IBM Global Financing (credit insurer for partners and suppliers) transferred its data to a blockchain, which led to the annual 25 000 disputes being solved in 75% less time between partners and suppliers, which resulted in savings of 40% on legal and administrative costs. To use and trust smart contracts, it is not necessary to have the knowledge and understand the coding structure and algorithms (Shojaei et al., 2019; Mason, 2019). However, codes that are used to write contracts are not legal languages of contract law and that presents a legal issue (Shojaei et al., 2019).

Dakhli et al. (2019) list two elements that are needed for a smart contract to work in construction:

- A definition of the precise tasks of the act of building,
- A listing of all the possible variants related to a given task (for example, the tiler was absent, and the electrician’s work was delayed because of that), where all the scenarios must be taken into account.

The obvious problem lies in the necessity to have fully defined terms in the contracts for an industry that comes with many uncertainties (Shojaei et al., 2019). Dakhli et al. (2019) present Figure 6.8 (left) as a transaction environment today in the industry. Transaction costs follow the black arrows, meaning that subcontractor is paid by the main contractor who is paid by the client. Dakhli et al. (2019) explain that transactions are not only about the money, but about contracts, agreements and collaboration – essentially costs of doing business. Currently, these rely on trust, and trust is easily broken when a problem occurs, and fingers are pointed to blame someone. Figure 6.8 (right) presents the view of the transaction costs with BCT employed, where the value flows smoothly across stakeholders, transactions are recorded in one system and are easily monitored.

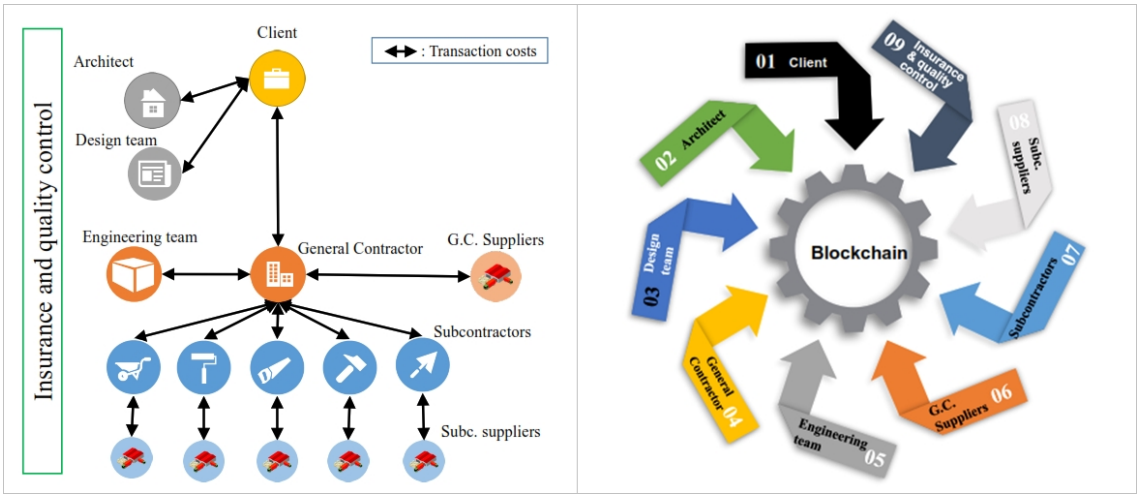

Figure 6.8: Traditional contractual relationships and the flows of money (left). Blockchain based construction (right), (Dakhli et al., 2019)

According to Hewavitharana et al. (2019), there are deterministic and non-deterministic smart contracts, where **deterministic** contracts only require information that is already on-chain, and with that can execute and work efficiently; whereas **non-deterministic** contracts need additional information from the trusted third party that is off-chain, so-called “oracles”. Knowing that part of the construction project is performed off-chain, a link between smart contracts and physical world is needed, and presents a major challenge (Catalini and Gans, 2016). Shojaei et al. (2019) acknowledge that this link is needed, and also adds a link with the BIM model to make a system viable.

6.4.3 BCT, BIM and IoT

Perera et al. (2020) claim that BIM changed the design paradigm but was unable to impact procurement. Perera et al. (2020) further state that blockchain has the potential to adequately address the procurement issues by filling the unattended gaps of BIM – for example the ownership of the model, the modification rights, the distribution rights, the liability for changes or errors (Ye et al., 2018). Shojaei et al. (2019) claim that BCT integration with BIM and other technologies will bring a leaner procurement process and improved collaboration. Shojaei et al. (2019) developed an example of using BIM and BCT and is illustrated in Figure 6.9 and briefly described hereafter. An element – column (highlighted in Figure 6.9) is assigned with a unique ID and tied to the physical world by IoT and the blockchain. In the shown list of blocks in Figure

6.9, each block describes a transaction that is already verified by the appropriate party and became a part of the blockchain. The workflow regarding the column starts with subcontractor or main contractor requesting a record on the blockchain for purchasing the column. Upon endorsement by the supplier, the block is created. The next record is requested by the supplier when the column is shipped, and upon the delivery to the construction site, the supplier requests another transaction requesting a payment. The main contractor endorses this transaction and the payment is transferred to the supplier, and also the funds for material on site are transferred from the client to the main contractor. When the column is installed, the contractor requests the last transaction that needs to be endorsed by the inspector. Shojaei et al. (2019) conclude that BIM and BCT together can link the physical and digital world to control the cyber-physical space.

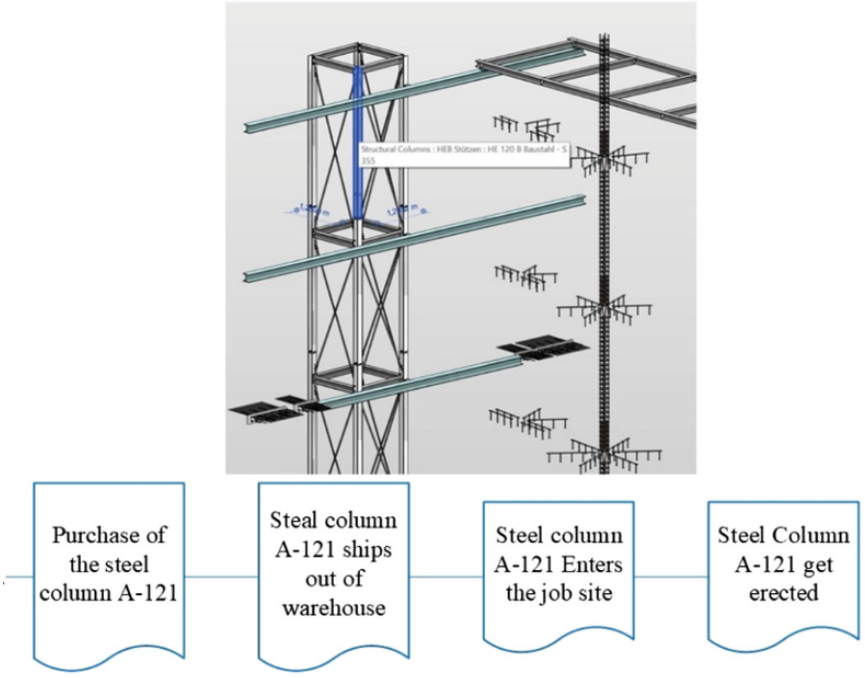

Figure 6.9: BIM structure and the corresponding blockchain of the column, adapted from (Shojaei et al., 2019)

Ye et al. (2018) summarised the interconnection of BIM, IoT and BCT using an analogy named “Cup-of-Water” with the idea to graphically show the importance of integrating these three technologies (Figure 6.10) . BIM, IoT and BCT are complementary in the following way: With IoT (based on sensory technology and RFID), off-chain information is fed to the system, with BIM tradition paper-based documentation is completely digitalised in the whole building lifecycle and with the BCT, the data and information are managed well (Ye et al., 2018). Figure 6.10 shows BIM as bottom - as a management od digital information and creating digital twins, and therefore it is a baseline, BCT is a cup wall – as it defines the method of storage of information and IoT is water, which feeds the system with accurate information. Ye et al. (2018) explain that without BIM, the “water” cannot be conserved, without IoT, the cup is empty, and without BCT, the “water” cannot be managed in a secure and transparent environment.

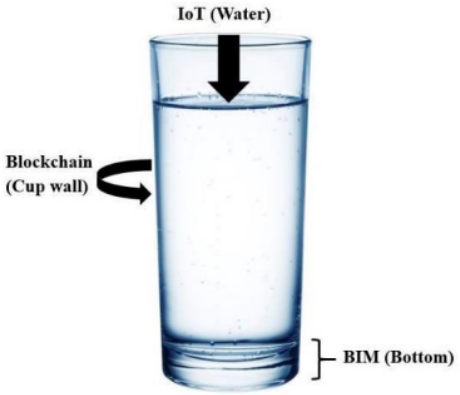

Figure 6.10: Cup-of-Water Theory, where water is building data and cup is the approach how these data are stored, transmitted and shared, (Ye et al., 2018)

6.4.4 Construction Industry-Specific Challenges

BCT is new to the construction industry, so its challenges, as well as opportunities, are yet to be fully realised (Hamma-adama and Kouider, 2020). Wang et al. (2017) group challenges into technical, construction-business related and human-related challenges.

Technical challenges. BCT is in the early stages of development and some limitations need to be overcome. Li et al. (2018) mention the problem of ensuring the legitimacy of data that is uploaded to the blockchain, where the rules for authentication are needed. Further, human error in coding smart contracts is viewed as an issue (Li et al., 2018) and also not having legislation about how is blockchain legally binding (Reuters, 2017). Finally, as shown in the above sections, it would be difficult to implement BCT without simultaneously developing other technologies (Kifokeris and Koch, 2019).

Construction business-related challenges. Belle (2017) mentions the comments referring to the industry not being ready for BCT since the industry is slow in setting up standards for digital cooperation. Companies are resistant to change their ways of doing business (Li et al., 2018). Sawhney et al. (2020) denotes it as a conservative world view of the whole industry. Additionally, BCT has some conflict points with Enterprise Resource Planning (ERP) systems that many companies have invested in the last few decades (Wang et al., 2017). According to Sawhney et al. (2020), adoption of innovation requires a clear value proposition for the stakeholders and considering the fragmented and complex value chain of the sector, it is difficult to document financial gains of the technology. Next, there is a shortage of sufficiently skilled people who would have an understanding of both construction and BCT (Li et al., 2018).

Human-related challenges. Lack of understanding of blockchain technology makes it unattractive (Wang et al., 2017). Navadkar et al. (2018) claim that the biggest fear comes from trusting and relying exclusively on technology. It is argued that there is no guarantee that technology will never make a mistake, which could lead to serious consequences if essential government information are handled (Navadkar et al., 2018).

Finally, Crosby et al. (2016) state the advantages of BCT outweigh the regulatory issues

and technical challenges. Barima (2017) supports that mentioning the internet, as a similar technology that moved through phases of development and some of the issues are needed to appear, for the system to improve over time.

6.5 Summary

In finalizing this chapter, two keywords often associated with BCT and related misconceptions will be clarified. The first one is *trust*, as BCT is often described to reduce the trust gap (Hileman and Rauchs, 2017) or as a "trust machine" in Economist (2015). However, at very least, trust must be placed in the underlying cryptography, or in the case of a private blockchain, in the central authority and/or the validators (Dakhli et al., 2019). Another misconception is that BCT should be used in cases where intermediaries hold a lot of market power, however, BCT does not need to be a *disintermediator* to generate value (McKinsey, 2018). As noted by McKinsey (2018), BCT's strategic value is in the reduction of transaction complexity and cost, and improvements in transparency and fraud controls.

This chapter presented the fundamentals of BCT, with key concepts that support the system and possibilities to configure the blockchain. Further, the influence of BCT on TC was presented. Regarding ex-ante TC, the reduction could occur in search, information and verification costs, whereas in ex-post TC, dispute resolution and accompanying costs could be reduced by employing smart contracts. Next, the implication for the governance structure was reviewed, with the insinuation of blockchain as a disruptor of TCE and as a new governance mode. Finally, the literature on the intersection of the construction industry and BCT was presented. Private blockchain was presented as an appropriate configuration of for the industry. Further, smart contracts as the most researched area were reviewed, and a view on the cooperation of BCT, BIM and IoT were described. Many potential benefits of the technology were presented throughout the section, and lastly, barriers that technology confronts were briefly touched upon.

CHAPTER

7 Interviews with Experts

This chapter provides the considerations behind the chosen interviewees in respect to the problem formulation and it presents findings from the interviews.

To find out who to interview about the subject of blockchain technology in the construction industry, it is important to know who has the knowledge about it in Denmark. Experts here are considered the ones who have these insights and/or researched the BCT in the industry.

7.1 Chosing the Interviewees

Falk et al. (2019) have written a white paper which describes possible solutions to how BCT could be used in the construction industry. Falk et al. (2019) state that there were 56 areas of use with BCT in the construction industry. Each of the areas of use was evaluated against the following questions:

- Which value is added?
- What does it need to be implemented?
- What are the largest barriers?
- Who has the ownership?

The evaluation identified 11 cases which were reduced to 8 cases after further research. The project "Byggeriets Blockchain" started based on the aforementioned (Falk et al., 2019) and was funded with 6.6 million DKK by Industriens Fond.

7.1.1 "Byggeriets Blockchain" Project

The project "Byggeriets Blockchain was created to evolve BCT in the Danish construction industry, and to let companies come up with solutions to use BCT in a way that is better than what is done today. The projects that were funded were divided into 4 categories: Project solutions, Company solutions, Value chain solutions, and National business solutions. Within the categories are the following projects (Industriens Fond, 2019):

- **Build Trust - Chain of Custody:** A project about tracking construction materials, together with the decisions, approvals, responsibility and the physical and virtual locations.
- **Digital Beast - Material Logistics:** A use case that researches a digital twin. It includes a logistic label with a QR-code on the materials and GPS-solutions for scanning.
- **IoT Audit - Connected Sensors:** A use case that uses sensors connected to the internet through the blockchain, which then collects, stores, shares and analyses the data from the sensors.
- **Come Together - Client Decision Planning:** A use case looking into creating a central gathering for validation of decision. A UI fitted for all the actors of the project is made that can synchronize with the common gathering and gives an overview of the decisions made.

- **OnSite - Jobplan, -log, -check:** A use case that observes creating a job log and time register for craftsmen, quick and simple check of job log for employers, and is working on the construction site.
- **BIM Partner - Sharing of BIM-objects:** A use case looking into integrating more materials to BIM-models, integrating different models and tracing changes.

7.2 Introduction to interviewees

The companies working on the project Byggeriets Blockchain and mentioned use cases were contacted and asked for interviews which would further reveal the possibilities of BCT in the construction industry, with respect to reducing TC. The interviews were conducted by following before prepared interview guide (Appendix A on page 79), which consists of questions roughly divided into following groups: introduction questions, questions regarding Byggeriets Blockchain project and use cases, use of BCT in the construction industry, influence in the procurement process and impact on TCs, and finishing off with barriers for BCT in the industry. Out of the nine companies involved in the project, five of them agreed to participate: HD Lab, Züblin, IBM, Vilhelm Lauritzen and DI Byg. Since not all companies participated, information regarding all use cases was not collected, for example, companies working with the use case ComeTogether – Client decision planning did not respond to the invitation for interviews.

7.2.1 Niels Falk - HD Lab

Niels Falk is the CEO of the company. The company is making digital solutions for the construction industry and is closing the existing gaps by making the technology services, 3D models, 4D plans or laser scans and are working with different things such as robots, exoskeletons, laser scans, predictive modelling and blockchains. Niels has about 2 years of experience with blockchain and was one of the main authors of the white paper (Industriens Fond, 2019) and have been the main describer of all the use cases in the project "Byggeriets Blockchain" (Appendix C on page 91).

7.2.2 Mayes Ali - Züblin

The company is an international contractor owned by Strabag. The interviewee's role in the company is a digitisation and implementing digital tools to optimize the manual processes. The interviewee only has theoretical experience with BCT, but that is also what is needed in the project they are participating in. The interviewee is working with the use case **Build trust** which is tracking a building component, in this case, a window in every place in the value chain (Appendix D on page 103).

7.2.3 Lars Spindler - IBM

The company is doing different projects within BCT eg. IBM Foodtrust, Windwire, and Tradelens with Maersk. Lars is a leader of a digital strategy practice group in IBM. In the last two years, he has been working with BCT and he is helping clients understand how BC can add value to their business. IBM is involved in 3 of the use cases, the first one is Design Tender, which makes a better connection of the requirements made by the architects and engineers and components selected by the contractors in the tender phase, and this will secure that all the products selected meet the requirements. The second use case is Chain of Custody, which is tracking the designed

product to its place of mounting in the building, which helps to create the digital twin of the building. The third use case IBM is involved in is Build Trust, which is connected with the two other cases, about tracking building components from idea to demolition (Appendix E on page 111).

7.2.4 Jakob Guldbrandsen - Vilhelm Lauritzen Arkitekter

The interviewee is working on the ICT and BIM side of the projects, but also on the internal development of digital solutions. Eight months ago the interviewee had no experience with BCT but gained both technical and theoretical knowledge through the work with the project. The company is in the use case Build Trust together with Züblin and IBM (Appendix F on page 117).

7.2.5 Søren Cajus - Dansk Industri

Søren Cajus do not have the personal experience with the technology, but a coordinating role in relation to the use cases that are in progress. He pushes the different companies to make the work agreed in the different use cases (Appendix G on page 125).

7.3 Findings

7.3.1 BCT in the Construction Industry

All five of the interviewees agree that BCT will bring better collaboration to the industry through transparency, better data collection, searchability and history of every activity or decision that had taken place. Interviewees talked about the subject from different standpoints as they work on different use cases. The interviewee who coordinates the whole project and use cases expressed that use cases should result in several solutions that will be tied together with a *"digital superglue"* (Appendix G on page 125).
One interviewee talks about today's problem with selecting components in the design phase by the architect and when the information exchanges "hands" and each party is developing their documentation, in the end, the supplier gets a request for a different component than the one selected by the architect. In that respect, BCT could make the process more transparent and is a joint solution for increasing efficiency for the entire value chain (Appendix E on page 111). Additionally, the interviewee mentions the benefit of having a digital trail so it is known who did exactly what, which level of detail in drawings and who is a responsible party. Another interviewee (Appendix F on page 117) sees better collaboration between different disciplines and phases of the construction project in a way that information does not get lost when it is *"thrown over the wall"* or passed on to another discipline. The interviewee gives an example of working in the design phase of the project for 2 or 3 years with 100 employees and then 1000 pdf-s of drawings is sent to the contractor because the project is entering the execution phase. It is expected from the contractor to understand the information in a couple of months and in a way that is presented, even though pdf-s were made in the perspective of designers. The interviewee concludes that the blockchain, as a shared platform, will enable disciplines to work how they work best without having to adapt to other ways of working. So, people will not have to change the way they work, just where they put their work (Appendix F on page 117). Another interviewee (Appendix G on page 125) also talks about current problems in the value chain when information is passed along, data gets lost, which also causes double work. Another problem he mentions is that nowadays what you build, is seldom what has been designed. There could be many good or bad reasons for

that, for example, it might be that the contractor found out that the architect designed something wrong or because of misunderstanding. The problem here is that it is extremely difficult to find out why there is a difference between what is being built and what is being designed. Two interviewees (Appendices C on page 91 and D on page 103) also mentioned that data is not lost, but it is locked in “information packages”. Each participant in the project attach meaning to data and then it becomes information. As information, it might be of no use for other participants in the project. Considering these problems, BCT can bring traceability to avoid duplication and lost data, to have better efficiency, quality and sustainability. In the end, fewer resources, both man-hours and physical resources will be used.

Another point talked about was the benefits of using BCT instead of a traditional database. One interviewee sees the industry as a chaotic network organisation with huge amounts of data, many transactions and autonomous parties. He discussed how collaboration is done in such a way that it is not easy to digitise it with traditional databases (Appendix C on page 91). Another interviewee mentioned a setup that traditional databases do not have, and blockchain does. Namely, if all the participants of the project are considered, each has its own value drivers for the project, which in turn results in diminished trust between parties. BCT and the application of smart contracts as a gatekeeper will remove the component of placing trust in other people to such extent. BCT will be set up in a way that it is specified which data has to be handed in. For example, a BIM model of specific Level of Detail has to be uploaded and is read by the application which hands over data to the blockchain. Therefore, a model is either accepted or it is not, and that is a feature that traditional databases do not have (Appendix F on page 117). Further, it was discussed the fact that in traditional databases, it is unknown who made updates and possible mistakes, while on the blockchain is created a digital stamp every time someone does something or decides something (Appendix E on page 111). Another problem noticed by the same interviewee is the tendency of some companies to take down their information from the joint database at the point they finish with their work package, which would be impossible with BCT. One interviewee acknowledged all the benefits of BCT in comparison with a traditional database but highlights the importance of feeding the blockchain with only relevant data for a party that is supposed to receive it to avoid creating an archive with all possible data (Appendix D on page 103). She gives an example of a window, where the person who installs it has the information he needs, the worker who maintains the window has information relevant for him, and finally, in 50 years, a person who will pull the window out need his own package of information.

An additional benefit of BCT noted was having the insight into companies that are very efficient and living up to the timeline and deadlines, which might be useful for clients and developers to have a more efficient construction project (Appendix E on page 111). Also, one interviewee sees the possibility of BCT to pick up data in a standardised way to prevent it from dying with the handover of the building, which usually happens nowadays (Appendix F on page 117). This would allow a better learning process from one project to another.

Generally, the participants in interviews have a very positive attitude and predictions of using BCT in the industry. One interviewee even said that the more he is learning about it, the more it looks like *“the blockchain and the construction industry was a match made in heaven”*, as the technology can handle large amounts of information transaction in a large organisation where trust is not established (Appendix F on page 117). Another interviewee compares the technology to the WWW (World Wide Web), as it is also an embedded technology that solves some problems

and gives some benefits without even think about it (Appendix C on page 91).

7.3.2 BCT in the Procurement and Tendering Processes

Procurement is in a way intertwined into use cases through design and planning phases while the tendering process is currently not a part of any active use cases in the project Byggeriets Blockchain. One of the interviewees explains that it is so because tendering is organised efficiently today and there is not much to fix. Additionally, tendering involves competition, winners and losers, and sharing data on a ledger cannot offer any benefits to the process (Appendix G on page 125). Another interviewee points out to feature of transparency, which will enhance the tendering process by allowing bidders to know the conditions they are being evaluated on and working with the newest version of data (Appendix F on page 117). Besides having the latest version of requirements, one interviewee says that BCT will allow the contractor to drive the process very smoothly because he can easily divide work packages, send them out, collect them again and place a bid. If a change occurs, everyone will be notified, from the contractor to the supplier (Appendix E on page 111). Two of the interviewees also talked about the possibility of having a better version of "Trustpilot" for companies, which will not be based on personal reviews but facts (Appendices C on page 91 and D on page 103). In this reputation system, a client can get historical data and find out which company can do a specific job, what kind of works they previously have done and how well they succeeded. Similarly, the interviewee mentioned that traditional pre-qualification rounds can be taken out if an automated system like this would exist (Appendix C on page 91). From a system like this, one can get the information on previous work of the company, success, available capacity, the exact project team (architects, engineers) that have worked on a specific project etc. In contrast with the interviewee who thinks there is no need for BCT in the tendering phase, this interviewee thinks that this will even be the first phase where BCT will be implemented. Another interesting view he expressed is that with offering work on blockchain, the project can be dissected into much smaller pieces and offered to companies with lower capacities (Appendix C on page 91).

7.3.3 BCT's Effect on Pre-Contractual Transaction Costs

All interviewees indirectly talked about the effect on TC throughout the interviews. Some options of increasing efficiency and cost reductions with BCT were mentioned in the previous subsection, for example, the possibility of completely avoiding having the traditional pre-qualification rounds. One interviewee says that transparency about actors and their performance that can be captured on the blockchain might influence the reduction of TCs (Appendix C on page 91). Another interviewee gives an example of one of the company's projects where more than 500 transactions had to be handled. A lot of money and time was spent in evaluation the offers from subcontractors and handling transaction, and a different system where the company could keep track of those would make a big difference (Appendix D on page 103). One interviewee focuses on the indirect impact of the BCT on TC through having a better understanding of the whole project, which would ultimately reflect on the cost savings (Appendix F on page 117). Two interviewees see the reduction of TC through having a technology that can process large volumes of data, which would lead to better decision-making processes, less time spent on information search and documentation (Appendices C on page 91 and G on page 125). It is claimed that the world is now at a technological point where machines are better at handling complexity than humans are, and 10 years ago it was the other way around, what is linked to better and faster decision

making (Appendix C on page 91).

7.3.4 BCT's Effect on Post-Contractual Transaction Costs

The effects of BCT on ex-post TC are found to be most praised among the interviewees, where they talk about the impact on the speed of processes, number of intermediaries and the influence of smart contract on overall efficiency.

One interviewee mentions the reduction of transaction time from 5 days that are needed to get an invoice approved and paid to 8 seconds to execute the same process on the blockchain. In the same way as payments, the processes of getting approvals, validations and quality assurance could go much quicker with the aid of BCT (Appendix C on page 91). One interviewee gives an example happening on the construction site where a subcontractor takes a picture and document the work they have done in the week, then quickly initiates quality assurance process and when the quality check is done, the payment is released (Appendix E on page 111). It was also suggested that some activities will be reduced that are currently being used to communicate and translate what is happening, which could lead to reduced demand for lawyers (Appendix C on page 91). The same interviewee highlights the important feature of efficient evidence gathering on the blockchain. At any point, the blockchain can give information on any activity that has happened – every time someone makes a change, hands in a document, downloads, uploads or decides something, it is recorded. This ability to fetch a record in any given time will result in a significant reduction in TC of searching for information for resolution of disputes. Another interviewee focuses on smart contracts and their ability to ease the current contractual complexity of the projects (Appendix F on page 117). To illustrate it, he mentions an example of the project where the number of contracts was extremely high and complicated, since the company had a contract with the client, with themselves because they have made a company together with another company etc. With all these contracts it was difficult to handle all the requirements and even to know if they are on the right track in the project. He concludes that smart contract could be of immense help in situations like this one, but remarks they have to be used cleverly or it will be as complicated as it is today but on a different platform. Using BCT would also avoid a lot of conflicts that occur, since figuring out who made which mistake is time not spend on developing a project. BCT could help avoid that and add value to the project (Appendix F on page 117). Other interviewees also mention the conflictual nature of the industry and ability to lower TC and even having fewer conflicts because of the synchronised view of reality (Appendices C on page 91 and G on page 125). One interviewee mentions that non-value-adding activities that currently exist will be removed but there will be some other coordination and management costs, so it is not possible to remove all TC, just to change the process (Appendix C on page 91). There is also another important factor noted that will have a major influence on reducing TC and will come with BCT, and that is *"the good cousin of the blockchain"* – standardisation (Appendix G on page 125).

7.3.5 Challenges

According to interviewees, the notable barrier to BCT in the construction industry is a low level of digitalisation in the industry. One interviewee says that the industry now is electric, and not digital. He says that the critical mass needs to be convinced to use BCT to pull the rest of the industry, where the critical mass is in the phase where the most data is produced – design phase. The interviewee identified consultants and contractors as players who would need to lead

the change towards BCT (Appendix F on page 117). Another interviewee says that BCT will be a big jump for the industry, referring to the digitalisation level of the industry, but says it could also be potential. If a new solution that delivers a lot of value is introduced to an environment with low digitalisation, it could accelerate the adoption of solution (Appendix E on page 111). However, one interviewee stays critical and states that it may be that BCT is not the best solution to deal with the problems that the industry has (Appendix G on page 125).

Next problems mentioned are of technical nature. One interviewee has hands-on experience of programming an IFC file into blockchain and states it is not an easy task to make blockchains that are needed for the industry (Appendix C on page 91). Another interviewee mentions an anecdote that an IT company who researched the implementation of the blockchain for the construction industry and experienced problems with navigating and pinning down the complex network of participants, interconnections and processes that characterises the industry (Appendix D on page 103). One interviewee expresses the lack of use cases that shows the advantages of BCT and says that there need to be at least 100 use cases for organisations to start picking up and using technology (Appendix F on page 117). Another mentioned barrier is a lack of standards and a need for formatting data in the same way across disciplines (Appendix G on page 125).

The problem of cost model and governance was the subject of all interviewees when asked about barriers. With the blockchain being a distributed database and everyone is a part of it, the issue is who will pay for it and who will develop it (Appendices D on page 103 and G on page 125). The interviewees acknowledge how investing in BCT would be costly for small and medium companies, so the cost model proposed is pay-per-use on a platform with developed industry standards (Appendices C on page 91 and E on page 111).

Next challenges to overcome are grouped as human-related. In that manner, one interviewee mentions that for people to accept the solution it has to be made so easy and invisible that people cannot feel it is there (AppendixD on page 103). She also recognises the hesitating mindset often found among construction people towards new technologies. Another interviewee says that there are different companies and people found in industry, but if the industry is summed up into one person, *"the construction industry is the guy who needs results before he embraces something"* (Appendix F on page 117). This statement supports the aforementioned claims that there is a need for more successful use cases and invisible change.

CHAPTER

8 Interviews with Construction Professionals

This chapter provides the considerations behind the interviewees chosen in the second round for the research in respect to the problem formulation

8.1 Purpose and Consideration

The information gathered from the findings in Chapter 7 are analysed and from that, a new interview guide is made to present BCT to professionals in the construction industry and ask them how BCT can affect their work processes. The questions for the construction professional can be seen in Appendix B on page 83.

8.2 Introduction to Interviewees

To find the persons to interview there was looked in the report by Bunic and Gøtze (2019), where 9 companies in the area of Aalborg were interviewed about TC in the construction business. All of the companies were contacted to participate, but in the end were the 3 developers, who have agreed to participate in the interview about BCT. Developers have a good overview and understanding of the construction industry and are digitally developing if judged by the shift from using BIM as 3D model towards using it as a data loaded model (Bunic and Gøtze, 2019). For these reasons, it is deemed that they could give a current perspective of BCT in the construction industry.

8.2.1 Karsten Westergaard - S. Enggard

Karsten Westergaard is the chief of projects in the company. He has 28 years of experience in the construction industry. The company is based in Aalborg and has two sides, a development department and a real estate department, that makes both housing and commercial constructions. The company is a private developer, which means they can choose the way of tendering they want to. The interviewee has no knowledge about blockchain and blockchain technology prior to the interview. The company does between 10-20 contracts on each of their projects, this depends on the contract type of the projects they make.

8.2.2 Søren Fonseca Pedersen - Kuben Management

Kuben Management is primary a legal and economic advisory for social housing, where they organise tenders. The company has architects, engineers and legal advisors in the company, but does not do the technical specifications. The interviewee has little knowledge about blockchain before the interview. The knowledge he has is associated with cryptocurrency. The company

does between 5-10 contracts on each of their projects depending on the contract type used.

8.2.3 Kenneth Lundholm-Stenkjær - Vivabolig

The interviewee is the chief of projects in the company, and has 13-14 years of experience in the construction industry. The company is a public housing organization. The interviewee has little knowledge about blockchain before the interview and the knowledge he has is associate it with cryptocurrencies. The company does 10-15 contracts in each project depending on contract type.

8.3 Findings

The companies that are interviewed are developers and client advisors located in Aalborg. They were asked to comment on different use cases that was presented by the interviewer during the interview.

8.3.1 Immediate thoughts on blockchain technology in the construction industry

The interviewees have never thought of BCT as technology that can be used in the construction industry. After a brief introduction, some points were made that the technology can be useful in development and construction of the building, but when the building is handed over to the one who is facilitating the building, there can be difficulties, because if the building is facilitated ad hoc as S. Enggaard does, it is hard to believe that the data is put into the blockchain (Appendix H on page 131).

8.3.2 Design Tender

The **Design Tender** use case is described to the interviewee, where it was explained that there will be a higher transparency in the information exchanged between different parties in the value chain, and an automation in registering when there changes are made to the models because this will be linked to the blockchain, which includes the information about the decisions that are made in the process of designing the buildings. An interviewee states that this makes sense, although he thinks that it is already done in some way today, but maybe not as automated. He also states that it would be beneficial if the requirement specification can be done in a smoother way than it is done today (Appendix J on page 145). One interviewee states that this sounds like a version control, where it is available to all parties. The immediate thought is that the increased transparency can be beneficial for the construction industry. On the other hand, he is in doubt that it maybe increases the curiosity of other parties int the project, which decreases the efficiency (Appendix I on page 139).

8.3.3 Chain of Custody

The use case **Chain of Custody** is described to the interviewees as a system, where one can track building materials digitally from the idea to the demolition of the building. It is claimed by one interviewee that the value of many of the materials is not calculated into the economics of a construction project, and the functionality will be outdated before the demolition of the buildings (Appendix J on page 145). Another interviewee claims that there can be benefits by knowing

about the bearing construction for recycle purposes. It can be helpful for the contractors, but not for a building consultant (Appendix I on page 139).

8.3.4 Logistic of the Material

The use case **Logistic of the Material** is explained to the interviewees as the delivery of the materials connected to a blockchain, so one can know how far the production is in the process, when and where the materials are delivered at the construction site. One interviewee states that the system is sort of what is being done today in some of the projects his company are doing, but that is important for the contractor to know where the materials are on the construction site at all times, to be most efficient (Appendix H on page 131). An other interviewee claims that this will not add value to the project, because when a construction manager orders some materials, he orders them to a time, and it does no difference if they come at 09:00 or 09:03 (Appendix J on page 145).

8.3.5 Job Log

In the interviews there were a description of the use case **Job Log** where it was explained that there is a log of achievements, both on company and personal level, and it is linked to the blockchain with real time, true data. This can secure the validity of the reference list of the companies. It was explained that this can be useful in the pre-qualification rounds of the projects, so it is easier for the clients to choose the contractors. One interviewee assumes that everyone who are entering a tender have an updated reference list, in documents like word or excel etc. He also says, that they sometimes hire a company to ensure the legality of the pre-qualification, which can be cut with the BC solution (Appendix J on page 145). Another interviewee mentions that one can follow the ongoing changes and additions to the reference list, but says that one still needs to have a qualitative analysis of the material (Appendix I on page 139). One interviewee states that he does not see the benefit from this solution compared to the ones used today (Appendix H on page 131).

8.3.6 Scale

The interviewees were asked, on the basis of their understanding of blockchain technology, how it can reduce the costs of the following 6 statements on a scale from 1 - 5, where 1 is Not at all, 2 is Not really, 3 is Undecided, 4 is Somewhat, and 5 is Very much, as shown in Appendix B on page 83. The answers to the questions can be seen in Figure 8.1. These costs that are subgroups of transaction costs were explained to interviewees as follows:

- Verification costs: costs of finding information and verifying companies.
- Networking costs: costs of operating in the market without intermediaries, finding business opportunities.
- Costs of writing contracts: drafting contracts and adding special conditions.
- Costs of enforcing contracts: solving disputes and disagreements, costs of courts and lawyers.
- Negotiations: costs of meetings, preparation and negotiations.

Table 8.1: The answers on a scale of 1-5 whether the BCT can improve the construction industry in 6 different places.

Companies	S. Enggaard	Kuben Management	Vivabolig
of Business verification (contractors, consultants)	3	1	2
of Networking	1	1	1
of Writing contracts	3-4	3	2
of Enforcing contracts	3	3	2
of Shortening transactions execution time	3-4	n/a	4
of Negotiations	1	2	3

The interviewees were asked to elaborate on the answers they gave and sometimes the interviewee also elaborates on what the possibilities of BCT are regarding the different statements. One interviewee states that the contracts are fairly standardised, and it is only the attachments that differs from project to project, so the BCT will not change a lot for them in that regard (Appendix J). The interviewee from Kuben Management did not give a number on the statement about shortening of transactions execution time, because he has little knowledge about that part of the project. One interviewee mentions, in regards to verification of business, that it depends on how many they have to verify, because if it is 5, they can handle it, but if it is 20 then the technology can be helpful (Appendix H on page 131).

CHAPTER

9 Proposals for the Construction Industry

This chapter will present a conceptual proposal for the application of BCT in the procurement process and general recommendations for the industry, inspired by preceding research.

9.1 Purpose and Consideration

Based on collected knowledge from two rounds of interviews and literature, a proposal for implementing BCT in the industry was developed. The first round of interviews showed a massive potential of BCT for the industry, whereas the second round of interview provided with a "reality check" and possible pitfalls of the technology. Coupled with theoretical knowledge, insights were gathered, scrutinised and discussed. Brainstorming sessions resulted in two levels of the proposal. The first one is a conceptual model, where a procurement process was conducted with the aid of BCT, concerning the reduction of the unnecessary TC. The second level consists of general recommendations and perceptions that were collected during this research. These are sometimes obvious and straightforward but should be kept in mind in order to promote further research into BCT in the industry.

9.2 Conceptual Model of BCT for Procurement and Tendering

The initial focus of the thesis was the construction procurement process, which broadened on the industry due to the lack of existing research of BCT in that area. However, the procurement and tendering processes are still covered and examined as the TC are the foundation of the thesis. After all, bringing the procurement process on the higher level of efficiency is a subject of numerous reports published during the last few decades, as shown in Section 1.2.

Remarkably, the use of BCT for the procurement process was not heavily studied in the literature as the other uses were. A few authors marginally touched up benefits of BCT for the procurement process, but it was not further described. The reason might be various definitions of the term procurement or often interchangeable use of terms procurement and tendering. Here, the procurement process is perceived as outlined in Figure 9.1 and based on Flanagan and Jewell (2018) and Lewis (2015).

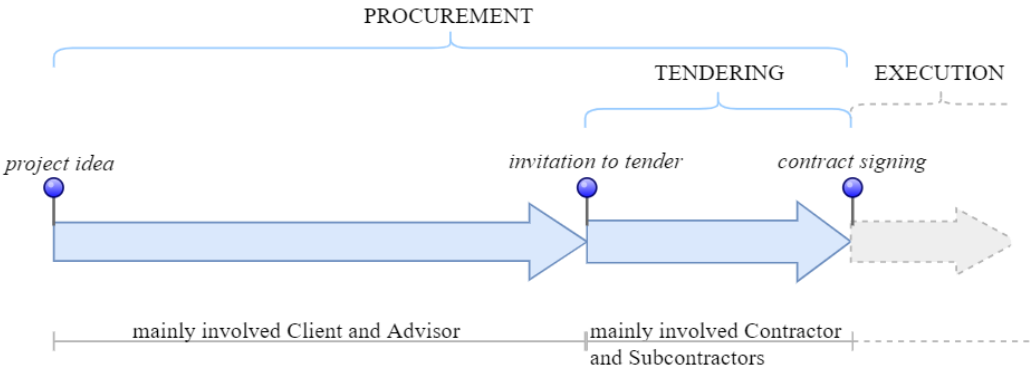

Figure 9.1: Procurement and tendering, (Bunic and Gøtze, 2019)

It was noticed that the Byggeriets Blockchain project also does not specifically consider the procurement phase. Although it was frequently noted that the whole construction project process is covered by the eight use cases, the particular use in procurement was not discovered through the interviews. The opinion of the interviewees on the use of BCT in the procurement and tendering is opposed. While one interviewee claims the tendering today is already efficient and due to competitive nature, there is no need for sharing technology such as BCT (Appendix G), another interviewee claims it might be the very first phase with implemented BCT (Appendix C).

For this proposal, a public procurement model was chosen for multiple reasons. Firstly, the procurement phase, together with the initial design, is the first step in procuring the construction project. There are many participants and opposed parties (bidders) involved, with various regulations to follow, so transparency, trust and traceability embedded in BCT are a significant advantage. Additionally, public projects are carefully observed because of corruption and collusion possibilities, so a technology that reduces costs for taxpayers and increases transparency could be welcomed. If BCT would be set up in this starting phase of the project, whether public or private, it will also give incentive to pursuing the implementation of the technology in later stages. Finally, one of the barriers that need to be overcome to implement BCT is linking off-chain to on-chain matters. Thus, the industry will have to find ways to link everything that is off-chain, buildings, building components, machinery and transport vehicles to the blockchain. The qualifying factor for the procurement to be the first to use BCT is that majority of activities can be accomplished on-chain.

The following conceptual model is developed in two stages, making of decision map and through iterative thinking process to explore how BCT could fit the procurement process.

Decision Map

This process helps to determine if the use of the blockchain is justified in a particular case and the configuration of blockchain most suited to do it. The decision process is offered by many authors with small differences in questions to adapt it to the industry in question (Li et al., 2019b; Wüst and Gervais, 2018; Turk and Klinc, 2017). For making a decision, the map by Turk and Klinc (2017) will be used, since these authors also used it for the cases in the construction industry. The map is shown in Figure 9.2, followed by a description of every answer to the posed questions.

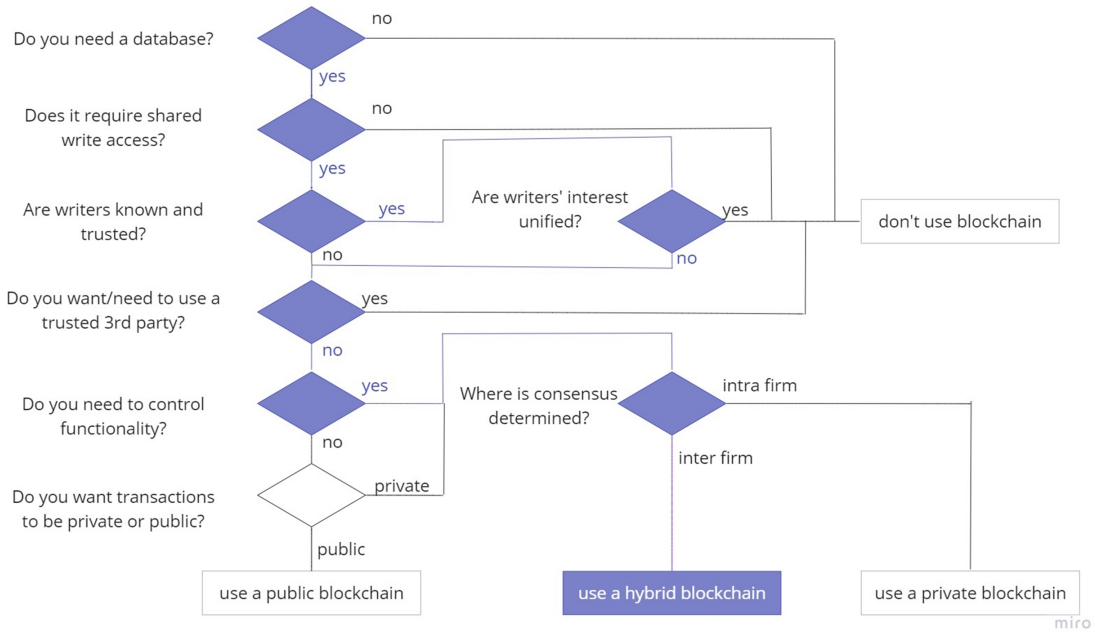

Figure 9.2: The decision taken on what kind of blockchain to use in a public procurement case, adapted from (Turk and Klinc, 2017)

The series of questions (blue path in Figure 9.2) led to the use of hybrid blockchain for the case of organising the public procurement process. This is reasonable since in the procurement process multiple companies are participating that should be pre-approved by a central authority. Here follows an explanation of the decision process:

- *Do you need a database?* Yes, there is a need for the database in the procurement process, and especially in tendering where documents, updates to documents, contracts and communication occur.
- *Does it require shared write access?* Yes. If a company decides to participate in a tender, it automatically needs a write access.
- *Are writers known and trusted?* Yes, writers are known to the central authority. However, it depends on the criteria to enter the blockchain network if they are trusted, but even then, it is unclear whether a company can be trusted.
- *Are writers' interests unified?* No, each writer comes it with own objective and interest.
- *Do you want/need to use a trusted third party?* Turk and Klinc (2017) state that trusted third parties have not been usual in the construction project. Even if there is a third party, they have to walk a fine line between two opposing sides (Mathews et al., 2017). Despite it was found through interviews that a third party is used for organising tenders and procurement, this question was passed with a thought that even a company that is a third party would greatly benefit with the BCT in navigating numerous bids, evaluations and contracts.
- *Do you need to control functionality?* Yes, the functionality of the network has to be controlled since the use case involves publicly funded projects.
- *Do you want transactions to be public or private?* The transactions during tendering and procurement should be private so there are no attempted misuses from unknown parties. However, at the point when the procurement process is finished, there is a possibility to allow a special view for the public. This aspect will be further explored later in this section.

- *Where is consensus determined?* The consensus is determined inter-firm, between companies that are entering the network.

The outcome of the decision process shows that public procurement process could benefit from the use of BCT, specifically a hybrid blockchain. The important thing to mention is that there still has to be a neutral central authority to prevent misconduct.

Conceptual Model

This model presents how a procurement process would proceed on the blockchain. The model was developed by following steps in a typical procurement process made by Lewis (2015). Lewis (2015) provided a detailed list of the actions that might be taken by the public client and a contractor during the procurement process. It is advised to consider that process might differ depending on the procurement route and tender procedure. Additionally, in this conceptual model, some actions that do not require record on this blockchain are left out (for example, consultation with an advisor is an action that is not recorded on this blockchain).

In the model are various concepts embedded that were thought of during this research and inspired by interviews and literature study. They will be explained through the process. The idea to develop a conceptual model on a collaborative platform (Miro) in this way and with information that is shown, came from one of the interviewees, Mayes. A similar process is used by the participants of Byggeriets Blockchain project in their use cases. The model is shown in Figure 9.3 and explained hereafter. The numbers are used only to simplify connecting a textual description with a specific stage in Figure 9.3.

The Figure shows a conceptual model of the procurement process with accompanying activities, participants and additional information. The Activity represents a record on the blockchain, Writer is a member who can generate a request/transaction/record, Reader can see it, and Verifier verifies interactions and updates the state of the ledger. Given that sizes of exchanged files are large, cloud-based storage should be used, and blockchain is recording transactions. It is imagined that there is a database accessible through blockchain with all companies. The type of company is not specified, but since the process starts with the Client and Advisor already paired up, it can be imagined that they search for the Main Contractor. Here follows a brief explanation of every step:

The whole process has to be verified by the authority and they update the state of the ledger.

1. Client issues an invitation to prequalifications. He defined project and evaluation criteria to prequalify contractors. The invitation is visible to all the companies on the blockchain.
2. Client requests a list of qualified contractors based on evaluation criteria. Database of companies may provide information on references, CVs of team members who worked specific project, the financial health of the company, work capacity etc. One interviewee suggested this step could completely remove traditional prequalification rounds (Appendix C).
3. However, it was pointed out in one of the interviews with professionals that sometimes prequalification criteria are qualitative, so pulling data from the database would not be sufficient. Additionally, the same interviewee pointed out that legislation allows for a company to argue if it wants to enter pre-qualification rounds (Appendix I). For this reason, in the model, a step is added where company B expresses interest and argues to enter the competition.
4. After deciding who passed the prequalification round, Client uploads notification that shortlist of companies is available. Shortlisted companies are notified they are shortlisted

but do not know their competitors.

5. Client issues an invitation to tender. The documentation, with evaluation criteria, is stored and available for download.
6. Next is imagined that Company A found an important mistake in the tender documentation and requests clarification on the blockchain. This is read by the Client and Advisor, who review the documentation with new information from Company A.
7. Upon reviewing the documentation, the Client and Advisor agree that there is a mistake and they issue an update to the tender documentation that is visible to all the bidders.
8. In this step a **reputation system** comes to light. It was suggested by one interviewee that companies could build their reputation on the blockchain when they do their work well and in time (Appendix C). With the idea of using #AECoins to reward contribution found in Mathews et al. (2017), in this step is shown that Company A is rewarded for their contribution to enhancing the quality of tender documentation. These coins might not have a monetary value, but they will build the company's reputation on the network. This reputation system would have to be developed with a set of rules and it would give incentive to companies to report when they find discrepancies, which brings value to the whole project.
9. A meeting or briefing might be requested if it is appropriate for the selected tendering procedure. This and possible negotiations or formal site visits could be one of the only off-chain activities occurring in the procurement phase. However, they could still be scheduled and recorded on the blockchain.
10. Companies submit their bids into the cloud storage and on the blockchain is written the record of each company submitting the bid.
11. A deadline for bid submission was pre-defined by Client and when the deadline passes, the submission is automatically closed, and new bids cannot be uploaded.
12. Opening the offers is done on the blockchain in order to ensure transparency. The activity is visible to the companies that competed.
13. When the best offer is selected and the contract awarded, the three shortlisted companies have an overview of evaluation criteria and each other's bids.
14. Once the tendering process is finished, an authority managing the network could issue a public key. This would provide a **transparent tendering framework** where anyone interested could get an insight into the process (Sheer Hardwick et al., 2018). The public view could be controlled and limited to protect sensitive information. This kind of system would give an extra layer of transparency since society is also a stakeholder in public projects.

The presented conceptual model gives a general view of the reach of BCT in the procurement process. Needless to say, it barely scratched the surface and a lot is left for discussion: cases of using different procurement methods and tendering procedures, networks for setting up and collecting information for subcontractors and suppliers before the main contractor submit a final bid, collecting information into databases, standardisation and rules etc. However, the model indicates that pre-contractual TC might be reduced with the implementation of BCT. Namely, search and information costs and communication costs could be reduced. Also, prequalification rounds would become much shorter and more precise in the selection of companies that can do a specific job. Finally, collaboration rewards could encourage participants to be more committed and the whole tendering process would not be so demoralising as it is today when much of the efforts put into preparing the bid turns out to be wasteful.

All things considered, it is important to stay critical and do the research into new emerging technologies, as they can just as easily add additional complications to an already complex procurement process. However, a conceptual model, like the one showed, presents a thought experiment that can help identify weak points or great potential of the new technology.

9.3 Recommendations

Throughout this thesis research, considerations upon implementing BCT in the industry were collected and hereafter they are formulated as recommendations for the industry:

- **Endorse more projects. Make more use cases.** Byggeriets Blockchain is a remarkable initiative that will contribute to the development of BCT in the industry. As Buterin (2015) said: *"there is no "killer app" for blockchain, but rather a very long tail of marginal use cases among particular groups, all of which adds up to a lot."* One interviewee mentioned that the construction industry has to see the results before embracing something (Appendix F). Thus, there have to be 50 or 100 use cases and then the industry should judge if BCT is the route to higher efficiency or not. In line with the above mentioned, McKinsey (2016) states that industry bodies should invest and create incentives because they can support companies to define new standards for emerging technologies, develop pilot projects and success stories.
- **Partner up with technological companies.** For developing BCT solutions, high-level skills in programming are needed and understanding of the workings of the construction industry. Thus, the best results should be yielded when these two skill sets are combined. With that, the team can very fast produce a minimal viable product, test it and get feedback from the customers. It is also important to think about customers and users first, and then technology. In these ways of working, use cases can be made and different companies through the value chain can see the financial benefits of the technology.
- **Commit.** Implementation of this kind of technology requires a substantial commitment. Firstly, the industry's members should commit, each to a possible extent. That means that one company can start using BCT and have some cost savings and more efficient processes but BCT can be fully exploited when all the project participants (or at least, the critical mass) use the technology. Secondly, the industry will need to commit to investing in other technologies that are complementary to BCT: BIM and IoT. These commitments seem overwhelming, but the change will not happen overnight, it will be gradual and steady (Iansiti and Lakhani, 2017), as the technology has to go through many stages to overcome challenges and discover potentials.

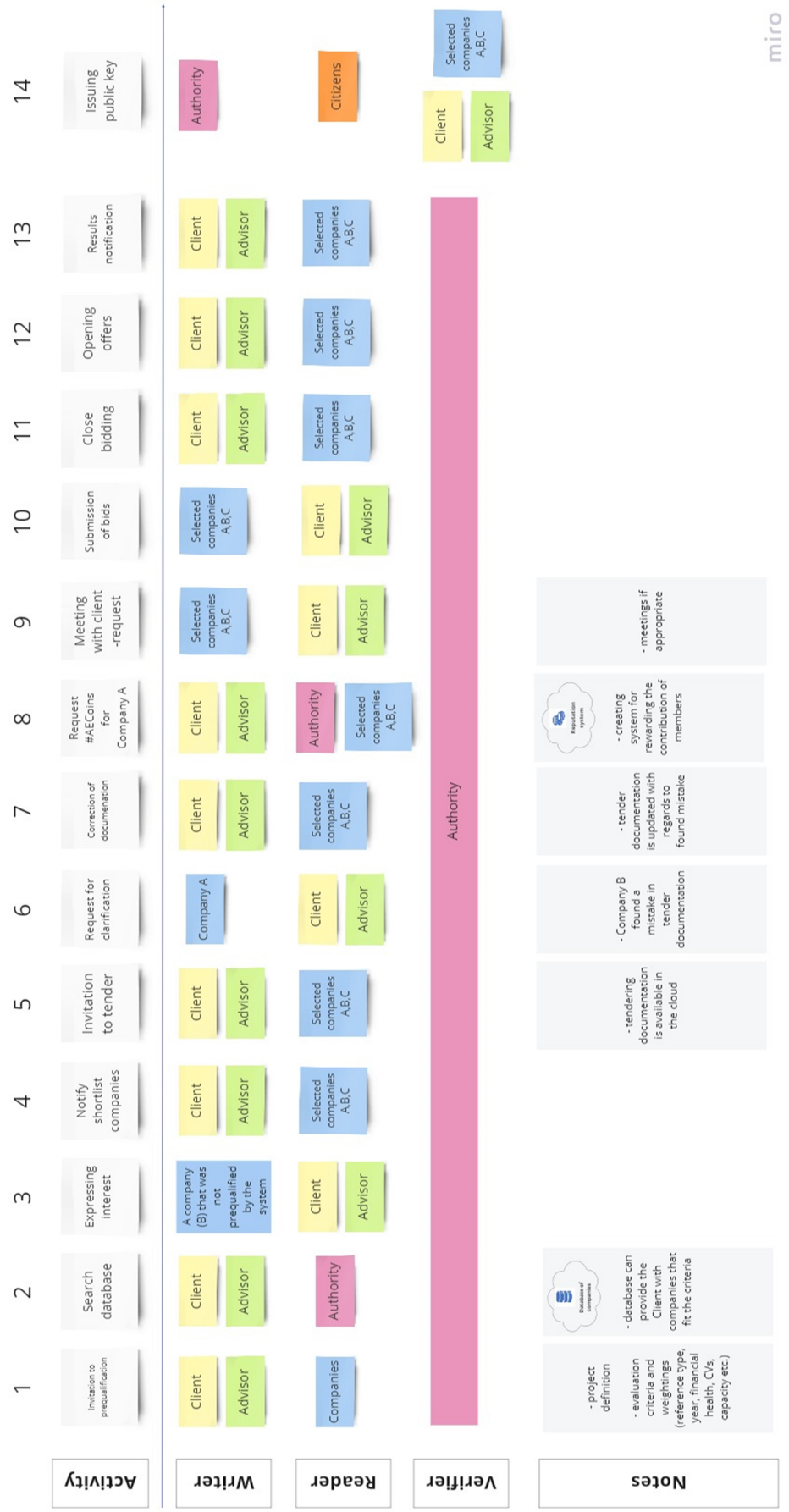

Figure 9.3: A conceptual model of Blockchain Technology for the public procurement process

CHAPTER

10 Discussion

This chapter discusses the findings from interviews and compares them, debates about the proposed solution and combines those with knowledge from literature.

Through analysing collected data, multiple discussion points were identified. Firstly, two opposed understandings and impressions of employing BCT in the construction industry were found in separate rounds of interviews. Next, the effects of BCT were being assessed by using TC framework throughout the thesis. In that respect, the effects on ex-ante TC, ex-post TC and governance mode were discussed. Being the emerging technology that gained a lot of public attention, BCT faces many challenges and even more in this traditional industry, which is often characterised as a technologically backward industry. Thus, the challenges BCT confronts are discussed. Lastly, the proposed conceptual model is discussed as opposed to existing software solutions.

10.1 The Understanding of BCT

The first impressions of interviewing “blockchain experts” and “construction professionals” are apparent optimism and unawareness, respectively. In the first round of interviews, from five people who work with BCT in Bygerriets Blockchain project, two of them are deeply involved with BCT, two are working in IT departments of construction and architectural companies, and one has a coordinating role of the project, but does not have deep knowledge of BCT. This interview group consists of people with actual hands-on experience with coding smart contracts and applying them to the blockchain and people who familiarised themselves with BCT in recent years, mostly on the level of reading papers and research. That being said, even though they do not have the same levels of understanding BCT, they share enthusiasm and belief into the revolutionary abilities of BCT in the industry. In the second interview group, three people are working in somewhat digitised companies. It is difficult to measure digitalisation level of a company, but for this discussion, it is sufficient to say that these companies started to move from using BIM for 3D visualisation towards using BIM as data loaded model. Having said that, it was interesting to notice that throughout the interview about BCT in the industry, these interviewees were dismissive towards BCT. Even after the interviewer described the use cases of Byggeriets Blockchain project and talked about benefits, these interviewees did not recognise the value of BCT. The first reason for that might be their first association of BCT are cryptocurrencies, which received a lot of bad press in recent years. Other reason might be that this technology appears as something as complex as BIM and the promised benefits of BIM and industry transformation are still anticipated (Mason, 2019). Whatever the reason might be, this difference in the understandings between two interview groups is highlighted to keep in mind the standpoints from which the BCT is observed by interviewees. The perspective of construction professionals did give a “real picture” and does say something about the current position of BCT in the industry. However, the future and the potential of BCT in the industry should not be judged

based on inadequate information.

10.2 BCT in Reducing Ex-ante TC

Through the thesis, many aspects of pre-contractual activities that could be modified with BCT to reduce unnecessary TCs were noted.
In the procurement and tendering process, the opinion of experts is conflicted, with one who does not see the use of the blockchain as the sharing technology in the competitive environment of tendering, and other who sees it as the first phase of implementing BCT. The literature review showed that BCT will bring increased efficiency and cost savings to procurement but does not specify how. The conceptual model of BCT implementation in the procurement developed in Chapter 9 showed that costs of pre-qualification rounds and information search costs could be reduced. With the reputation and database systems, the whole process could be more efficient, which would indirectly result in reduced TC. Through interviews with experts was also talked about the indirect effect on reducing TC through better, automated processes, easier decision-making, and faster tracking. For example, one indirect impact on costs could be through use case Job Log. Namely, the designing tool can be connected to the database of references through the blockchain and architects can pull data about the contractors who have the skill to execute the design that is being made. This can make cooperation between the design team and the execution team better, and the tender material sent out can be more buildable than it is used to be. The long-hoped-for functional information loaded BIM might be achieved with BCT as the underlying technology. On the blockchain could be tracked who owns the model, who has the right to modify, who made changes and with whom lies liability for mistakes, and these are exactly the current pain points of BIM (Ye et al., 2018). A favourable feature is that design phase can occur almost entirely on-chain so there is no need for the immediate development of IoT technology, although the best course of action would be to develop these in parallel. Moreover, BIM and BCT could provide with the best set of information, which would lead to decreased bounded rationality and in turn considerably reduce TC.

10.3 BCT in Reducing Ex-post TC

From the interviews and reviewed literature, it appears as ex-post TC will be reduced substantially, especially if the full potential of the BCT comes to life. This is the point where experts agree with professionals. As seen in table 8.1 on page 54, there are three areas that the construction professionals rated higher, meaning that BCT can make associated activities more efficient. These three areas are writing and enforcing contracts and shortening the transactions execution time. These responses go in line with the use cases, which makes sense as they were presented for the interviewees. However, this does not undermine the impact of BCT on ex-post TC. Firstly, the reduction will occur through implementing standardised contracts like AB and FIDIC in the code of self-executing smart contracts. Secondly, the transaction time will reduce significantly when the activities on the construction site will be linked to the blockchain, which will protect companies from insolvency and give an opportunity to smaller companies to take a part of the work. Thirdly, both groups of interviewees agree that the use of BCT will alleviate the problem of frequent and expensive disputes in the industry. Some of the professionals argue that the disputes take a lot of work and can slow down a project completely, and similarly, the experts claim that resources spent on solving disputed are resources taken away from the

project. Disputes can result in long and expensive processes of searching for the time and place of mistake, and that is information that BCT could provide in a matter of seconds. Furthermore, a blockchain that ensures transparent, traceable and shared records might promote the culture of taking responsibility for own actions, better fellowship among different disciplines, which would reduce the number of disputes.

It appears that the possibility of a significant reduction in costs gave interviewees a positive outlook on the use of a smart contract. However, many issues have to be resolved for smart contracts to reach the level described above. Smart contracts have to be coded up to the smallest detail in tasks, and while this might be achieved, uncertainties that usually occur in the construction projects cannot be predicted in the contracts. However, if the private or hybrid network is used, consensus might be reached to change or update smart contracts. Next issue is legislation, because the code that the contract is written in, is not a legal language of the law. On the other hand, the parties entering the network can sign traditional contracts that they will adhere to the rules of the smart contract. In the construction industry, a major problem might be the number of activities that happen in the physical world, off-chain. That makes the sensors on machinery and buildings susceptible to hacking and possible fraud.

This discussion showed the potential and enthusiasm regarding smart contracts. The agreement of experts, professionals and authors from literature point to the notion that this might be the area of the blockchain use, where investments will be made since the significant cost savings are inevitable. With the application of smart contracts, it might appear that lawyers will become that third party that will be pushed out. However, it is more realistic that lawyers will have to change slightly the way they work now and cooperate with software engineers.

10.4 Impact of BCT on the Governance Type

Winch (2009) claims that the pure market and pure hierarchy have rare application in construction projects. While he is right regarding hierarchy, which is unsustainable in the modern construction industry, as confirmed by Hughes et al. (2006), he might be wrong regarding pure market with BCT rising and finding its application. With today's mostly private investments in projects, network organisations are preferred governance type. This mode makes sense since it reduces opportunism and information asymmetry, and preference of long-term relationships, fair play and mutual respect in Denmark gives the network governance additional strength. On the other hand, one interviewee described the industry as a chaotic network with astronomical amounts of data and participants (Appendix C), which would suggest a slow shift towards different governance type. As BCT will bring trust in the system with features of transparency, security and immutability, and the trust will not have to be placed in the relationships anymore, opportunistic behaviour might be reduced (Davidson et al., 2016). Additionally, the burden of the complexity will be taken on by the system, which will allow reduced bounded rationality and better decision making. Some authors claim that BCT will enable extensive market governance type. However, in the construction industry, Hughes et al. (2006)'s claim is still relevant when he says that it is not the question of market or firm, but how to efficiently structure all the relationships and the complex network of contracts. The solution might lie in Davidson et al. (2016)'s question of why do some transactions occur in blockchains, rather than in firms or markets? The blockchain might be the solution to efficiently structure all the relationships that occur during a construction project.

10.5 Challenges

As mention in Chapter 7 there may be an only small improvement for each of the parties in the value chain, which can have the unfortunate outcome that no one of the parties wants to develop and pay for the technology. So it is important to tell the industry that if this system is implemented they will all get a little part of the cake, which will eventually end in more value for the money, when constructing a building.

Today many people in the construction industry do not have faith in technology, and often they are wondering if the "computer" is calculating the tasks wrong. This is a vast misunderstanding because computers are only doing what they are told to do, and calculation mistakes are done more often by people than computers. The reason for this interpretation is often based on human fear of losing their job. Because of the fear of letting tasks go to the machine, there is a possibility of opportunistic behaviour towards the implementation of smart contracts in the industry. On the other hand, several of the interviewees want the process to be smoother and more efficient, so the point might be that the system needs to prove its place in the industry before it can be implemented fully.

Dakhli et al. (2019) states that two elements have to be done before smart contracts will work in the construction, and one of them is defining precise tasks of the act of building. This statement can be beneficial for the contractors, and at implementation, it can make it easier for the small contractors to compete in the market. One can argue that this will be a step towards changing the whole industry because today many projects are executed in turnkey contracts, where the turnkey contractor invites subcontractors to do some of the work. With smart contracts, there is a possibility to save this link, and then save money. Important to note in this context is that to make the smart contracts there needs to be done a lot more work on the project before entering the tendering phase.

To implement a blockchain solution in the construction industry requires that someone is the first mover. Typically is the construction industry very conservative and want to see results before implementing new things. The implementation of BIM in the industry has been an ongoing process since the '90s and the impact of BIM is still awaited. Considering that, it is not a surprise that the companies will be reluctant to invest in even newer technology. Additionally, bad press over cryptocurrencies diminished the image of the blockchain. Nevertheless, there is no doubt that some companies can divide hype from real potential and will start developing marginal use cases and gaining first-hand experience with BCT.

10.6 Solution

Conceptual Model in chapter 9 might look similar to software that is already used in the industry to manage tender processes. However, the difference is that the solution in the conceptual model is connected to a blockchain. One can argue why do not the existing actors in the software market change to a blockchain solution if it can do the same. The reason is that the technology is different and therefore it is expensive to change the system. Additionally, existing systems that are on the market are specialised for each part in the value chain, where the BC solution eventually will be industry-wide. The fact that the BC solution is similar to what is already out there can result in construction professionals thinking it is not necessary to change into another

system. On the other hand, this might mean it will be easy to adopt the BC solution. From this study, there is no doubt that a blockchain solution will give a higher transparency, which is something all of the professionals interviewed strive for.

CHAPTER

11 Conclusion

The final chapter answers the sub-questions and the problem formulation.

How can BCT benefit the procurement process?
Through the project, it was found that by using BCT there is a possibility to remove the pre-qualification round. That is achieved by having a blockchain system that has the records of the required information regarding contracting companies (e.g. past references, craftsmen' resumes, the financial health of the company). This will give the ability to have a better understanding of the companies that are placing a bid, and eventually save money in the procurement phase. The blockchain technology can provide higher transparency in the process, which will grant the clients to make smarter decisions that eventually lower the costs.

The conceptual model made in Chapter 9 shows a concrete example of how technology can be used to improve the procurement process.

What type of TC can be impacted by BCT and how?
BCT can impact both ex-ante and ex-post TC. Ex-ante costs that can be reduced are costs associated with pre-qualification rounds and searching for information. Pre-qualification rounds can be removed from the process by gathering data of the blockchain. Ex-post costs that can be reduced are contracting costs and costs of dispute resolutions. Smart contracts play a major role in reducing these costs by standardising contracts and reducing time and cost spent in evidence gathering for dispute resolution. Additional costs can be reduced indirectly through blockchain's features of employing smart contracts, transparency, automation and security.

How does BCT affect disputes in the construction industry?
It is not possible to remove all disputes in the construction industry, but with BCT there are the benefits of better data sharing, so all parties get the same information, text information and decisions will not be lost, because it will be linked to the project, and the requirements will always be updated, which gives the derived effect of fewer disputes. In case of a dispute, the evidence regarding the situation in question can be gathered of the blockchain. The traceability that BCT provides may trigger more responsible behaviour in the industry because the requirements and decisions always will be present.

How can BCT be implemented in the industry?
It is important to notice that in the construction industry blockchain is a new technology, which means that there are few use cases executed at this time. To implement BCT in the industry, the first thing to do is create more use cases, and do test runs of the system on a smaller scale, until it proves its importance. To speed up this process, a solution can be to partner up with technology companies that have experience in BC solutions in other industries.

How can blockchain technology benefit the construction industry in relation to reducing the transaction costs?

BCT can reduce both ex-ante and ex-post TC. In addition to reducing costs, it can benefit the industry by enabling high collaboration levels in a trusting environment through transparency, traceability, trust in the system and security. If the whole industry eventually can embrace the blockchain technology, between market, firm and blockchain, the maximally minimized unnecessary transaction costs will be on the blockchain.

It can be considered that researching blockchain technology as a system for a truly collaborative working environment in the construction industry is a worthwhile goal. However, seeing that BIM has been gradually applied in the last few decades, but its full functionality is still awaited, it is expected that the process of implementing the blockchain technology will be as well gradual and slow. That being said, the thesis group's objective is to add this thesis to series of other reports, articles, books, conferences and workshops that are pushing blockchain technology in the construction industry to reach the *tipping point*.

"The tipping point is that magic moment when an idea, trend, or social behaviour crosses a threshold, tips, and spreads like wildfire."
- Malcolm Gladwell, The Tipping Point: How Little Things Can Make a Big Difference

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APPENDIX

A Interview Guide for Experts

Briefing:

First of all, thank you for participating in our project. This study aims to explore the usage of blockchain technology as means to reduce transaction costs in the construction industry.

You will find that our questions will be very variable - ranging from flighty to more specific questions.

Of course we have some questions we want to go through, but otherwise, we encourage you to talk freely from the heart, for example, “What you find important”.

Abbreviations used:

- *BCT - Blockchain Technology*
- *CI - Construction Industry*
- *TC - Transaction Cost*

Frame of reference	Reflections	Interview questions	Danish translation
Intro questions, to know the basics. This is a necessary part to show that the interviewees have the knowledge to offer useful insights on the research topic (Rowley, J.,2012).	We ask these questions to provide a basic profile of interviewees.	What kind of work is your company doing? What do you do in the company? What is your experience (practical and theoretical) with blockchain technology?	Hvilken slags arbejde laver din virksomhed? Hvad laver du i virksomheden? Hvad er din erfaring (praktisk og teoretisk) med blockchain teknologien?
Questions about the Byggeriets blockchains project. An article regarding the project on Industriens Fond website (https://www.industriensfond.dk/byggeriets-blockchain) states that the project intends to use blockchain as leverage to increase productivity, digitalization and investment in new technology in construction.	We want to have a closer insight into this project since this was a starting point in selection of the companies for interviews.	We have read that there are 8 cases within this project. Which one is yours and what are you doing? Describe. In which phase is your project? (Procurement, construction…)	Vi har læst der er 8 cases i projektet Byggeriets blockchain. Hvilke(n) er du engageret i? Beskriv? I hvilken fase af byggeriet er de(t) projekt du arbejder med (Udbud, udførelse, osv.)

Questions about BC in the CI. Wust and Gervais (2018) suggests that permissioned blockchain shares similarities with a traditional database, which naturally brings up the question whether a blockchain is better suited than the database.	We want to know about the extent of usage of BCT in the construction sector.	What problems can BC solve in the CI that we couldn't solve with a traditional database? How can BCT benefit future projects by learning from the former ones?	Hvilke problemer can BC løse i byggebranchen som vi ikke kan løse med en traditionel database? Hvordan kan BCT gøre fremtidige projekter bedre ved at lære fra tidligere?
Possibilities in procurement and implications for TC. Perera et al. (2020) claims that BCT is the first concept since the internet and e-procurement that is extending the procurement revolution. Mathews et al. (2017) mentions procurement as the strategic issue where savings through TCs and time could be achieved with internet-based technologies.	We want to know about the possibilities of BCT in the construction procurement process and subsequently on ex-ante and ex-post transaction costs.	How will the ledger benefit the procurement and tendering phase of the construction projects? (ARUP, 2019) report states that BCT will be developed and adopted in procurement between 2040 and 2045 - in all the other areas they predicted earlier adoption. - Do you agree? What are the reasons for that? We're working with TCs and reducing the unnecessary part of TCs - if we look at the pre-contract TCs (searching for contractors, organising tenders, meetings, evaluation of offers, negotiation, drafting a contract) - BCT should cut those costs. Do you agree and/or can you elaborate?	Hvordan vil ledgeren forbedre udbudsfasen af bygge projekter Skal BC og BIM gå hånd hånd, eller er det muligt kun at bruge BC (f.eks. i udbudsfasen) - F.eks. BIM er ikke effektivt i standard lejligheds projekter i udbudsfasen Blockchain and the built environment siger at BCT er udviklet og inkluderet i udbudsfasen mellem 2040 og 2045 - i alle de andre område er inklusionen af det forudsagt tidligere. - Er du enig? hvad er grunden til det? Vi arbejder med TCs og at reducere de unødvendige TCs. - Hvis vi kigger på

		Similar question for post-contract TCs (disputes resolution, mitigations) - how will BCT benefit minimisation of TCs here?	prekontraktuelle TCs (lede efter contractors, organising tenders, meetings, evaluation of offers, negotiation, drafting a contract) - Er du enig i at BCT kan eliminere disse omkostninger ? kan du uddybe? Lignende spørgsmål for post-kontrakt TCs (uenigheder, dagsbøder) Hvordan vil BCT være en fordel for TCs her?
Questions about barriers for the BCT in the CI Being a new technology, BCT faces many challenges. They can be divided in technical, construction business - related and human - related challenges (Wang et al., 2017)	We are interested in the challenges that technology faces as perceived by the experts in the matter.	What do you think are the barriers to implement this technology in the CI? How much of a problem is a mindset of “construction people”? Is it an expensive technology? - because for example BIM is, and CI doesn’t invest much into R&D)	Hvad tænker du er barriererne ved implementeringen af BC i byggebranchen? Hvor stort problem er mindsettet af “bygge folk”? Er det en dyr teknologi? - Fordi f.eks. BIM er dyr, og Byggebranchen investere ikke meget i R&D

APPENDIX

B

Interview Guide for Professionals

Frame of reference	Reflections	Interview questions
Intro questions, to know the basics. This is a necessary part to show that the interviewees have the knowledge to offer useful insights on the research topic (Rowley, J.,2012).	We ask these questions to provide a basic profile of interviewees.	Do you know/have you heard of BCT? Have you ever considered usage of BCT in the construction industry?
ICE,(2018) mentions well-known projects and the number of contracts signed as a relevance to the use of BCT.	We want to know to what extent could BCT support contract management during a construction project.	How many contracts do you sign per project? How many companies would you estimate that are engaged in one project?

Explain BCT shortly if needed. It's a distributed database and each participant in the project has a copy of it. It is transparent and protected from deletion and tampering. Every agreement, every process, every task and every payment has a digital record and signature. In every moment you know who is doing what, what has been done etc.

Frame of reference	Reflections
Description of the use cases. Use cases and examples gathered from the 1st round of interviews.	We want to know the construction professional's view of the current usage of BCT in the construction industry.
Description + question.	
3 use cases: 1. "Design tender". Making the process from an architect's selection of material and requirement to the supplier who is supplying the material more transparent so it's known that the client is getting what was selected in the first place.	

2. “Chain of custody”. Tracking a material that was selected from the factory to the construction site, making sure that it is the right building component and that it is installed in the right place in the building. Craftsmen can scan the product and see all the specifications, architectural drawings, installation guide

3. Logistics of the material. Knowing when the product is arriving at the construction site and knowing where is it stored.

What is your view of those?

Frame of reference	Reflections
About procurement phase and TC. Data gathered from interviews and literature.	We want to know the construction professional’s view of the usage of BCT in the procurement and tendering process.

Description + question.
BCT will enable all the companies involved in the tender process to have the updated version of requirements. There was also talk about having all the references from employees and companies ob blockchain, so PQ round would be much faster and easier for clients. Do you see any other ways in which the BCT would benefit the procurement phase and reduce TCs?
Regarding post-contractual TCs, that are incurred by dispute resolutions, searching for a “guilty” party etc. - it has been said that BCT will reduce those costs. That is because everything that is happening in the project from the beginning to the end has a digital trail. So when the mistake is identified, it’s not a problem to point why and when it happened. What is your view of that?
How much will BCT as you understood it reduce the following costs: Very much 5 - Somewhat 4 - Undecided 3 - Not really 2 - Not at all 1 - cost of verification of companies (contractors, consultants…) - cost of networking - cost of writing contracts - cost of enforcing contracts - shortening transaction execution time - bargaining Do you wish to elaborate on some of these…?

Frame of reference	Reflections
About smart contracts. Data gathered from interviews and literature.	We want to know the construction professional's view of the reduction of TC by using BCT.
Description + question.	
One of the interviewees talked about smart contracts. That is a digital form of a contract that automatically executes the terms of the contract. For example, when a subcontractor installs a building component, they document it and initiate the quality assurance process. Their work can then be quickly checked for quality, and the payment for that subcontractor is automatically released. Even though it will probably take some time and money to set up these systems, what impact will it have?	

Dansk

Frame of reference	Reflections	Interview questions
Intro questions, to know the basics. This is a necessary part to show that the interviewees have the knowledge to offer useful insights on the research topic [Rowley, J. (2012)].	We ask these questions to provide a basic profile of interviewees.	Kender du til BCT? Har du nogensinde tænkt på at bruge BCT i byggebranchen? *Kort beskrivelse af BCT hvis nødvendigt:* Det er en fordelt database og hver aktør i projektet har en kopi af det. Det er transparent og beskyttet fra at blive slettet manipuleret. Hver aftale, hver process og hver betaling har er digitalt gemt og har signatur. I hver bevægelse i projektet ved du hvem der har gjort hvad og hvad der er blevet gjort.
		Hvor mange kontrakter laver I i løbet af et projekt? Hvor mange virksomheder estimerer du der er involverede i ét projekt?

Frame of reference	Reflections
Description of the use cases. Use cases and examples gathered from the 1st round of interviews.	We want to know the construction professional's view of the current usage of BCT in the construction industry.
Description + question.	
3 use cases: 1. "Design tender". Lave en til arkitektens udvælgelse af materialer og krav til leverandøren mere transparente, så det er kendt hvad bygherren får og hvad der er valgt til at starte med. 2. "Chain of custody". Følge et materiale fra idé til nedrivning af bygningen. Herunder specifikationer tegninger drift etc. 3. Logistics of the material. Vide hvornår materialet kommer til byggepladsen og ved hvor på pladsen der er opbevaret. What is your view of those?	

Frame of reference	Reflections
About procurement phase and TC. Data gathered from interviews and literature.	We want to know the construction professional's view of the usage of BCT in procurement and tendering process.
Description + question.	
BCT vil gøre det muligt for alle virksomheder der er involveret i udbudsfasen til at have en opdateret version af kravene. Der er også tale om at have alle referencerne fra ansatte og virksomheder i en blockchain, så PQ runden vil være meget hurtigere. Kan du se andre måder BCT kan hjælpe udbudsfasen, og reducerer TC?	

I henhold til post-contraktuelle TC, der forekomme ved problemløsning og at søge efter den "skyldige" part etc. er det blevet sagt at BCT kan reducere disse omkostninger. Det er fordi alt der sker i projektet vil have en digital tvilling. Så nå der opstår et problem kan man altid finde ud af hvem der er skyld i det.

Hvordan ser du det forekomme?

Hvor meget vil BCT som du har forstået det reducere de følgende omkostninger:

På en skala fra 1=ingenting til 5= rigtig meget.

- of verifikation af virksomheder (contractors, consultants…)
- af networking
- af at skrive kontrakter
- af at håndhæve kontrakter
- begrænse transaktioners udførelsestid
- forhandlinger

Er der nogle du vil uddybe på?

Frame of reference	Reflections
About smart contracts. Data gathered from interviews and literature.	We want to know the construction professional's view of the reduction of TC by using BCT.

Description + question.

Vi har afholdt interviews med nogle af de mennesker der i DK arbejder med BCT, én af dem talte om Smart Contracts. Det er en digital form for kontrakt som automatisk udfører kontrakten. F.eks. hvis en UE installerer en bygningskomponent, dokumenterer de det i en kvalitetskontrol. deres arbejde kan derefter hurtigt kontrolleres for kvaliteten og udbetalingen af penge kan komme med det samme derefter.

Selvom det vil kræve tid og penge at lave sådan en løsning, hvilken effekt vil det give?

APPENDIX

C Transcription of Interview with HD Lab

Interviewee: Niels W. Falk Interviewer: Casper Gøtze

C: What kind of work do you do in your business?

NF: We are a specialized company working with technology for the construction industry. We either close the gaps in the work people do by making the technology services or 3D models or 4D plans or laser scans. Or we make some technology packages that people work with. We work with different things, robots, exoskeletons, laser scans and predictive modeling and blockchains. We primarily work with technology for the construction industry as consultants.

C: What are you doing in the business? Is that everything?

NF: Yes, I am a CEO so I am part of the whole thing and we are 16 employees. I have the primary focus of running the business and then I have my fingers deep in the blockchain, exoskeletons and robots, and our reality capture business. Then it is Sasha who runs everything we have on generative design, 3D models and VR etc. There I do not have my fingers as far down in the code.

C: What is your experience both practical and theoretical with BCT?

NF: Up until a couple of years ago, I had the knowledge I could talk to at a dinner party level. I understood bitcoin and had read articles in Vine and something like that. About 2 years ago, I got into it a little more, and built a blockchain into hyperledger. I took one of the boys computer stripped it, and threw ubuntu on and a fabric. Then I started to boot a blockchain and see if I could put an ifc model in, where each object was a block. Then I started to get some experience with it. After that, I started a project that we got the bloxhub to support, the so-called "blockchains in construction", where we did a lot of interviews and a lot of workshops. Where we subsequently published a whitepaper as I wrote in February 2019, called blockchain in construction. After that, the "industry fund" came up with this call on blockchains, then I wrote an application on the building blockchains, which we then got the money for, which has been running since the summer holidays. So I have hands-on experience, I've coded the blockchain I've read about it, I've written about it. But mainly with the construction industry in mind, I'm not super when it comes to cryptocurrency.

C: We have read that there are 8 cases in the building blockchain, which are you involved in?

NF: I am committed to everyone as I project coordinate it. Specifically, in HD-Lab we run the one that is about IoT and the one about the job log, and then we are at BIM, but I have helped describe everyone, so I can forward and backwards all cases if it is .

C: At what stage of construction is what you are dealing with, is it tendering, execution or?

NF: It's different, some of it is in the design phase. There are 3 of the cases that are linked together in reality, which are about design, execution and facility management for recycling, the case that IBM is running with züblin, which has been taken 3 cases and put together, because that is exactly what was a little funny. Then there's the logistics case, it's such a pre-production. The IoT case is both operation, build and can be used in the design phase, it is the entire construction life cycle. One of the cases is IoT, ie these censors and throwing them into some buildings and then ripping the data out of it and throwing it into a blockchain.

C: What problems can blockchain solve in the construction industry that traditional databases cannot?

NF: We will find that out. We have some hypotheses that ... there is something about the way you collaborate in the construction industry that is not very easy to digitize with traditional databases, because it is very much such a table world you work in. I have written a list of things that are interesting about blockchain. Where blockchain clean database has a greater potential than regular SQL database and we used it a bit when sorting for the cases. What we basically hope for with blockchains is there are some of the use cases we find difficult to solve by digitizing because the construction industry is a network organization and because it is chaotic and autonomous and because there are astronomical amounts of data and because there are many transactions between autonomous parties, all these things are like something that characterizes the construction industry, it can be difficult to digitize it, the way the collaboration is done, the way the design is developed, we believe that blockchain might have some characteristics that do that we can build some solutions that can handle the volumes of data that can handle the decision-making process and the data we have better than conventional solutions.

C: I've heard the podcast you made on Spotify that only about 10% of all data is collected and 2% of it is used.

NF: You could say that some of what we hope is actually the problem in the construction industry, the insight I have right now that we have a lot of data collection where we get some information. We talk in the project, what we call vertical information flows instead of horizontal data flows. When you want to use data, e.g. when you have a building you have taken over, how do you find out where some stump comes from or how it should be used, or how much it cost, such things. There you would like to be able to access some data. The best case is the one with the window in the existing building. So you say, where does it come from? what did it cost? who has made the decision that it should look like this? and can it be used for anything if we tear down the building? The questions are quite reasonable to ask, but you can't answer that because the amount of information you have in the conventional way of doing it is data converted into information, ie. quality assurance reports or photos or drawings that are probably stored digitally, but it is information, the data is locked, it is so destroyed it has been stuck in some very hard structures in some documents, in some calculations in some photos and in some drawings , so we may have it all available digitally. But in reality it is only electronic so we have information not data. Ie The grid structure in reality is too tight. there is too much structure in this for us to access the data. It's the same one can look at the data on the chain of custody and traceability elsewhere, in the food trust and tracer and all the other cases that are on the blockchain that can do it there. What was the problem was sitting on some digital manifestos, contracts, stamp

passports and approvals, etc. So you had this vertical information flow but not a horizontal data flow. But there we try to say that if you now hand over this data instead of handing over the vertical information flow, that you destroy its data or hand it in a fax etc. but then you hand it down in a blockchain instead of , then we may be able to access it instead. That's the big idea and the other big idea about it, is to automate some of these deadly transactions going on out there, where some approve or some pay or some do ... Completely as one has seen in the banking industry, where blockchain and smart contract just goes in and eats approvals and operational work for you can say we can just throw a smart contract on top of the blockchain and then we can automate the approval processes and transactions etc. where it takes 5 banking days to get an invoice approved and paid, it becomes 8 seconds, if you can stack a proof height that can be calculated to be good enough, you will get your money the moment you add the last proof. And this is about creating digitized consensus rules that can go out and make approvals, where the whole network says that if it meets these rules and guidelines then approves looted.

C: It is also something that you can spend on quality assurance on the building, if you say now this building part is finished for this contractor, then you can unlock that they get the money right away.

NF: There are several values in this stack, one is that everyone has to put their data into the same blocks so everyone has access to it. We understand that some of it can be locked with encryption, so you can't see the calculation data of it, but the fact that you hand in your real data, into a common information model instead of sitting and translating your data to some information that you then remove all the secret from and put into a common information base that you can't use for a fuck. It is one part of the common database and we are actually on some valid and ok data. The other part of it is, there are many who spend time and money sitting around waiting for approval or validation, or running around and getting poor quality assurance done, it was something we can automate and get much more out of much earlier. There are two main things to it, and it talks a lot about us getting some higher quality and some more sustainability and cheaper, all the things we want in construction, but it's about higher transparency, better collaboration, better data collection, we has a lot of data and eventually you get digitized the areas that are not digitized just today. This is one of the reasons why one of our cases is the builder's decision-making plan, it is such a field that has been said that you can not power. It is an overly complex process and it is something you have to get some people into. Where I say, let's try and see if by putting the data down in a blockchain if you can absorb all the transactions, changes and different angles that are on this, it can be used to remove some of that complexity because we have reached a technological point where machines are actually better at handling complexity than humans are, and 10 years ago it was the other way around. So being able to diagnose a broken knee or being able to look at a screen in an airport whether it is an airplane or whether it is a meteor, people have had to use it because the machines were not good enough for it, but they are in fact now.

C: How can BCT make future projects better by learning from the past?

NF: Basically, we think we can build some better data models. One of the gripes is when you make a construction case and do what you need to do, as part of your services, you should automatically have some data deposited in some different data layers. Then we just use BC to build these data layers. We do not believe in one monolithic data model for a building, ie. you have some BIM, you have some documents, etc. But you do some data layers that allow you to

query down into a project and say what was really going on here if those data layers are roughly the same, across projects, then you can also query across projects. Some of it is partly about getting some better databases, about which construction works are and what the process has been to propel them, but also that you can go in and do some reports and searches across the projects. In fact, one of the things we look at in the IoT project is if you put sensors in a lot of different buildings and all the sensors end up in a blockchain, then you have a world where you can go out and say. I like to think of this weather and this sunlight and with this humidity outdoors, how it translates into indoor climate in some different buildings. You will be able to go down and look in this blockchain and get some data released from it.

C: So you have some live recordings to start from, instead of all these simulations, maybe you can also do the simulations better because you have access to this live data?

NF: Yes, or just access to the data you need for the simulations, rather than something you guess.

C: Yes, that's how I think it often is now, so you have some standards you drive that are justified by some empiricism.

NF: One of the more perverse and long-term dreams we have is if you have a better digital twin of the projects and you need to build in the future, so you say the resource bank you have is your existing construction. So when Danske Bank says that now we want to build a new head office, we say yes that's fine enough, but when you tear something down, you have to use half of the materials in the tear down for it. But then you have control over what elements we have to build on afterwards. So what windows and what concrete elements and what are we having around us as resources. So all this recycling thinking, you need some better digital twins too. A long way, we believe that being able to document in a better way partly because of automation and partly because of the data structures, but also so that it can be used to make some digital twins you can query better if it is to get some better simulation data or it is to find out where we have some windows or what are some windows we have to build from.

C: It can be difficult to look at the windows as it is when standing by the building, or insulation material for that matter.

NF: There is such a good story. Do you know where the largest copper deposit is on the globe

C: no.

NF: All those guesses like South Africa or Australia or something like that. But, where most copper is, New York. We just can't get it out because it's in the buildings. But if you are going to recycle your copper, then you have to have control over what kind of copper is inside. The data can be collected in many ways, including by taking the resistance in the current you send out into the mains. Then you can calculate how much copper is out there and put in some databases. But there is a lot to try and capture any data that is automatically saved in some commercial process and then able to reuse it, and that is real data and there is plenty of it.

C: How will BCT and the ledger improve the tendering process in construction?

NF:. . . We don't quite know, we have some ideas on how to use BC to build some different tender material. You could imagine that you can take your BIM model and schedule, and all that and put them in some blocks and you sell those blocks from. So, in reality, it's about making some better

information packages, one you have when you have drawings, schedules, and contracts. That you can make a procurement system where you take your project and throw it into a few blocks, just like you do when you do... For example. there are some hotels that are being offered on smart contracts, now we have to see if they become anything at all, as the world looks right now. But there you have some such hotels that instead of having classic stocks you make a bitcoin solution where you take off all the collatorals and cut them up and then you can crowdsource the funding for a hotel so you bought shares in a hotel, but instead of it being a split share, you have bought 1/1000 of the royal suite, then you can get a business model where you, for example. have bought 1 m^2 of the casino floor, then you may be making faster money than if you have 1 m^2 of the royal suite. This is actually something you can't do with the conventional models. There you are with these blockchain models to junk bond hotels, or vacation homes, or anything like that, so you can buy for $ 1 you can buy in and you can buy into functional areas or you can buy into the installations or whatever it should be. These are the same mechanisms you will need to make an offer. Instead, here are all the drawings, here's the whole schedule, you can't tell us what you need to do to make what we call the masonry, then we can go in and take those blocks and realize them and say we will fix it here, and then they can stack a proof high that is high enough, then they get the money with the blockchain solution, instead of having the whole regime we have today. There were actually some who made a system, I do not know if it is an urban legend or whether they got it out and running, but I have seen a presentation that shows a little about how this can change the supply system, which was in Africa, that everyone drives with their mobile app just like Google maps they drive down there, and because they all have phones with accelerometers in, we can see when there is a hole in the road, because everyone drives across the road, their phones bump in the same places, so they tracked it and said they would like to offer that if you took out a contract to remove the hole in the road, the local residents next to the road could fill the hole with gravel as long as the hole was gone when driving over with cars, you got a payment, so if you maintain the road, you claimed it, where you say, I can stand for this 100 meters road, then fill the holes, then you get a $ 1 a week. The problem is that down there costs so little to fill the holes, and there are so many holes that it can't pay for them to dig a hole, to do work for themselves. But it probably won't work in Europe, which we probably would ... so down in Sicily they will probably dig 100 holes in the road, to be paid to fill them up. But it was such a place to make another offer on where to crowdsource, there are some who will solve this block, it can be 1 hole, or 1 km road, etc. But then you go out and take responsibility for it, and as you get this validated proof of the work done, it may be with pictures and time spent or what do I know. But and partly that performance is out there, you get your payment, but that is how you can change, and I know it is a very narrow example, but you can do the same with a school, so you say, now we offer this school, there must be this indoor climate, there must be happy students, etc. Then people can go in and sign up for the different sub-contracts, and split these sub-contracts, right down to the fact that there is one sitting with a block that says I have to put a window in and grout it, and when I can prove it with different evidence, then I get my payment and then it stacks all the way up through the system. In this way you can imagine that you get some different supply systems.

C: It may sound like that, I just have to understand it. If you do this, you still have a client and someone to manage it, how it should look, etc. or invite people in, we have an idea that it should look like this.

NF: So you can offer it in a different way, and the client is not such a national bank, understood

in the way that it is not a domain that is super tightly described, there are as many ways to be a client as there are clients. There must still be some who order the construction, pay for it, and use it afterwards, there must and still will be architects, etc. But it will change how to manage the process and transparency in who is with which parts of the project.

C: Will it also enhance cooperation between the various actors?

NF: Yes, or eliminate the need for it. I don't know, I think it's tight enough to put my head on the block for that. It will at least change the collaboration and it will remove some activities that are currently being used to communicate and translate what is happening. You'll probably need fewer lawyers anyway.

C: It is right down in our hat, or what you say, because we want to lower the transaction costs in construction and write about it. And you could say that lawyers are there to make it safe and right. One could say that lawyers are some who do not add real value to the construction itself, some would think. A lot of money is spent on the process that you will be able to save in that process.

NF: There is clearly such a transparency thing, and it is not easy to make such a blockchain I would say, it was difficult enough for me to put an ifc file in a blockchain and I didn't even try to make a tender or a smart contract on. But we try partly with our BIM project and see if we can not get BIM models put into blockchains as you can see what is designed and substitute. and then we try the job log project and see, you can make these transactions, called these designs translated into reality and then make a smart contract that pays for it. and if you can succeed, then you can do some things that remove all the non-value-adding activities that currently exist in coordinating and managing etc. Because the information is accessible to people. But there will be some other management costs and coordination costs, so it's not possible to remove it all. It will change that process.

C: Should blockchain technology and BIM go "hand in hand" or is it possible to use BCT in the tender phase itself?

NF: Yes yes, BIM is really a terrible technology when you think about it in a data context. BIM is such an 80s technology called information modeling.

C: You'd rather have it called BDM (Building Data Modeling)

NF: We talk about digital twins, so we came from a world where there was something called CAD and then something called 3D models and then something called BIM, then something called virtual design and construction. Now we are moving towards something where you get the whole operation too and status here and now with. So BIM is just a way to make some very enriched 3D models. But BIM technology, there is a huge difference in what you mean when you say BIM not. It is, in fact, a very specific discipline dealing with some very enriched 3D geometry models. Roughly speaking, this means that spreadsheets and blockchains must go hand in hand or can they be separated. Digital geometry information is probably central to this. You can say on the other hand, BIM is also where we have invested most in digitalization in the construction industry, ie collaboration tools such as box and project web and big360 and dalux and all those on one side and BIM on the other. This is where something has been thrown in. So both are going to be included in the data volumes that you have to handle.

C: There is an article called blockchain and the building environment which states that the blockchain technology it was developed and included in the tender phase between 2040 - 2045 where it is predicted to be earlier in other areas of construction. Do you agree with it, and is there a reason for it?

NF: I think it is, if you sit down and look at how things are implemented in the construction industry, it is something that things have to go into the design phase, then the construction phase, then it has to be in the tender phase and then it has to be in the operational phase. If you look at the journey that has been if you look at project web and with BIM etc. then this is how it looks. So I can easily understand that claim that saying this is going to start in the design phase. I have a picture that it may be different with blockchain than with everything else. So I understand well what they say, but I think you have to look at who has the commercial or who is it opportunistic for the commercial who can earn the box on this coming in. So I guess it can come much earlier in the supply phases than that. I think the tendering phase could be the first place to put it.

C: Okay, but traditionally is it the other way?

NF: Yes. In fact, I hope that the operational phase is one of the places where this goes first. But it is murderously difficult to say what order it will be implemented in.

C: Yeah, it's still in its infancy?

NF: Yes. I usually compare it to the internet, when the internet was 10 years old people sat there doing all sorts of crazy things out on the internet, and that's also what we're going to see with distributed ledger technology and blockchain technology, that now comes to be all kinds of people who are going to do all kinds of things that are ridiculous. And all of a sudden there are some who make a twitter or an itunes etc that build a cornerstone, and it is difficult to predict who will just make a solution that will be commercially adopted. If you look at what drives today's technologies, it's not necessarily the best or first ...

C: No, no, you also find out new things by doing all sorts of stupid things. Then you might learn a technology by making something completely ridiculous.

NF: It's about continuing to evolve with its user e.g. Facebook looks noticeably different now than it was when I first started 15 years ago, or how long ago it is now.

C: It is also a huge change from that you could not have it on your mobile device to the closest to where you are most often on it.

NF: I think that blockchain, if we speak 2040 there, I think that blockchain is dead as a concept understood in the sense that it becomes a technology inside the stomach of a lot of technologies and it becomes just another database. In my opinion, BCT today is a very specific way to create a database with some very specific rules and some very specific advantages and then there are some pre-packaged, ie some maggi cubes on the web that you can use to do that with . So in reality, these are some maggi cubes if you have to make chicken stock or if you have to make vegetable soup, then this works very well. If you are going to try making tomato soup then maggi dice are not the way forward, it is a bit the world we are in. As I say on the podcast, WWW does not know what my kids mean but it becomes an embedded technology that solves some of these problems and give us some of these benefits without even thinking about it. You can say why does this application work, it does it because over a corner sits one BC and solves it there.

C: As I understand it, the underlying thing is that the application gets some UI that shows things easily just like you have all sorts of others eg. mobile pay, etc. there is also something else behind.

NF: Yes exactly. It is a little time to show which solutions you build with BC which are good.

C: We work on transaction costs and on reducing unnecessary ones, so if you look at pre-contractual TC, which is to look for contractors, organize tenders, meetings, evaluations, bids and make contracts, etc. how to reduce TC with BCT ?

NF: So it takes someone to build the systems as a basic assumption. But if we take it, then there is a potential if anyone goes out and makes these systems that if you imagine we make these systems that you talk about earlier, where you offer things as blocks and which can be shared further etc. then you have seen such a reputation of record system so you can see who you paid to get things done earlier and how well they succeeded in it etc. So this whole search process with what do we think about them and everything else, you have something better than Trustpilot because it's fact-based that you can say if you offer this kind of thing, then you can see historically this carpenter can do it, at the price, the quality, and there's no hassle with it, etc. So all that record reputation management and all this with the skills are the ones at all. There you can go out and automate a whole lot of the processes. So you can go out and take the whole pre-qualification round and all that writing "jibrish". And then you can go out and take your performance and say you have entered your performance data, we can see already when we offer it who is what has done something like this before how much can they of that kind and how much success have they had it before and you can see if they have the capacity for it etc. So there are a lot of things that are handheld processes where you call and ask and provide and discuss and need 14 days to get a answers that you have to read through and have to do every possible turn me into ass reviews that can be automated so that one's value network can become. You can reach a situation so when you design it you can sit and watch, this is only 5 people in DK can make, and they are bad at it, potentially. Because you get those data layers built up with performance data that way. If you go down and take it like a really tight job log where we make a blockchain where we need some to put windows in, then we do that window insertion thing. it collects because of smart contrast we deposit data called, we know what evidence is, we know who has done these things, right down to the operator level, so we can see well it may be that Jensen carpentry says can do this, but the carpenter who is actually the one who put this window in is no longer working, and those who work there now, are some idiots who can't figure out putting a nail in a dog shit without destroy both. There is a lot of transparency about actors and performance that can be captured in those chains that can be used to remove part of transaction costs but can also be used to build reputation systems.

C: It's smart, it can be hard to see today, if you see a company name that it's not the same artisan coming again.

NF: That is the system that you have today, and it is absolutely crazy to provide references, they are still sitting, if we go to the contractors 'website or the architects' website then all their references are lying and you have to show by reference that you have not done it before. When I was in MT Højgaard there you also stood and said, well we have built the Little Belt Bridge and the Great Belt Bridge, etc. But there were not any of them who helped build it, who work there more. So there are such old-fashioned reputation systems that the experience stays in

the companies and all that is not right. Nowadays, when people tour every 5 years instead of staying there for 25 years that knowledge stays there. One can, for example. take a company like Pihl they profiled on being the new Pihl which can be the same as the old Pihl and twenty shark wherever it goes, but there are 5 people going again and a logo.

C: In relation to the post contractual transaction costs, ie disagreements disputes and you have to do things for each other etc. Do you think there is something in BC that can do better?

NF: Yeah, it's there. The whole thing with evidence gathering, which is in the blockchain, and the one with that you can go back and see who has, if you imagine the whole design process, that all the changes are in the blockchain that does not have to put all design but all the changes, every time someone pills in a model, it throws it in a block, every time someone shoots a drawing, then you stamp it in, every time something is handed in, every time it being downloaded, all those things. All the transactions that take place on the design including the builder's decisions. Then you can always go back and see who has changed something, who was what said and done, etc. Who is the reason why things look the way they look. It's going to be a huge grail in that world, too, just on the logistics side, the digital logistics solution that we're trying to build a pub on. Also just who has received, where has it been in the square what is being ordered, just get the ones that chain up, it is so pretty important too. There are dents in the post contractual, mostly that you have a digital twin in saying what happened in the process.

C: Yes, because you can forget it as a person, and you can also get a different view of what has happened than what actually happened. So you don't always remember everything that happens. But if you can also track, let's say there is a contractor who has taken a screenshot of an old model or a not completely updated model to build on, you can then warn him that there have been changes, based on what he now because you can see it?

NF: yes, if you build the system. The question is all the time. . . . I understand where you want to go, but my point is that the technology doesn't fix a mess, so you don't make more money using BIM or blockchains, but BCT allows you to accelerate building some systems where you can secure it . So the existence of blockchain is not going to change the number of conflicts we have in the construction industry, but there are some who bother to build and use some systems that can continuously document these things and where you can say that it may not be a monolithic system but data spread out across a lot of different places, but we know it's trapped somewhere. Then we have seen a digital copy of reality, which is honest and transparent that we can access. So we can inquire as to what was going on, what was happening, and we cannot today. So just making a chain of custody on goods or documents is a huge advantage. There is also something called certificate safe I can't quite remember what it is called, but they make a blockchain solution for universities, which when you publish your diploma and diplomas, it smokes through them and then it gets thrown on a block chain. If you send your resume to someone, you can put links on, they can see all your diplomas and when you click in you can see if it is validated and it is a diploma from DTU etc. Then everyone is your educational papers verified. You can do the same on construction products. Now they make it on louis vuitton bags then you can go in and find it on Aura and find your louis vuitton bag and see if it is a real louis vuitton bag and you can even see if the pieces are made of endangered animals or if they are sourced sensibly so that the type of system when built up sensibly counts automatically, then it will give us a lot of answers to the questions we otherwise sit and spend time finding out plus that our performance of the buildings at 1 - and 5 years of review we should be able to see just such a thing with some blockchains with

some sensors in how the building performs and what kind of data we get out of them. Instead of having to go out and do a review and pull out windows and put the thermometer up in the seagull on the building to find out how it is. But it says a lot about that with 1, that someone is bothering to build those systems and there is a commercial anchor on it, so there is someone who can make money making the systems, and 2 that you can get automated the data collection then when you sit and model, then you sit down and write down the blockchains automatically when you write meeting reports, then you write down the blockchains when you are in dalux and do a window simulation so all the right data is thrown into the right blockchains just like when universities make a diploma they write the right things down the blockchains with their automatic systems.

C: What do you think there are barriers to implementing blockchains in the construction industry?

NF: There are many. One is that you think it is the blockchain so there is that with BC to solve it, that already turns on 4 warning lights of people who think it is something like this with Russian hackers and bitcoins and that style. It is a lot to stop talking about BC and then talk about the systems and applications to build. I also believe that there is a very low understanding of the importance of working with data in the construction industry. They are still debating whether to work digital information, there is a competence barrier. There is a cultural barrier to blockchain as a concept, because you think it is something other than it is, I think there is a competence barrier when it comes to working with data in general, there is not really anyone interested if they did it, then there were several who had thrown themselves over it, but you think it is more fun to work with people and drawings and concrete than it is to sit and work with data. Over at the bank they have understood it with banknotes and bank books, it is not interesting anymore, but working with data is interesting, so there I think we are 25 years behind in the construction industry. So I think this, with transparency and automation, is not something you trust in the construction industry. The thing is that you can look across the systems and automate the processes. I do not know how many times I have heard, what if the computer is wrong?

C: It doesn't.

NF: Firstly, computers are very rarely calculated incorrectly, and when they do they are right then it has consequences, but I can promise you that all your employees they calculate incorrectly, even the best employee at Ramboll calculates incorrectly. They calculate really badly and it takes a long time, so it is, If the computer calculates incorrectly vs. when your employee is wrong, but you just don't have the confidence in the computers and the automation.

C: But that's maybe because it's hard to give responsibility to one if it's the computers that made a mistake?

NF: After all, it's totally mind-boggling, these same people don't mind letting google maps guide them or have a robotic mower. It is only because these are the processes they themselves sit and peel into, you cannot leave them to a robot.

C: Doesn't it require everyone in the entire process to contribute to the data collection?

NF: Well, I strongly believe that somebody has to go out and build some systems that have a different business model and we have to automate the data collection. I think that by saying it is data exchange that creates value on the one hand, how do you achieve it, you do that by

building some systems that automatically collect the data when people do what they need and then remove it from work from people because now you no longer have to do it because it does the system for you, so you remove some work from them, but you in turn get a lot more and better data and look at the other end. But we have to make some systems and some application that remove some tasks and solve some problems.

C: is it an expensive technology?

NF: No it's not, it's a surprisingly cheap technology, just like the internet and WWW it's a cheap technology, you can easily spend a lot of money on it but basically it's just like the internet. It's crazy so cheap it is to create a web page and write something on it that can compete with, you can compete with youtube for 6000 kr. And so it is with BC. pt. it's free to use hyperledger, which is a lot, the whole github is filled with free stuff and stuff. Then there are some of those in between solutions that cost something. For example, if you using Asher Microsoft's database world, you can use their tools for free if you pay to use their virtual machines, so we're talking about soft, which isn't easy either, but if you know how to work with blockchain and know how to code them and so on and a little c-sharp or whatever else you can, it's a cheap technology.

APPENDIX

D Transcription of Interview with Züblin

Interviewee: Mayes Ali, Zublin

Interviewers: Casper & Ana

16 April 2020

C: What kind of work does your company do?

M: I'm in Zublin. It's a contractor. I think we are about 70 000 employees in Europe and it's owned by Strabag. So we're pretty huge. Not that big in Denmark, but it's nice to have colleagues that know everything because you have all the fields.

C: And what do you do in the company?

M: My role is more about the digitalisation, so I implement digital tools and optimase all the manual processes so we can be more digitised. So, that' basically it, if I should say it in a very short way. And then, I was invited to participate in the BC project, where we got, I think it's a 7 mil kroners from Dansk Industri, yeah, Industriens Fond. And then Zublin is one of the participants. So we are part of 1 case out of 6, I think.

C: And what is your experience, both practical and theoretical, with BCT?

M: Right now there is no practical, there is only theoretical, and that's what we have to deliver in the end. We have to deliver a report and tell them, tell Dansk Industri, if we could use BC in the building industry or not. So that's basically it. And it's really nice to just test it and just try everything. But we are holding a workshop next week, hopefully, it's not 100% yet, but there we'll be testing our app and get some feedback from different roles.

C: I think you sent mail about it when we first contacted you.

M: But right now there is only 4 participants so, so... we might do it in the near future. So... I don't know yet.

C: And that would be in your office or?

M: No, online. We're actually gonna do it online. We'll do it in Miro if you know that? It's actually a free tool. It's to do online workshops. It's pretty cool.

C: Yeah, that's nice. We've read that there are 8 cases within this project you talked about. Which one is you doing?

M: It's the one called „Build Trust" which is about tracking. So that's the one.

C: Can you describe it further?

M: Yes, so, what we really want to do is that we want to track part of a building. In our case, we tried a test, for a window, and say, okay, what happens to this window, when we design it and when we have to install it basically. And can we like...I'm not so familiar with the words in English. Det er nemmere på dansk, fordi jeg har sagt det så mange gange før. But how can we pull out all the data that we have in all the different softwares in each process. Where this information about the window actually lives. So, that's what we really want. And then in the end there will be so much transparency in the process, from the design to the execution, and how will this benefit all the roles in the project. And right now we don't really know who will it help the most. And that's what we want to use the workshop for. Yeah, to ask the different roles like: what are you getting out of this? Because right now if you build a building, and you stand after 20 years, or just 5 years, and you point a window or sth like that. It's basically impossible for you to get out all the information about this window. Because just in our part of the project, which is the execution, we use around 17 different digital tools. And you have a little part of information about this window in all these different tools. I mean, you will never get information you need in the end. So we just do it because there are some rules and laws that tell you, you have to document different things, but in the end you don't really know what is happening.

C: So you log the data but no one really knows where it is? And how to gather it?

M: Exactly. It's basically impossible. So when we stand after 50 years and we want to reuse this window, we can't because we don't know what happened to it or anything. So right now we just destroy our buildings and if there is something we can use, we reuse it but because we don't know anything about our buildings. So that's what we want to do in the end. Like that's the goal. So we can go in and say: okay, we know everything about everything in here. So we begin to think about how we can reuse all the things, and all the parts of the building.

C: This tracking thing, which part is it, in procurement or execution or design phase or what is it? Or is it found in every part of that?

M: What do you mean about the tracking thing?

C: This case you're...?

M: Yeah, ok. So, I think I know what you mean. So, what we have developed is an app. And within this app you can go in and sign in as a role that you are in the project. And then you can choose what part of the building do we want to track. And this decision has to be made from the beginning. So it would be a designer, or an architect, so he or she will go in and say: okay, for this project we want to track the window. Okay fine. Then he put in the descriptions, the drawings, whatever he has regarding the window. And then the next one in the phase, he will get this information...I think I want to show you, it's much easier to describe, just a second. Okay, so, there you go. Do you see my screen? So what I tried to say before is that we have some information about the window here, here, here and here. And here we have different phases. And there's a lot more but this is just really rough. So we use different platforms in each phase and this is and this is where I am where we use 17 different, just to point out the issue. And what we want to do with the BC, this is a representation of our BC, and our idea is to basically to pull out the information regarding the window here, and the same for the other phases. So in the end, every participant can have access to all the information. But yeah, this is just for the window. Or

for just one part of the building. And our goal is to do it for all the different parts of the building. If that makes sense...

C: Yeah, of course it does.

M: But we have to start someplace. So now is just a window.

C: It's also fairly new.

M: So what we did within the project, it is that we went in and say, okay we have to make it more detail to understand what kind of information do we actually need. And who is the participant, and we did like a design thinking with IBM, because they have to develop the app. And they were like shocked, because they were like: we never tried to work with processes that has so many different roles. It's the first time. So this just shows it will be even harder for us because so many people have to collaborate. So what we did was that, to say, okay, we will start from here actually, and all the things and the ideas before design, we'll not focus on that right now. So our solution will start from design where we go in and say: here we point out what kind of window should it be, and you know all the dimensions, colors and bla bla bla. So everything is described in here. And then we have to find out what kind of information will be available in the projektering phase, I don't know in English...

A: Yeah it's okay.

C: I can't remember.

M: Yeah we have to point that out for every single phase – to say what is the delivery of the data of each phase. So that's what we try to do. So here we said, okay, so we had data information from each phase, and that's what we need for blockchain. Because that's the only information or data we want on our BC. We don't need the rest of the information. Because it was really hard for us to say, okay, what is the difference between our BC and just an archive, because we could just do an archive. But we want to , if you stand from 50 years in the future, you can point to the window and know exactly the things that you need to know. Regarding the reuse, or the I don't know how to..the economic cycle of it. If it makes sense...

C: It makes sense. We talked with Niels fro HD Lab. We also talked about that you can get the information of who made the decisions and so on with this technology.

M: And that's another aspect of it. And of course you will get so many beneficial within this because it's on BC and it has the characteristics regarding the things that Niels told you as well. And that will be just a bonus in there. But that's not the way that we want to use it in our case. Our focus is only to be so clever about building parts that we know actually how to reuse it in the future. So we're not really going to use the BC while we're designing and executing. If it makes sense...

C: So it's underlying technology like a spreadsheet or something else. App that you use to put the information into the BC.

M: And that's how it is right now. And when it gets clever enough, we can...our goal is to make it automatic. So it just pulls out the information it needs. So no one has to work with it.

C: So you have some machine learning.

M: But in the beginning of course everyone has to do it manually.

C: To teach the machine learning things. It actually leads to our next question. What problems can BCT solve in the CI that we can't solve with traditional databases?

M: That's a very good question. But I will go back and say if we think about what's the characteristic of BC is, a normal database is not, how do say it in English, it's just a centralised database, when here it's distributed. So we don't have to think about how we put it there, but the database it will...I don't know how to say it.

C: Then try in danish

M: Altså, den vil opføre sig som vi arbejder i stedet for den anden vej. I en normal database vil du typisk strukturere den på den måde du planlægger noget. Det er det vi gør med alt, vi går ind og planlægger ting, vi vil gerne have at det skal være sådan her, og vi skal proppe ting ind sådan her og sådan her. Det er svært for folk at følge, at vi har så mange mangler og så mange fejl. Så med blockchain der bygger den databasen efter hvordan du arbejder, så den afspejler den virkelighed der er.

C: Så i stedet for at man sidder og planlægger, da det godt kan være svært for to forskellige personer og se forskellen, eller se hvad der egentlig sker.

M: Ja, selvfølgelig skal der være nogle regler og retningslinjer, men det der med at have et centraliseret database hvor du propper ting ind og trækker dem ud igen, så her lever de bare live hos alle. Det tror jeg er den største forkel, og så er der også alt det her med kryptering osv. Som også er meget stærkt. Men det er den her gennemsigtighed, men det er også det der kommer til at være en udfordring, fordi folk ikke er vant til det. Og der mange der ikke har lyst til at det skal være så gennemsigtigt. Det er en anden diskussion som vi ikke har åbnet helt op for endnu, og det tør vi ikke.

C: Nej, lad os lige finde ud af hvad det kan, for vi åbner op for det.

C: Next question. How can BCT benefit future projects by learning from the former ones?

M: That's a good question. I mean, we got a lot of, we've learned a lot from the Tradeland and from the Walmart, we looked at what they did and we're working with IBM, so we ask them a lot. Like, how did they solve their things? And they said...Yeah, so we got some inspiration from them, but again, it's not the same set up. Because we have so many different participants, and we have so many different roles in the building industry. Which they don't have. They have just one power system and they can just tell everyone: use our platforms, and everyone will do it. So that's a big difference there. But I mean for the technical part and for the stuff like that we got a lot of inspiration from there. So I think in the future project, I hope there will be some future projects, if we find out that we can use it in the building industry. I think it's all about adaption and it really depends on how people will look at it, and how people work with it. And the most important thing from our side for this to be a success is that we have to make it so easy and so invisible, I would say, that people can't really feel that it's there.

C: Can you imagine that you have now like 17 different apps to use if that's what people like, that all writes down in the BC and you can access the information people put in, so people use apps they are comfortable with.

M: Yeah, so you mean you can access all the information and data via the BC?

C: Yeah. Even though they use different apps for it. Or different Uis for it.

M: But then you have to ask yourself who is that going to benefit? Because the project manager, he will just use the apps that he's used to. I don't think that he doesn't need to use the BC.

C: Let's say you put the BC underneath the apps he's used to use. So he will gather data automatically by the things he used to do. But other people can access it in the BC manner.

M: Ok, I understand what you mean. That's the idea. But again, the project manager is not interested in the client's needs to see everything he does. So it's hard to manage that somehow. I don't think we will get away from that. But it could be really...because we have a lot of issues when sth go wrong, we don't really know who did it. Or who's responsible. So that could be a really really strong tool in there. To track all the different things.

C: So to have a performance measure for every part of the construction. How will the BCT benefit the procurement and tendering phase of the construction projects? Or how will the tracking benefit it?

M: Again, it's basically the same as before. It's just a different process, but the interesting thing about the tendering process is that you have so many different roles in there. Because you have to send something out to the distributor and so on. And you can keep track of that. We don't really have that right now. So that could be a positive thing. But I don't know if you were searching for something more specific.

C: Yes. There's a report of ARUP 2019 that states that BCT will be developed and adopted in procurement between 2040 and 2045 - in all the other areas they predicted earlier adoption. Do you agree with that? And what could be a reason for that?

M: Sorry, can I get it again?

C: So this report states that BCT will be developed and adopted in procurement between 2040 and 2045 - in all the other areas they predicted earlier adoption. Do you agree with that?

M: Maybe. I don't really know actually. What would you mean that the big difference is between this process and the other processes is? I mean why should it do that? I don't know. Maybe I don't really get it.

C: We're working with TCs and reducing the unnecessary part of TCs - if we look at the pre-contract TCs (searching for contractors, organising tenders, meetings, evaluation of offers, negotiation, drafting a contract) – could BCT cut some of those costs?

M: Definitely.

C: In what way?

M: I mean if you think about how many different transactions there is between so many different people. I don't remember the exact number but I think there was about, it was more than 500 transactions we had on our last project. It was actually when we built blocks, and that was only on contracts. So I can't imagine how many more different transactions there is but...that's like a really big thing. And I know that we spent a lot of money and time in doing that.

C: In evaluating all the offers?

M: Yeah, exactly. That's one of it. But also handling all the transactions. Because we have so many subcontractors that we have to deal with. So if we could keep a track on that, it would make a big difference for us.

C: That's cool. Similar question, so now we're talking about post-contract TCs (disputes resolution, mitigations) - how will BCT benefit in reducing the TC?

M: I don't really know actually, I haven't really thought about it. I think that's more Niels project. Because Niels is looking at transactions. We haven't really discussed that in our case.

C: That's good. Let's take another question. What do you think are the barriers to implement this technology in the CI?

M: The barriers would eb that we have to find out technical how to pull all this information out of the different platforms. So there's like a very big technical part of it. And then we also need to understand what makes, what's the value in it. Does it make any value if we just pull everything out, I don't think so. So we need to make process or the workflow of how to make it efficient. And how we can benefit from it. And then we need to...I think the next big question is like who is going to own the BC? And who's going to develop it? So, but we haven't really discussed that yet. Everyone is afraid to talk about it. But that would be the next big thing. But if you develop something, if you define it, and you say we want to put this and develop it and it will cost you a lot of money, but because BC is so open and transparent, everyone would benefit from it. So why should he pay for it? So that's the next big question. And I think it's going to raise a lot of red flags.

C: But if you have the main key to the BC. You also have a lot of power and see what happens in a lot of projects. But that's all the encryption you can make.

M: Exactly. Because right now when we buy a platform, we will become the owners, which means if anything goes wrong, it's only us who can pull all the data. But when we talk about BC, everyone has the same rights. I don't know what will happen or that's a game changer for us. I don't know.

C: If it come to that, it will definitely be a game changer because the people don't own data the same way we see it now.

M: And then a question who is going to pay for that.

C: So I see all the work from computers will be distributed

M: And then..I remember Niels talking about, you can put up some rules and say okay, for instance, a worker, he will only put 4 drawings up there. So he should pay less than the contractor who is putting 80% of all the information up there. Or something like that. But I don't know. But maybe you could do a BC on that actually, and make some transactions...of I don't know.

C: to make a distribution key. Of the cost. How much of a problem is a mindset of "construction people"?

M: My everyday struggle basically. When you work with digitalisation in the CI, you feel it about everyday. I think it will be a big issue. Because there is a lot of other cool tools that make sense

right here and right now and that people not really want to use because they are not used to. So I think that BC will be...maybe in 10 years you will start to see some people using it actually. I don't know, maybe I'm very pessimistic. But I worked in digitalisation in construction for 3 years now, and it has been a struggle. And it's getting much better now, because people are starting to see...okay, this is the future, we need to step up. But still...

C: Maybe you could also sell it on when using BC it's easier to reuse things in 50 years. So if you use it now, it could benefit us. M: What I always tell them is try to imagine that you can actually pull all the information and all the knowledge out of your building because you don't do that right now. You could be so clever.. And then you can put it up with other BCs from other projects and then see the difference.

C: But is it also easier with BC to compare processes and decisions that are made in the process?

M: Of course you have to add some other tools on it. But yes, I would say so. If you track a window on 10 different buildings. I would say that you can see the difference from the processes and how it went.

C: And you could make some performance measure, and if it's done in most efficient way

M: And then you can...you could also make a trustpilot of all the different roles there and say which company did it best, and are they doing sth in other way that we're not used to. I don't know, but there's a lot of things to get out of it.

C: And we're back to the question we want to share things. Like Niels also talked about that job log case he had where you can track people in companies, instead only the company. Because some companies have references of projects they did, but maybe the people who did those projects, are not in the company anymore. So they don't have the competences they say they have. Actually we don't have any more questions.

APPENDIX

E Transcription of Interview with IBM

Interviewee: Lars Spindler, IBM Interviewers: Casper & Ana 17 April 2020

C: What kind of work is your company doing regarding BC?

L: IBM is a technology company so we develop software, we develop different BC solution, leveraging software. So hyperledger etc. But we also develop specific solutions for clients. So we have a software arm and we have a consulting arm where we also develop solutions, customize solutions to client. But if you look at IBM on a global scale, we also have industry platform, BC solutions like IBM Foodtrusts, like Windwire, Tradelens with Maersk, etc.

C: And what do you do in the company?

L: My role is. . . I'm leading up our digital strategy? practice group. So one of the areas in the consultant business.

C: Ok. And what is your experience with BCT?

L: I have been working with BCT and clients in the last 2 years. So actually, I've been working with clients helping them understand how BC can add value to their business processes, and developing solutions. So both leveraging IBM's industry solutions like Foodtrust, but also developing solutions here, specifically for Danish customers.

C: Yes. We've read that there's that project with Industriens Fond where there are 8 cases in this project. Which one are you participating in and could you describe them?

L: Yeah. So IBM's involved in 3 use cases. The 1st one is around, we call it "design tender", so it's basically the design process, so what's happening with the architect, engineers in terms of designing the building and all the requirements coming out of the architectural drawings in relation to the building materials that should be used. So that process and trying to connect the requirements and the products that are actually selected in the tender process. So the reason for this is, I think in reality the industry is experiencing problems where building components are specified by architects and engineering companies. But when it comes into the tender process, like a big contractor will then say, okay we will now develop a proposal for this building. Then they will go to their subcontractor, they will go to craftsman, they will go to subsuppliers etc they will go to producers of the materials and that's quite a big process if you have a big building. So it takes a long time, and there are many many building components involved. So then they get all these products in, based on the requirements and sometimes they end up selecting a product that does not fit a requirement. There have been some instances where some sort of a board used on the outer layer of a building. . .

C: Yeah that was MgO boards.

L: Yes exactly. So that is one of the examples. So we're looking at how BC can actually help us

make that process more transparent and also avoid situations where a product selected does not live up to the requirements. So that's one use case in the very first part of the building project. And the next use case is called "Chain of custody" so that's basically how can we follow and make sure that the product that is specified and selected in the design tender process is also the product that is actually delivered on the construction site and the product that is mounted in the building in the right location. So there is also room for error in terms of the suppliers of the material, they can ship the wrong product, maybe they don't pay notice to that on the construction site because they are busy, they are also on the deadlines and then they end up maybe a window that wasn't the right window. And nobody finds out, right? So what they talk about in that process is also, I think, there are the architectural drawings that are developed upfront, but when the building is done, you update the architectural drawings because changes have happened during the building process. So this is where the better understanding of what's actually happening and where are these products sitting. So what we're looking at in the process is as part of the design process, the architectural company and the engineering companies, when they do the requirements on the different building components, and the materials to be used, there is also a specification on where each of these building components should be in the building. So you think about the floor plan, and you think about a north wall, south wall, etc. and which floor. So using BC and digitalizing all this process, we can then take these documents which are part of the design tender process, because the material suppliers will also provide information about how to install the products so then we can allow this digital information to be accessible to the craftsman on the worksite. So they can see, okay, the drawing, as an example, if they scan a product barcode on the construction site, they are ready to mount a window, then they can see, okay, yes this is actually the right product for this construction because we know that this barcode, this product, is part of this building, which they have signed into, is part of a digital solution. They can also see the architectural drawings of where the product should be installed, from the architect. So this is the problem today – the craftsmen don't have necessarily the architectural drawings. So they are using some other drawings that a construction company can come up with. Because each party is developing their own documentation, there's room for error, right? So we want to take the architectural drawings and make them available to the person on the construction site. So here they can also see the installation guide, because each of the material suppliers, as part of them supplying or coming in on a tender with product, they will also have "this is how you install our product in the right way". They will also have documentation about the maintenance of that product. So that is valuable later on. So, for example, window, how often should you paint the window, how do you look after the window, right? Oiling the hangers etc right? So it's basically looking at that whole process to making sure that we can also document where each product have been installed in the building, and with that, we have basically, a digital twin, of the whole building. We can see a digital copy what's installed where, we can see all the specifications, and you can also see then, which is the last, the third use case, the whole recycle part on a product. So if you want to tear down that building 30, 40, 50 years later, you can see, okay, what are the windows made of, okay, which parts can we recycle, take them back to the producer of the windows or take them back to the recycling station. That makes sense?

A & C: Yes.

C: I had a question in the start about the tendering process but I'll come back to that later. So next question. What problems can BC solve in the CI that we couldn't solve with a traditional database?

L: Good question. I think there's something here, I mean, they are using databases today. So one problem is that they don't have a joint database. So what we're hearing is early on in a project, for example, one party could actually say, here's a box folder, let's use it for exchanging information, right? So they put up all the information, right? About the requirements, about the products coming in from the tender, etc etc. But then, let's take an example again, if then later on a product is selected and it turns out not to meet the requirements, how do you figure out who made the error? If everything is sitting in the joint box folder. And this is where BC comes in. Because we make a digital stamp on a BC every time someone makes a change and someone makes a decision. So then you have a trail, a digital trail, who did what. And you can identify where did the error come from. So that's one example, right? Another thing and this is not BC specific, but, what we're also hearing is that sometimes one of the companies putting up this box folder, making it available, they will then take it down, remove all the information, when their part of the process is done. Because we've done our work, we'll take down the information. And then the architect might say, well, we have a lot of requirements up there that could be relevant for people on the construction site, or how do we now communicate with the other parties. This is also where having a joint solution for the entire value chain is relevant. It's not BC specific, but you could say the components of BC where you have a distributed ledger, a distributed database across different parties allows everybody to chip in with information and use information based on the same data model so to speak. Right? The same point about the accuracy of the data comes also when you go into the chain of custody, if something is installed in the wrong manner you can go back and see what happened. Was it because the craftsman didn't actually scanned the product he received on the construction site and just mounted the product, or was it because it was shipped the wrong product by the manufacturer and etc. Right? So you have a very specific paper trail that allows you to understand where did what go wrong. I mean, what also happens is, this is where it becomes interesting maybe for the developer, so the company financing the building, right? If you have the digitalisation of these 3 use cases, so you basically have from start until finish, you have an overview of what's happening. Also, date by date. You can see how's my construction progressing on all the different components. Which means you can also see, which of our construction, subconstruction parties are very efficient and living up to the timeline, deadlines, which are not so efficient. So you get transparency about how to drive a more efficient construction project. We're also looking at, it's one of the other use cases that's an about logistics and about barcodes, where we're looking at how do you optimise the delivery of the products into the construction site. I've heard some numbers, from some of the participants saying that up to 20% of the time spent on a construction site is actually spent on finding and moving products, materials that you're installing. It's quite a lot time, right? If you look. . .

C: Inefficient.

L: So if you can make that process more efficient, with just in time deliverables, etc. and understand also where are the materials on the construction site. If you sometimes have a huge construction site. We're also looking at having different barcodes with different types of information. Not just about the product, but where the product should be delivered on the construction site. So, there's also obviously a business case around how to make a construction process more efficient, time-wise. Being able to save. You can also say there are also some benefits here about the craftsmen, the subcontractors if they take a picture and if they document using a solution, what they've installed today, and in this week for example, then they have documentation of the work they've done which means you can quickly initiate the QA process,

so the main contractor will then do the quality check on what they've done, if it's alright, then you could actually release the payment. So all the companies could get their money before... as it is today, right? They have to wait all the time.

C: It's 2 3 months. It can go up to.. And that's a lot to have. How can BCT benefit future projects by learning from the former ones?

L: What are you thinking when you say project in relation to..?

C: Construction projects.

L: I think there's a lot of... a different use cases. But if you look towards the food industry for example, where I'm also working with companies in food and food safety. It's also about traceability, right? It's understanding where's the product coming from, where has it been, how long time, this day and the other. So, that also ties in with the chain of custody. What is the origin of the product we're installing and understanding where it's coming from and why it was changed etc. So there's sth about traceability, that sort of goes across different industries. There's something about making processes more efficient if you look at the Tradelens with Maersk and the shipping. It's also digitalising a process where there's a lot of different documents you're standardizing, digitalizing, having the same digital model. So that allows the whole value chain to work together in a more efficient way and this is partly also what we're doing here. We're kind of developing a joint data model which is based around building components. So the building components. For example, building components would be floors, ceiling, walls, windows, doors, toilets etc right? We're creating a data model, where, when you're doing a tender you need to provide specifications under each building component. So, when we're in the design, so the architect and the engineering companies will have to put up the requirements for the walls, under the wall building component. Which then means, when you're sending out the tender for the product and materials, they will then get assigned the building component that they should actually deliver a price on, right? And then they supply the products specs and the products pricing for each of these components. So then we have a way of searching and making this data searchable as well. And we have a joint kind of data model.

C: okay. As of right now, my understanding is, that when they send out when the building owner send out the tender, the contracting companies, are making changes to the drawings to make it more efficient, or make it to their work style and so on. So they will make new requirements, I suppose that that's just the change in the BC they make when they send the tender. Then you know, of course, there's up to 5 different companies who do that. Okay. I don't know if that was...

L: And sometimes, the architectural company will specify a requirement for building component on one level. On L100 for example. And then they will ask a contracting company, to say – you have to specify down to L400. So it's the way of working that sometimes you can't specify in detail because you don't have the skills, you need a contractor to do that and that's also where: okay, who owns this, who's responsible for actually finishing the requirements in terms of also selecting the material etc right? So there's where BC comes in so well, right?

C: That's great. I haven't thought of LOD. That's pretty cool. Then the architect says we have L100 then specify who must do the next level, so it's buildable. How will the BCT benefit the procurement and tendering phase of the construction projects?

L: The procurement. . . well, hopefully, it will make sure that all the companies involved in the tender process, so all the companies asked to provide the quote, they will have the most update, or the latest version of the requirements, right? So for them, it should hopefully be more efficient because there will not be changes or if there will be changes they will be notified also using the BCT. Because we can see, now there's actually change to this requirement, because it's being specified by the contractor. Okay, when they upload a new thing, okay we can notify the 3 companies that are working on a quote, who've been invited to provide a quote on that specific component, right? That should be more efficient for them because they know that they're working on the latest version of the requirements.

C: And it's updated all the time. Let's take the next question. There's a report that states that BCT will be developed and adopted in procurement between 2040 and 2045 - in all the other areas they predicted earlier adoption. Do you agree and what are the reasons for that?

L: I don't have that overview, I would say. I'm not able to answer that.

C: I don't know if I said it, but we're working with TC and reducing the unnecessary part of them - if we look at the pre-contract TCs (searching for contractors, organising tenders, meetings, evaluation of offers, negotiation, drafting a contract) – can BCT reduce those cost?

L: I think that's what we just talked about. Because, it makes that tender process more efficient because you know all the time which is the latest requirement that we're working on, but we're also looking here since we're building a joint database, data model, and maybe this is not so much BC, this is more a solution, how do we make an attractive solution for the different stakeholders and participants to actually use, so we're looking at also some functionality, where the contractor, he will get access to all the building components and all the requirements. But then you can go in and say, okay, now I want to take these 5 building components and start the tender process with these 3 companies, the next 5 I want to send to someone else, right? Because it's different skills right? Doing a bathroom is a different skill, doing roof. . . so it's also a platform that will allow the contractor to drive this process very smoothly, and go in and select, okay, I have these building components, send the tender process out, and invite these companies, these are the building components, invite these. And then you get all the information gathered in one place, any changes to the requirements, all the parties are notified. And contractor can then gather all the pricing, and look through, and say: okay these are the prices I want to take forward, and put in my final offer for the developer, right? So it's should also make that process more efficient.

C: So dissect a tender material to send out to tender out, to subcontractors. Similar question for post-contract TCs (disputes resolution, mitigations) - how will BCT benefit that?

L: Because of the 3 use cases where we're basically starting from the design of the building to when the building is finished, we have a digital trail of everything that's happening from the architectural drawings to requirements, to the product selected, products delivered, products mounted, to the QA.

C: Facility management.

L: So anybody say okay this is your fault or it wasn't our fault. You have a digital trail, you can see what happened and where and who's actually responsible. So that's where BC really plays in, right?

C: Yeah, that makes sense. What do you think are the barriers to implement this technology in the CI?

L: I think what we're hearing is that the CI is not very digitalized today, so obviously it's going to be a jump for them to start using new technology, but I mean, it could also be potential. If you're coming from a low level, and you introduce a new solution that delivers a lot of value, it could also really accelerate the adoption of the solution. We're also looking very much into the whole user experience so we're developing a solution for the different types of participants. So for the architects, engineering companies, so the advisors, developer. We're looking from the developer point of view, as well. Looking from the contractor, the subcontractor, the craftsmen. So there will be different UI solutions for these different participants, and we're looking at how we make this as easy to work and understand as possible. And a part of our process, we're working with IBM design thinking, which is IBM's user-centric process for developing solutions, where we make sure that we focus on understanding the user and the user's needs more than focusing on starting with technology. So this allows us to develop sth which hopefully will drive value to the user from day 1. But we're also interviewing, we're just about to start a process where we're going to do user research, bringing in users, and get them involved with prototypes and wireframes we developed and getting feedback from them. Having said that, we're working in a project group where we already have a representative from a contractor, we have a representative from an architectural company, so they are part of our development process. So they the insights on how things are today.

C: They can give information quite easily. How much of a problem is a mindset of "construction people"? I don't know how much you've worked with... here I think more like craftsmen.

L: I think... you said about the adoption, right? I think part of the adoption question is also who are you developing a solution for? The big players, the medium size players or the small players, right? There are many small players. And some other things we're talking about here is if you look at small companies, 1,2,3,4,5 or maybe 25 people – investing in software to run their business can be quite costly, compared to how big they are and the revenue. So if you could develop an industry standard, a new platform, which, where they don't have to buy the software, but maybe it's pay per use or we don't know what the cost model will look like yet. You could open up a solution where a lot more players would be able to use, there's a benefit from this, without having to pay the same kind of cost, as they're doing today. Each buys their own small solution to help optimise certain processes.

C: That makes sense. And the last question, is this an expensive technology?

L: I wouldn't say it's expensive. We're working very much from, as I mention, from the design thinking perspective, and part of this is also to develop a vision of where we want to go on the long term, but very quick to define, what we call, a minimum viable product. So what's the minimum product we can develop in maybe a couple of months time, 3 -4 months time, which could actually deliver some value. And then get some feedback from customers and users, and then develop the next functionalities in phase 2,3,4 and 5. So I wouldn't say it's costly technology, no.

C: That's cool. That was our questions. Run through very quickly. But we kept it into the timeframe.

APPENDIX

F Transcription of Interview with Vilhelm Lauritzen

Interviewee: Jakob Guldbrandsen

Interviewer: Casper Gøtze

CG: Which kind of work are your company doing?

JG: I work at an architect company, so we do architectural stuff

CG: What do you do in the company

JG: I work on projects mainly on the ICT and BIM side on the project, but basically anything on the project. Then i work on the internal development of digital solutions mainly focused around BIM models and the work with BIM models and the work with data and so on,

CG: What are your experience with BC technology?

JG: If we we rewind 8 months it would be nothing then after getting into byggeriets blockchain project i don't think i know that much but talking to others that know nothing gives me sort a sense of i know a little bit more than a bit. It is mainly on the theoretical side or talking about blockchain as a concept and then know starting to dive into knowing about blockchain more specifically or technological.

CG: In byggeriets blockchain as we talked about, we read that there are 8 cases which of those are you working with.

JG: Im working on the one called "Build trust" runned by Züblin and IBM which is about tracking the building components in a project, from idea to product. today i think in the design process i think we looked at a window and there were around 60 dokuments where that window was mentioned, but we could not see any direct link for that window where we could see each of those documents. So it could be that i model that window in a BIM model, and in a work description we would write look at that window in revit and manually write it into a work specification and there the contractor would write it in a mail or something like that. So there was no, that setup was very prone to people misreading or making an error or misunderstanding. So that's what this project would like to handle, so who has decided what.

CG: And it could be like the old story from H.C. Andersen with one feather goes to 7 hens.

JG: exactly and actually if you know the MGO plate case, that's actually us at vilhelm lauritzen who came to be the responsible party for that, and the reason for that is, we for our work specification, of cause i have been told from the guy who participated in the trials, so of cause he thought that it wasn't our fault but the reason why we were found guilty because we have specified

the right product in our work specification, but the contractor have suggested another MgO plate. We have said, as long as it meets the same requirements in as in the work specification then it's fine, but it didn't. But what we did wrong was that it was a new product, so what we should have told the client is that this is a new product, we dont know it so therefore you are taking a chance. With a setup like build trust, everytime a product should change specification you would be able to remind everyone this is a new product, then you need to inform the client, so it is streamlined information about building components.

CG: Another question about that, we know when they put those MgO plates on the building, no one knew exactly how it would work in the danish weather conditions, they were used in China for instance where it is fine, but in Denmark there is different weather conditions. Could you through BCT get the information on how the different building materials or components perform in constructions. Like this we tried here and put that into blockchain so when you say we want to use a specific type of window how do that perform, do you have the data distributed to all.

JG: You would have the possibility to do so no doubt about that, that be taking advantage of the distributed ledger like taking our experience and the put it up, but you will have to handle extremely large amount of data before you got to that. It sounds like a use case, but it's not something we are following at build trust.

CG: Ok. but it is maybe possible

JG: Yes it is maybe possible

CG: As i heard the build trust project, there is in designing, tendering, execution and FM right?

JG: Yeah so basically it should be something that follows the project of the building from idea to demolition and reuse, you would also have the possibility, like today if you tear something down, you don't know what condition the windows for instance have, you don't how that have been maintained through its life, so what you would be able to do with build trust, you have the possibility of having like, eg. if you take your car to the carshop you have the book within the car where you can put a stamp on, now it has been serviced, the oil have been changed and so on. Here you can get the same thing by adding the information to a specific window. so you can say, i want to buy these windows for whatever reason and i can see here that they have been painted and they have been maintained, they should be in good shape, so the buyer has a better chance of putting a value to the building component.

I am also involved in the IoT audit, have you talked to Niels (Niels w. Falk)

CG: Yes

JG: Okay, the you know about the IoT audit . . . Im also involved in a project called BIM partner which is a way to. . . We would like to investigate if its possible or how it's possible to combine BIM models with a blockchain. And we are the responsible party for that one. So we are basically going to take a blockchain and i think its an ifc model it is going to be and put them together and see what happens, to see what kind of input can we feed the blockchain with and what kind of output could we take from it. We have some ideas of what we can use it for then we can see how it sticks.

C: What problems can you solve with blockchain technology that we couldn't solve with traditional

databases?

JG: I taught at the beginning what can... i could see the immediate use of blockchains in monetary issue like i own this now you own that so on.... I couldn't really see what could the building industry benefit from the blockchain, but reading more and more about it i couldn't help but think that blockchains and the building industry was like a match made in heaven, because the thin blockchain does really good or distributed ledger technology is handle transactions of informations in a large organisation where trust is not established or where there is possibly not needed to be trust.

CG: So to understand it, you don't need to build a trust between actors or the parties in the organisation.

JG: Yeah exactly, so if i'm working on a project as an architect i have my key performance indicators or my, like the value for me at the project is not necessary shared with the engineers or clients or contractor and the same thing goes for all the other parties, so the contractor says dear architect we understand you and we will work to get everything you have drawn together or move that on to the building site. I do not necessarily trust them i know that is a very direct for of trust but the organization within a building project is very like they have a different setup... We have different value drivers. The thing that blockchain does is exactly that so if you for instance setup a smart contract or a gatekeeper, you have to hand over this data, for instance if you take a BIM model which needs to be LoD level XX then you hand over a model, if you have an application that can read the LoD detail based on some quantitative parameters and can hand over that data to the blockchain then the model is either accepted or not accepted. There is nothing in between, like yeah but no. If it's not accepted then it's not accepted. That is a thing you can setup, that you cannot with a traditional database.

CG: Because we worked a lot in the tendering phase, and this project is also based upon that, would that say if you make the tender material as an architect you send out LoD of level 1 and then you ask the contractors who bid on the project, to design to LoD 4. Then the system will only accept the bit if it met the requirements, and is it then easier to review the offers and manage which one to choose.

JG: It is only as easy as you make it yourself the smart contract, or the criteria you set up is still you who set it up. But yeah, if you are able to do it in a quantitative way like then you would be able to do it much easier but as it is with tenders, there is a lot of qualitative measures that needs to take place. For instance the information you share like a contractor. We boil it down or we made a post it wall with what happens in a building project and what happens in the different phases and where did the different person or actors in a building project where were they concerned and what we could see is if you take the phases the ending and the beginning of phases it was much like a wall or a hedge where you take your material for instance as an architect I would take my drawings and my specifications and so on and the i will throw it over the wall. Then the contractor on the other side would say, I need answers for this and this and this, and that was his main concern that have I missed something i have missed out on if i have misunderstood it etc. So if we in some way could make that wall transparent or if we could make that transaction more transparent, then it would be much more easy for people to understand the project.

CG: So to have, its because the contractor thinks there is hidden information in this material you throw over the wall and it's hard to get the information or how should i understand it?

JG: I think it's just lik if you have worked let's take a big project if you have worked for 2 or 3 years and you have intensiv may 100 people have worked full time and then you send some drawing, maybe 1000 pdfs and the you expect the contractor to understand the entire project you have used years on building, in a couple of months. And to sum it up or to put more in top of that, you also expect him to understand it the way you have presented it, in a way he may not have seen it before, so it could be drawing, or ways of setting things up that he hasn't been used to. Does it make sense?

CG: Yeah, it must be difficult.

JG: Yeah extremely and all the contractor wants is just to understand the project so he can build it the way the client wants it. I know there are lots of people that wants to put like the contractor is a bad guy he just want to make money, the architects are the one with the soft pencil the engineers etc. I think all in all people just want a good project and i think using the concepts within blockchain like the shared platform it would be able for people to do what they like to, the good part about that is that you don't have to change the way that people work we just have to change where they put their work. Does that make sense?

CG: Yeah it does, where they put it, and how they share it, so it is more transparent and hopefully easier to grasp.

JG: Exactly of course there is a long way.

CG: How can blockchain technology benefit future project, by learning from former ones?

JG: I think that the way we build up a lot of data, an incredibly large amount of data at each project, but most of the time it is changing, but what i see is that most of the time there is probably something used by the contractor but every data dies with the handover of the building. I know there is something that is saved but it is not like we hand over data that can be read in machine learning or anything like that. And we have the possibility with using BC, to use something like machine learning to based on the data we pick up in a standardize ordered way.

CG: That would be good, so you say right now most data dies with the handover? So you have to build the deep plate again

JG: If you would take like, I would like to know the amount of extra bills in the building process, so how many extra bills are there? based on m^2 then you wouldn't be able to take 50 projects and then within a day or two just get all that data out you want. You would have to work a week or so with each project in order to get that, and then you have to ... But if you have the data in a standardized ordered way, you would be able to get your data from one place. I heard a guy, he said "it's not like BC invents the 6th sense but it gives him the possibility of not getting ... i think he was economics guy he did a lot of graph with the stock market ... and he had to pull data from 30 databases, and with blockchain he was able to combine it to just one, so he would only have to get his data from one place.

CG: How will BCT or the ledger benefit the procurement phase of the construction projects?

JG: I would say again transparency and also knowing as the person who is bidding, knowing the conditions that he is being evaluated on and knowing the right thing, so he has access to the data.

CG: There is a report that states that BCT is implemented in procurement between 2040 - 2045 in all the other areas it is stated that it would be implemented before, do you agree or what do you think the reason is for this.

JG: So you 2040 it would be implemented in the procurement, i can not see why, i dont know, standing as a outsider, or standing outside, not knowing what blockchain is or not knowing what it can do, or how long it takes to develop stuff, its not like there is 1000 different use cases active using BCT i would say the main use cases you would be able to count them on one hand like use in big companies, so i think before we see 100 use cases using BC and really taking advantage of the distributed ledger technology it would be hard to guess how soon people would pick it up at other places so if it is 2040, it could be, if it shows to be valuable, then it is a free market and people would say we need that. I think if we say 2040, it might as well be 2100 or anything.

CG: Yeah of course it is just a prediction. When we talked with Niels he talked alot about that people need to make these use cases to make the system, to use BCT on everything, stupid stuff and so on like the internet started.

JG: If you take a look there is a report from deloitte insight from 2019. It is a report based on a survey they did and when you read it everything is very positive or there are a lot of people there is very positive about. You have to take it with a grain of salt, because in 2018-2019 BC was the talk of the town because of the price of a Bitcoin just exploded. If you read this the it looks like everybody wants blockchain now because . . . At that time the use cases on blockchain were low like 1 or 2, so what was it they wanted to do, i don't know. There was a lot of concepts but. . . Until you are beginning to see projects that use it in active way it would be hard to guess would it be next year or in two years. But as soon they start coming, it is like with the iphone, nobody knew they wanted an iphone until they saw it. This is hard to talk about, i know Niels have talked about this (internet WWW) . . . So it is hard to promote BC, not that i am, but to say this is cool because so and so, because it sounds very unsexy. To answer your question whether it would be in 20 or 5 years. I just see indicators in the technology that makes me think that it is going to happen sooner.

CG: Like mentioned we are working with transaction costs and with reducing the unnecessary part of the transaction costs, if you look at the pre contract TC, how do you think BC can cut those costs?

JG: Can you elaborate on what Pre contract is.

CG: It like searching for contractors, organising tenders, meetings, evaluation of offers, negotiation, drafting a contract

JG: It is a bit arbitrary or a bit indirect but i think if the contractor knows the project better or if the contractor understands what kind of system he is supposed to work in, i think there could be a benefit, if it is directly visible in the amount of money paid i don't know but i definitely think that it would give a better performing building.

CG: Niels talked about using smart contracts on this to saving money on lawyers to make the contracts because when you meet the requirements put in the BC, it would automatically accept, instead of someone who needs to write a lot on it and so on. As of right now i don't know exactly how that process is, because i haven't tried it.

JG: I don't know if i have tried it or i totally understand it. But in a project i have work on a couple of years, det nye hospital nordsjælland in Hillerød and the amount of contracts, the amount of pages is extreme, there is so many requirements. We have contracts with the client we have contracts with ourselves because we have made a company together with a swiss architect and we have then hired ourselves, so there many contracts. Right now it is extremely difficult to handle all of those requirements and knowing are we on the right track, do we have what we need etc. so by using a technology like blockchain i definitely think that you would be able to, or you would have the tools to make the contracts where it would be more direct or more apparent if you meet the requirements or not. Because in smart contracts you can make as difficult as we do today, but on the other hand you also have the ability to much more streamlined and it could be measurable.

CG: Would it also solve some disputes between parties when these contracts are getting streamlined? So everyone knows better what is agreed on.

JG: I don't know if it could solve the disputes but i think it could avoid a lot of those conflicts we have today.

CG: It would be the same for me if we solve them or avoid them, even better if we avoid them.

JG: When we on large projects whenever we have to use our time on solving issues or figuring out who has said what, and what agreement was made and who was supposed to do what. We are directly 1 - 1,5 away from adding value, we would not be able to develop the project, when we are digging up who said what and when. So if we can avoid that then we can add value to the project.

CG: A similar question for the post contract TC how will BCT benefit in reducing those costs.

JG: If i understand the question correct it would benefit from everyone being on the same page from the beginning. So again the way is see it if you better understand the project you are working on and you better understand what kind of situation or what kind of agreement you have, then it would be much easier for people to understand. It's a lot about streamlining data and information and be able to see the history, why are we doing this to begin with

CG: What do you see are the barriers to implement BCT in the construction industry.

JG: I think that there is a low digitalisation in the construction industry right now, i believe that niels told you that we are electric and not digital yet. I think getting everybody along, and managing. It doesn't have to be everybody who plays along but in order to get it to work, there have to be a lot of people participating. To get a critical mass.

CG: So you say like, it doesn't have to be every carpenter who have to play along, who works on the site, but maybe their managers and the construction managers on site should play along?

JG: Yeah and you also need to have, where most data is being produced today, of course i know that in the operation of a building there is tons of data being produced, but today a lot of the data we can actually use in many cases are produced in the design phase. So if we can get the consultant and the contractor to play along, then i would see it as being more easy as if not.

CG: How much of a problem do you think the mindset of construction people are?

JG: There is a lot of different people in the construction industry. There is a lot of people who embrace it and i think that what i begin to see. I could say in the last year i have seen a lot of people who previously was very stubborn who is all of a sudden starting to say it is very important to have a BIM model in a meeting. Like the possibilities to look around in a BIM model, and some of the most conservative people i know have started to say that.

CG: Yeah, and it only took around 20 years.

JG: YEah exactly. So i would say that it is very hard to answer the question like a summing up the whole industri as one person. If you should sum it up into one person, the construction industry is the guy who need results before he embrace something

CG: So he needs to see the things work before doing anything.

JG: Exactly, and then he need some nutcases like us to do it.

CG: Last semester we talked with a lot of contractors, who said that before the technologic solution will be implemented the need to see results from it.

JG: Im working on a project with a client that is super nice, and a contractor who is also very forward thinking, and there were this stamford sci fi summer school, i'm not sure if you have heard about it? And then DI(Dansk Industri) before this virus stuff happened, handed out tickets, if you had something you wanted to pitch, where the client had been a central role in the development in the digital development on a project they would like to pay the whole trip, and i just asked the contractor, shouldn't we apply and he said i don't know i think it is a good idea, but i have to ask my bosses first, and their response they would much rather show what they had done than what they were going to do, the strange thing is that they were actuallly doing it on a huge project. and working in a much smarter way than anyone has done before, but simply because they are from Jutland and you don't brag about something you are going to do. You can brag about something you have done. I was like okay then we don't apply.

CG: Is the BCT an expensive technology?

JG: I would say that BCT is very scalable you can use a very simple use case and the you can make it very complex like for instance the Bitcoin industry is not very complex or is not very hard to set up, it took one guy i think, but then it took a lot of people to contribute. So i think it depends on the use case. It's like what niels said compare it against the internet where you can use barely any money to make a webpage that is very simple or you can make it very complex. It depends on what you want to use it for.

APPENDIX

G Transcription of Interview with DI

Interviewee: Søren Cajus
Interviewer: Casper Gøtze

CG: Nice workshop that was yesterday.

SC: Yes, both and, I think it was a Miro that you could get input in an easier way.

CG: Yeah I think so too. Then they wrote something, but the points that came in were not discussed.

SC: No it didn't, but it was also difficult to get an overview, it was difficult for the participant and it was difficult for the facilitator, and it was not the right tool to brainstorm with.

CG: I was happy because I had not attended if it was personal.

SC: No... It allowed more people to join.

CG: You've got the questions. First question, what is your experience in BCT?

SC: I do not have any personal experience as also shown in our workshop yesterday, so I am the coordinating actor in relation to the specific pioneer projects we have in the overall BC project, so I am not included in the workshop of the various actors. I visit them sometimes when they sit in their workshop. But I am not an active participant and I do not have an active role in the specific projects. They refer me in return and I press them on my stomach to hear if they reach the things they need to achieve and things go as they should.

CG: Then I will skip the question of what you do in the 8 cases, because you do not.

SC: It is a coordinating and a managerial role for them and not a technical development role and the various cases are described in our application, but we also have some slides if you are interested in hearing how and what it goes for each and every how far it is to her.

CG: What problems can BC solve in the construction industry that cannot be solved with a traditional database.

SC: That's a good question because that's exactly why the overall project is set in the world, it's to find out if we can solve something with BC that we can't solve today. The problems we have today are really double work and that data / information is lost across the value chain. i.e. When someone finishes a task and throws information over to the next one to work on the next, data is lost. This is what we will try with some different sub-projects to ensure that data can live on, so that you get some traceability that you avoid duplication, ie. you get better efficiency. You also get a better quality because you don't have to re-enter a lot of data and reinvent the deep dish. In the end, we may be using fewer resources, both man hours but also physical resources

materials, and that way there is some sustainability in that as well. So it's productivity, quality, traceability and sustainability.

CG: Now I have talked to both Jakob and Behrad who talk that information is just thrown on in the construction industry. We have also had a few interviews with some of those who work in Aalborg as developers, and they can sometimes see if you have this traceability that you are going to change some responsibilities in the value chain, now I talk most the tender phase and the initial phase. Please leave a comment for this.

SC: No, now I don't really know what it's all about. But you have a general challenge in construction, that you first design a building, then you have to offer it and then you have to build the construction. And the rule of thumb is that what you build is rarely what has been designed, and there can be many good reasons for it, but there can also be many bad reasons for it. It is very difficult today to find out why there is a difference between what is being built and what is being designed. It is a big problem and you do not know why things were different, is it the contractor who found that the architect designed was wrong or was it because he did not understand it or something completely 3. When you hand in a project to an operator and it has not been documented so much that it has been built, you have a design and you have the construction delivered and when the two things are different, then it is a little difficult for the operator to find out how exactly do i have to run this building because the building i have to work in is not the same one that has been designed and it presents a lot of challenges. That's one of the things we're trying to get here. When we talk about designed house it is also a simplification, because it is designed many times, iterations happen all the time. Sometimes we can't quite figure out what's the latest version and what's the right version, and why the versions change. It is very difficult to browse the pdf files today and find out what is the current one and why it is different than before.

CG: I also talk to a developer who says you need to make a revision log of changes, but then the discussion might be what are changes. Where via BC you post the changes automatically, you do not have to have that discussion.

SC: It's no different than any word document we know today, which is also versioned. That is why there are many types of solutions that we look at in the BC project, they are often found today, but they exist within certain points in the value chain, the whole hops about this is that we try to make some digital super glue in quotation marks. , which makes sure to tie together all the solutions we know today, so it's a digital infrastructure. Where IT providers can pick down from BC and integrate into their own solutions into BC and thus ensure that they get data from the other players in the value chain and where it is difficult to get data from today.

CG: It can also be difficult for those who submit the data to register compared to those who need them, because they have different starting points.

SC: Most of the IT systems that are established and that are super cool are there to solve some problems for some different players and that is they are target group in a particular player circle and solve some problems. The problem is that a certain player circle must have some data from some other players elsewhere in the value chain and they have fun enough some other IT systems that optimize their way of working, but many of the IT systems have difficulty integrating and I know there are open APIs on some of them, but it is still a hassle to share data across these value chains and that's probably where the primary benefit may be with BC, is that you

have some databases like are safe and validated and just have the history that lets everyone know when some data is coming from there, we know the rules of the game for them and we know how they are. and then the various IT systems can get the data they get from BC integrated into the IT systems they offer their customers. A lot of it is some kind of infrastructure. This is how it will probably be for many BC that the value in BC is infrastructure. Sometimes you never see yourself as a customer, or the solutions are not a standalone solution linked to a BC, but it can be a solution that can be anything else but where you integrate the data from BC and there can be other solutions where it is based solely on BC and the projects we run are a mishmash of solutions we see almost one by one with BC and other times we just see BC as pure infrastructure that other solutions can pick in.

CG: It's smart, it's also a technology that works below the surface.

SC: Well, no matter what, the user who needs to find data shouldn't understand what BC is and that kind of thing. It's the same as buying a car today, you don't have to know how the engine works.

CG: What can BCT help future projects learn from in the past?

SC: I think it's a little difficult question because I don't think there is one-to-one learning where we say we have to do a project tomorrow and because we have BC, we have some systematic learning so we do it better than the construction we did last year. I think more of the benefit lies in the project we start tomorrow, where we have the opportunity to get data from architects, data from the contractor and data from the developer all the places where we have some data challenges today, not all places because we try to knock down some different places, but the places we turn down, it will be easier and complete the construction tomorrow, because you can optimize logistics and because you can have a searchability or history on what materials are where . You can find out how the decision-making process has been and where we have the BIM models and how it has evolved that we are trying to crack down on, but it is not really learning we are trying to crack down on as we did last year, it is more about breaking down some data barriers that we have today, which make it easier for you to make better decisions and you have an easier time finding data and documenting what you do.

CG: Now you're talking about not working so much with the tender phase, how can that be.

SC: I don't know if we have a problem with the tender phase, as it is today. If there are data problems in the tender phase, either it is because we have a blind spot on it, but I also have a hard time seeing what it really is for some data challenges you have with the tender phase as we know it today.

CG: yes, in fact it is also a picture I get of it. The project we are working on is that you can improve the bidding phase because you have this schism that 5 there is PQ that offers and they spend some money to work on it and to make an offer and based on it is There is a winner if we talk about contracting. That way there are 4 who lose that job and that is how it works today. If you can do it in a smarter way, or can you do it to save some money, this is what we are trying to investigate.

SC: All the honor and respect for looking in that direction and there are many ways to make tenders. But this is because as a loser, they have lost their efforts and therefore there is a lot of

value being lost because a lot is spending a lot of energy on and submitting an offer and then it will not turn into anything and all that energy is lost. It just has nothing to do with BC and data sharing.

CG: No, and I know, well, that's just our angle on it is can you use BC to improve that process.

SC: I don't see it for me, and it can also be because I'm not very inventive and the point of the tender is that you want to have a competition in such one there are winners and losers and I don't see that it could be different whether you associate with a BC or not.

CG: We are working on lowering the unnecessary TC, if we look at the pre-contractual TC what can BCT help on there?

SC: I am also a little uncertain about this because I am uncertain about it is project related to the tender forms and TC. I am not sure whether there is administrative hassle in connection with tendering, whether the relevant data can be obtained in relation to bidding or what it may be. So I don't think there is so much to come by, but it may also be because I don't know enough about it. We are more so that once you have found a contractor, it is the link between the tender material and the design and the link to what is being built. There we have a focus, but not for the supply itself.

CG: That's fine too, and you can say within the economy around TC you also talk that if you have a high transparency in it and high confidence it will automatically lower TC. These are two of the things that BCT does.

SC: Confidence is important. There is a conflict culture in construction and that conflict culture is a huge problem and it lowers productivity and it increases ... there is a lot of hassle attached to a conflict culture and therefore there are some different movements in the industry on how to reduce that conflict culture, one is that you see a consolidation in the industry where you try to cover several different parts of the value chain, it can engineers buy architects because if it is inhouse as you see at Ramboll then the architects and engineers do not show up and quarrel because they is under the same roof, it may also be that contractors are beginning to expand their value chain, thereby reducing TC.

CG: Clearly. After all, a project has been made in KBH called Trust project. SC: Yes, I know that well. There is also another way to do it. It's that the builder chooses the contractor he knows and trusts and skips all the other links and says dear friend we have this project together and we had one yesterday and it worked fine now we have one today and it works fine too and if you behave well tomorrow, then I'll come up with a new project. In this way you cut the offers and all the conflicting interests you have with many actors in a project.

CG: Exactly, but unfortunately it is only possible in private organizations.

SC: Yes, but after all it is also the largest part of the market. What you can say about BC and Trust if you take it overall, there are some indirect effects but basically if you are better at sharing data and you get the same view of what is up and down in a case then it can contribute that one gets synchronized one's view of reality and many conflicts are due to one having different realities, but just that one has the same reality helps reduce the number of possible conflict points, so overall, the way around that you get a uniform and better data can contribute to fewer conflicts. Because there is less to argue about.

CG: It also answers my next question about post contractual TC. Because removing points of conflict.

SC: Yes in a broad sense.

CG: Of course, we do not know 100% that this is what is happening yet, but that is the goal of the project. or one of the goals.

SC: Yes it is a derived effect that if we get a consistent way of sharing data and using data, then we expect fewer conflicts to come because we get a synchronized view of reality. And then we also expect you to work smarter because reducing duplication reduces errors in work, etc. But the derived effect of that is that we expect fewer conflicts.

CG: It was also based on what Lars (Spindler) showed on the app that was developed yesterday, in that the artisans themselves can take data from the system around having to send invoices instead of having to enter it themselves. If it is consistent with what you get, what the contractor gets and the subcontractor and have to send on, then there are fewer opportunities for conflict.

SC: After all, it's a derivative effect of BC. Data sharing and BC have a good cousin called standardization. That's basically what it's all about, but if you have to get something out of sharing data then you have to format data and structure it in a way that fits into the systems. Funny enough, you have to standardize the way you exchange data, because then you don't have to re-enter or reformat data to fit it into your own system because the one you got data from has another system. So standardization and BC and data sharing are something that goes hand in hand.

CG: What do you think are the barriers to implementing technology in the construction industry.

SC: It's a little difficult, firstly, it may be that BC is a bad solution or it doesn't have to be a bad solution, but there may be better solutions to solve the problems we are dealing with. Of course it is a barrier, but it is a good barrier because then it is not because you do not get the solution, but then you get the solution in a better way. It may also be that BC is the best solution, but it still does not matter and there I can see 2 barriers, one is governance, it is basically a distributed database where everyone is part of a database, but who has to pay for that and that kind of thing. So governance can be a challenge, who is it, what we are talking about is data infrastructure across the value chain, but who is going to make it, is it the contractor, is it the developer, where does the solution come from and if it is a commercial player, what is the payment model, who should pay for this, which everyone benefits from indirectly but is not tailored to exactly one specific customer, so governance and business model can become a challenge. The other thing, we are sitting and messing with some of the specific projects. We have a lot of data we can throw over the fence to the next, and will be able to hang on the clothes line (synonym for BC) But we can also see that this data is formatted differently and therefore does not fit the next in the value chain and therefore one has to process the data manually. So lack of standards is also a challenge.

CG: So it requires a set of rules for what the standards are.

SC: Yes, it does take some time to try to make some standards above and some standards below. But at least there are some barriers there may be. So having what we call the good profit solutions ie the IT systems we know today, they are super cool in each their area, then it may be that someone says it is so bad that we have to key in a bit and piste in our systems to make it fit.

So the thing is that you may not have this burning platform or you just got used to having 1 hour of typing work each week. The win accrues to everyone, but it also means that everyone gets a small benefit from this, it also means that it can be difficult to find the ones that pull the load, to get it implemented and get it out as a market solution.

APPENDIX

H Transcription of Interview with S. Enggaard

Interviewee: Karsten Westergaard Interviewer: Casper Gøtze

CG: First question, Do you know about BCT?

KW: It's not something I've really come across yet.

CG: So basically, if you have a house and you sell it to me, then you have a block called you own a house, and a block called I own a house, and that's what you link together. You can always track it, so you can track it back in time and see who did what and who owned what. The difference from doing it normally, and then doing it here, is that you have such a church book where it says, but it's available to everyone, it's called a distributed ledger so it's distributed to many, and it's always up to date, that's what it can. And that's one of the technologies that you try to bring into this. From what I have briefly stated, you think it can have an effect on the construction industry.

KW: So what you're saying is that one can find back what one has done on a given property at another time, it's such a log.

CG: Yes, you can call it a log, but you can use it in other respects as well. With a log of what happens where you can say from the idea phase in a building, you can say for each component that they should for example. start in LoD 1 and then you can track it all the way to the demolition of a building so you can see what is happening, how has been selected and done in the various stages. So, for example, with a window can track how it is treated and have an idea of its value at the demolition.The problem right now is that the buildings that were built 50 years ago do not know what has happened, so you do not know what to use it for.

KW: The first thing I hear is that you also need to register things along the way in the system, and it probably also requires you to dial in, so you keep it updated.CG: This should then end up in an app on mobile or tablet, where quality control along the way puts data into the blockchain. Plus the one in the log says that change here has been made. So you can't change anything without anyone seeing that something has been done.

KW: That's the first step, then, is development. There I can see that it makes sense to collect all the data, but the day the building is completed and the developer gets the keys from the contractor, then the property is run and goes into the next phase. And this is the one I can see that is a challenge, because then it goes into such a company as ours, which does things ad hoc. We do what is necessary for the property, we are not the ones who write a lot of things into logs, things get done, but getting it registered as such is not something we are good at. It generally believes that things are done, but to register things, so far we are not at all.

CG: Someone also thinks it's a waste of time.

KW: There are many who think it's a waste of time. But I think that is just as much because you are not instructed to enter. It is a matter of habit, but also the question of what to use it gives it some value for one to register.

CG: Those in DK who are working on it right now, they have been granted funding from the Industry Foundation of 100 million, but it was back in the summer of 2019, so it's really new. How many contracts do you make during a project?

KW: It's different from project to project, but with us we make quite a few appointments. Primarily what we have is turnkey and main contractors, so many times we go out and make a contract with an architect and an engineer who does a sketch project for us, and that goes a long way in the process before hiring a contractor. Then we say that the contractor takes over the contracts with architects and engineers as we have made by contract. So the responsibility lies somewhere. We make turnkey contracts, and then we make contracts with architects and engineers. Sometimes we run main or large contracts, we can do this for large commercial buildings, where we run a clean engineering contract. You have to do what gives people, we own an element factory, so we buy concrete elements for ourselves and then the contractor sets it up. But it is economics and DB, if there is technology for 35 million, then he has to earn 10-15% so sometimes we do not feel that we get value for that money, then we would rather make the deal ourselves. So we know there is more coordination work, but you can do a lot for 4-6 million.

CG: How many companies are involved in a project in doing? To Subcontractor Level

KW: Between 10-15, if you look for it, there can be terribly many. With subcontractor around 10-20

CG: Brief description of BCT It is a distributed database and every player in the project has a copy of it. It is transparent and protected from being deleted and manipulated. Every appointment, process and payment has been digitally saved and has a signature. In every movement of the project, you know who has done what and what has been done. Then I will talk a little about the use cases there are, first "Design tender". Make a solution for the architect's selection of materials and requirements for the supplier more transparent, so that it is known what the developer gets and what is chosen to start with. What do you think about it, can it help in lowering transaction costs?

KW: What is the transaction cost now?

CG: It's that you have meetings and conversations and meetings, many of the things that go on before you sign a contract, the pre-contractual TC and the Post contractual are disputes and solving problems that happen along the way.

KW: We get a pretty good description of what it is we get a price for, so we make a construction program that we get a price for, it's more a material description we make, with demands for quality level. Now we are a private builder, so we can specify that it must be specific products. For public they can only specify quality level. There is rarely anything in doubt there. Therefore, there may be something anyway, if the price runs out on a given product, then it may be that the contractor tells us that there is another product with the same quality that is 20% cheaper.

CG: Something it can do in the future is, it takes a lot of work, but you can see how different products perform in the buildings, that you want to have an expression of in BC, so you can see it in the design process.

KW: So you want to draw experience from the system for upcoming projects.

CG: It requires the various actors to be willing to put the information into the blockchain.

KW: As it works now, we look back at what we did 5 years ago and what does it look like today? And there are also many times we can see, we have built homes for 8-10 years, there is also with what products we have to put in, what products there have been complaints about. So we look back a lot at what happened to the materials when we look at what we need. What quality we choose depends on whether it is something we have to operate ourselves or something we have to sell on. Many of those we sell to will also have some qualities and some products they know that can hold on to the long run. There I can see that maybe you can pull some things out of it.

CG: As it is, BC is just the technology behind it, just like WWW for the Internet, but it has to be expressed via an app or UI, which should be easy to operate, but upload these databases so that it is distributed .

KW: Now that you say databases, does that mean it will be posted so everyone can see it? It is not specific to a property or is it more generally it collects data?

CG: It depends on how you set it up, but you can easily encrypt it and give access to few. If you own the BC, then you can grant access to people to access parts of it. And then they can see it, otherwise it is encrypted so they cannot see what is happening, but it is still inserted into it and can be found again, but it raises another question, if everything is encrypted, gives it any value, and will it be different from what we have today. Next case 3. Logistics of the material. Know when the material arrives at the construction site and know where the site is stored. It is registered so everyone knows that this component is delivered here on the site and it is verified in BC so you can see that it is right, what is happening here.

KW: That makes good sense. I can see some construction projects now, where others in the square can see where the materials are delivered. We are building some slightly higher point houses, there is a lot of logistics in it and with the schedule because we are building upwards, it is not like building a long house, here is a staircase up and down. What we do there is pack the materials to a floor of hallways and crane it up. We get all materials packed from the supplier to each floor. There are many times when you build upwards at that height, it can be cheaper in my world to put 2 more plasterboard on, because if you are missing then it costs a lot to get up. I can see that with the logistics, and we have been working on this for some years, and for the schedule, to get things packed.

CG: If you have this interface, then every craftsman can see that it is right here in the construction, it is probably released similar to the current one, but it may well provide a different solution. Another thing it can do is in relation to the tender phase, BCT will allow everyone involved in the tender phase to have an updated version of the requirements, which also means that you can have all references for employees in the companies so PQ can go much faster, can you see that BCT can help in the tender phase and reduce TC? Now I know you don't have that many people asking.

KW: Yeah, we don't have that many, we ask that way. But it is more tender, where you go out and ask, and then they invite, you can do that. Collect all the data there somewhere, but we also have platforms we work with, Byggeweb and there are many platforms, many of the companies have their own platforms, we work with something called Ajour, where you can also exchange data and documents where you can see from how much you have access to. You are also constantly informed if there are new things. This is how many times when we tend to our projects, it comes up, we have used google sometimes a place where we put things up and then we can give the contractors access to see the materials every time we post something new up, we send an email that there is new. It's something of the same, but maybe just more structured the other system you're putting up.

CG: One of the things I have heard you do today is to look at the different companies, what do they have of references, in relation to what they are going to build, but it is at the company level that there is, for example. the new Pihl, which runs on that they still have references from the old, but there are only maybe 5 men from the old, they really know what they did back then, then some questions come. Where this, with this system, you can see who is in the business and what they have done. So you have a carpentry company you ask, are they still the one who went out and put these windows in last time, or is he changed, and then you have some brand new swings and they can do the same so you can get a better overview of what the different companies can do.

KW: You are absolutely right, this reference follows the company, but it is more these construction people who have the competence.

CG: So this should be transparent and up to date all the time if you use this system, and at the same time if you need someone who can do just that, it will come up with the companies that have these skills in it .

KW: That's an advantage I would say.

CG: So I think it's something that can help the developer or the builder more than it's something that can help the different contractors.

KW: I know at least in the consultancy industry, so it's more about what the employees can do, then it's his or her skills that decide it, and not the company.

CG: It makes sense that MT Højgaard has built the Great Belt Bridge, after all, not everyone in the company has done it.

KW: These are the competencies of the various people in the company. So that makes good sense.

CG: So the question is how much of TC can be saved by lowering TC in PQ, for the Contractor it is probably not the big difference, they still have to put the data in, but it may be easier for the builders and faster to select the real people.

KW: I think so.

CG: Also because you can put what is called a smart contract, you can say that we have these different parameters that you have to meet, if you do, then you are automatically moved on to the next round, so they put their evidence in, that we can do this and then it says it's ok. And then

one can move on to the next.

KW: You can pretty quickly select or search out who has the qualifications, it might make good sense.

CG: It may well be that it saves nothing for the contractor but the builder. Next question According to post-contractual TC that occurs in problem solving and searching for the “guilty party” etc. it has been said that BCT can reduce these costs. That’s because everything that happens in the project will have a digital twin. So when a problem arises you can always find out who is to blame. How do you see it can help?

KW: I stand there just a little bit (reluctantly) That’s again, it requires it to be put into the system.

CG: If we assume it is.

KW: Then it might be easier to find a culprit.

CG: yes, but does it help?

KW: I don’t think that helps solve it. There is still something to be said about things, you can probably record so much in the systems, but much is still in communication, where you have to sit and talk about how you read it. There are some things you can read in many ways from the background. This is also where many of the conflicts arise.

CG: Because you have read differently?

KW: Yes understood differently, right away I don’t think the system can solve it. If it could, it would be smart. It may help along the way and create more clarity or transparency, it thinks it can in the long run, but it does not resolve the conflict if there must be one in the end.

CG: No, it requires you to look past the conflict and then work on it, and then resolve the conflict later, whatever the trial or whatever.

How much will BCT, as you understand it, reduce the following costs: On a scale of 1 = nothing to 5 = really much.

- of verification of companies (contractors, consultants. . .) 3
- of networking 1
- of writing contracts 3 -4
- of enforcing contracts
- limit the execution time of transactions
- negotiations

KW: Verification, is that the selection?

CG: yes, that is the selection or say they are good enough for the task.

KW: I think it will give something, but whether it is, I have a hard time saying it depends on the task, if only 5 are inviting, we can handle it, but if it is maybe 20 then it can it is a good work tool. 50/50.

CG: In terms of networking?

KW: I have a hard time seeing what it can do, networking, it’s collaboration?

CG: Well, knowing the right people.

KW: I have a hard time seeing that, it can provide an advantage.

CG: in the context of writing contracts?

KW: Of course you have some documentation you have gathered along the way, so it must be in there, so you have clarity, it must be an advantage whether it is 3 or 4, it must be at that level.

CG: In terms of enforcing contracts

KW. Well, there are a lot of things inside, so of course it will help, but conversely as we do today, you have a contract and our contract basis is also electronic, both for us and the contractor. So by us it won't make any difference, because we have a fair control over the paperwork, but it may be more on the other path where we start communicating more with each other so that they are put right and you can quickly find them again. On some of the tasks, there may be several 1000 emails back and forth. Some are relevant and others are irrelevant, so it takes a fair amount of time to clean it up. Immediately, I don't think it helps that much, so it's 50/50, but it has to come up with some tests first, you must have tested it here before it makes sense.

CG: Limit transaction execution time.

KW: There must be a time saving in that you have things gathered in a place where both parties can go, but how much I do not know, a 3-4 pieces.

CG: Negotiations.

KW: It does not shorten the negotiation process, where you face each other and get control of things, of course you have all your cheap stored, and what is the starting point. I do not think the negotiation process will be less for that reason. Along the way, we go through all the points, so I know that not everyone gets to grips with it, but it is also the ones that end up with the conflicts. The negotiation process itself does not get faster.

CG: There is a proposal for making a tender on a blockchain that would reduce TC. The process goes like this. Let's say that each of 5 contractors bidding for a project spends X kr. in TC for submitting a bid, and it's estimated that a contractor wins only 1 out of 5 bids. A client selects 5 contractors through PQ (also on BC), and those selected commits X kr. into a blockchain account - that is the amount of money that would be spent anyway on a bid attempt. Then a 3rd party - engineering company makes the "statement of work" for the project (scope, tasks, deliverables, schedule, requirements), and based on that work the contractors bid. The winner is paying the engineering fees (X kr.) to the company that produced the report.

So pros and cons what do you think of this idea.

KW: What it comes down to is everyone spitting X KR. into a common pool and what is it that you get for the X kr., is it the engineer setting up something, or is it the tender material already in there?

CG: It is the engineer who reviews the tender material and thereby selects a winner and thereby receives the amount they spend, and the losers will receive what they have given in cryptocurrency.

KW: Just to get it right, what is it they get for the X kroner they have become PQ, point 1, then they also have to pay x kroner to get the information. I just can't understand how it makes sense, understand me right. If you've got the material, they need to save some money on dealing with something to make sense. In the old days, we had something called calculators, e.g. if I laid out a task and I had to build a house, then 5 carpenters were invited. So instead of each carpentry company figuring out quantities, then a calculator company goes in and takes the task, measures the quantities up on the project, and then the carpenters could buy the calculations so that they do not have to sit and do it themselves. So the carpenters priced those quantities. What is often a big task when it comes to pricing is to draw quantities out of the task, which is not to set prices. Then they also compete on the same quantities all together and thereby the same terms. But conversely, you make a calculation mistake, then everyone makes a calculation error.

CG: We talked about it a little bit, but we held interviews with those who work with BCT in construction and they talk about putting smart contracts on. An example of how it can be used is if a craftsman installs a building component, then they do a quality check of what they have done when you put it into the blockchain, you can say that they have met the requirements for what must be done and thereby they will then be paid that money right away.

KW: It will check that this work is done, then it will pay the price for that work in the system.

CG: Of course, there has to be a level of evidence for this to be done. Although it will take time and money to develop a system for this, how do you think it will make an impact.

KW: Again, it's something that requires getting it under the skin. But it can of course save some time with some construction and project managers who do not have to realize and look at the place that things are set if you have to document inside BC. It requires in my world that a lot of data has to be entered into the system, it is both something with schedule and logistics and also the whole pricing, so you know what value the piece of work is.

CG: You can also divide it into 500 m^2 blocks, and then you say I put kitchens in them, then you can get the money released for it. As I have heard, it can take up to 4 months before you get the money.

KW: It doesn't happen here. We often run according to payment plan which is agreed in advance, what month we have to pay the money. So we have a schedule where we have also tied up the economy. There are other companies that run with accounts and quotation plan, so you have put 3 windows in and then you get money for it. Then you look more generally. That account requires some more work on location.

CG: It may be that if you have to get an approval from the municipality that you set up a smart contract that says the requirements must be met, then it will be able to automatically approve, instead of a person having to look through all the documents to approve. So a building maturation process can be diminished or the rules governing it.

KW: Yeah, maybe it's more agile, or a faster process.

CG: Maybe no more agile, but a faster process.

KW: Because once you get there that you entered this documentation and you put it into the system, it can release to the next step, rather than some person where it takes 14 days to 3

weeks for that to happen something. I can see that there is some future in it.

CG: As it is now, in DK there are these 8 use cases on it. There are not many in the world around it in the world.

APPENDIX

I Transcription of Interview with Kuben

Interviewee: Søren Fonseca Pedersen. Interviewer: Casper Gøtze CG: The first question I have is, you know about BCT.

SF: Very overall. And immediately associate it with cryptocurrency.

CG: That's also how it came up here a couple of years ago. Have you ever thought that it could be used for something in the construction industry?

SF: Not immediately.

CG: I will describe it briefly. What it can do is that it is a distributed database where every player in a project has a copy of it, it is transparent and protected from being deleted and manipulated, every agreement, process and payment is digitally stored and has a signature. In every movement of the project, you know who has done and what has been done. How many contracts do you make during one project?

SF: It depends on the form of the contract, but because we work mostly with turnkey contracts, it is only the turnkey contract that we make an agreement on. And of course we have our own consultant contracts with the client, but they are not as such part of the project. Then, under the contract, there may well be a need for contracts with sub-advisers and then still where we are and advise and if we talk main or specialist contracts, then there are the respective number of agreements to be entered into with various advisers. The starting point is total advice, so it's a deal. Then there may be some basic purchase agreements and such some things next door.

CG: How many companies do you estimate are involved in a project.

SF: What should I count sub-advisers with?

CG: Last time I interviewed, it was to the Subcontractor level.

SF: typically there will be 4-5 sub-consultants and subcontractors, then there may be an architect and engineer who is connected, so I would say between 5 and 10 is the most typical picture we see.

CG: There are some use cases I want to present and then you can leave your comments on that. 1. "Design tender". Make one for the architect's selection of materials and requirements for the supplier more transparent so that it is known what the developer gets and what is chosen to start with. The BC may be that you have put your data into it and then every time you make a change you do not delete anything, but on the other hand you make an addition so that you constantly have a log of what has happened and who has done what, then you can constantly see who has made a decision on this and what is decided.

SF: I actually hear it as version control and that version control is available to all parties, instead of just the architect sitting and drawing as a starting point? And I immediately think that the transparency it can provide is positive, I can be a bit doubtful of the utility in terms of what it can be used for, because if I, as a builder or other consultant, have to look into what the architect has done, and when, and start commenting on it along the way, we begin to shirk some responsibility between the various parties in the construction industry. There is no doubt that it will be able to handle and relieve some of the challenge we have today, about having to keep a log of changes at the developer meetings, in connection with partly the audit in connection with the developer meetings, there are some requirements in AB system that we must keep a change log, but it is always up for discussion, how much does it take to make a real change, there is some level of detail there, but I think there might be some help to see what is happened when.

CG: Yes, and it does it automatically, because that's how the whole system is built and makes the change log by itself, so instead of having to sit and have the discussion, it's just made. Next thing 2. Chain of custody. Follow a material from idea to demolition of the building. Including specifications drawings operation etc. So in the end you can see what can this building component, how is it maintained so that you have a better picture of what is the value of the particular building component at the time, in addition you also have assembly details for this building component with specification on how to remove the component so that it can be used again.

SF: I don't know if I can say anything qualified for, it's still such a new area and there are a lot of things and it's hard to recycle materials in construction today for us. Because as soon as we are inside something bearing, we talk steel so there must be calculations on it. And it is difficult today to do on used building materials. So, one could say, some of the most used is brick, and I don't know how necessary it is to have such a long track record on it. It should be more of a data basis for all this lifecycle cost calculations that you have to do in connection with various certified buildings today, which can help to capture an experience base.

CG: It can provide an experience base later on for these lifecycle calculations. Then there is a third called logistics of the material, where you can know when a material arrives at a construction site and where on the site it is stored. This is being tracked so that you have a live image of it all the time, and it is distributed so that everyone has it with real data, and the main rule with BC is that it is real and valid data you get out of it.

SF: But it's interesting to the contractor, to manage his subcontractors and manage his site, as seen from my side as a building consultant, that's kind of subordinate. I expect it to be delivered on time, and I think it's something a contractor wants to close us and a builder into, I doubt that, if there has to be an argument for getting an extra payment and getting time extensions, it is a negotiation parameter on their part.

CG: So from your point of view, you may not see the idea in this, but it's also the position you have. BCT will enable all companies involved in the tender phase to have an updated version of the requirements. There is also talk of having all the references of employees and companies in a blockchain, so the PQ round will be much faster. Do you see anything any way in which technology can help the supply phase and lower TC?

SF: You will of course be able to save a little time in having to make changes and additions to ongoing offers and clarifications, but I think you still have to deal with the issues it raises that

you need to change it. And you may also be moving to a great extent, thinking at the beginning that those who are going to bid must be alert to what is coming and you can say as it runs on tender materials, that is the slightly more solid form that comes in it doesn't come all the time, so you don't always have something new to deal with, as bidders, so I could well imagine a risk that bidders are pretty enough at the garden gate, and thus end up getting offers that are made on different conditions, it depends on how much we change, as a starting point we should not change anything once they are offered, but it can not be avoided that some clarifications and some changes.

CG: You probably also get questions from contractors for clarifications.

SF: We do. Often when it is the technical stuff, it is a sub-consultant who answers the questions, then there is one that we have very often in and when we do not project, then there is an engineer who answers many of the questions regarding the supply, that's often what's in a construction program.

CG: If we go back to the PQ round, which technology can say, when you have to choose who is going to PQ, it can do it automatically by setting some parameters and saying that they should be met, and they have employees with the right qualifications.

SF: There is no doubt that if you can automate something in the calculation and thus in the selection and especially in the argumentation, because it is often the argumentation that you spend some time, ie when we evaluate on references, then there is always a qualitative assessment of the references in question, which you cannot necessarily capture in such a quantitative indication of which year of construction and how many m^2 so what is the complexity of the reference, how new it is, ie. the one who is 2 years old, may be better than the one who is 1 year old, so there is no doubt that you can qualify if you can automate something, but I do not think you will avoid us. Next comes the practice that there must be an opportunity for a trading room from the developer to be able to choose and argue in the choice of who gets qualified, after all, it is no secret that the legislation allows for some trading space, and thus also the possibility of to argue for or against, if you know there is a particular company you want to join a PQ, and can argue it, then it is not illegal to do so. If you leave it to the technology completely, you are depriving the developer of the options.

CG: I can see that the technology is there to automatically select the options, if you say I need these things, then it can give you a list of companies to PQ, then they are already prequalified, and then Of course, the company you have set out in advance should be included in that list.

SF: Yes it should be in that list, it's also about how you design your offering.

CG: There is what is called a smart contract, one can lie on BC, I do not know if you are familiar with the term?

SF: No.

CG: Smart contract is something you are at BC, and then you can for example. At PQ, you put your requirements into the smart contract, if the companies can then fulfill these requirements, by stacking a proof of the things they can, then they will automatically become PQ, for the project. That's why you can skip a step, but of course, if you get 20 bids, then you won't get that much more then have in a selection process.

SF: but there is no doubt that we spend some time as a consultant on tenders, both to make the assessment in PQ, but also to evaluate the offers when they come in. There are some tenders where there are many offers, and it is a comprehensive process.

CG: Also a comprehensive process of choosing the right one.

SF: I am not so afraid that it will take the work from us

CG: I don't think it's something that makes you work less.

SF: No, these are just some other things to work on.

CG: yes, and then one can hope more of the money spent is spent on better construction, that's the whole goal of it. According to the post-contractual costs associated with problem solving and searching for the guilty party, it has been said that BCT, because everything that happens in the project, will have a digital twin, which when a problem arises, will one could always find the culprit in it.

SF: Such a system is no better than the data coming in and they will come automatically when you do something. But you quickly learn to bypass systems as well. So something along the way, you will be able to find out more quickly who is the cause of this and who is it that is carrying the economy on this, but I would think there is also someone who will think in how the system is used.

CG: Would you say that, although you can quickly find out who the guilty party is, do you think it will help to solve problems faster or do you think it is more trust between people and you can work around a dispute.

SF: I don't think it will make it any faster, I think the discussion will be about some other things. Then it will be turned into some technical details. I think far down the road, it is confidence that is crucial to how quickly you will be able to take those discussions.

CG: How much will BCT as you understand it reduce the following costs: On a scale of 1 = nothing to 5 = really much.

CG: of business verification (contractors, consultants. . .)

SF: You mean compared to today, where we have the SPD we evaluate on?

CG: Yes I think so.

SF: That's not what we spend a lot of time on today. So 1

CG: of networking

SF: If that's the cost of still having a dialogue and meeting the builder and advisor asking questions and so on, then I don't think it will change anything. 1

CG: of writing contracts

SF: So it's rare that I find it so much the building program and those there. Beware, what I immediately think is much of the time spent on writing contracts is not really the question of how the supply is screwed up. Of course, some time is spent getting the benefits voted on, but

otherwise there are often other issues that arise in contract signing, which is one of the things that we should really be in place at the time of the tender. But it may be the world's issues in terms of guaranteeing and in terms of payment terms. Order between individual documents. My ignorance would say that it probably 3, it is neither for nor against.

CG: of enforcing contracts

SF: It's also a 3's

CG: limit the execution time of transactions

SF: I don't know

CG: One of the things you can do with BC is by setting up smart contracts, so you can say if you have different parts of the building, for example. a carpenter who sets up kitchens. By putting a smart contract on, he can prove through his quality control that now I have done this, then through smart contract you can stack a proof high, which can then release the money for the part of the construction that the person has made . So it will automatically happen when he has done his part which is proven in a quality check. Another place to use it was in relation to government approvals. Where you can put smart contracts around it. If you say I would like to build here, then with the data you have on it, you can prove that you have the right conditions to build. Then it will automatically give you permission to build there.

SF: There, of course, it could give something. Whether it's a lot or a little, it's hard to.

CG: I don't know how much time you spend on it now.

SF: This is rarely something we spend time on, because when we bid for a total contract, it is the contractor who has to provide the authority approval. It is often very early in the total contracts we offer, so the whole design and the whole of being on target to be able to give building permission for it, it is the contractor who needs it. Thus, it is also he who manages the entire economy, so the only thing between the contractor and the builder is a down payment for the rate plan that is agreed. So that is why I am of course aware that the tasks lie with the contractor, but I have a hard time assessing how much time they spend on it. I know, of course, that we spend significantly more time in the places where we are a total advisor to a client, because then it is us with that task.

CG: Yes, so spend in more compared to a total contract.

- negotiations

SF: I probably have to be at the negative end again because the negotiation is needed in any case. But, on the other hand, I certainly will not rule out it will save some time, so 2.

CG: Well, it is fair enough, those who are leaders in it in DK, in the summer of 2019 have been approved by DI 100 million. to develop the technology and make use cases. So it is quite new and therefore it is also difficult to say 100% what the different things can, because it is still in the development stage, and with small use cases. So for us it is to hear what you say about what works with construction on a daily basis. We have interviewed those who work with BCT on a daily basis. But that's what we just talked about.

APPENDIX

J Transcription of Interview with VivaBolig

Interviewee: Kenneth Lundholm-Stenkjær Interviewer: Casper Gøtze

CG: My first question is if you know about Blockchain technology?

KL: A little bit, what I know about it is that it's typically something you use when dealing with cryptocurrencies, or I don't know that much about it.

CG: Have you ever thought about whether it can be used for something in the construction industry?

KL: No.

CG: I can give you a brief description of BCT: It is a distributed database and every player in the project has a copy of it. It is transparent and protected from being tampered with. Every deal, every process and every payment has is digitally stored twin and has signature. In every movement of the project, you know who has done what and what has been done.

KL: It sounds like a good idea how ... the fact that having transparency in all processes and activities is something we struggle with every day. But how to get there, I'm excited to hear more about what's on my mind.

CG: We'll get into that later, I'll have some other questions first. How many contracts do you make during a project?

KL: It depends on the type of contract, but it is called one contract per contractor, if it is a professional contract, then it is 6-8 pieces of it, it is a total contract, then it is only one, and is it a main contract, then if it is 1 within the contract area, then there is within the adviser agreement, then it is typically a total consultant agreement, and if it is a turnkey contract, then that advice is also included, then you also avoid it. Possibly. a developer consultant agreement one to 2 basic purchase agreements, 3-5 agreements for various feasibility studies, then there is an agreement with the bank regarding financing. Otherwise, there is something about offer and acceptance. But it's not because like, it's also a deal, but formalized agreements are what I read up there. So, if it's a professional contract, it's no more than 15 appointments. And it's probably closer to 10.

CG: Then you also answered my next question with how many companies are involved in a project. If it is to subcontractor level.

KL: Provided it is not negotiated in several stages, it will end.

CG: if you include suppliers, there are a lot more.

KL: Yes, a professional contract can also be divided into several sub-disciplines, you can easily have a carpentry contract that is further cut into several things, where the contractor hires another company to do.

CG: It's 10 - 15?

KL: Yes.

CG: I will describe 3 use cases made with BCT, the 1st one is called design tender. It's like doing a thing for the architect, where the selection of materials and requirements for the supplier is more transparent, so it is known to the developer what you get and what is chosen to start with. And then I'd like your comments to start with.

KL: It sounds like a construction program, but let me just hear what do you say there is the transparency in it?

CG: It is BC that is simply a distributed database where you have blocks that are linked together, so every time the architect makes a change it is put into the blockchain, you can see that there is a change log all the time. In addition, you can take advantage of previously known materials, how they performed in buildings, but this is not what this case is about. It is about having a transparency about what choices have been made in the process and making the choices. And you have the introductory meetings, then you can enter BC. What things need to be done and then you can see when they will be changed in the process.

KL: The thing about having material properties early on, I think it makes good sense if that is it ... Can you put a few more words on how such one, I assume it is some form of writing. So if you have to build a house well then different building parts must make up that house. Is it the ones you want to try to define at that level, so here you have a concrete back wall, it should be able to do that and that, here you have a plinth, it should be able to do that and that.

CG: Yes, what you also want is that BC distributes, if you have any data you put in around a wall, it will automatically be able to distribute that data to an IFC model of the building, so all the decisions around components in the building, it will be able to gather, instead of having 60 different places and mails for the information to be stored.

KL: Isn't that what you do when you put data into the digital model?

CG: Well it is.

KL: But it is manually some distance down the road.

CG: This program can just like link the different things, and it's like also making an interface that is distributed so you get real data.

KL: I can kind of sense what's going on there. Some of that is already happening today, but probably not so automated. As you describe it there. And then there is little that goes a long way, what we define in a developer organization is functional requirements, so we are not down and define at component level

CG: No but you can say LoD that you have to have a certain expression and quality on the floors?

KL: Well, exactly.

CG: So it doesn't have to be specific, it can be up to the contractor's interpretation, so there is room for room. What you are doing today that we talked about last time. The goal of this case is to make it more transparent.

KL: It's a good idea, we would also like this requirement specification process to run much more smoothly than it currently does.

CG: Let's talk about the next case, it's called chain of costity where you can follow a material with specifications, drawings, operation, etc. from idea to demolition, what do you think about it.

KL: That you can just follow the individual building part from its birth to its second life. like a cycle. I think this is something that could be a good idea and it all comes down to just being there, there are some costs involved in tracing at the level there, which is probably why it needs to be done more automatically and digitally etc. otherwise it is difficult to keep track of the individual bricks.

CG: You could say that brick is not the place where it is most needed.

KL: what will it be for example?

CG: Right now the project is about windows, where you follow a window's life, so you first have an idea it has this geometry, then comes higher LoD during the design phase, then you also give information about how it is installed and it has still the properties with u value etc. Then you get information about how it is operated so you can see the value of the window when you tear it down. This also gives you greater knowledge of the value of a building for recycling, during demolition.

KL: Yes, but the money I put into a building does not necessarily reflect a resale price, you can not say that way.

CG: No, but building components, if you know how to take them out and how to use them again, they also have a greater value than if you didn't know anything.

KL: That's right, but the windows are a good example, we are replacing them in a big style right now. Because they are technically functional, ie. they no longer have residual life in them, and also because they may have some energy properties that may be a bit upgrading to modern energy windows, relative to what was before, a little. It's not something that justifies so much, but the fact that they've gone to it because they have a lifetime and it's expired. Then they are changed.

CG: Sure, but this chain of custody is a place to start. This with BCT is also quite new, but it is a use case you have started with a window, to see you can follow it from idea to finished construction, to see what the possibilities are. The next is logistic of the material, and this is where one can know where a thing is coming on the construction site and when it is coming. It will always be an updated and true form it comes with because it is verified by several, that is what the system is good at.

KL: What you point out there. Today, there is some form of material storage, which at least for the individual performs where he stumps her, where should he use it. So the question is, who is it a benefit to, who wants to know where all the things are, at all times? It may be good to have it, but I'm just trying to figure out the value proposition in it. What is it worth to be able to.

CG: It's definitely something for the contractor to be able to do that, to be able to keep track of things, and in terms of planning. It is also so that you can see that the materials have come from the factory and are on their way to the construction site, so you always know when things are happening but you as developers may be irrelevant.

KL: No, I would like to, I think so too I said last time if we can help create more value in the value chain, then we should probably get something out of it too, somehow, I think There is nothing at all. But just the one where, as a contractor, you enter into an agreement with your supplier, when something should be delivered. It is like if you go to a construction market and agree that some things should be delivered on Friday before 12:00 then that is the case unless there is something changing. It should be to get some real time, because otherwise you do your planning after that. If you solve a problem, there is a problem with this at all.

CG: I think that's something you do today, but it's to get all the information gathered in a BC. But right now, as you describe it, I might well doubt it solves a problem today.

KL: Whoever has the idea of having all the data somewhere, it's great and all those who have tried it, go cold at extremely high handling costs to keep track of the data. It doesn't pay to use that kind of resources on the data collection so if what you describe causes some of it to occur automatically.

CG: yes, it will.

KL: Then there's a greater rational in that. But I think ... and the reason why you don't bother to spend more resources on it is because there is a marginal benefit in having control over whether some materials land on a construction site at. 9:00 or 8:57, It doesn't matter.

CG: So those things will be registered automatically in BC, of course you have to say that the materials have come, but that's the only thing you have to do.

KL: After all, you still have to sign up for the receipt, so there must be more layers before the value. But as I see it, quite a lot happens, there are some who work with the logistics.

CG: What you can say with BC is that when you have transactions between then it means that when one hands something over to another, it's the link and then it's a new block coming up the chain, and then it's the link together. So compared to receiving material where you acknowledge it, it will create a new block and then it is automatically stored. That is the goal of BC, it should not change the daily workflow. So the time spent registering will not change, but it is new and it takes time to adopt. Then you will also have more real-time idea of what is happening. In a construction project.

KL: Yes, there are several who have flirted with detectors or cameras up, and then you can see that there is activity in room 200, someone is doing something there, so you are down to this building's departmental level, for who does what and where .

CG: It is also part of this project, called IoT audit, the goal is also to send sensors that record all things, then you can see a building type, then there can be a month where it has rained all the time , then you can see how you performed in relation to other weather conditions. So you have some performance measurements for different weather conditions, and how space performs later in a building, the data you can put in a BC as well. We don't have much to say about this in this

interview. Next thing, BCT will allow all companies involved in the tender phase to have an updated version of the requirements. There is also talk of having all the references of employees and companies in a blockchain, so the PQ round will be much faster.

KL: No. Assuming that all companies that enter the public tendering market, I would say have an updated reference, it has a database, whatever it is in word or excel or whatever it may be. Then there is something with a relevance, how many years do you go back before it is irrelevant how a company has performed, I think we usually go back 3-5 years, longer, then the reference is obsolete, then we have a limitation it's called 5, that's how we can put it in a spreadsheet, the companies we deal with, to what we ask them, they don't have infinitely many references, so I think the amount of data is too limited to ... if you take PQ, if that is your reference, then you throw in 5 references that match what needs to be built. I don't think there is enough to get in there.

CG: It's interesting.

KL: it is for the consideration that if you are a company that offers in the public tendering market, then the premise is that you have a reference list, if a nursing home as an example, if you take the contracting companies in the country that build the most nursing homes , then you are not lucky if they can deliver 5 over a 5 or 3 year period, so much volume is not at all.

CG: What you want to know here is that you who must select those who become PQ first and foremost can see references on both employees and the company, today it is often that you only have the company reference on it.

KL: It depends on if you ask for resume on key people and you get it.

CG: On the other hand, it will not provide more work, but in the same way as having the credentials in the company, one must also be able to do this, it's just another way of storing the data. You will be able to set up a smart contract from your company and that means that for PQ people, you have some requirements to meet, you put them into the smart contract and then the companies will automatically become PQ based on the requirements you sets up.

KL: That's right, there's a little bit of manual work by putting things up against each other, which might be something that if you have a standard way of putting this data up, so instead of setting it up its own resume template, then it must be according to a given standard and the reference must also be set up in a certain way. Today it's just PDFs, it's dead documents where you can deduce from them what's here, and there I can see the idea of updating a database of these performance metrics and then you pull it that from and something comes out at the other end. I will not reject what we also pay for ... The performance of PQ and in evaluating and evaluating what makes it high is that we hire some to do it because they guarantee the legality that they Do it on an objective and factual basis, etc. This is because there are some tough rules and sanctions if you do not do it properly if you are a public builder. That there are some who have a liability insurance that this is the way you do it and this is the selection that applies.

CG: And it happens in a fair and real way.

KL: Exactly, but the more objective a basis such a thing can go on, the less you need someone to make a professional assessment on it, so you can be right.

CG: So if you can save such a link that takes one chooses an objective and fair solution, then you have clean hands in that regard.

KL: You do not need the same kind of manual quality assurance if you have something that is clear and unambiguous and a database that is organized.

CG: According to post-contractual TCs that occur in problem solving and searching for the “guilty party” etc. it has been said that BCT can reduce these costs. That’s because everything that happens in the project will have a digital twin. So when a problem arises you can always find out who is guilty of it. How do you see it will help at TC?

KL: where we have the greatest financial uncertainty, it is in relation to whether there is something missing in the project we are offering to the contractor, not that there is anything wrong with it as such, but just whether it is clear and unambiguous . And if it is not clear and unambiguous and there is a bit of extra work for the contractor, they claim an additional payment. It fills in more than definite design errors and remedies. The additional requirements are most fulfilling.

CG: Yes, as a contractor, that is what you can make money by reading the tender documents.

KL: So you always have to read it thoroughly, and in principle you also have to be loyal to the holes in the cheese, within the framework set for it. But it is us, it is the builder’s duty to deliver clear and unambiguous project material, and there we are quickly caught by not delivering the same project twice, which makes it difficult.

CG: And that can be said, that’s just it.

KL: And you could say that your technology can help with that. And you can just configure common and good solutions that make sense.

CG: And you can also come up with a concept that is faster.

How much will BCT, as you understand it, reduce the following costs: On a scale of 1 = nothing to 5 = really much. of business verification (contractors, consultants. . .)

KL: 1 There’s too little to bring in, but there’s something. 1-2, I’ll give it a 2’s so we can see how we level it.

CG: of networking

KL: 0

CG: So totally out of scale?

KL: So 1.

CG: of writing contracts

KL: 2

CG: of enforcing contracts

KL: I would say that our contracts are fairly standardized, so the contract itself is also quite adequate in terms of what to do and what not to do, but it relates to a project so the contract wording itself fetches you don’t know anything about it. But the attachments to the contract

project, I think there is something to download, so 2.

CG: Limit transaction execution time

KL: With full implementation and that it works as it should, and you can see everything while it is going on, I would like to give it 4.

CG: Negotiations

KL: 2, don't wait a little 3. Because you have a better foundation and a more unambiguous basis.

CG: Is there anything you want to elaborate on?

KL: no not beyond what I wear. What is called transaction where sit down and write on some papers, with what to do and what not to do, I think there is very little to get there, but I think there is much more to be gained from making a project clear and unique.

CG: We held interviews with some of the people working in DK with BCT, one of them talked about Smart Contracts. It is a digital form of contract that automatically executes the contract. Eg. if a subcontractor installs a building component, they document it in a quality check. Their work can then be quickly checked for quality and the payment of money can come right then. What effect do you think it will give.

KL: So our quality assurance today is partly digitized, so everything you have to document you upload to a portal, typically by taking a picture of something and writing something about it, then you can get further with it there, so it can certainly because there are a lot of manual errors in, both having to report but also that someone is sitting at the other end looking at what has been reported and making their assessment of whether it is in relation to the contract or not and we do not avoid looking at things one by one physics and it takes time and cost money. If you can somehow strengthen the contractor's self-control and thus also. Now you have to be careful what you say, but the contractors also sometimes make mistakes in relation to their quality assurance where they mark something that the requirements are met, but they prove that it is not and it is like because there is incorrect registration risk.

CG: After all, it will be just as long as you work with people.

KL: It will be there, so if you could eliminate it somehow. Then you also avoid the one who knows if the error registration is a mistake or if it is intentional, so that would be great.

CG: The goal of this is also that when you do a quality check that it is tied to an IFC model throughout the construction. I know there are programs today that are already trying to do, but there can still be depending on which contractor it is and how they register, the information can be in many different places around what happened, with BC you can put all the information together and link it to the IFC model, so no matter how you do it it will be linked together.

KL: I think this is a good idea, I think you have to take note that a large part of the industry does not know what an IFC model is and an even bigger part, so I know it well, but many do not know, and there are even more who don't know how to use it there for anything. So there is clearly an investment in if everyone has to commit and everyone should be able to work in such a digital setup. Because otherwise a whole lot goes on just one by one on a construction site, where you agree where things should be. Then there is also the fact that the more you want to increase your

digitalization level in your digital model, the more expensive it is, it is quite expensive to leave a model with information. If I want to draw all the contacts and fittings, I want it incorporated into the model, so it is purposeful and detailed as the level, it costs a lot of money. That yield I should be able to see, otherwise it is better just to draw square boxes and say this is the house. Of course it is exaggerated, but there was a lot going on in the old days, and then you had to figure out how to build it, so a lot has happened and I think it is going in the right direction. But right now it is too expensive to refine these digital models and that data is too difficult to access. So we lay people, we have a hard time doing so much with it. We can figure out going around the models and taking goals, but otherwise it will require you to upgrade if you want more than that.

CG: I can see that, so it should be made easier for lay people to

KL: Yes it does if it is to be made public.