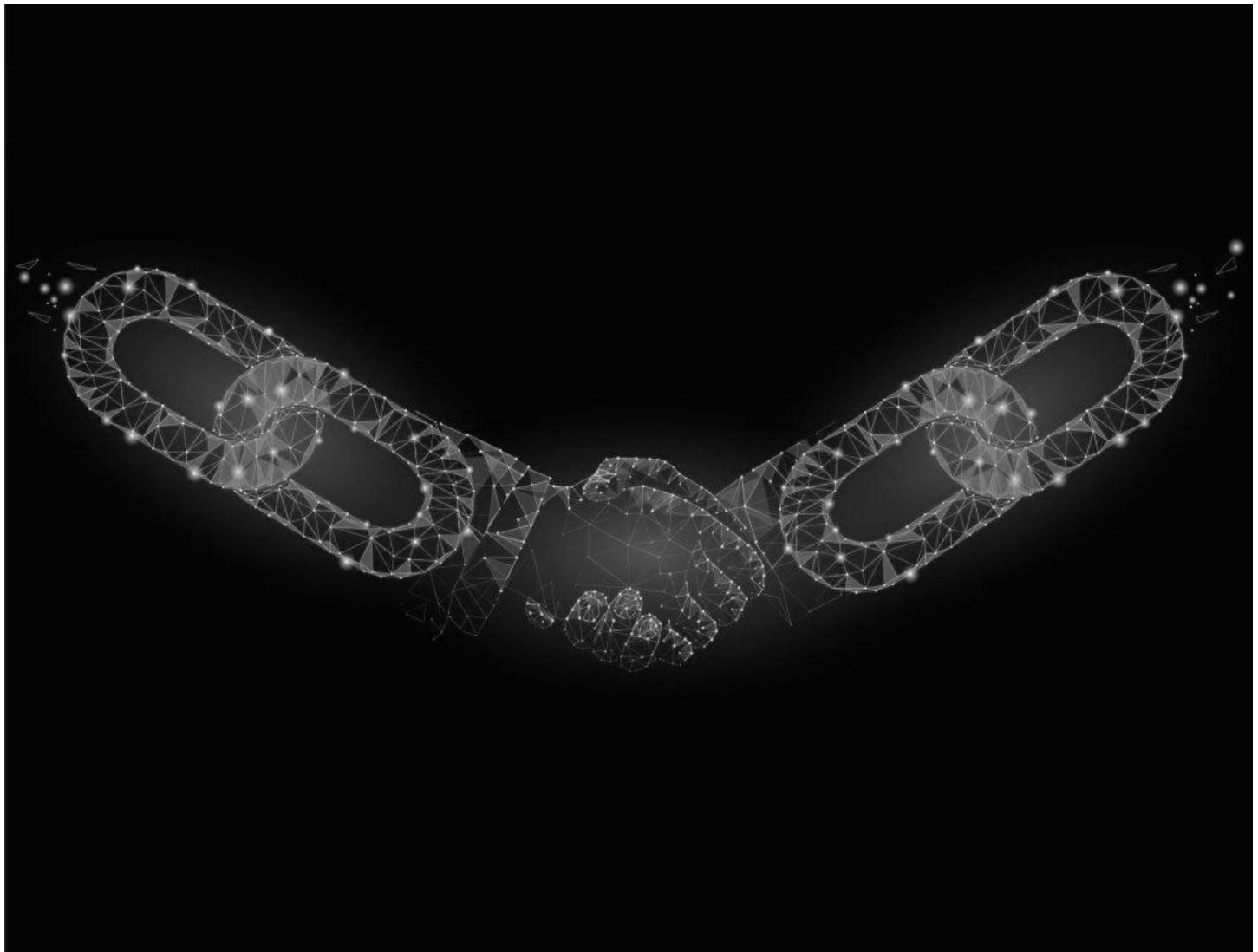


Blockchain in a Construction Project

Master Thesis

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Colophon

Title

Blockchain in a construction project

Under title

A design science research towards reducing conflicts between contractor and subcontractor using a Blockchain solution

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“Continuous improvement is better than delayed perfection”

- Mark Twain -

Preface

In front of you lies the thesis "Blockchain in a construction project". A Design Science Research (DSR) towards reducing conflicts between contractor and subcontractor using a Blockchain solution. This thesis has been written to fulfill the graduation requirements of the Construction Management & Engineering program at the Eindhoven University of Technology (TU/e). From November 2019 to July 2020, I have been researching and writing the thesis.

In the fall of 2017, a hype started around Blockchain technology and crypto currencies. At the time, I watched the developments surrounding both phenomena with full interest. After completing my last courses, I started looking for a challenging thesis topic. I came across two previous theses from students about the application of Blockchain technology in the real estate sector and in a housing association. Based on the potentials of Blockchain technology, the challenge arose to investigate the application of Blockchain in a construction project.

Several people took part in my research with enthusiasm and great interest. Without them, answering my main research question would have been almost an impossible task. In particular, I would like to thank my supervisors Bob van Thiel and Raymond Opdenakker for their guidance and support during this challenging process. I would also like to thank Alex de Vries of PricewaterhouseCoopers for answering all my questions when I got stuck. Further, I would like to thank all respondents and other people who contributed to this thesis for their cooperation and their time.

I also want to thank my family and friends for their wise advice during the research. I have been able to discuss my research with a number of fellow students and I would also like to thank them for their input and advice. Finally, I would especially like to thank my parents who have motivated me throughout the process to successfully complete my thesis.

I hope you enjoy your reading.

Samir Kuah

Almere, August 15, 2020

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Management Summary

The construction industry is a significant contributor to the Dutch economy. In 2018 the construction industry employed over three hundred thousand people, contributed about 4,5 per cent of Gross Domestic Product (GDP) and included a production of more than €70 billion Euro (CBS, 2019). However, the industry continues to be labeled as a serial productivity underperformer (PWC, 2013). Different studies address different factors that cause low productivity in the construction industry. However, these studies almost exclusively represent the perspective of governments, clients and main contractors, whereas the voice of subcontractors has been entirely missing from the construction productivity debate (Loosemore, 2014a). A major omission as the subcontractors performs almost all physical work on the construction site.

The main research question in this study is; *To what extent can the potential of Blockchain technology be applied to reduce the conflicts between contractor and subcontractor during construction projects?* The research method used for this study is the Design Science Methodology (DSM). DSM is a relatively new approach to research (Reubens, 2016), with a goal to construct a new reality (i.e. solve problems) instead of explaining an existing reality, or helping to make sense of it (Iivari and Venable, 2009). Research, of course, aims to develop knowledge, but Design Science Research (DSR) is not driven by pure knowledge problems, but by field problems. A field problem can be defined as a situation in reality, which according to (some or all) stakeholders can or should be improved. Its key research product is a generic solution concept, i.e. a generic intervention or system that can be used in addressing the type of field problem in question (Van Aken, 2012).

During construction projects, there are often various conflicts between contractor and subcontractor. The causes of these conflicts are diverse and in the worst cases leading to disputes. In case of disputes, the work is usually (temporarily) stopped. A temporary stop of work can again directly affect the delivery date, which can have an effect on the end users. Due to the high diversity of causes of conflict, this research focused on identifying one single bottleneck that causes conflicts. On the basis of an in-depth literature study, previous research reports and interviews with various stakeholders it was confirmed that payment problems are an important bottleneck that causes the many conflicts between contractor and subcontractors during construction projects. After that, requirements have been drawn up that a possible solution must meet to solve the payment problems and to reduce the conflicts between contractor and subcontractor.

The most important requirement for the solution is that payment agreements must be irrefutably recorded and must be able to be executed automatically so that late payments, or in the worst case no payment at all, can no longer occur. In addition to establishing the agreements irrefutably, it must no longer be possible to adjust the agreements after both the contractor and the subcontractor have signed the contract. This will create trust and transparency between contractor and subcontractors. Moreover, the automatic execution of payment arrangements, after the work has been performed and approved by a contractor's representative, will minimize the likelihood of default and ensures that subcontractors can receive their money on time. Over

time, this will ensure that loans, bank guarantees and credit insurance become superfluous, so that in addition to reducing conflicts, higher returns can also be achieved.

During this research, Blockchain technology was raised at an early stage as a possible solution to reduce the conflicts between contractor and subcontractor. After identifying payment problems as a bottleneck that causes conflicts between contractor and subcontractor, as the DSM guidelines indicate, another solution was also considered to solve the identified field problem. In addition to Blockchain technology, another possible solution that could meet the requirements was the use of a traditional database. Payment agreements can be recorded and automated both in a traditional database and on a Blockchain. Both solutions were investigated and compared with each other during this study. However, a traditional database will always be managed by a database administrator (DBA). Because of the DBA, the use of a traditional database means that the chance of fraud is always present. A DBA has the competence to adjust contractual agreements on a traditional database whereas agreements recorded on a Blockchain can no longer be modified by anybody after agreement. As a result, a traditional database will never be able to provide the same trust that Blockchain technology could offer. Based on this, it was decided to apply Blockchain technology to work out a solution.

A smart contract has formed the basis of the elaborated Blockchain solution. A smart contract is an automated transaction protocol that implements the terms of the contract. Contractual clauses in smart contracts are automatically enforced when a certain condition is met. Blockchain is not the same as a smart contract but makes smart contracts possible. In the new situation in which payments will be made via Blockchain, first of all, as in the current situation, a subcontracting agreement will be drawn up and signed by both contractor and subcontractor. This original subcontracting agreement will then be uploaded to a Blockchain using a Proof of Existence web application. With the help of this web application a digital 'fingerprint' will be generated automatically. Hereafter, the smart contract will be drawn up. In the smart contract, the reference to the original subcontracting agreement will be made based on the generated 'fingerprint' and the contract conditions as drawn up in the original subcontracting agreement will be translated into smart contract code. Payments than will be linked to those conditions. After the work has been completed and approved by the contractor's representative, the smart contract will automatically make the payment. The payments will be made using crypto coins and will be sent automatically from the smart contract to the subcontractor's digital wallet.

A diagram has been drawn up that describes the Blockchain solution step by step. Using this diagram, the Blockchain solution has been validated by an experienced subcontractor, the chairman of the Dutch Contractor's Federation (in Dutch: AFNL) and by a Blockchain specialist. Based on the answered sub-questions and the validation, it could be confirmed that there is a great deal of potential to solve the payment problems in such a way that the number of conflicts between contractor and subcontractors decreases when using Blockchain technology. On the other hand, there are still enough challenges to actually implement the Blockchain solution. Such as convincing a contractor and adjusting a number of technical pitfalls of the Blockchain solution. By further developing the solution, it may in the future be a breakthrough for the many conflicts between contractor and subcontractors during construction projects.

Management Summary (Dutch)

De bouwsector levert een belangrijke bijdrage aan de Nederlandse economie. In 2018 had de bouwsector meer dan driehonderdduizend mensen in dienst, droeg de industrie voor ongeveer 4,5 procent bij aan het bruto binnenlands product en omvatte de bouwindustrie een productie van meer dan € 70 miljard euro (CBS, 2019). Echter, de bouwindustrie wordt nog steeds bestempeld als de industrie met een lage productiviteit (PWC, 2013). Verschillende studies kaarten verschillende factoren aan die de lage productiviteit in de bouwindustrie veroorzaken. Deze studies vertegenwoordigen echter bijna uitsluitend het perspectief van overheden, opdrachtgevers en hoofdaannemers, terwijl de stem van onderraannemers volledig ontbreekt in het debat over bouwproductiviteit (Loosemore, 2014a). Een grote nalatigheid aangezien de onderraannemers hedendaags bijna alle fysieke werkzaamheden op de bouwplaats uitvoeren.

De hoofdonderzoeksvergadering in deze studie is in hoeverre kunnen de potenties van Blockchain technologie toegepast worden om de conflicten tussen aannemer en onderraannemer tijdens bouwprojecten te reduceren. De onderzoeks methode toegepast voor dit onderzoek is de Design Science Methodology (DSM). DSM is een relatief nieuwe benadering van onderzoek (Reubens, 2016) met als doel een nieuwe realiteit te construeren (d.w.z. problemen op te lossen) in plaats van een bestaande realiteit uit te leggen of te helpen een betekenis te geven (Iivari en Venable, 2009). Met onderzoek wil men natuurlijk kennis ontwikkelen, maar DSM wordt niet gedreven door pure kennisproblemen, maar door veldproblemen. Een veldprobleem kan worden gedefinieerd als een realiteitsituatie die volgens (sommige of alle) belanghebbenden kan, of moet worden verbeterd. Het belangrijkste onderzoeksproduct is een generiek oplossingsconcept, d.w.z. een generieke interventie of systeem dat kan worden gebruikt om het type veldprobleem in kwestie aan te pakken (van Aken, 2012).

Tijdens bouwprojecten vinden er vaak verschillende conflicten plaats tussen aannemer en onderraannemer. De oorzaken van deze conflicten zijn divers en lijden in het ergste geval tot geschillen. Bij geschillen wordt het werk doorgaans (tijdelijk) stilgelegd. Een tijdelijke stop van werkzaamheden kan weer direct invloed hebben op de opleverdatum, wat directe gevolgen kan voor de eindgebruikers. Door de hoge diversiteit van oorzaken van conflicten, focuste dit onderzoek zich op het identificeren van een knelpunt dat voor conflicten zorgt. Op basis van een verdiepend literatuuronderzoek, eerdere onderzoeksrapporten en interviews met verschillende belanghebbenden, kon bevestigd worden dat betalingsproblemen een belangrijk knelpunt vormen. Op basis hiervan zijn er eisen opgesteld waaraan een mogelijke oplossing zal moeten voldoen om de betalingsproblemen op te kunnen lossen.

De belangrijkste eis voor de oplossing is dat de betalingsafspraken onomstotelijk vastgelegd en automatisch uitgevoerd moeten kunnen worden zodat te late betalingen, of in het slechtste geval helemaal geen betaling, niet meer voor kan komen. Naast het onomstotelijk vastleggen van de afspraken moet het na ondertekening van het contract door zowel aannemer als onderraannemer niet meer mogelijk zijn de afspraken aan te kunnen passen. Hiermee zal er vertrouwen en transparantie gecreëerd kunnen worden tussen aannemer en onderraannemers. Daarbij zorgt de automatische uitvoering van betalingen, nadat de werkzaamheden zijn uitgevoerd en goedgekeurd door een vertegenwoordiger van de aannemer, ervoor dat de kans op wanbetaling nihil wordt. Met de tijd zal dat ervoor kunnen zorgen dat leningen, bankgaranties en

kredietverzekeringen overbodig worden waardoor er naast het reduceren van conflicten, ook hogere rendementen behaald kunnen worden.

Blockchain technologie wordt tijdens dit onderzoek al in een vroeg stadium aangekaart als een mogelijke oplossing om de conflicten tussen aannemer en onderraannemer te reduceren. Na het identificeren van het knelpunt, betalingsproblemen, is er zoals een DSM richtlijn aangeeft ook een andere oplossing onderzocht dat het veldprobleem op zou kunnen lossen. Naast Blockchain technologie was een andere mogelijke oplossing de toepassing van een traditionele database. Zowel op een traditionele database als op een Blockchain kunnen betalingsafspraken vastgelegd en geautomatiseerd worden. Beide oplossingen zijn tijdens deze studie dan ook onderzocht en met elkaar vergeleken. Een traditionele database zal echter altijd gepaard gaan met een database beheerder. Door een database beheerder is bij het gebruik van een traditionele database de kans op fraude altijd aanwezig doordat een database beheerder de middelen heeft contractuele afspraken aan te passen terwijl afspraken vastgelegd op een Blockchain niet meer aangepast kunnen worden. Hierdoor zal een traditionele database nooit het vertrouwen kunnen bieden aan de onderraannemers die Blockchain technologie wel zou kunnen bieden. Op basis hiervan is besloten Blockchain technologie toe te passen om een oplossing uit te werken.

Een slimme overeenkomst (smart contract), heeft de basis gevormd van de uitgewerkte Blockchain oplossing. Een smart contract is een geautomatiseerd transactieprotocol dat de voorwaarden van het contract implementeert. Contractuele clausules in smart contracts worden automatisch uitgevoerd wanneer aan een bepaalde voorwaarde is voldaan. Blockchain is niet hetzelfde als een smart contract, smart contracts worden uitgevoerd op een Blockchain. In de nieuwe situatie waarbij betalingen via Blockchain zullen verlopen, zal er allereerst net als in de huidige situatie een onderraannemingsovereenkomst opgesteld en ondertekend worden door zowel aannemer als onderraannemer. Deze originele onderraannemingsovereenkomst zal hierna geüpload worden op een Blockchain via de Proof of Existance webapplicatie. Met behulp van de webapplicatie zal er een digitale ‘fingerprint’ gegeneerd worden. Hierna kan het smart contract opgesteld worden. In het smart contract zal allereerst verwezen worden naar de originele onderraannemingsovereenkomst aan de hand van de digitale ‘fingerprint’ en zullen de contractvoorwaarden die daar in staan vertaald worden naar smart contract code. Aan die voorwaarden zullen dan betalingen gekoppeld worden zodat na het afronden van de werkzaamheden en goedkeuring van de vertegenwoordiger van de aannemer, er automatisch door het smart contract overgegaan kan worden tot betaling. De betaling zal plaatsvinden met cryptomunten en zal automatisch van het smart contract naar de digitale portemonnee van de onderraannemer toegestuurd worden.

Van de Blockchain oplossing is een diagram opgesteld. Met behulp van dit diagram is de Blockchain oplossing gevalideerd door een ervaren onderraannemer, de voorzitter van Aannemersfederatie Nederland (AFNL) en door een onafhankelijke Blockchain specialist. Op basis van de beantwoorde deelvragen en de validatie kan bevestigd worden dat Blockchain technologie veel potentie heeft de betalingsproblemen dusdanig op te lossen dat het aantal conflicten tussen aannemer en onderraannemers zal verminderen. Aan de andere kant zijn er nog genoeg uitdagingen om de Blockchain oplossing daadwerkelijk te kunnen implementeren. Zoals het overtuigen van een aannemer en het aanpassen van een aantal technische valkuilen van de Blockchain oplossing zelf. Door de oplossing verder te ontwikkelen, kan het in de toekomst een doorbraak vormen voor de vele conflicten tussen aannemer en onderraannemers tijdens bouwprojecten.

Abstract

The construction sector is labeled as a serial productivity underperformer compared to other sectors. Several studies have focused on the causes of low productivity in the construction industry. However, studies aimed at solving the problems from a subcontractor's perspective are scarce. A major cause of low productivity in the construction industry from a subcontractor's perspective is the many conflicts that arise between contractor and subcontractor. With the help of interviews, an in-depth literature study and previous research reports, it could be confirmed that the problems surrounding payments from contractor to subcontractor are an important bottleneck for the many conflicts between them during construction projects.

The aim of the research was to determine to what extent the potential of Blockchain technology can be applied to reduce the conflicts between contractor and subcontractor during construction projects. The research method used for this research is Design Science Methodology (DSM). The main research product is a generic solution concept that can be used to address the type of field problem in question. In addition to Blockchain, a traditional database has also been studied as a possible solution for the raised field problem. Both solutions have been compared with each other. However, based on the factor of trust that a Blockchain technology can offer more than a traditional database, it has been decided to work out a Blockchain solution.

With the Blockchain solution; a smart contract executed on a Blockchain, payment agreements can be irrefutably recorded and payments are made automatically after work has been carried out and approved. The contract terms and associated payments are programmed in smart contract code and can no longer be modified after signing. The solution has been validated by three experts. There is a great deal of potential to reduce the payment problems that lead to contractor-subcontractor conflicts with the use of Blockchain. However, there are also sufficient challenges such as convincing a contractor to apply the solution and other limitations of Blockchain technology. Overall, Blockchain certainly has the potential to create a major breakthrough in reducing conflicts between contractor and subcontractor during construction projects.

Abbreviations

API	Application Programming Interface
BG	Bank Guarantee
BIM	Building Information Modeling
DBA	DataBase Administrator
DLT	Distributed Ledger Technology
DSM	Design Science Methodology
DSR	Design Science Research
EAM	Enterprise Asset Management
ERP	Enterprise Resource Planning
GDP	Gross Domestic Product
IoT	Internet of Things
MFP	Multi Factor Productivity
PBA	Project Bank Account
PWC	PricewaterhouseCoopers
QDAS	Qualitative Data Analysis Software
SME	Small and Medium-sized Enterprises
SLT	Shared Ledger Technologies
SQL	Structured Query Language
TFP	Total Factor Productivity

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I. Introduction

1.1 Background

The construction industry is a significant contributor to the Dutch economy. In 2018 the construction industry employed over three hundred thousand people, contributed about 4,5 per cent of Gross Domestic Product (GDP) and included a production of more than €70 billion Euro (CBS, 2019). However, the industry continues to be labeled as a serial productivity underperformer (PWC, 2013). When comparing the construction industry to other economic sectors such as manufacturing it can be seen that the construction industry is as a slow adopter of potentially productivity enhancing technologies (Loosemore, 2014b). Currently, poor productivity is cited as a key aspect of failure in the construction industry (Farmer, 2016). Conversely, it is one of the biggest areas for potential improvement with McKinsey Global Institute (2017) reporting a global productivity gap of \$1.6tr that can be tackled by improving the performance of the industry, see figure 1.

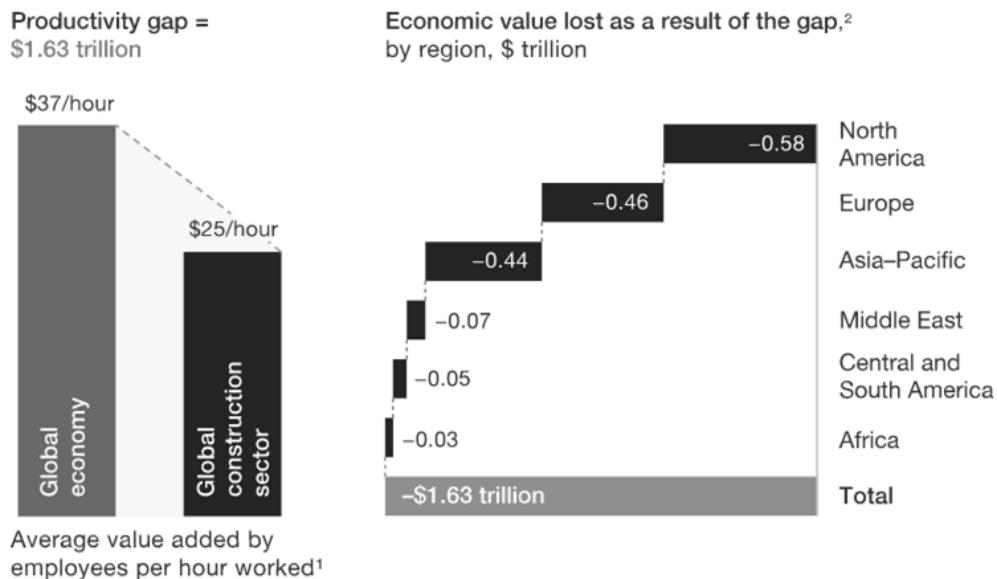


Figure 1: Lagging construction productivity costs the global economy \$1.6 trillion a Year (Source: McKinsey Global Institute, 2017).

The simplest measure of productivity is labor productivity (output per worker) which is normally measured as: value added per employee or; quantity produced per employee (Horner and Duff, 2001). But increased output per worker is not necessarily an accurate measure of productivity since it does not take into account how new technologies can affect productivity. The technology-related element of productivity is called "capital productivity" – the output or return on capital invested (Loosemore, 2014a). But both capital and labor productivity are single factor measures which in reality are very difficult to separate. So multi factor productivity (MFP) bundles both labor and capital productivity measures together into one measure to provide a more complete measure of productivity. However, MFP does not take account of other variables such changed management practices and work environments on productivity. Such measures are called total factor productivity (TFP) but these data are not easy to get and it is

often seen as unreliable (Loosemore, 2014a). There are very few studies of total factor productivity in the construction industry and the literature is not as extensive as it is in many other industries about this subject (Abbot and Carson, 2012). However, despite the fact that the exact measurements and figures about total factor productivity are lacking in the construction industry, it cannot be denied on the basis of other studies that there is still enough to be gained on productivity. Nevertheless, as Howell (1981) pointed out, cost effectiveness must remain a yardstick of productivity evaluations; escalating construction costs and projects exceeding budget continues to be a major problem.

Different findings from different international researches could be found concerning the causes of poor construction productivity. For example, In the UK, Horner and Duff (2001) and Chan (2002) found that the main causes of poor construction productivity had to do with poor management and planning, lack of trust and contractual conflicts. In the USA, the Construction Industry Institute (2008) analyzed over three decades of research and found that technology improvement was the key to productivity improvement. They stated that potential labor productivity improvements associated with the use of technologies in construction range from 30-40 per cent. The same conclusion could be found in the article of Lönnqvist et al. (2010), in which they argued that a lack of investment in technology compared to other industries was a major productivity problem. Ailabouni et al. (2009) stated in their article that in the United Arab Emirates management transparency and accountability are one of the main causes of poor construction productivity. In Kuwait, Fulford et al. (2014) pointed poor collaboration as important key impediments to productivity growth in the construction industry, Chandler (2013) came up with the same conclusion for Australia. In the long term, the construction sector also prides itself on the market if it does not innovate. Due to the increasing efficiency, industry produces more and more per working hour, which means that products often become cheaper. In construction, however, the costs increased faster, so that new construction and renovation became more and more expensive (ING, 2018), see figure 2. Innovation of new technology can ensure that construction companies work more efficiently. More and/or higher quality is built per hour worked, which increases productivity.

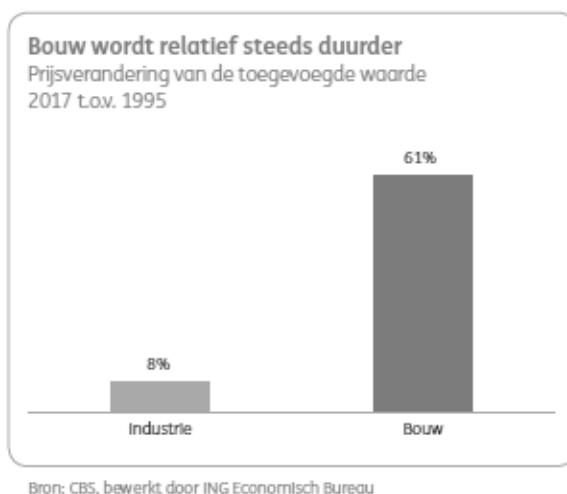


Figure 2: Construction is becoming increasingly expensive; price change of the added value 2017 compared to 1995 (ING, 2018)

There are many factors in different countries holding the productivity performances in the construction industry back. However, Loosemore (2014a) argued in his article that these studies almost exclusively represent the perspective of governments, clients and main contractors, whereas the voice of subcontractors has been entirely missing from the construction productivity debate. A major negligence given that they employ the vast majority of people in the construction industry (Chalker and Loosemore, 2016). Yet subcontractors are absolutely central to the construction industry and represent the front line where the physical task of construction is undertaken on site. The situation is the same in many other countries where subcontracting is the dominant form of employment in the construction sector (Loosemore, 2014a). Subcontracting still continues to account for between 70 and 90% of construction works by contract value (Chiang, 2009; Hartmann and Caerteling, 2010). This means that the subcontractors should not be disregarded if the productivity on site has to be increased. Therefore, it is also important to raise the issues from the point of view of a subcontractor in order to ultimately improve construction productivity. Conflicts between contractor and subcontractor can have a major impact on the progress of the construction project and precisely because the subcontractors play such an important role, it goes without saying for the entire construction industry to try to reduce these conflicts. Moreover, nowadays construction projects tend to be bigger and more expensive than projects in other industries. This means that they carry a lot of fear and risk. Mistakes and bad actors can end up costing stakeholders an enormous amount of money which has made conflict prevention a major challenge.

1.2 Problem Definition

As raised by Loosemore (2014a) in his article '*Improving construction productivity: a subcontractor's perspective*' many studies lack the issues that subcontractors experience during construction projects and as a result can influence the construction process. Nowadays, the construction industry tends to manage fears and risks during a construction project through the use of contracts. These are contracts that are concluded between client and contractor, but also between contractor and subcontractor. However, contracts between contractors and subcontractors are often cumbersome and litigious (National Society of Professional Engineers, 2014). Currently, much of the empirical research work on trust is dominated by a focus on improvements in client and main contractor relations through the use of collaborative procurement procedures and contracts (Eriksson and Laan, 2007), whereas studies that should improve the relationships between contractor and subcontractor are rarely performed.

In the construction industry, since differences in perceptions among the participants of the projects, conflicts are inevitable. If conflicts are not well managed, they are quickly turned into disputes. Disputes are one of the main factors which prevent the successfully completion of the construction project and thus indirectly affect productivity in the construction industry. Therefore it is important to be aware of the causes of disputes in order to complete the construction project in the desired time, budget and quality (Rauzana, 2016). Nowadays, disputes are still arising between contractor and subcontractor involved in a construction project. In a report made by Arcadis (2019), a dispute is defined as a situation where two parties typically differ in the assertion of a contractual right, resulting in a decision being given under the contract, which in turn becomes a formal dispute. The global average value of disputes in the construction industry in 2018 was \$33 million (US) (Arcadis, 2019). Subcontracts are often used in most construction works so as to meet the target and demand from the owner of the project. However, Owner/Contractor/Subcontractors' failure to understand and/or comply with contractual obligations became the top cause of construction disputes for 2018 (Arcadis, 2019). Moreover, Poerdiyatmono (2007) stated in his article that there could be confusing of terms in the contract documents because the terms can cause a double meaning which corresponds to the contemporary study by Arcadis (2019), in which it is stated that their results suggest construction contracts are too complex for the parties and administrators to understand. This may increase the probability of a conflict after construction work has begun.

In addition to contractual problems, literature also shows that payment problems are the cause of many conflicts and in some cases even disputes. An issue that is not new, in fact has been reported in most construction projects (Lagiman, 2017). Delayed payments have been cited as the most significant shortcoming in the subcontracting relationship especially where the main contractor uses the "pay when paid in terms of contracting" (Abdullahi, 2014). This situation puts the subcontractor under intense pressure in meeting its financial obligations and hence, friction develops between the two parties (Okunlola, 2015). In most cases, late payment is normally due to the lack of adequate supporting documentation, different specifications from original plan and on site, as well as payment rules clauses that allow the main contractor to delay the subcontractor payment (Tayeh, 2009). Consequently, a conflict may occur between the contractor and his subcontractors that can lead to relationship problem between the main contractor and subcontractor (Lagiman, 2017). To summarize, the literature has confirmed that

the conflicts between contractor and subcontractor are a major problem in construction and can influence the course of a construction project, and indirectly the productivity on the construction site. The causes of the conflicts are very diverse. In the course of the study, this will therefore have to be further defined in order to come to a good saturated research.

1.3 Research Question

As described in the problem definition, there are conflicts that take place between contractor and subcontractor with various consequences. In the worst case, these conflicts can result in disputes. In the event of disputes, work usually comes to a (temporarily) halt, which does not benefit both the productivity on the construction site and the project as a whole. The problem definition in paragraph 1.2 mentions a number of general causes that lead to conflicts, however, these causes are very diverse and still need to be explored further. Based on the examples of causes that are mentioned in the problem definition, a database in which contracts can be included and automated can offer a possible solution. A type of database with which this could be done and which is currently also in full development, is Blockchain. This has led to the following main research question with associated sub-questions.

Main Research Question:

To what extent can the potential of Blockchain technology be applied to reduce the conflicts between contractor and subcontractor during construction projects?

Sub-questions:

1. How does the subcontracting process in the construction industry proceed, where contractor is responsible for subcontractor?
2. How are the contracts between contractor and subcontractor in a construction project structured these days?
3. What is a bottleneck that causes the many conflicts during construction projects between contractor and subcontractor?
4. What is Blockchain technology and how does it work?
5. What does a Blockchain solution that could reduce conflicts look like?
6. To what extent can a Blockchain solution contribute to a better project outcome from a contractor's perspective?
7. What limitations does the Blockchain solution experience?

1.4 Scientific Relevance

As stated by Loosemore (2014a), subcontracting is the dominant form of employment in the construction sector. Given the importance of subcontractors in the construction industry and the economy as a whole, there is clearly a need for a more balanced perspective in the literature. A technology that has the potential to reduce conflicts between contractor and subcontractor, and thereby stimulate productivity on site is Blockchain. Blockchain technology attracted attention as the basis of crypto currencies such as Bitcoin, but its capabilities extend far beyond that, enabling existing technology applications to be vastly improved and new applications never previously practical to be deployed (Underwood, 2016). This shows an increasing number of publications each year, which suggests also a growing interest in Blockchain technology (Yli-Huumo et al., 2016).

Although various sectors are now exploring and testing Blockchain applications in their processes, its investigation in the construction sector is still meager and at a conceptual level (Mason 2017). Furthermore, results from the study made by Yli-Huumo et al. (2016) show that focus in over 80% of the papers is on Bitcoin system and less than 20% deals with other Blockchain applications including e.g. smart contracts and licensing. The majority of research is focusing on revealing and improving limitations of Blockchain from privacy and security perspectives, but many of the proposed solutions lack concrete evaluation on their effectiveness (Yli-Huumo et al., 2016). To this end, this study will add something by determining the potential of a new technology for a field problem that is rarely addressed in the literature.

1.5 Practical Relevance

Past decades, different technologies passed under review. Think of Enterprise Resource Planning (ERP) systems, followed by 3D CAD, Building Information Modeling (BIM) systems, and Enterprise Asset Management (EAM) systems. Most recently, Internet of Things (IoT) with RFID tech has been the focus, as well as drone, scanning, and imaging solutions. All these changes, however, have created only modest productivity improvements in projects. The amount of data captured has definitely increased exponentially, but as a whole, the construction industry is just keeping pace with inflation (Matthews, 2018). The reason why is because one continued drag on efficiency in construction is a chronic lack of trust in the construction industry (Chalker and Loosemore, 2016). On a construction project, for instance, there are usually a wide variety of companies involved. Typically, you have to wait to get all the contracts accepted and signed by all these companies. Furthermore, as a contractor you have to pay all the companies involved and wait for their status reports, most of these activities are still carried out manually. On the other hand, subcontractors are also waiting for their money, for example, to be able to pay their own staff. Moreover, during the project, as indicated earlier, discussions may arise about ambiguities in various contracts. A technology that may have the potential to improve this situation by automating the process, is Blockchain.

1.6 Reading Guide

This master thesis is set up in such a way that every reader can follow the line of reasoning. In chapter 1 the background information, problem definition and the research questions of this study could be found. Chapter 2 Subcontracting in Construction Industry provides a comprehensive picture of what the role of a subcontractor used to look like in a construction project and how a contract between contractor and subcontractor is structured these days. In chapter 3 the research method that will be used during this study to answer the main research question will be explained in detail. In chapter 4, the study will be further delineated to a single bottleneck causing conflicts. That bottleneck will be identified using empirical research tools. Next, in chapter 5, the basic elements of Blockchain technology will be further explained and the most important possible solutions will be compared. The best possible solution will be worked out in Chapter 6, after which that solution will be validated by experts in chapter 7. Based on this validation and the answers to the sub questions, the main research question will be answered in chapter 8.

III. Subcontracting in Construction Industry

In chapter 1: introduction, it is discussed that the causes of conflicts between contractor and subcontractor are diverse and that more research is needed to find out what exactly is a bottleneck for the many conflicts. Before identifying the bottleneck, it is important to first know more about the background of subcontracting in the construction industry, what type of subcontractors there are, what a contemporary contract between contractor and subcontractor looks like and lastly, the risks and problems that are associated with subcontracting. The following two sub-questions will be answered in this chapter *How does the subcontracting process in the construction industry proceed, where contractor is responsible for subcontractor?* And *How are the contracts between contractor and subcontractor in a construction project structured these days?*

2.1 Background of subcontracting in construction industry

Subcontracting is a term that has been used for decades, in principle since time immemorial but it became an increasingly popular practice in the Australian construction industry in 1960's and over the years, it has established itself as an integral part of the industry's production process (Uher & Davenport, 2009). According to Souza and Formoso (1993), in that time, a lot of building construction companies tried to improve their efficiency in the constructive processes, which ended up contributing to a reorganization of company structure through the definition of a competitive strategy. One of the strategies adopted by companies was subcontracting, which can reduce some activities for the main contractor in the construction process with the transfer of a significant part of the work to third parties (Farah, 1993).

Nowadays, construction has been, and continues to be an industry complemented by numerous subcontractors, who are vital in construction projects as their specialized skills and experience helps in ensuring the work is completed according to the time, cost, quality, safety and environmental requirements of the client and statutory bodies (Thomas and Martin, 2004). According to Albino & Garavelli (1998), the general contractor's performance is strongly dependant on subcontractors. This statement is reinforced by Mbachu (2008) who argued that the ability of the general contractor and consultant to deliver the project within time, quality and cost depends largely on performance of subcontractors. Therefore, proper management of subcontractors, if ignored, can cause a great impact to the construction project and can extend into and affect the operation of the main contractors' organization. In that case, issues concerning subcontractors should not be overlooked in defeating the challenge of achieving planned budget, quality and schedule (Tesha et al., 2017)

Furthermore, specialized works makes construction process more complex, and thus creating difficulty for the main contractor in fulfilling the client's requirements (Lian, 2012). To solve the problem, specialized knowledge and experience of a subcontractor must be used by subletting parts of the contract to subcontractors, who end up offering their consultancy to overcome the demand on special expertise, advanced equipment, and huge investment cost (Tesha et al., 2017). The percentages of outsourced work to subcontractors increased over the past decades causing the main contractors are acting as construction management agents only. It is common for the main contractors to subcontract 80% to 90% of the construction work to subcontractors (Kumaraswamy & Matthews, 2000). Besides that, main contractors prefer this option because the qualified subcontractors perform their work specialty more quickly and at a lesser cost than main contractor himself (El-Mashaleh, 2009).

2.2 Difference between contractor and subcontractor

Generally, the key distinction between contractors and subcontractors is privity of contract with the owner. Privity means hired by the property owner. Main contractors are hired directly by the property owner, while subcontractors are typically hired by a party other than the property owner, namely by the main contractor. Thus, contractually, main contractors are responsible for the construction of projects, but they rely on subcontractors and/or specialist contractors and suppliers to execute the works (Clarke and Herrmann, 2004). They do this to reduce their overhead and operating costs, improve efficiency, and achieve a more economic delivery of projects (Arditi and Chotibhongs, 2005). Subcontracting work by main contractors has helped reduce project delays by 45% (Hatmoko and Scott, 2010).

2.2.1 (Main) Contractor

The main function of a contractor is to seek out contracts and to provide the necessary coordination and oversight to complete the project on budget and on time. Rahman et al. (2014) mentioned in their study that collaboration is necessary in construction project to ensure the success of a project, especially to the main contractor that holds the greatest responsibilities towards the development of the project. This means they will focus mostly on the owner and bigger picture issues. Their scope of works includes planning, coordinating and supervising their subcontractors before delivering the construction project. According to Schaufelberger (2009), the main contractor undertakes the project based on the client needs. As time has gone on, the construction industry has moved more towards specialization. Back then, one contractor may have performed a variety of different functions and taken care of the project all by them, top to bottom (Benarroche, 2019). Nowadays, these contractors more commonly hire others to perform specialized work, the subcontractors.

2.2.2 Subcontractor

Compared to the general contractor, a subcontractor's work is more narrowly focused. Most major construction works at site are performed by the subcontractor and the main contractor role has become limited in the execution of work at site (Hartmann et. al., 2009). Contractors rely heavily on the specialized services of subcontractors to reduce costs and increase efficiency on construction projects. Through their specialized services, subcontractors execute specific tasks that contractors could not perform on an efficient way. Due to their expertise in a specific field, they are especially good at product and service delivery. Most of the time subcontractors know exactly what materials they need, where to get them and the time required accomplishing their task (Benarroche, 2019).

2.2.3 Selecting a Subcontractor

Most of the time a main contractor select the subcontractor through a bidding process (Blomback and Axelsson, 2007). Awarding a project to the right subcontractor is critically important as it may affect the overall project performance. On numerous building projects, commonly 80–90% of the tasks are performed by subcontractors (Hinze and Tracey, 1994). However, The common practice when selecting a subcontractor is through the 'lowest bidding'

(Singh and Tiong, 2006). But as stated by Lagiman (2017), the main contractor must be aware about problems that may arise later, particularly on issue regarding poor quality of workmanship and low productivity which can create claims and disputes. The quality a subcontractor can offer is in most cases more important than the price; often a contractor here makes a mistake in selecting the subcontractor to perform the work. Thus, the main contractor has to do a list of supplementary selection criteria such as looking at its past performance, financial status and team working capacity of a subcontractor before selecting. That will give more impact on the final output performance. More about this in paragraph 2.5; this focuses on the risks of outsourcing work to a subcontractor.

2.3 Types of subcontractors

As mentioned earlier, there are many types of subcontractors, each with its specialism and often identical working method. However, according to how subcontractors come to be engaged by the main contractor, subcontractors can be classified into three categories; Domestic subcontractors, Nominated subcontractors and Named subcontractors

2.3.1 Domestic subcontractors

A domestic subcontractor is a subcontractor who contracts with the main contractor to execute work forming part of the main contract. Herewith, the work of the sub-contractor is the responsibility of the main contractor as far as the contract between the main contractor and the client is concerned (Cheng Ying, 2010). Most domestic subcontractors are normally appointed directly by the main contractor. Hence, the scope of works of a domestic subcontractor includes all the works stated in the subcontract in accordance with order from the main contractor (Lagiman, 2017).

2.3.2 Nominated subcontractors

In contrast to Domestic subcontractors, The nominated subcontractor is normally appointed by the project stakeholder or directly through client. According to Cheng Ying (2010), the definition of nominated subcontractor is any merchant tradesman specialist or other person, firm or company that is nominated in accordance with the contract to be employed by the contractor for the execution of work for which prime cost has been inserted in the contract. Thus, nominated subcontractors are imposed upon the main contractor after the main contractor has been appointed. Moreover, nominated subcontractor does not need to report progress to the main contractor since they do not have a formal contract with the main contractor and their payment is paid directly by client (Lagiman, 2017).

2.3.3 Named subcontractors

The last of the 3 categories are the Named subcontractors. These subcontractors, just like domestic subcontractors, are selected by the main contractor. However, the main contractor's choice is limited to a list of acceptable subcontractors provided by the client (Tesha et al., 2017). Thus, A named subcontractor is a subcontractor that the client previously sought tenders from and they may pass these on to the main contractor, although it is the responsibility of the

contractor to negotiate an actual price with the named subcontractor. Because of this, the contractual relationship is less complicated compared to nominating subcontractors and means that the named subcontractor may be treated as a domestic subcontractor of the contractor hence avoiding the client's liability.

2.4 Subcontract between contractor and domestic subcontractor

Based on the types of subcontractors explained in paragraph 2.3, to demarcate, the study will be limited to the domestic subcontractors. The subcontractors who have a contract with the contractor where there is no direct link between the client and the subcontractor. The scope of works of a domestic subcontractor includes all the works stated in the subcontract in accordance with the main contractor.

Subcontracts are often used in most construction works so as to meet the target and demand from the owner of the project. A subcontract is a contract between general contractor and subcontractors, which includes provisions that transfer certain responsibilities, obligations, and requirements from the general contractor to the subcontractor. Subcontracts contain a detailed scope of work, the payment terms, provisions for changes, warranties, arrangements for temporary facilities and any other special subcontract requirements. In the Netherlands, the contractor and subcontractor usually contract on the basis of the law or on the basis of the UAV 2012. The latter conditions are bilateral and are widely applied in practice. In the Netherlands, a standard form or a domestic subcontract has not been published yet, however, various examples of contracts between contractor and subcontractor can be found. Rosli et al. (2018) argued in their paper that there is also no standard form for a domestic subcontract in several countries, including Malaysia. It is important that in any contract, terms of contract has to be specified clearly. The terms of a subcontract should define with clarity the full set of rights and obligations binding both parties and should be fair and reasonable to both parties.

However, Hinze and Tracey (1994) found that subcontractors appeared to be at a decided disadvantage when entering agreements with general contractors. Subcontractors entering a domestic subcontract with a contractor appeared to accept this disadvantage in many instances without sensing any recourse to change the circumstances. Contractors are often in their power because they can switch to other subcontractors if contractual conditions are not accepted by the subcontractor with whom they are negotiating. Hinze and Wilson (2000) found that subcontractors assure that general contractors usually take advantage of high competition among subcontractors to impose low prices. This therefore indicates that it is a difficult decision for subcontractors to refuse contract terms drawn up by the contractor. Some of the historic problems expressed by subcontractors include the hawking of prices by main contractors in order to obtain lower prices from others (Tayeh, 2009).

2.5 Risks of Subcontracting

Subcontracting on construction projects is a common and well-established practice. Contractors enlist the services of subcontractors to achieve certain objectives, including obtaining cost reductions, securing access to specialized services, and risk sharing (Choudhry et al., 2012). The increase in sub-subcontracting can be attributed to the increased complexity of construction projects, the shortage of experienced workers, the temptation to increase profits and risk reduction. However, Subcontractor failure has been listed as one of the risk allocated to general contractor in construction contracts. This is supported by El-Sayegh (2008) who stated that subcontracting is risky and can lead to low quality, delayed completion and unsafe practice.

As Turk & Kline (2017) have stated in their paper, construction is a collaborative process. Collaboration around any economic activity requires trust. The relationship between the contractor and subcontractors is one of the keys to any successful construction project. However, a subcontractor has always the possibility of them to breach contract and to create a dispute with the contractor, which is a major risk. On the construction site itself during the execution of a project, the power slowly switches to the subcontractors because in practice the main contractor cannot provide the construction site with necessary resources. Unlike contractors, subcontractors are specialist agents in the execution of a specific job. As explained earlier in this study, subcontractors continue to play a vital role in executing significant portions of construction work is a key characteristic of a construction project which delivers labor up to 90% of the total project (Kumaraswamy & Matthews, 2000). For this reason it is very important for a contractor to properly manage his subcontractors and to prevent conflicts.

Through subcontracting, the risks of contractors are in some ways reduced as errors in estimating added costs caused by delays or extra workforce requirements are assumed by the subcontractors (Loh and Ofori 2000). However, despite these potential benefits, risks also depend on this, the quality of subcontracting work deteriorates when incompetent or inexperienced subcontractors are engaged (Choudhry et al., 2012). If work is carried out incorrectly, conflicts may also arise, for which it is very important to continue to communicate with relevant subcontractors during the implementation of the project. Conflicts between contractor and subcontractor can therefore lead to delays and/or additional costs for contracting another subcontractor. According to Mbatha (1986), the subcontractors are the main cause of delay in projects since the majority of the construction work is implemented by subcontractors and the relationship between the general contractors and their subcontractors differs from project to another. Their duties and responsibilities are subject to misunderstanding and poor communication, so the construction field has witnessed several problems and conflicts between contractor and subcontractor.

2.6 Contractual problems

Subcontracts are often used in most construction works so as to meet the target and demand from the owner of the project. Some contracts awarded to the subcontractor contain several contracting issues that will cause problems between the main contractor and the subcontractor when executed on the site later on. Improper project management either by the main contractor or the subcontractor may lead to problems between the main contractor and subcontractor. A domestic subcontract, which could be a simple written contract or just an oral contract, may have undefined and unclear terms and conditions which can lead to disputes and work suspension (Yik and Lai 2008). Domestic Subcontractors often use a non-standard form of a contract to form a subcontract relationship with the main contractor. In general practice, the contract terms were drafted by the main contractor. Most main contractors impose their own standard terms on subcontractors and these often contain one-sided provisions which place these subcontractors at a disadvantaged position in a dispute (Rosli et al., 2018). Most awarded subcontracts do not have formal discussion between the contractor and the subcontractor. The problem normally happens when the involved parties make or execute the contracts. Different examples of contracting problems could be given such as unclear and or missing details in the drawing, incomplete contract, changes in design and so forth. This may increase the probability of a conflict after construction work has begun and can end up in dispute or in the worst case delay of project.

As stated, that the lack of the use of a standard form for subcontracting agreements with domestic subcontractors poses a problem. To safeguard the interests of subcontractors and main contractors, it is wise to utilize a standard form of subcontract (Choudhry et al., 2012). Standard form agreements will contain provisions that are readily understood by the contracting parties and the allocation of risks will be more clearly delineated. A number of problems can be avoided by using a standard form of contract. Some contractors have their own lookalike forms of contract that appear to be standard form agreements, but they contain onerous provisions. Simple contracts and oral contracts lead to disputes and work suspensions, as they frequently do not address many of the issues that may arise during the execution of construction work (Choudhry et al., 2012). In the research of Chalker and Loosemore (2016) results show that respondents who said they had clearly defined contracts with their main contractors tended also to say that the relationship they had built with their contractor was important to trust. This indicates that an emphasis on relationship building tends to result in clearer (and probably fairer contracts) and by extension, according to Cheung et al. (2011), less conflict during a project. Conversely, fair and clear contracts can also ensure trust and a good relationship between contractor and subcontractor.

2.6.1 Payment problems in the construction industry

In addition to the general causes of conflicts between contractor and subcontractor with regard to limitations in current contracts as explained in paragraph 2.6, during this research another problem that will not be overlooked when determining a bottleneck that causes many conflicts between contractor and subcontractor during construction projects, are problems with payment arrangements established in the subcontract. In many countries, laws have been drawn up

regarding payment periods, but as stated in the literature in the current construction sector, different tricks are always being carried out by major contractors to circumvent these laws.

In the Netherlands for example a payment period of a maximum of 60 days applies. However, research by the Dutch Contractor's Federation (AFNL) show that the construction sector is not aware of the law of 60 days at most and payment periods of 90 days or more are no exception (AFNL, 2018). Large construction companies tend to use their dominance and bargaining power to force smaller firms into accepting longer payment terms, while they should also obey the law. Sensitivity of subcontractors to cash flow challenges as a result of these poor payment practices also tends to increase with decreasing enterprise size (Wagenvoort, 2003). Construction is notorious for payments moving at a glacial pace. It is not uncommon at all for subcontractors to wait a long term before receiving payment for their work. This credit-heavy system places an excruciating burden on a subcontractor. In order to keep working, often, the project costs are financed by themselves until payday. For a lot of subcontractors this creates a very big challenge and also involves many risks (Benarroche, 2019)

III. Research Methodology

In chapter 2, the main features of sub-contracting in the construction industry are discussed. It has been explained how subcontracting originated, what type of subcontractors there are, how a subcontract is drawn up in the Netherlands and what the benefits and risks are of subcontracting. This chapter will explain which research method will be used for this study to answer the main research question.

3.1 Design Science Methodology

The purpose of this research is to determine to what extent the potential of Blockchain technology can be applied to reduce conflicts between contractor and subcontractor, resulting in, among other things, higher productivity at the construction site. Different causes of the current conflicts between contractor and subcontractor are mentioned earlier in this study; However, it is important for this research to delineate the study to a single bottleneck that causes many conflicts between contractor and subcontractor since the causes for the conflicts between contractor and subcontractor are very diverse. It is not the aim in itself to identify the largest cause of conflicts, but rather to identify a bottleneck that causes many conflicts and is experienced by stakeholders in practice. That identified bottleneck will form from then on the core for the rest of this study. The research method that will be used to answer the main research question is the Design Science Methodology (DSM).

The field of organization and management studies has a significant and ever increasing published research base, often criticized as fragmented and of limited relevance for practice. A design science approach to management has argued that more room for the development of solution-oriented or prescriptive knowledge would increase its relevance (Denyer et al., 2008). Design Science Research (DSR) is a relatively new approach to research (Reubens, 2016), with a goal to construct a new reality (i.e. solve problems) instead of explaining an existing reality or helping to make sense of it (Iivari and Venable, 2009). Research, of course, aims to develop knowledge, but design science research is not driven by pure knowledge problems, but by field problems. A field problem can be defined as a situation in reality, which according to (some or all) stakeholders can or should be improved, like the fuel efficiency of engines, the speed of microprocessors, the condition of cancer or heart patients, and traffic congestions (Van Aken, 2012). Students are trained to become professionals, able to use their knowledge to design and implement solutions for field problems (Denyer et al., 2008). DSR aims to produce knowledge to be used to change – intending to improve – reality. Compared to ‘disinterested’ explanatory research this involves many more ethical and political issues: is the intervention or system to be designed, further developed and field tested ethically desirable or acceptable? Which parties can be expected to profit from the use of the new intervention or system? And for which parties may their interests be harmed? For much DSR these issues are fairly trivial, for other DSR they can be very significant (van Aken, 2012).

The known field problem is that conflicts arise between contractor and subcontractor for various reasons. As a result of these conflicts, productivity on the construction site stagnates and the project does not benefit. In chapter 2, various causes of these conflicts have been addressed on the basis of a literature study. In chapter 4, the study will be delineated by identifying a single bottleneck causing many conflicts between contractor and subcontractor. The demarcation will be realized with the help of both an in-depth literature study and empirical research instruments. After the empirical findings have been processed in combination with the in-depth

literature study and a bottleneck that causes conflicts is identified and confirmed, requirements will be drawn up with which the solutions must comply in order to solve de field problem. These requirements will then be further formulated on the basis of design propositions, based on CIMO-logic. CIMO-Logic is a way to continuously connect designs and research and also comes from the DSR where designs take place to acquire generic knowledge. Van Aken (2012) explained the CIMO-Logic, based on the paper by Denyer et al. (2008), as follows; C (problem-in-context), I (intervention), M (mechanisms) and O (Outcome): for this problem-in-Context it is useful to use this Intervention, which will produce through these Mechanisms this Outcome. It is important to note that the CIMO-logic is just what it says, a type of logic (Van Aken, 2013). The outcomes of the application of the CIMO-logic are the design propositions.

As mentioned earlier, DSR is driven by field problems. More precisely, a DSR project is driven by a type of field problem. Its key research product is a generic solution concept, i.e. a generic intervention or system that can be used in addressing the type of field problem in question. The solution concept is put into context by a design proposition, the solution concept constitutes the core of the design proposition. A design proposition follows the basic pragmatic theorem: if you want to achieve Y in situation Z, then perform action X. The core of the pragmatic theorem is the action X; in the design proposition this is the above mentioned solution concept (Van Aken, 2012). Thus, the design proposition is not the complete solution for any given field problem, it is an input to the designing of the specific solution. Moreover, Van Aken (2012) states that actual design propositions need not to be formulated as one-liners. The size of given proposition can range from indeed a one-liner to an article, a report or a whole book. Below an example of a design proposition by Opdenakker (2012) based on the CIMO logic retrieved from: *Design Science: Valid Knowledge for Socio-technical System Design* (Van Aken, 2012):

The field problem is the desire to improve the performance of virtual teams in the field of product and process innovation (C). A virtual team is a geographically distributed teams, so a team with very limited face-to-face contacts between team manager and team members. The developed solution concept was a face-to-face kick-off meeting at the start of the project (I). This intervention was not expected to solve the whole field problem, but was intended to produce a significant contribution. The desired outcome (O) was an effective team, rather than good project performance as there usually are several more factors (including team external factors) impacting team performance than team management. The primary mechanisms (M) were empowerment (team members must be able to operate largely unsupervised, so need to be able to use much discretion in their actions), collective insight in the team task and collective commitment to make the project a success. Knowledge of these mechanisms is essential to design a good kick-off meeting: in order that the desired outcome is to be realized the kick-off meeting must be much more than a ritual; it must be designed in such a way that these mechanisms are triggered.

After the design propositions have been formulated using the CIMO-logic, the first solution concepts can be described that could solve the identified bottleneck that causes conflicts between contractor and subcontractor. These solution concepts will be described in chapter 5, after which the solution that fits best will be further elaborated and explained in chapter 6. It is of great importance to describe the elaborated solution concept in such a way that in chapter 7, when validating the solution, the experts can assess the solution objectively. During this research, a number of sub-questions will be answered per chapter, which, together with the

results of the validation, will ultimately form the conclusion in Chapter 8 by answering the main research question.

3.1.1 Design Science Research Strategy

To comply with the DSM guidelines, a strategy will be applied for the DSR as explained in the paper by Van Aken and Romme (2009). If one is interested in developing design propositions for a given type of field problem (Chapter 1: Introduction), one starts with a systematic review of the existing knowledge-base on that issue (Chapter 2: Subcontracting in Construction industry), to be followed by a research synthesis in which the findings from multiple different studies will be made more generalizable and applicable (Chapter 4: Identifying Bottleneck). The review and synthesis can produce design propositions, as explained earlier (Chapter 5: Blockchain Technology) to be developed further, but can also uncover gaps in the existing literature. The solution concepts that arise from the design propositions will be compared with each other, after which the solution that best fits the problem will be further elaborated (Chapter 6: Blockchain Solution). The solution will be tested by various experts (Chapter 7: Validation). Based on that validation and the answers to the sub-questions, the main research question will be answered (Chapter 8: Conclusion) and will produce new findings.

The findings are incorporated in the existing knowledge-base, which in turn may lead to further research questions, and so forth, see Figure 3. In a relatively mature field of research, systematic review in itself can produce field-tested and grounded design propositions. In a new area of research, field research is needed to generate data on the basis of which a first set of initial design propositions can be defined, which then in turn drives further experimentation and development. Testing a design proposition to find out whether it works can be done by means of statistical tests, clinical case studies, pragmatic experimentation and action research (Van Aken and Romme, 2009). However, this research is in a new area of research. As a result, the researcher of this study has chosen to hold an expert interview as validation. The expert interviews will bring new insights that can provide added value for further research.

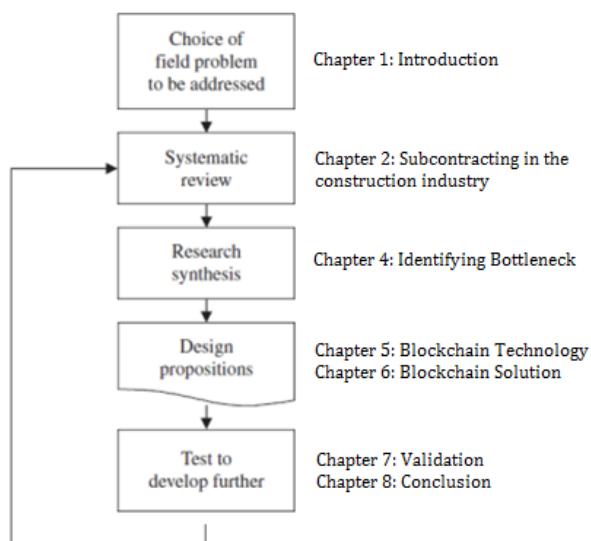


Figure 3: The design science research cycle (source: van Aken and Romme, 2009); adapted by the author of this thesis (2020)

3.2 Data Gathering

DSR can, in principle, use all known methods for data gathering and analysis (van Aken and Romme, 2009). During the literature study, various causes of the conflicts between contractor and subcontractor were discovered and raised. The conflicts took place in different phases of a construction project, e.g. during the drafting of the contract between the contractor and subcontractor, during the execution phase or after work has been completed. The purpose of this research is to reduce conflicts between contractor and subcontractor whereby both parties benefit. However, due to a time limitation for this study, it is important to demarcate the study into one bottleneck that causes many conflicts between contractor and subcontractor. The demarcation of the study is not possible in this case with only a literature study, therefore other data must be collected to ensure the reliability of the study. Data will be collected from stakeholders involved in the construction industry. The aim is not to find out the main cause of conflicts, but rather to find out what stakeholders involved in a construction project experience and causing the conflicts. The data that will follow from the stakeholders in combination with an in-depth literature study should ultimately lead to the identification of a bottleneck that causes many conflicts between contractor and subcontractor. During the literature study desk research was applied as a method to collect data. The following paragraphs will explain which method will be used to get input from those stakeholders.

3.2.1 Selecting a Data Collection method

In order to define the research a different type of data collection must be applied. Conflicts still arise these days between contractor and subcontractor. As explained above, to get more input about the causes of the conflicts input from stakeholders involved in the construction industry is needed. In order to get data from those stakeholders, empirical research tools will be used. The term empirical means: knowledge based on real world observations or experiment, and is used here to describe field-based research which uses data gathered from naturally occurring situations, rather than via laboratory or simulation studies, where the researchers have more control over the events being studied (Flynn et al., 1990).

According to Flynn et al. (1990) five types of empirical data collection methods can be distinguished:

- *Historical Archive Analysis:* Historical archive analysis uses unobtrusive measures, including physical traces and archives (Bouchard, 1976).
- *Participant Observation:* Participant observers become part of the process being observed, in order to record what participant's experience.
- *Outside Observation:* Outside observation uses an unbiased observer to collect data, often employing some methods for ensuring that data is collected systematically.
- *Interviews:* Obtaining data for in-depth knowledge or subjects with limited scientific knowledge.

- *Questionnaires*: A questionnaire is a research instrument consisting of a series of questions for the purpose of gathering information from respondents

To identify a bottleneck that causes conflicts between contractor and subcontractor during construction projects, in-depth interviews will be conducted with stakeholders from the construction industry.

3.2.2 In-depth Interviews

In-depth interviews are one of the main methods of data collection used in qualitative research. The purpose of in-depth interviewing is not to get answers to questions, nor to test hypotheses, and not to evaluate as the term is normally used. At the root of in-depth interviewing is an interest in understanding the lived experience of other people and the meaning they make of that experience (Seidman, 2013). At the heart of interviewing research is an interest in other individuals' stories because they are of worth. Interviewing provides access to the context of people's behavior and thereby provides a way for researchers to understand the meaning of that behavior (Seidman, 2013). A basic assumption in in-depth interviewing research is that the meaning people make of their experience affects the way they carry out that experience. The experiences of the interviewed participants will be used to delineate the research.

Interviewing involves more than talking with members of an organization and, perhaps, taking notes. In-depth interviews vary from informal conversations to more formal interviews, which may be unstructured, semi-structured or structured. Each type has advantages, and regardless of whether your interview is on the phone or in-person, knowing the type of interview you are conducting will help make it more successful. Pollock (2019) explains the three types of in-depth interviewing as follows:

- *Unstructured Interviews*: An unstructured interview is a type of interview in which the interviewer asks questions which are not prepared in advance. Instead, questions arise spontaneously in a free-flowing conversation, which means that different candidates are asked different questions. The main advantage of an unstructured interview is its personalized approach. This is especially useful for technology roles where the experience of candidates can vary dramatically. Additionally, since unstructured interviews allow for a free-flowing conversation, they feel more casual, which puts the candidates at ease, resulting in a more natural and honest interview. Because different candidates are asked different questions however, it is harder to compare their answers and evaluate candidates equally and objectively.
- *Semi-structured interviews*: A semi-structured interview is a type of interview in which the interviewer asks only a few predetermined questions while the rest of the questions are not planned in advance. Since semi-structured interviews combine both the structured and unstructured interview styles, they can offer the advantages of both. They allow for the objective comparison of candidates, while also providing an opportunity to spontaneously explore topics relevant to that particular candidate. But compared with structured interviews, semi-structured interviews are less objective and legally harder to defend.
- *Structured interviews*: In structured interviews, questions are planned and created in advance. All candidates are asked the same questions in the same order. Since in structured interviews all the candidates are asked the same questions, it is easy to

compare their answers and hire the right job candidate. You can evaluate candidates in an objective and fair way, which also makes structured interviews more legally defensible. On the other hand, structured interviews are harder and more complicated to develop. You have to test them and make sure interviewers follow them precisely.

It is important for this research to determine a bottleneck that causes many conflicts between contractor and subcontractor. Therefore, it is important to include stakeholder experiences in this study in order to actually identify that bottleneck. In chapter 2, some of these causes have already been outlined on the basis of the literature. The purpose of the interviews is to obtain detailed information with the possibility to deviate from the generally formulated questions within the limitations. The type of interview that will be conducted to achieve that goal is the semi-structured interview. Results of the interviews could be found in chapter 4: Identifying Bottleneck.

3.2.3 Coding

When the semi-structured interviews are conducted, the results of the interview will first be transcript in order to analyze the gathered data. The method that will be used to analyze the data is coding. In coding researchers use their background knowledge about the context of the textual passage being investigated and, in general terms, their knowledge about the area of investigation. Order is placed in the interview data on the basis of coding. This process usually consists of three steps and is called the Grounded Theory. The grounded theory is as follow in three steps explained in the book: *A companion to qualitative research* by Flick et al. (2004):

- *Open coding:* In open coding data are 'broken down' analytically, and in this the principle of grounded theory shows itself: from the data, that is from the text, a succession of concepts is developed that may ultimately be used as building blocks for the model. As a first step it is advisable to analyze single short textual passages (line by line). Subsequently larger paragraphs or even whole texts may be coded.
- *Axial coding:* This step serves to refine and differentiate concepts that are already available and lends them the status of categories. One category is located at the centre and a network of relationships is developed around it. Typically, axial coding is used particularly in the middle and later stages of an analysis. In the same way as open coding, axial coding is applied to very short textual segments (in the sense of a detailed analysis), to larger extracts or to the entire text.
- *Selective coding:* In this phase the researcher is particularly active as an author on the basis of the categories, coding notes, memos, networks and diagrams so far developed. In addition, concepts are developed into a theory and exceptions are sought through constant comparison

The primary purpose of these three steps is to form a theory or contribute to it. In addition, this process helps to determine theoretical saturation. This means that nothing new is discovered when collecting extra data. In this case by taking additional interviews.

3.2.3.1 Qualitative data analysis software (QDAS)

Coding can be done by hand, for example by using different colors of highlighters or writing the theme with a pencil. However, this process is often faster by using software. Qualitative Data Analysis Software (QDAS) offers tools that assist with qualitative research such as transcription analysis, coding and text interpretation, recursive abstraction, content analysis, but also the grounded theory methodology explained above.

The QDAS that will be used in this research is Atlas.ti. Atlas.ti is an analysis program that is used to make information from raw primary and secondary data. In the analysis program it is also possible to import different types of data. The analysis can be carried out in several ways, but in this research this will be carried out according to the grounded theory approach as described in paragraph 3.2.3.

3.3 Applying the findings

After the process of grounded theory has been carried out as explained in the previous paragraph, the requirements can be drawn up. The requirements will be drawn up on the basis of an in-depth literature study and the interview results. The requirements will be further formulated to design propositions based on CIMO-logic, from which solution concepts will emerge, see paragraph 3.1. It is therefore of great importance to obtain good input from both the in-depth literature study, in which related information is examined about the identified bottleneck, and from the empirical findings. Based on the solution concepts, the solution that can best solve the problem will be further elaborated. After this, the solution will be validated by experts.

The validation of the solution by experts will also be done using semi-structured interviews. It is of great importance for the experts to explain them clearly what the problem is before validating the solution. When describing the solution, both the advantages and the limitations of the solution will also be mentioned. By applying semi-structured interviews to validate the solution, the experts are given space to tell what they think of the solution and where they see improvements. It is important to determine on the basis of the elaborated solution which experts will have an addition to the research. It is possible that the respondents from the first round will be approached again. But it is also quite possible that on the basis of the elaborated solution it is determined that other experts are needed to validate the solution in a proper way.

3.4 Reliability of the research

In order to obtain the same results if the exact same research would be carried out by another researcher, an attempt was made to ensure the reliability of the research by making use of official and sufficient scientific articles during the literature study. It is very important that the sources are clear and background information can be retrieved if necessary. In addition, semi-structured interviews will be used to ensure that respondents are not put into words, but that they can freely give an opinion on the bottleneck to be identified. The requirements that follow from this will be substantiated in such a way that another researcher will arrive at the same requirements when studying the same bottleneck that leads to conflicts between contractor and subcontractor. However, it is possible that another researcher could come to a different bottleneck that causes conflicts between contractor and subcontractor. This has to do with the fact that the number of respondents remains limited in this study. However, it is several times stated that the aim is not to identify the biggest bottleneck for the conflicts, but a bottleneck experienced in practice by various stakeholders. The quality of the solution to be worked out will be guaranteed by having the solution assessed by an expert in the field before proceeding to validation. The limitations of this study will be further explained in Chapter 8: Conclusion.

IV. Identifying bottleneck

In chapter 1: Introduction, it was discussed that the construction industry is known for its low productivity compared to other sectors and that the conflicts between contractor and subcontractor during construction projects are a cause of this. The study by Loosemore (2014a) then revealed that the important role of the subcontractor in the discussion regarding productivity in construction is avoided. Chapter 2: Subcontracting in the construction industry explains why a subcontractor plays such an important role in a construction project and how the subcontracting process in the construction industry proceeds, where contractor is responsible for subcontractor, supplemented with a number of possible causes of conflicts between contractor and subcontractor based on the literature study. In this chapter, the aim is to identify a bottleneck that causes these conflicts between contractor and subcontractor during construction projects using a in-depth literature study, earlier research reports and semi structured interviews with stakeholders from the construction industry. Based on the findings, the requirements that a possible solution should met will be drawn up at the end of this chapter. The following sub-question will be answered in this chapter: *What is a Bottleneck that causes the many conflicts during construction projects between contractor and subcontractor?*

4.1 Bottleneck

As explained in Chapter 3, semi-structured interviews were conducted to identify a bottleneck causing conflicts between contractor and subcontractor during construction projects. In order to prepare the questions for the interviews, it is first tried to find out what causes the conflicts between contractor and subcontractor that lead to disputes through the use of the portal of the Dutch Council of Arbitration for Construction (In Dutch: Raad van Arbitrage voor de Bouw (RvA)). Jurisprudence can be found in this portal. Jurisprudence is the entirety of judgments made by (Dutch) judges. Since this portal consists of thousands of lawsuits, it has been decided to contact a construction lawyer due to a time limitation for this study. The construction lawyer explained the following about a possible bottleneck that causes conflicts or in worst cases even causing disputes between contractor and subcontractor during construction projects:

(Architectural Lawyer) "*That there are many reasons in the literature why there are disputes in construction between contractor and subcontractor is because there are many reasons why a dispute can arise. Left or right it is always about money*"

Following this statement from the construction lawyer, semi-structured interviews with two experienced subcontractors and a chairman of the Dutch contractors' federation (In Dutch: Aannemersfederatie Nederland (AFNL)) has been done. It was attempted to find out whether money or more specifically, problems with payments is experienced as a bottleneck and leads to conflicts between contractor and subcontractor. Because the number of respondents is limited to 3, an in-depth literature study will also be carried out in combination with digging through earlier research reports in order to come to a reliable conclusion whether payment problems can be identified as a bottleneck in the conflicts between contractor and subcontractor. The reports have been requested from the Dutch contractors' federation, which include quantitative results of their research with regard to payment problems in the construction industry. On the basis of these three sources, the conclusion will be drawn at the end of this chapter to what extent payment problems form a bottleneck, after which the requirements are drawn up for a possible solution. But first the results will be shown in the following paragraphs.

4.2 Payment problems

Late payment is a common issue in the construction industry and subcontractors are not spared from it (Ping Ping, 2018). Subcontractors experience the primary effects of slow payments, including the cost of floating payments for payroll and supplies, higher risk of bankruptcy during down cycles, and challenges in growing a cash-intensive business (Rabbit, 2019). Ramachandra and Rotimi (2015) in their paper suggest that delayed payment is the second highest operational risk, after financial failure that causes project delays. Payment delays also cause stoppages to material delivery, which in turn, impact labor productivity at the construction site. Consequently, the success of construction projects, and ultimately, the survival of the industry are affected. Furthermore, it can be stated that the problem is not something of this century, but has been a problem in the construction industry for decades. Ramachandra and Rotimi (2015) state in their article that payment problems in the construction industry are not a new phenomenon, such problems have been widely acknowledged for more than four decades by previous research

(Appendix A – chairman SME) “*... A payment term was introduced in the past because an invoice was sent by post and a processing process had to be initiated at the recipient. However, this is no longer the case these days and so payment terms are obsolete, especially if the performance has already been validated, the bill can be paid immediately upon receipt*”.

Nowhere is the transaction of payments more disconnected than in the construction industry. Construction operates on an ever-escalating complexity of relationships, and a vendor may not actually know where their payment is coming from (Rabbit, 2019). For example, in the Netherlands, a self-employed person without personnel (in Dutch: ZZP) has a contract with a subcontractor. A subcontractor enters into a contract with a main contractor who has a contract with a development entity. The development entity is most of the time a separate entity from the developer who owns it. That entity takes out a loan from a financial institution to cover the costs of the vast majority of their contracts on the project (Rabbit, 2019). As a result, the self employed person without personnel and subcontractors are at the bottom of a long chain waiting for payments

(Appendix B – Subcontractor A) “*... I usually submit the first invoice about 10 days after starting work. I will receive the first payment about 50 days after starting work, until then I pay all my staff on time. I'm lucky to be able to pre-finance it all, but there are plenty of subcontractors who cannot and have therefore a pre-financing problem*”.

(Appendix C – Subcontractor B) “*The contract often includes progress payments. Thus what the contractors do is hold the payments ...*”

In a report prepared by Atradius (2019), which focuses on the outlook and performance of the construction industry, attention is also paid to payment terms and their effects in various countries worldwide. In Belgium, payment experience has been bad over the past two years and the number of non-payment notifications in the sector was high in 2018. Payment terms tend to be long in the Belgian construction sector, i.e. “60 days end of month” is very common. In France, payments in the construction industry take 70 days on average. Payments in the German construction sector take around 45-60 days. Furthermore, in Italy, payment experience in the

construction sector has also been bad the last few years and non-payment notifications were at a very high level in 2018. Average payment in the British construction industry is 75 to 90 days. In Australia, Payments in the construction sector take 30-60 days on average, and the level of protracted payments, non-payment notifications and insolvencies was also high in 2018. Payment duration worldwide in the construction industry is 60-120 days, on average. Payment behavior slowly deteriorated in 2017 and 2018, and this negative trend is expected to continue in 2019. An explanation for the many bankruptcies also has to do with many subcontractors traditionally have weak equity ratios, which is the proportion of equity used to finance a company's assets, and limited financial scope, which makes them vulnerable to payment delays and defaults.

(Appendix C – Subcontractor B) "*...an owner of a flushing company with 20 or 25 guys in permanent employment, was crying once three months after starting work because he could no longer pay his own staff*"

As indicated in the third quote of this paragraph, progress payments (or interim payment) are a well used method of payments in the construction industry. In construction, a progress payment is a partial payment that covers the amount of work that has been completed up to the point of invoicing. There are several ways to structure these payments. The most common ways of billing for progress payments are billing by stage or invoicing by percentage of completion. The study by Ramachandra and Rotimi (2015), in which they analyzed 40 construction payment dispute cases filed in the High Court in New Zealand, revealed that 28 out of 40 (70%) of the cases were related to progress payments, whereas 25% related to final payments. The fact that mainly progress payments cause disputes that end up at the High Court is shocking, because it can automatically mean that the work can be partly put at risk, which can endanger the delivery date.

4.2.1 Payment problems in the Dutch Construction Industry

In the past, certainly larger contractors in the Dutch construction industry sometimes used payment terms of 90 days in order to better manage their cash flow. As of July 1, 2017, a statutory payment term was introduced in the Netherlands with the aim that smaller companies could also manage their cash flow better. The government has a maximum statutory payment term of 30 days in the Netherlands and companies a term of 60 days. In addition, smaller companies are allowed to apply a longer payment term by statutory exception. After the law came into effect on July 1, 2017, there was a one-year transition period. That period was intended to give companies the opportunity to get started with their existing contracts. Many companies had contracts with longer payment terms and needed that time to make new agreements (Atradius, 2019).

Since 2013, Panteia has conducted every year a survey in collaboration with the Dutch Contractor's Federation (AFNL) to monitor the current situation for small and medium-sized enterprises (SMEs) in construction and infrastructure (In Dutch: MKB Bouw en infra). The study examines (developments in) turnover, work stock, influx of personnel, price development, operating result, investments and payment behavior. The reports were sent by Rielèn van der Hoek, spokeswoman for the AFNL to the author of this research in order to contribute to this

research. The results of Panteia's research have been included in this research and are further explained below.

Because of the transitional period of 1 year, the first effects of the introduction of statutory payment terms on July 1, 2017, could only be measured in the autumn of 2018. In the tables below the focus is on the payments to the 'BU & Sloop' sector, which means, Contractors Civil and Non-residential Building (B&U) plus Construction and Demolition companies, made by the 'Hoofdaannemers', these are the main contractors. First, the late payment numbers from the autumn of 2017, 2018 and 2019.

(te) late betaling:	hoofdaannemers				overheidsinstanties				particulieren			
	BU & sloop	GWW	GA	totaal	BU & sloop	GWW	GA	totaal	BU & sloop	GWW	GA	totaal
geen probleem	64%	51%	72%	65%	87%	69%	83%	85%	83%	42%	85%	81%
klein probleem	19%	34%	22%	21%	7%	7%	10%	7%	13%	56%	14%	15%
groot probleem	17%	15%	6%	14%	6%	24%	7%	8%	4%	2%	1%	4%
totaal	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 1: Late Payments: percentages from autumn 2017 (Source: Panteia, 2018a)

(te) late betaling:	hoofdaannemers				overheidsinstanties				particulieren			
	BU & sloop	GWW	GA	totaal	BU & sloop	GWW	GA	totaal	BU & sloop	GWW	GA	totaal
geen probleem	82%	48%	71%	74%	65%	82%	75%	71%	83%	42%	85%	81%
klein probleem	14%	46%	19%	20%	31%	17%	24%	26%	13%	56%	14%	15%
groot probleem	4%	6%	10%	6%	4%	1%	1%	3%	4%	2%	1%	4%
totaal	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 2: Late Payments: percentages from autumn 2018 (Source: Panteia, 2018b)

(te) late betaling:	cluster BU/sloop				cluster GWW				cluster GA			
	geen probleem	klein probleem	groot probleem	totaal	geen probleem	klein probleem	groot probleem	totaal	geen probleem	klein probleem	groot probleem	totaal
te late betaling door hoofdaannemers	78%	19%	3%	100%	64%	34%	2%	100%	71%	15%	14%	100%
te late betaling door overheidsinstanties	79%	11%	10%	100%	64%	32%	4%	100%	76%	11%	13%	100%
te late beling door particuliere opdrachtgevers	67%	22%	10%	100%	86%	11%	3%	100%	87%	12%	1%	100%

Table 3: Late Payments: percentages from autumn 2019 (Source: Panteia, 2020)

Table 1 shows that in the autumn of 2017, in the transitional period of the new law, 36% (19% minor problem and 17% major problem) of the SMEs surveyed from the BU & Sloop sector experienced problems with late payments from the main contractors. Table 2 shows the figures from the autumn of 2018. There is a halving of the percentage of late payment problems compared to the autumn of 2017, with a percentage of 18% (14% minor problems and 4% major problems). Based on these percentages, for now it can be stated that the statutory payment term introduced in 2017 started to pay off. However, table 3 shows the percentages for late payments from the autumn of 2019. Here, it can be seen that there is an increase in problems of 4% compared to 2018 while an improvement would be expected. 22% (19% minor problems and 3% major problems) of SMEs experienced problems in 2019 with main

contractors regarding late payments. A possible explanation is that the law had effect, but not everyone wants to comply with it yet.

The Panteia report also includes percentages of non-payments from main contractors experienced by SMEs in the BU & Demolition sector. Below the tables of autumn 2017, 2018 and 2019

	hoofdaannemers				overheidsinstanties				particulieren			
	BU & sloop	GWW	GA	totaal	BU & sloop	GWW	GA	totaal	BU & sloop	GWW	GA	totaal
geheel of gedeeltelijk niet betalen:												
geen probleem	80%	68%	72%	80%	97%	75%	100%	94%	91%	75%	95%	91%
klein probleem	14%	6%	22%	12%	3%	1%	0%	2%	9%	24%	3%	9%
groot probleem	6%	26%	6%	8%	0%	24%	0%	4%	0%	1%	2%	0%
totaal	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 4: Non Payment: percentages from autumn 2017 (Source: Panteia, 2018a)

	hoofdaannemers				overheidsinstanties				particulieren			
	BU & sloop	GWW	GA	totaal	BU & sloop	GWW	GA	totaal	BU & sloop	GWW	GA	totaal
geheel of gedeeltelijk niet betalen:												
geen probleem	84%	96%	84%	85%	95%	86%	76%	85%	75%	81%	90%	79%
klein probleem	13%	1%	6%	9%	1%	0%	12%	5%	25%	9%	4%	18%
groot probleem	3%	3%	10%	6%	4%	14%	12%	10%	0%	10%	6%	3%
totaal	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 5: Non Payment: percentages from autumn 2018 (Source: Panteia, 2018b)

	cluster BU/sloop				cluster GWW				cluster GA			
	geen probleem	klein probleem	groot probleem	totaal	geen probleem	klein probleem	groot probleem	totaal	geen probleem	klein probleem	groot probleem	totaal
geheel of gedeeltelijk niet betalen:												
(deels) niet betalen door hoofdaannemers	74%	19%	7%	100%	61%	37%	2%	100%	80%	5%	15%	100%
(deels) niet betalen door overheidsinstanties	90%	9%	1%	100%	90%	5%	5%	100%	87%	5%	8%	100%
(deels) niet betalen door particuliere opdrachtgevers	69%	20%	11%	100%	93%	5%	2%	100%	87%	12%	1%	100%

Table 6: Non Payment: percentages from autumn 2019 (Source: Panteia, 2020)

By analyzing the tables regarding non-payment problems in the autumn of 2017, 2018 and 2019, the same trend can be seen as in the tables of late payment problems experienced by SMEs from the BU & Demolition sector. Table 4 shows that in the autumn of 2017, 20% of the SMEs surveyed in the BU & Demolition sector experienced problems due to (partly) not being paid by the main contractor for the work they carried out. In 2018 there was a decrease of 4% compared to the previous year, see table 5. 16% of SMEs from the BU & demolition sector experienced problems due to (partly) not being paid by the main contractor. However, a large increase can be seen in the autumn of 2019. Table 6 shows that 26% of SMEs experienced problems in the BU & Demolition sector due to (partly) not being paid by the main contractor. An increase of 10% compared to autumn 2018. Due to the increase in problems experienced by SMEs in the BU& Demolition sector regarding both late payments and non payments, it can be stated that the introduction of the statutory payment term in 2017, certainly in the long term, has not yet had the effects that would be expected in the first instance.

(Appendix B – Subcontractor A) “...but the majority of the contractors will not adhere to a new statutory payment term of 30 days. The contractors will say that they will stick to their own payment terms and subcontractors should just accept that”.

4.2.1.1 Securing themselves against non-payment in Dutch construction industry

In the Dutch construction industry there are some ways subcontractors are able to secure themselves against non-payment by the contractor. Lexology (2019) explained two of these possibilities. The statutory right of retention is considered a remedy for subcontractors in case of non-payment by contractors. In certain circumstances, subcontractors can deny contractors and third parties access to the project site, or part of the project site, by closing it off. Sometimes this right can also be invoked against a mortgagee. Furthermore, subcontractors may suspend work in case of non-payment by a contractor. Both the suspension right and right of retention can be duly exercised only if certain legal requirements have been met and have not been contractually waived. The security for collecting a claim after a court decision can be provided by a bank guarantee, if provided, or a pre-judgment attachment. In practice, subcontractors can attach all contractor assets, such as materials, equipment, real estate and bank accounts (Lexology, 2019).

So there are several options to punish large companies if they do not comply with the payment term, but this is hardly used in practice. ‘*SMEs can punish these organizations, but most don't, because it damages the relationship. You can forget about the next job*’ explains Rielèn van der Hoek, spokeswoman for the AFNL in the Cobouw (2017). When one of the interviewees was confronted with this statement by Ms van der Hoek, he replied with:

(Appendix B – Subcontractor A) “*If I have to, I will play it through my credit company, who will then write a number of letters and put on a lawyer to force the contractor to make the payment and usually the money will than come in otherwise you can proceed to seizure. The main contractors prefer not to take that risk*”.

4.3 Factors Causing Payment Problems

There are different factors associated with payment defaults in the construction industry. More than 20 years ago, Hughes et al. (1998) gave a clear explanation of why there are problems with payments in the construction industry. Payment default is primarily due to two reasons: the ‘cannot’ and ‘would not’ pay attitude of payers. The ‘cannot pay’ situation refers to payers’ financial difficulties due to failure to seek funding or not having sufficient equity capital and improper cash flow management. The ‘would not’ pay situation lies with payers’ attitude (Hughes et al., 1998). It seems common for clients or main contractors to delay payment in order to manage their cash flow for other projects and reduce their overdraft facilities. Cotter (2005) suggests that it is due to the inability to pay scenario and that late payments could be unintentional, although would also result in dire effects to players in the industry. On the other hand, Kenley (2002) in his paper gives an example of the unwilling to pay scenario, he notes that payment problems are deliberate; contractors hold up money and use it to pay other projects, or for their own benefits.

(Appendix C – Subcontractor B) "*On the jobs where I have been, I know that the client pays the installments on time and that the first term for the start of the work was also received by the contractor*".

(Appendix A – Chairman SME) "*Liquidity is the reason why a main contractor postpones payments, so the subcontractor becomes (co-)financer of the main contractor. The excuse is that the main contractor himself has to wait a long time for the validation and the payment, which is nonsense when working for example for the government*".

Earlier in this study it was discussed that subcontracting still continues to account for between 70 and 90% of construction works by contract value (Chiang, 2009; Hartmann and Caerteling, 2010). This means that substantial upfront cash expenses would need to be sourced by these bottom tier parties to a contract (Ramachandra and Rotimi, 2015). Consequently; these subcontractors are the worst hit by undercapitalized contractors that cause severe financial difficulties to parties down the chain by not paying them on time. Furthermore, Ramachandra and Rotimi (2015) in their study focused on the underlying factors causing payment problems, with the aim of devising ways of mitigating payment problems. The study found that the top five out of 28 causes of payment problems in the New Zealand construction industry are; cash flow problems due to delays and non-payments experienced on other projects, disputes over payment claims and responses, cash flow difficulties due to lack of initial capital, attitude of payers, easy exit of players, and the general payment culture of the industry.

(Appendix B – Subcontractor A) "*You have to see it this way, the main contractors, and we are talking about the big names in the Netherlands, Heijmans, BAM, have a profit percentage of about 1-2%. They work with the money they have to pay the subcontractor with, which can be used to support other projects but also to pay for the personnel. So if they are going to pay the subcontractor directly, they have to take a short-term loan from the bank to cover their own costs. It will all work out in the long run, but it just takes way too long*".

4.4 Impacts of slow payments

Payments are one of the construction industry's biggest problems with regards contractual entitlements being paid late, not being paid at all or being held up as a result of disputes which can often result in business failure (Cardeira, 2015). Subcontract work contains uncertainties with regard to recovering payments from contractors. The uncertainty in payment is increased for subcontractors and suppliers over contractors because of the uncertainty in payment behavior of the contractor. Developers and financiers may not realize their role in the overall cost of a project. In a survey conducted by Rabbet (2019), they asked 66 construction subcontractors in the U.S. if they considered a reputation for slow payments when deciding how much to bid on a project, 76% responded affirmatively. In fact, this indicates that construction costs could be saved for a main contractor if they pay on time.

An even more interesting result of the survey conducted by Rabbet (2019) is that the subcontractors asked in the survey do not only consider how much to bid, but 63% of subcontractors decided not to bid on a project in the last 12 months because of a general contractor or owner's reputation for slow payments. This indicates that due to their reputation they may miss out on the more specialized subcontractors. Moreover, you can no longer have

different subcontractors bid against each other to bring in the job. If you as a contractor do not have the reputation of a slow payer you will also notice that several subcontractors place a bid which could save costs for a main contractor. Getting the best bids from the best subcontractors is essential to managing project costs and schedules.

(Appendix B – Subcontractor A) “Take for example one of the largest contractors in the Netherlands, which adhere to the contractual agreement of a payment term of 30 days, but from the 30th of the month. So suppose that you have finished work on the 10th of the month, the payment term will only start 20 days later, which in the worst case can just cause you to receive the payment 2 months later...”

It has already been mentioned that 70% of the disputes regarding late payments were related to progress payments. Late payment of a progress payment entails great risks for the entire project which results sometimes in project delay. Delay in a construction project could be defined in two ways. As the time overruns either beyond completion date specified in a contract or beyond the date that the parties agreed upon for delivery of a project. When a subcontractor is not paid on time, he could be forced to stop working with the result that the project may come to a temporary halt. Delays lead to additional costs for the main contractor, and if delivery date is not met, in many cases even a fine from the client. Rabbet's (2019) survey revealed that 30% of all respondents report that work has been delayed or stopped due to a delay in payments to crew members in the last 12 month.

Furthermore, it is common in the construction industry for main contractors to expect a discount either for prompt payment (cash discount) or as a special dispensation for being ‘in the trade’. Trade discounts relate to price reductions from the normal retail list price of materials and are available exclusively for the trade. On the other hand, cash discounts should only be allowed if the contractor pays promptly for the materials of subcontract services, although this ‘rule of thumb’ is often overlooked in practice (Ross and Williams, 2013). Ross and Williams (2013) mentioned further in their book that on the other side it is also common practice for subcontractors to offer discounts to the main contractor and some standard and in-house forms of subcontract include express terms requiring the subcontractor to offer a discount. Such discounts are intended as a reward for prompt payment and, consequently, if payment is made by the main contractor accordance with the terms of the subcontract, a discount of (say) 2½% may be deducted from the subcontractors payment, this is a cash discount, see figure 4. In the survey conducted by Rabbet (2019), 72% of subcontractors would offer a discount for payments within 30 days, resulting in an estimated industry-wide savings of \$44 billion.

	£
Total of subcontract price	780 000.00
Add cash discount ^{1/39}	<u>20 000.00</u>
Total subcontract price	<u>800 000.00</u>
	less 2½% monthly account
Consequently £800 000 less 2½% = £780 000	

Figure 4: Example of discount of 2½% in English Pounds. (Source: Ross and Williams, 2013)

(Appendix C – Subcontractor B) “*Yes I would give that percentage discount if I was always paid on time. And I think a lot of subcontractors with me...*”

However, it should be noted that, as far as subcontractors discounts are concerned, many main contractors take their cash discount even when payment is made late. Such discounts are frequently regarded as a reduction of the subcontract price and main contractors claim the discount whether or not the subcontractors account is paid on time (Ross and Williams, 2013). There are different reasons why subcontractors accept this. Sometimes Subcontractors do not understand how discounts work and sometimes because subcontractors are in a poor bargaining position. A subcontractor cannot force a main contractor to pay up unless the issue is taken to adjudication or litigation and the main contractor knows that most subcontractors will not bother to do this, and possibly risk losing future work, for a relatively trifling amount of money (Ross and Williams, 2013). There are also examples of subcontractors who are keen on this and who do not give a discount for the reasons mentioned above.

(Appendix B – Subcontractor A) “*No, I would not do that with the knowledge I have now. I see that as giving away unnecessary gifts. In the past, contractors have said that they would transfer the money if necessary, but would like a discount in return*”.

4.5 The Benefits of Faster Payments

The beauty of the construction ecosystem is that everyone benefits from faster payments, if subcontractors get paid faster, they can remove financing expenses and lower the costs for the project (Rabbit, 2019). The goal is for every stakeholder to benefit from faster payments. So not only in the interest of the subcontractor but also in that of the contractor. As stated before, in the survey conducted by Rabbit in 2019 in the United States of America, 72% of subcontractors would offer a discount for payments within 30 days. When a subcontractor gives a discount, the contractor benefits from lower costs and so does the developer.

The study by Rabbit (2019) also shows that 95% of the surveyed contractors indicate that they see an added value in paying the subcontractor faster. While one would think that contractors consciously keep the money in cash, for example to receive interest on the money or to finance other projects. Rabbit (2019) explains why it takes so long for everyone to get paid. They stated that this complicated series of contracts and relationships are managed through outdated manual workflows — like spreadsheets, PDFs, and emails — that are not structured to be streamlined in the 21st century. Until the industry agrees to transact on a shared platform to enable information to flow more smoothly, everyone will continue to suffer from the costs of painfully slow payment cycles (Rabbit, 2019).

Moreover, it was previously stated that reports were sent by Rielèn van der Hoek, spokeswoman for the AFNL to contribute to this investigation. In addition to the reports, the results of a pilot that was carried out by MKB INFRA from the Netherlands in 2015 was also sent. The goal of the pilot was to test an alternative payment scheme in which invoicing takes place at the start of work; Payments are received as soon as (part of) the work is finished; payment is made within 1 week after contractor received money on his bank account; and a forecast of the work for the next 4 weeks is the basis for mid-term updates of the payment schedule to avoid discussions afterwards. A number of pilots were subsequently carried out in various municipalities,

resulting in a reduction of the pre-financing by as much as 85%, decrease of the balance sheet total by approx. 25%, fast payments and interest advantage. Results of the pilot conducted are encouraging for applying a new technology to change the existing payment rules.

(Appendix A – Chairman SME) “*Yes, technologies that automatically make payments after work has been done could solve the payment problem in construction and infrastructure. Our pilot proves that a lot of money can be saved with coming up with new solutions. This saving means that more can be delivered for the same municipal budget*”.

4.6 Pay-When-Paid and Pay-if-paid clauses

Interesting phenomena that will be out of the scope of this study but have been mentioned several times in this study are: pay-when-paid and pay-if-paid clauses. The payments a subcontractor receives from a contractor are not necessarily limited to the contract price. A client can change a contract on his proposal. The contractor will then be compensated for any additional costs in a financial sense. Changes to the contract between the contractor and subcontractor may also result in a change to the subcontract. It goes without saying that the subcontractor would in turn have to be financed by the contractor for any additional costs. In such cases, the contractor will want to subject its payment to its subcontractor to the condition that it has received the corresponding amount from its client. Common terms in the subcontracting contract to settle this contingent payment are the pay-when-paid and pay-if-paid clauses (van den Boogaart and Dröge, 2015).

In their article, van den Boogaart and Dröge (2015) further explain the difference between these two clauses. Pay-when-paid and pay-if-paid are related, but not strictly the same. Pay-when-paid means that the contractor is only obliged to pay to its subcontractor once the contractor has been paid by its client. It is generally accepted that pay-when-paid does not imply that the contractor has discharged its obligation to pay to the subcontractor if the contractor is not paid by its client. The debt collection risk therefore rests with the contractor. This is different for pay-if-paid, in which case the contractor is only obliged to pay to its subcontractor if and insofar as the contractor has received payment from its client. The collection risk is therefore passed on to the subcontractor (Rowles and Cahalan, 2020)

In addition to the collection risk, it applies to both pay-when-paid and pay-if-paid that it is often difficult for the subcontractor to keep track of payments from the client to the contractor. In those cases it is impossible for the subcontractor to determine how much the contractor is obliged to pay to him. Due to the risks associated with pay-when-paid and - in particular - pay-if-paid for the subcontractor, these concepts are not permitted under all legal systems. For example, the UK Housing Grants, Construction and Regeneration Act 1996 precludes payment by a contractor to a subcontractor involved in a project in England, Wales or Scotland being subject to the condition that the contractor has received payment from the client. In many other jurisdictions, including the Netherlands, pay-when-paid and pay-if-paid are allowed. However, this arrangement is not common and subcontractors in the Netherlands are usually paid in accordance with the activities (Chao-Duivis, 2013). Therefore, both clauses will be disregarded further in this research.

4.7 Requirements

Based on the results of the interviews supplemented with the quantitative results and a more extensive literature study, it can be concluded that the aforementioned payment problems are a true bottleneck that causes conflicts between contractor and subcontractor. Earlier it has been discussed what the influences are of conflicts between contractor and subcontractor on the progress of a construction project, and indirectly also on the productivity in construction project. This paragraph will list the requirements a solution should meet in order to solve the bottleneck and reduce conflicts between contractor and subcontractor during construction projects.

Payment terms

First and also the most important requirement for the solution is the possibility to prevent nonpayment and exceeding the payment term. In addition to this prevention, it would be an achievement if payment terms could be made a lot shorter than is currently laid down by law without a contractor experiencing liquidity problems.

Trust and Transparency

The in-depth literature study and the interviews have shown that there is a lack of trust and transparency with regard to the fulfillment of contractual agreements and payments between contractor and subcontractor. This is reflected in the urgency of bank guarantees and the taking out of credit insurance by subcontractors. Therefore, it is a requirement for the possible solutions to regain trust so that a contractor can expect a subcontractor to keep to the contract, whereas a subcontractor must be able to rely on payment being made on time. In addition to the trust in each other that must be recovered, it is also important that both the contractor and the subcontractor trust the solution.

Pre-financing and loans

The interviews revealed also how important it is for subcontractors to find a solution to the pre-financing problem. Pre-financing includes the costs incurred by a subcontractor for the project before any payment has been made. At the moment, a lot of the pre-financing is paid with loans that contain high interest rates. Payment of the interest is directly deducted from the profit, which is often passed on in the invoice to the contractor by the subcontractor.

Efficiency

The last important requirement is efficiency. Before an invoice is processed, many administrative actions are involved. With the digitization of the world, the possible solution should also be able to achieve efficiency gains in the construction sector. It is important to take into account that the possible solution can lead to higher costs, which must be saved elsewhere in the process by implementing the solution.

V. Blockchain Technology

In the previous chapter, a bottleneck that causes conflicts between contractor and subcontractor during construction projects was identified with the help of empirical findings in combination with an extensive literature study and quantitative results from research reports. Based on the same findings, requirements have been drawn up that a solution must meet in order to solve the identified bottleneck or field problem. The first paragraphs of this chapter will delve deeper into Blockchain technology in order to answer the sub-question: *What is Blockchain technology and how does it work?* After that, the requirements set out in chapter 4 will be further articulated on the basis of design propositions, based on CIMO-logic. Subsequently, in paragraph 5.5, it will be investigated whether there are already possible solutions for the identified field problem in the literature. In paragraph 5.6 all possible solutions that could solve the field problem will be mentioned and explained, after which the best solution will be chosen.

5.1 What is Blockchain?

The construction industry will continue to be a key driver of economic growth for any country. It is one of the biggest industries in the world which contributes heavily to the economic development of a country. However, the productivity and the effectiveness of the industry have often been called into a question in this research. The technology for which it will be examined with this research to what extent it can reduce conflicts between contractor and subcontractor during construction projects is Blockchain technology. Blockchain has been heralded as a game-changing technology across multiple sectors. Indeed, its influence on the financial sector is already profound (Tapscott & Tapscott, 2016). Its potential to streamline processes, manage identities and save money have given the technology a mystique that is perhaps enhanced by a lack of understanding about how it works by the general public. Many sectors are exploring whether it is worth pursuing, not least of which the Architecture, Engineering and Construction (AEC) sector (Lamb, 2018).

Blockchain is a shared, distributed ledger that facilitates the process of recording transactions and tracking assets in a business network. An asset can be tangible, for example a house, a car, cash, land, or intangible like intellectual property, such as patents, copyrights, or branding. Virtually anything of value can be tracked and traded on a Blockchain network, reducing risk and cutting costs for all involved (IBM, 2017). Blockchain, a technology based on distributed ledger (shared database) technology (DLT) was first widely introduced in 2008 by Nakamoto (2008) as the underlying technology of Bitcoin to solve the double-spend problem by using a decentralized peer-to-peer Blockchain network without the need of a trusted third party. By purportedly solving problems of identity, security and trust in digital transactions without the need to trust in a third-party, the developers were able to produce Bitcoin as the world's first decentralized currency and as a proof-of-concept. However, Blockchain has many other potential applications outside the world of digital currencies, therefore it is important to remind that Bitcoin and Blockchain are not the same. Blockchain provides the means to record and store Bitcoin transactions, but Blockchain has many uses beyond Bitcoin. Bitcoin is only the first use case for Blockchain (IBM, 2017). On the other hand, the potential of Blockchain technology should not be compromised either, it is not a magic bullet and it is important to separate the hype from the potentials of Blockchain in order to understand whether it is a technology worth applying for a raised field problem or not.

5.1.1 Benefits of a Blockchain for a Business

The possibilities with Blockchain are endless, for many problems Blockchain technology can offer a solution. The investments in Blockchain are also increasing every year since 2014, see figure 5. However, not every solution is suitable, efficient or cost-effective. For this reason it is important to determine to what extent Blockchain technology can offer a solution to the identified field problem. On the basis of the book: *Fundamentals of Blockchain* by IBM (2017), the benefits of Blockchain technology for a business will be proposed. Below these main benefits are summarized and explained:

- **Time savings:** Traditionally, the transaction takes a lot of time in processing and initialing into banking organization. The using of the Blockchain technology helps to reduce the time for the processing and initialing to many times – from approximately 3 days to several minutes or even seconds. Transaction settlement is faster, because it is not necessary to work with the third-party organization or with the central administrator.
- **Cost savings:** All participants on a Blockchain network are known; as a result less supervision is needed because the Blockchain network is controlled by the participants themselves. This allows valuable items to be exchanged directly without the need of intermediaries (third parties) which in turn saves costs.
- **Tighter security:** Blockchain security features protect against tampering, fraud, and cybercrime. If a network is permissioned (private network), it enables the creation of a members-only network with proof that members are who they say they are and that goods or assets traded are exactly as represented.

A permissioned network is critical for a Blockchain for business, especially within a regulated industry like construction. A permissioned network offers enhanced privacy, through the use of IDs and permissions, users can specify which transaction details they want other participants to be permitted to view (IBM, 2017). Translated to a building project, a contractor can therefore decide what subcontractor has any insight in which transaction. Permissions can be expanded for special users, such as auditors, who may need access to more transaction detail. A permissioned network offers also improved auditability which means that having a shared ledger that serves as a single source of truth improves the ability to monitor and audit transactions. Moreover, a permissioned network increases the administrative efficiency. Pure digitization of assets streamlines transfer of ownership, so transactions can be conducted at a speed more in line with the pace of doing business (IBM, 2017).

What is blockchain worth?

Investments are climbing as more companies take interest in distributed ledgers

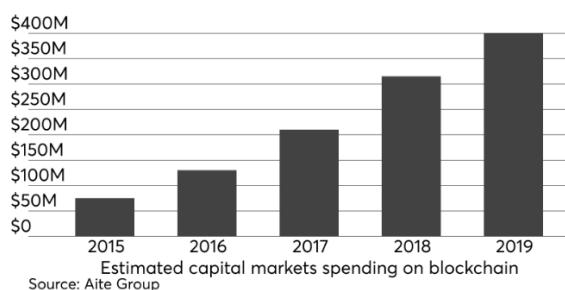


Figure 5: What is Blockchain Worth? (Source: Aite Group, 2019)

5.1.2 Blockchain Technology and Trust

Theoretically, trust is a social and psychological construct which is used to define the nature and quality of relationships between actors in a social system. Trust is not just an interpersonal phenomenon but is also of relevance to relationships within and between social groups such as families, friends, communities and organizations. This point is important in the context of construction project management where relationships exist at both interpersonal and inter-organizational levels (Chalker & Loosemore, 2016). Blockchain enhances trust across a business network. The main advantage of Blockchain is that involved parties do not need to trust when operating on a Blockchain network, regardless you can trust those who you conduct business with or not. Blockchain technology and trust go hand in hand because every transaction builds on every other transaction, any corruption is readily apparent and everyone is made aware of it (IBM, 2017). When oversight of a third party is needed, Blockchain can obtain as a solution by reducing the burden on the regulatory system by making it easier for auditors and regulators to review relevant transaction details and verify them. According to IBM (2017) Blockchain builds trust through four different attributes: Secure, private, and indelible; Transparent and auditable; Consensus-based and transactional; and Orchestrated and flexible. Below these four attributes are summarized and explained:

- **Secure, private, and indelible:** Permissions and cryptography prevent unauthorized access to the network and ensure that participants are who they claim to be. Privacy is maintained through cryptographic techniques and data partitioning techniques to give participants selective visibility into the ledger. By providing selective insight, for example during a construction project, various subcontractors cannot see anything about transactions to other subcontractors. Both transactions and the identity of transacting parties can be masked. After conditions are agreed to, participants can't tamper with a record of the transaction; errors can be reversed only with new transactions.
- **Transparent and auditable:** When participants in a transaction have access to the same records they can validate transactions and verify identities or ownership. Furthermore transactions are time stamped therefore they can be verified in real time by participants without the need for third party intermediaries.
- **Consensus-based and transactional:** All relevant network participants must agree that a transaction is valid. That can be two participants, but also multiple participants. After agreement the transaction can take place. This is achieved through the use of consensus algorithms. Each Blockchain network can establish the conditions under which a transaction or asset exchange can occur.
- **Orchestrated and flexible:** IBM (2017) addressed also in their book that because of business rules and smart contracts (that execute based on one or more conditions) can be built into the platform, Blockchain business networks can evolve as they mature to support end-to-end business processes and a wide range of activities.

5.2 How does a Blockchain work?

Now that it is clearer what Blockchain technology is, and what the benefits (especially for a business) can be if they start working with a Blockchain network, it will be explained how Blockchain actually works. The focus will be on a private, permitted Blockchain network for businesses because when applying Blockchain in a construction project it is dealing with private participants, namely a contractor and a subcontractor.

5.2.1 Why is it called Blockchain?

In his original white paper, Nakamoto (2008) defined an electronic coin, the Bitcoin, as ‘a chain of digital signatures’ known as the Blockchain. Blockchain owes its name to how it works and the manner in which it stores data, namely that the information is packaged into blocks, which link to form a chain with other blocks of similar information, see figure 6. As the number of transactions grows so does the Blockchain. IBM (2017) explained Blockchain in their book as Blocks that record and confirm the time and sequence of transactions, which are then logged into the Blockchain, within a discrete network governed by rules agreed on by the network participants. Each block contains a hash (a digital fingerprint or unique identifier); time stamped batches of recent valid transactions, and the hash of the previous block. The previous block hash links the blocks together and prevents any block from being altered or a block being inserted between two existing blocks. In this way, each subsequent block strengthens the verification of the previous block and hence the entire Blockchain. A major advantage of the method used by Blockchain is the invalidity and immutability of the database. In fact, Blockchain serves as a database for registering transactions, but the benefits and possibilities of Blockchain technology go far beyond the traditional databases that are used in businesses from different sectors these days (IBM, 2017).

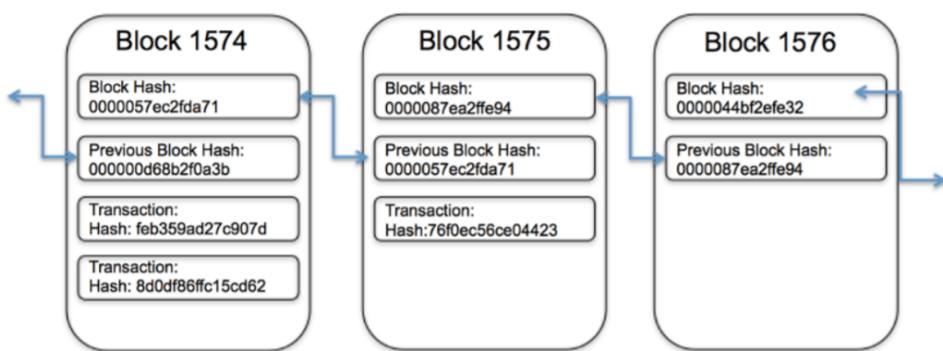


Figure 6: Blockchain stores transaction records in a series of connected blocks (Source: IBM, 2017)

5.2.2 Key concepts of Blockchain

During this study the focus will be on a Blockchain that can be applied in business, in particular business in the construction sector. A Blockchain for a business is a private, authorized network with known participants. IBM (2017) states in their book that there are four key concepts that must be understood by the reader before the potential of Blockchain can be appreciated; shared ledger, permissions, consensus and smart contracts. Each of these concepts will be described and explained below.

5.2.2.1 Shared Ledger

The shared ledger paradigm, as exemplified by Blockchain, was first introduced in Bitcoin by Nakamoto (2008) to enable a crypto currency, but a number of industries are seeing strong potential for generalizations that will dramatically increase the efficiency of many different kinds of business collaboration. Ledgers are nothing new they have been used in double-entry bookkeeping since the 13th century. What is new is the concept of a shared, distributed ledger. Shared Ledger Technologies (SLT) provide a new framework for supporting business collaborations that is based on having a high-reliability, shared, trusted, privacy-preserving, data repository (Hull et al., 2016). With a shared ledger, transactions are recorded only once, eliminating the duplication of effort that's typical of traditional business networks. Thus, a shared ledger registers all transactions in the business network, the shared ledger is the system of record and therefore also the only source of truth.

5.2.2.2 Permissions

Blockchain can be permissioned or permissionless. To return to the earlier example, Bitcoin is an instance of permissionless Blockchain, which is open and decentralized. Any peer can join and leave the network as reader and writer at any time. Interestingly, there is no central entity which manages the membership, or which could ban illegitimate readers or writers. This openness implies that the written content is readable by any peer (Wüst and Gervais, 2018). However, it is technically feasible to design a permissionless Blockchain which hides privacy relevant information but in the case of privacy, a permissioned Blockchain is often used. To only authorize a limited set of readers and writers, so called-permissioned Blockchains have been recently proposed (Wüst and Gervais, 2018). With a permissioned Blockchain, each participant has a unique identity, which enables the use of policies to constrain network participation and access to transaction details, see figure 7. With the ability to constrain network participation, organizations can more easily comply with data protection regulations. From a business point of view it is very important that not everyone has insight into all transactions that have taken place. According to IBM (2017) permissioned blockchains are also more effective at controlling the consistency of the data that gets appended to the Blockchain. With the ability to restrict access to transaction details, more transaction detail can be stored in the Blockchain, and participants can specify the transaction information they are willing to allow others to view. In addition, some participants may be authorized to view only certain transactions, while others, such as auditors, may be given access to a broader range of transactions.

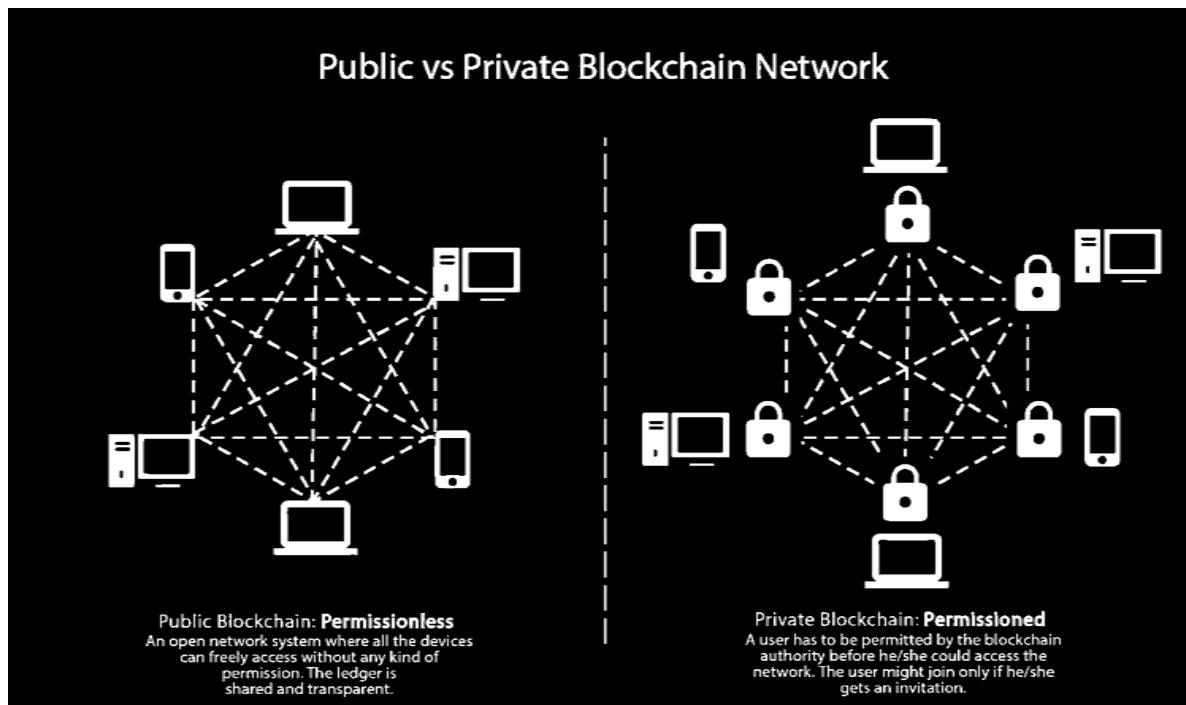


Figure 7: Permissionless vs. permissioned Blockchain Network (Source: 101Blockchains, 2019)

5.2.2.3 Consensus

In Blockchain, consensus is the process of agreeing on what the ledger's "true" contents are. The consensus mechanism forms the foundation of the trust one places in a Blockchain based ledger. In its simplest form, forming a consensus simply means that the set of computers maintaining a Blockchain agree that any particular block in the chain contains data that is a semantic component of the ledger, and that such a block is correctly ordered/positioned in the Blockchain (Novotny et al., 2018). On the surface, forming a consensus seems like it might be a simple problem, and in a perfect world, it might be, but in the real world many things can go wrong. The main challenge is protecting the process in the face of ongoing disruptions, including overt attempts by nefarious actors attempting to alter the ledger to their benefit, or to simply delay or disrupt the consensus process itself. Furthermore, hackers for instance, might compromise one or more of the machines maintaining the Blockchain and send out contradictory or confusing communications to the others. Other disruptions include transmission delays, equipment failures (machines do crash, and the power does fail), and software bugs (Novotny et al., 2018). The nodes (network participants) in the Blockchain network operate under the fact that there is no central authority governing over them. In a perfect scenario, all the members of the network always agree on the same new block to be appended to the Blockchain and there exists only a single Blockchain in the whole network. In reality, however, nodes might get disconnected from the network. Thus, a fault-tolerant consensus protocol is required which is agreed by all the nodes in the Blockchain to resolve any potential conflict. In a business network where participants are known and trusted, transactions can be verified and committed to the ledger through various means of consensus. IBM (2017) lists three in their book, including the following:

- **Proof of stake:** To validate transactions, validators must hold a certain percentage of the network's total value. Proof-of-stake might provide increased protection from a malicious attack on the network by reducing incentives for attack and making it very expensive to execute attacks.
- **Multi-signature:** A majority of validators (for example, three out of five) must agree that a transaction is valid.
- **Practical Byzantine Fault Tolerance (PBFT):** An algorithm designed to settle disputes among computing nodes when one node in a set of nodes generates different output from the others in the set. Blockchain for business features *pluggable consensus* — a way to implement whichever consensus mechanism is deemed best for any given industry segment.

5.2.2.4 Smart contract

The last key concept of Blockchain is a smart contract. The phrase “smart contracts” was coined by computer scientist Nick Szabo all the way back in 1994, just as the first full text web search engines were beginning to be launched. Nick Szabo (1997) believed that a variety of contractual clauses can be attached in the hardware and software in a manner to make the breach of contract expensive. According to Nick Szabo (1997), a smart contract is a computerized transaction protocol that implements the terms of the contract. The main advantages of using smart contracts besides traditional contracts is the efficiency of the contractual process, e.g. using smart contracts allows easily to maintain an overview of the past behavior of contracting parties. Contract terms are self-enforceable and can include references to legal contracts. Smart contracting minimizes the risk of malicious and accidental exceptions and the necessity for trusted intermediaries. Smart contracts today have now developed in terms of technological innovation and legal construction but the definition of a “smart contract” is still materially the same as Szabo defined more than 20 years ago (FinTech Network, 2017)

Smart contracts extend and leverage Blockchain technology. A smart contract is a collection of code and data (sometimes referred to as functions and state) that is deployed using cryptographically signed transactions on the Blockchain network (Yaga et al., 2018). The smart contract is executed by nodes (Blockchain network participants) within the Blockchain network; all nodes that execute the smart contract must derive the same results from the execution and the results of execution are recorded on the Blockchain. Blockchain network users can create transactions which send data to public functions offered by a smart contract. The smart contract executes the appropriate method with the user provided data to perform a service. The code, being on the Blockchain, is also tamper evident and tamper resistant and therefore can be used (among other purposes) as a trusted third party. A smart contract can perform calculations, store information, expose properties to reflect a publicly exposed state and, if appropriate, automatically send funds to other accounts (Yaga et al., 2018). However, it is important to note that not every Blockchain can run smart contracts. The smart contract code can represent a multi-party transaction, typically in the context of a business process. In a multi-party scenario, the benefit is that this can provide attestable data and transparency that can foster trust, provide insight that can enable better business decisions, reduce costs from reconciliation that exists in traditional business to business applications, and reduce the time to complete a transaction (Yaga et al., 2018).

5.3 Blockchain in Construction Industry

One of the main issues hindering the modernization of the construction industry is its inability to embrace technological advancements in comparison with successes seen in logistics, automotive and mechanical engineering industries. Blockchain, or distributed ledger technology (DLT), is regarded as having the potential to transform many global industries including construction (Li et al., 2019).

Many researchers have expanded their research in many operations in the construction industry. In various articles suggestions are given on how Blockchain could improve the construction industry; Novotny (2018), Turk and Klinc (2017) have discussed in their paper how Blockchain technology can communicate with the delivery of a project along with smart contracts. From Hewavitharana et al. (2019) point of view, the quality and the accuracy of the surveying data can be enhanced with the Blockchain technology as it allows storing a large number of previous records. According to McKinsey global institute (2017), Blockchain is capable of handling government policies which need to be fulfilled for the sustainable development. According to Dakhli et al. (2019), Blockchain could have potential impact, in terms of cost, for a real estate developer. From the above examples it can be stated that the studies into the application of Blockchain in the construction industry are very diverse. However, most articles are based on the potential of Blockchain instead of solving the problems that limit construction in its productivity at the construction site.

5.4 Design Propositions

In this paragraph, the requirements outdated in chapter 4 will be elaborated into design propositions based on CIMO-logic. The interventions in those design propositions form the basis of the solutions to be worked out, which will be explained in the following paragraphs.

Payment terms: The field problem is payment problems in the construction industry that causes conflicts between contractor and subcontractor (C). The intervention is using a technology in which payment agreements can be recorded unconditionally (I). When recording the payment agreements unconditionally, then the agreements must be kept (M) and the desired outcome is no late or non-payments in construction projects which will reduce the number of conflicts (O).

Trust and Transparency: The field problem is payment problems in the construction industry that causes conflicts between contractor and subcontractor (C). The intervention is using a technology that can be trusted and can provide confidence (I). The technology must demonstrate that it can provide trust and transparency (M) and the desired outcome is that bank guarantees and credit insurance become superfluous (O).

Pre-financing and loans: The field problem is payment problems in the construction industry that causes conflicts between contractor and subcontractor (C). The intervention is using a technology in which payments are carried out more often and in smaller quantities to the subcontractor (I). Therefore, it must be possible to record multiple payment arrangements (M) and the desired outcome is less overhead costs for the subcontractor (O).

Efficiency: The field problem is payment problems in the construction industry that causes conflicts between contractor and subcontractor (C). The intervention is using a technology which can process invoices automatically (I). Payment arrangements must therefore be programmable and automated (M) and the desired outcome is reduction of liquidity problems for the contractor (O).

When combining the solution concepts (I), two technologies could serve as a solution: a Traditional Database and Blockchain Technology

5.5 Project Bank Accounts

Based on the identified bottleneck in chapter 4, it was also examined whether there are already possible solutions for this problem in the literature. An interesting phenomenon, Project Bank Account (PBA), was encountered in the article: *Blockchain in the built environment and construction industry: A systematic review, conceptual models and practical use cases* by Li et al. (2019). In 2005, a solution was devised in the United Kingdom to prevent the impacts of insolvencies, non-payment and late payments by the National Audit Office, namely Project Bank Accounts (PBA). A PBA is an electronic bank account that is set up by the client or the client and the main contractor to ring-fence funds for different contractors by putting the funds into a trust. Once triggered by completion of contractual obligations, payments are made by the client directly and simultaneously to members of the supply chain associated with it. However, it is good to say that the project bank accounts are managed manually. The risk of fraud will therefore always remain because, for example, the contractor can influence the bank so as not to pay out the subcontractor on time.

5.6 Traditional Database

A frequently recurring question in a research related to Blockchain technology is: *Do I actually need Blockchain technology to solve this problem or can I not just use another solution?* Based on the design propositions, it can be stated that a traditional database can also be used as a solution. In order to get an answer to the question whether Blockchain technology can be better applied to solve the problem identified in chapter 4: Identifying Bottleneck, it will first be determined what the possibilities are with a traditional database. After this, both possible solutions will be compared with each other in order to determine which solution fits best to solve the field problem.

Recently, the European Commission has announced 30 billion on new investments in technology initiatives including those involving Blockchain (EU Government, 2018). However, there is considerable debate in the community about the value of Blockchain over a shared database. For example, in the paper of Chowdhury et al. (2018) Narayanan contends that private blockchains are just another name for a shared database. Others, in the same paper like Greenspan, see several differences between private blockchains and Structured Query Language (SQL) databases. From trust building to robustness Blockchain can be seen as a very new technology, which is why the previous paragraphs explained in detail what Blockchain technology is, how it works and what its features are. Since a traditional database has been used for decades, most are familiar with the use of a traditional database.

Traditional databases, unlike Blockchain, are centralized ledger which is run by an database administrator (DBA). A traditional database also exhibit unique feature including the ability to read and write. Here, only the parties with proper access can do write and read actions. Traditional databases also exhibit the ability to store multiple copies of the same data and their history. This is done with the help of a trusted centralized authority who manages the server. A database utilizes data structure to store information. All the data that is stored in a database can be queried using a special querying language known as Structured Query Language (SQL) (Singh, 2020). SQL is a programming language used by almost all relational databases to search, manipulate and define data and to manage access. SQL was first developed at IBM in the 1970s and has led to many extensions from companies such as IBM, Oracle and Microsoft. Although SQL is still widely used today, new programming languages are beginning to emerge (Oracle, 2014). A database can work with almost every type of data and can help support all the modern enterprises out there. Also, it can be scaled to support millions of records (Singh, 2020). Traditional databases use client-server network architecture where a user can modify data that is stored on a centralized server. A single authority controls the database and authenticates a client's credentials if they want to access it. This means that read and write access is only possible via applications that are controlled by the entity. If the security of the single authority is compromised, the data can be altered, deleted, or leaked to the public (Yanowitz, 2018). Moreover, just like with a smart contract enabled by Blockchain, payment arrangements can also be recorded and automated in, for example, an oracle database. In addition, payments can also be made more often and faster using a database. The efficiency criterion can also be reached by using a database. However, when using a database, someone will always have access to the data. A third intermediary can therefore always be manipulated, which means that there could always be suspicion on the part of the party that has no influence on the DBA. This limits the trust aspect that must be created with the help of a solution.

5.6.1 Advantages of Traditional Database

In terms of speed and performance Blockchain, especially Bitcoin, is notoriously slow. This is because Blockchain works on a consensus mechanism wherein effort must be expended in ensuring that nodes in the network reach consensus. For example, it takes 10 minutes to confirm a transaction in the network. This time could go up to 60 minutes if there is any soft fork happens in the network. Traditional databases have been around for decades and have seen their performance increase every year. Centralization brings many benefits to the database. For example, online payment systems. Traditional database systems can be designed to handle thousands of transactions per second. Thereby, If the DBA finds a performance bottleneck, he can replace or re-engineer the system to allow high volume of transaction (Chowdhury et al., 2018).

Furthermore, a misconception about Blockchain is that data in Blockchain is kept encrypted. However, this is not true. The data is digitally signed by the transacting parties but not by default encrypted. In fact, it is an open ledger system, where anybody can join and verify any transaction in the network. The privacy or confidentially of the participating parties are kept by using public key cryptography. The transactions reveal the transacting parties and the data in the transaction (e.g., amount of coin in case of crypto-currency). For many applications, especially financial, the full transparency enjoyed by every node in a Blockchain network is an absolute deal-killer. In traditional databases, only one central location has full visibility into a database's contents.

Requests to read data also go through this central authority, which can accept or reject those requests as it sees fit.

5.6.2 Traditional Database vs. Blockchain

Chapter 4 Identifying Bottleneck revealed that a contractor has control over when payments will be made during a construction project. It has also emerged that various tricks can be applied to delay payment if necessary. As a result, many subcontractors have lost trust in the contractor, which also explains why bank guarantees and credit insurance still need to be taken out today. It is therefore very important that the solution can ensure trust between the contractor and the subcontractor. For this, any third party that could manipulate the data must be excluded.

Data can automatically identify and correct itself based on coded business logic and consensus, because of this, participants are intrinsically able to trust it. When two businesses work together, they almost never share a single database with a single set of records, because the database is being maintained and updated by a database administrator (DBA) (Baalessanvu, 2020). That DBA is being paid by one of the companies, in this case for example the contractor, and thus has a stake in the success of the contractor but not necessarily the subcontractor. If they want to make a change that benefits their company, the subcontractor would never know. Alternatively, on a more nefarious note, if a competitor decides to pay off the DBA, they can make any change they want to the database without either participant ever knowing (Baalessanvu, 2020). When Blockchain technology is incorporated into the data process, you remove the single point of failure, in this case the DBA, after the data corrects itself, the unalterable record of changes will also indicate which participant tried to make the change. With the data process secured, a business can trust the data shared between the contractor and subcontractor.

There are features such as performance, confidentiality and privacy which favor a traditional database. However, this can be refuted by the various protocols that are under development, with the aim of guaranteeing the privacy of companies that use a Blockchain platform. In addition, developers are busy improving the performance of various Blockchain platforms. This confirms that there are possibilities to catch up on those points compared to a traditional database, with the very important aspect, Trust, as an extra addition.

Moreover, returning to the PBA's discussed in paragraph 5.4. A next generation of the PBA could be a smart contract enabled by a Blockchain. Like PBA, a smart contract also has the possibility to include funds in a contract and to protect subcontractors against bankruptcies. PBA's are managed manually whereby a smart contract could be automated. This increases efficiency, creates shorter payout periods and minimizes risk of fraud, back office costs and operational risks (Nowiński and Kozma, 2017). To conclude, based on the above comparisons, with corresponding substantiation, a Blockchain Solution will be further elaborated in the next chapter to a level that validation by experts in Chapter 7 can be properly performed.

VI. Blockchain Solution

Chapter 5 explains what Blockchain technology is. In addition, based on CIMO-logic design propositions have been drawn up and it has been explained why Blockchain technology is a better solution than a traditional database for the field problem identified during this study. In this chapter, A Blockchain solution will be further elaborated so that the solution can be validated in chapter 7. Initially, the current payment procedure will be described and schematized in paragraph 6.1. After that, The Blockchain solution will be described and schematized in paragraph 6.2. The two schemes will be used as a tool to demonstrate the problem and present the solution to the experts who will validate the solution. Moreover, in this chapter the following sub-question will be answered *What does a Blockchain solution that could reduce conflicts look like?*

6.1 Current payment procedure

As explained above, the current payment procedure will be first discussed. It will be explained in detail how the current payment procedure works so that the differences with the new situation where payments through Blockchain will expire, could be made visible. To explain the current situation, two different sources were used, the respondents interviewed in chapter 4 and the general purchasing and subcontracting conditions of Heijmans (2016), a major contractor in the Netherlands, see appendix G. Before looking at the diagram of the current payment procedure, some important terms will first be explained that are related to the current payment procedure.

6.1.1 Formation and Content of the subcontract

It starts with the creation and content of a subcontract. After a contractor has accepted the work of a client, the subcontractor must guarantee that the bid made will not be withdrawn for 6 weeks. In the event that the subcontractor submits his offer in the context of participation in a tendering procedure by the contractor, the subcontractor must guarantee that the bid made will not be withdrawn up to six months after the contractor has accepted the project from the client. If the subcontractor is assigned to carry out the work, the subcontractor must return the contract concluded by mutual agreement, unaltered and signed, to the contractor within 14 days of the date of sending the contract. A subcontractor therefore has 14 days to object to the content of the agreement. If the subcontractor has already started with the implementation, the agreement is automatically accepted on the conditions as stated in the agreement. The agreement between the contractor and subcontractor includes all technical and administrative provisions of the applicable specifications, relating to the main contracting agreement between the client and the contractor and everything else whereby the contractor is connected to the client under the main contract agreement, insofar as this is directly or indirectly related to the agreement between the contractor and subcontractor.

6.1.2 Bank guarantees and Credit Insurance

The contractor who assigns a work to a subcontractor naturally expects the subcontractor to perform the work in accordance with the subcontracting agreement. The subcontractor, in turn, expects the contractor to fulfill his payment obligation. However, as explained earlier in this study, this is often not the case, as a result of which the realization of the construction project unexpectedly comes into question and the parties fail to fulfill their obligations under the building contract. However, the contractor and subcontractor can contractually cover such

undesirable events prior to construction by means of financial security. Usually this takes the form of a Bank Guarantee (BG). According to the new Civil Code 89/2012, a BG can be defined as follows: "A financial guarantee is created with a statement from the guarantor in a guaranty that it will satisfy creditors based on the guaranty up to a specified amount of money if the debtor fails to fulfill a specific debt to the creditor or if other conditions defined in the guaranty are met. If issued by a bank, a foreign bank or a savings and loan association such financial guarantee is called a bank guarantee". A BG is therefore an agreement between the subcontractor and the bank in which the BG to pay a maximum amount to the contractor during the term of the bank guarantee if the contractor is entitled to this because the payment conditions - included in the BG - have been met. This gives the contractor certainty that the subcontractor can and will fulfill his contractual obligations (or replacement compensation). The amount of this bank guarantee, whether or not expressed as a percentage of the contract price, is often determined in the special conditions of the subcontracting agreement. In many cases, a contractor requires that proof of this BG must be in their possession within thirty days of the conclusion of the subcontracting agreement. Furthermore, research by Chovancova et al. (2019) has shown that insufficient attention is given to all of the issues related to financial guarantees and the depiction of their costs in the cost price of construction contracts; their research show that the share of bank guarantees in the cost price is not negligible. The importance of BGs rises during periods of recession and logically from the increased risk that the investor must face. An accurate depiction of the costs incurred for BGs has proven to be very complicated in reality (Chovancova et al., 2019).

Against the BG, which serves as a guarantee for the contractor, subcontractors often defend themselves against the contractor's default by taking out credit insurance. Credit insurance protects the subcontractor against the damage he suffers from unpaid invoices. Simply explained, credit insurance provides more certainty that the subcontractor will be paid on time. The subcontractor receives money from the insurer if the contractor is unable to pay for the services provided by the subcontractor through, for example, a bankruptcy or suspension of payment. With credit insurance, a subcontractor pays a premium on his turnover. When the subcontractor receives money from the insurance company, because the contractor does not pay on time, the insurance company takes over the claim and then tries to get paid by the contractor. Just like Bank Guarantees, credit insurance also entails costs and the percentage covered by claims payments often amounts to between 75% and 85% of the turnover of the subcontractor (KVK, 2020). So in addition to the costs of taking out insurance, the subcontractor also often loses a large part of his turnover in the event of nonpayment by the contractor.

6.1.3 Inspection and Approval

The subcontractor must perform the work according to the requirements of good and sound work as stipulated in the agreement between the contractor and subcontractor. Inspection of the work must be requested from the contractor, stating by the subcontractor on which day the work will be completed. Usually this request is submitted in writing, unless agreed otherwise by the contractor and subcontractor. The inspection of completed work must be carried out by the contractor as soon as possible, the day and time of the inspection will be made known to the subcontractor at least 3 days before the inspection. After the contractor has approved the work, the subcontractor receives a written approval of the work; the receipt.

6.1.4 Invoicing and payment

If the subcontractor has fulfilled all his obligations under the agreement, the subcontractor can invoice the agreed price to the contractor. The subcontractor's invoices may relate only to the construction site and to the works actually performed as stated in the attached and approved written approval of work (the receipt). The invoice will always state the contractor's references, as stated at the top of the subcontracting agreement. It also states the correct accounting imputation, as communicated by the contractor. Furthermore, the invoice submitted must be accompanied by the original of the cumulative and detailed approval of work, signed by the contractor's representative on the construction site. The invoice must be submitted to the branch / district office of the relevant subsidiary acting as the contractor, unless a different method of invoicing has been agreed. After this, the payment term starts, with the contractor making payment within 60 days. As mentioned earlier in this study, 60 days is also the statutory maximum payment term. Payments will be made on the basis of an agreed term schedule in the contract, or if it is missing, after completion of the work. Furthermore, in many situations, the subcontractor is often obliged to submit his final invoice to the contractor within 4 weeks after delivery.

6.1.5 Diagram Current payment procedure in a construction project

Now that the current payment procedure and what it involves is discussed, a diagram can be drawn up. This diagram will only show the actions from a construction project that is directly or indirectly linked to a payment from contractor to subcontractor.

A number of accepted contract conditions for drawing up this diagram will be assumed:

- The contractor and subcontractor have agreed on payment in terms. Whereby each term is linked to a number of activities that must be carried out by the subcontractor before he can claim completion of the relevant term.
- The diagram will only show the course of the first term and the duration it will take before the contractor makes the first payment to the subcontractor.
- Hereby, we assume in the diagram that the activities linked to the first term are completed approximately 3 weeks after the start of the project
- Moreover, it is assumed that the project will start on Monday July 1, 2019.

This result in the following diagram, see figure 8:

Current Payment Procedure

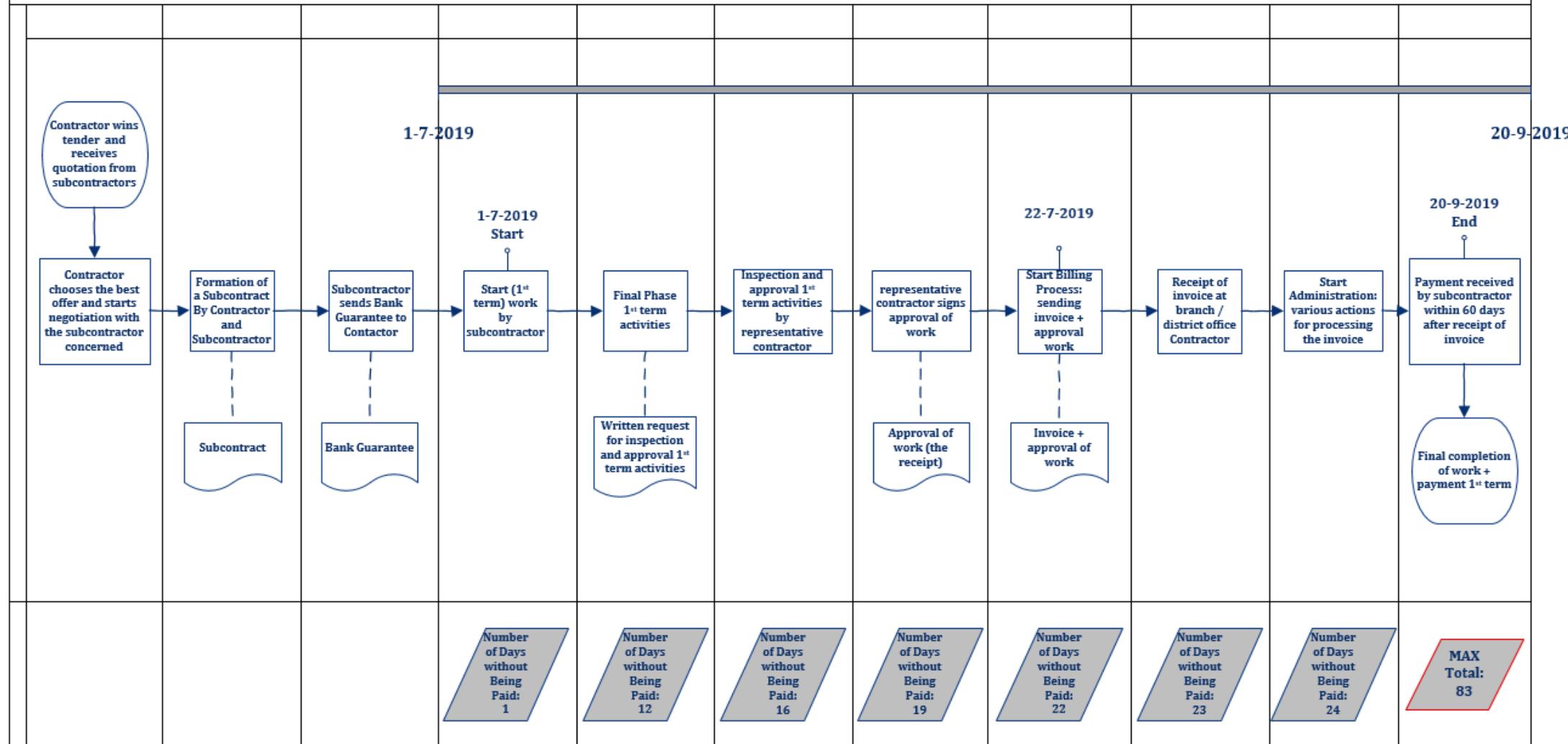


Figure 8: Diagram of the current payment procedure in the construction industry

6.2 Payment through Blockchain

This paragraph will explain what the new payment procedure will look like with the application of Blockchain, or to be more specific, with the application of a smart contract enabled by a Blockchain. First of all, there will be a look back at what a smart contract is, supplemented with an explanation of how a lifecycle of a smart contract looks like. After that, it will be explained step by step how applying a smart contract in a construction project will look like.

6.2.1 Lifecycle of a Smart Contract

Chapter 5: Blockchain Technology has briefly explained what a smart contract is and how it works. This subparagraph will further elaborate on this. As mentioned earlier, according to Nick Szabo (1997), a smart contract is a computerized transaction protocol that implements the terms of the contract. The main advantages of using smart contracts besides traditional contracts are the efficiency of the contractual process. Contractual clauses that are embedded in smart contracts will be enforced automatically when a certain condition is satisfied. Blockchains are enabling smart contracts. Essentially, smart contracts are implemented on top of blockchains (Zheng et al., 2019). The approved contractual clauses are converted into executable computer programs. The logical connections between contractual clauses have also been preserved in the form of logical flows in programs, for example using IF-THEN statements. The execution of each contract statement is recorded as an immutable transaction stored in the Blockchain. Smart contracts guarantee appropriate access control and contract enforcement. In particular, developers can assign access permission for each function in the contract. Contract enforcement ensures that the contract execution is deterministic. Once any conditions in a smart contract are satisfied, the triggered statement will automatically execute the corresponding function in a predictable manner (Zheng et al., 2019).

According to Sillaber and Waltl (2017), the life cycle of a smart contract typically consists of four broad phases, see figure 9. These four phases are creation of the smart contract, freezing of the smart contract, execution of the smart contract and finalization of the smart contract. In their paper they explained each phase as follows:

- Creation of a smart contract: The creation phase can be divided into an iterative contract negotiation and an implementation phase. First, the parties have to agree on the broad content and objectives of the contract. This can be done online or offline and is similar to classic contract negotiations. All participating parties must have a wallet on the underlying ledger platform. Its identifier is in most cases pseudonymous (Tschorß and Scheuermann, 2016) and it is used for the identification of the parties as well as of the transfer of funds. After agreeing on the objectives and content of the contract, the agreement has to be turned into code. To validate a smart contract's execution behavior and content, most smart contract environments provide the infrastructure to create, maintain and test the contract. As can be seen in classic programming languages, the transformation of requirements into code requires several iterations between the stakeholders and programmers. Smart contracts will be no different and will probably require much iteration between the negotiation and implementation phase. After the parties agree to the codified version of the contract, it is submitted to the distributed

ledger during the publication phase. Moreover, smart contracts cannot be modified after being accepted by the Blockchain, changes in the smart contract are not possible and require the creation of a new contract.

- Freezing a smart contract: After the smart contract has been submitted to the Blockchain, it is persisted by a majority confirmation of the participating nodes. In exchange for this service, and to prevent a flooding of the ecosystem with smart contracts, a fee has to be paid to the miners. From this point onward, the contract and all parties are public and accessible through the public ledger. During the freeze phase, any transfers made to the wallet address of the smart contract are being frozen and the nodes take on the role of a governance board, ensuring the preconditions for executing the contract are met.
- Executing a smart contract: Contracts that are stored on the distributed ledger are read by participating nodes. The contract's integrity is validated and the inference engine of the smart contract environment (compiler, interpreter) executes the code. The inputs for the execution are collected from the smart oracles and involved parties (commitment to goods through coins) and the smart contract's functions are executed. The execution of the smart contract results in a set of new transactions as well as a new state of the smart contract. The set of results as well as the new state information are submitted to the distributed ledger and are validated through the consensus protocol.
- Finalize a smart contract: After the smart contract has been executed, the resulting transactions and the new state information are stored in the distributed ledger and confirmed according to the consensus protocol. The prior committed digital assets are transferred (unfreezing of assets) and with the confirmation of all transactions, the contract has been fulfilled.

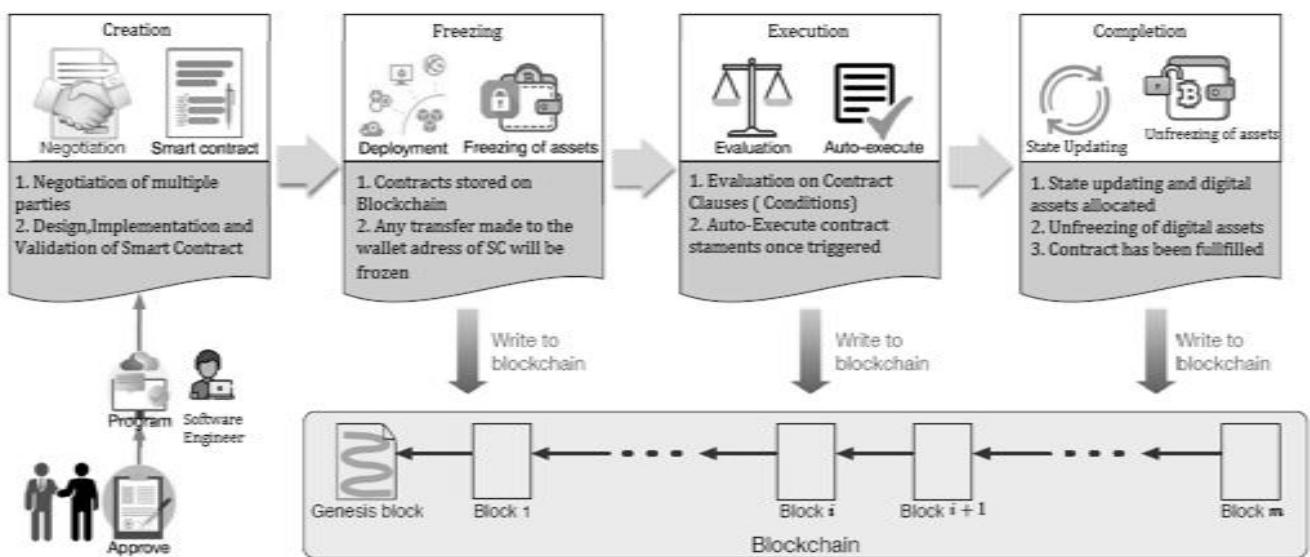


Figure 9: Lifecycle of a smart contract (Source: Zheng et al., 2019) adapted by the author of this thesis (2020)

6.2.2 Proof-of-Existence (PoE)

Paragraph 6.2.1 explains what a smart contract is and how the life cycle of a smart contract looks like. Since this study is dealing with an exceptional case, namely the application of a smart contract in a construction project, the lifecycle of the smart contract will deviate from how it is explained in the literature. Below it will be explained step by step what the implementation of a smart contract in a construction project will look like.

Paragraph 6.1.1 formation and content of the subcontract explains how a contract between contractor and subcontractor is concluded and what the content of this contract is. In the new situation where payments will be made via smart contract enabled by Blockchain, the formation and content of the contract will not differ from the current situation. However, the contract must be digital, for example by having the paperwork signed, then scanning it and saved as a PDF-document. After this, the digital subcontract must be uploaded to a web application called Proof of Existence.

Validating the existence or the possession of signed documents is very important in any legal solution. The traditional document validation models rely on central authorities for storing and validating the documents, which presents some obvious security challenges. These models become even more difficult as the documents become older. The Blockchain technology provides an alternative model to proof-of-existence and possession of legal documents. Proof of Existence is a simple service that allows one to anonymously and securely store online proof of existence of any document. This service simply stores the cryptographic digest, its SHA256 digest of the file in the Blockchain, linked to the time in which a user submits his document (AIR, 2016), see figure 10.

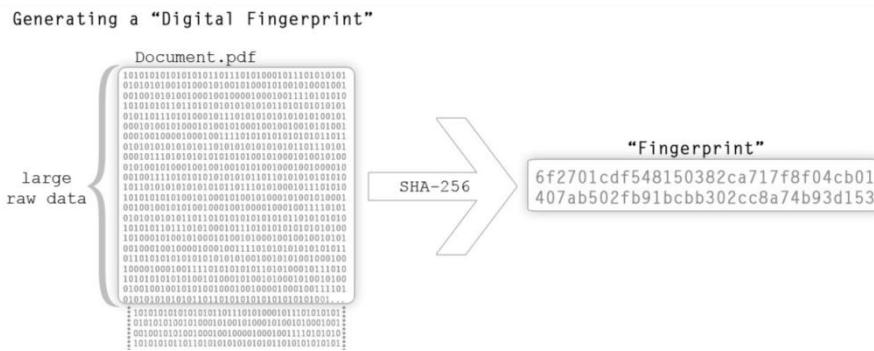


Figure 10: Generating a Digital Fingerprint (Source: Moai, 2016)

It is worth noting that the cryptographic digest or simply said, a digital fingerprint is what is stored on the Blockchain, and not the actual document, see figure 10. In this way, the user does not need to worry about the privacy aspect and protecting his information. This allows then a user to later certify the existence of a document that existed at a certain time. By leveraging the Blockchain, a user can simply store the signature and timestamp associated with a legal document in the Blockchain and validate it anytime using native Blockchain mechanisms. The major advantages of this service are security and privacy that allow a user to give decentralized proof of the document that cannot be modified by a third party. The existence of the document is validated using Blockchain that does not depend on a single centralized entity (AIR, 2016).

The subcontract is uploaded on the Blockchain so that later during the drawing up of the smart contract, reference can be made to the fingerprint of the original subcontracting agreement, which will make the smart contract also (partly) legally binding. If disputes arise with regard to the content of the smart contract, the subcontract can be demonstrated using the unique fingerprint and it can be proved that the undersigned subcontract already existed at a certain moment of time. As Blockchain is used to store the document proof, the existence of the document can be certified without the need of a central authority. Moreover, once the contract is signed and put on the Blockchain and somebody tries to re-upload it, the system will only recognize it if it is completely and fully the same document. The slightest change will be recognized that is different from the original document, which gives the security that certified data cannot be changed

6.2.3 Creating a Smart Contract

After the signed subcontract has been uploaded on a Blockchain and a fingerprint has emerged from it, a software developer/programmer who can write the smart contract code can be contacted by the contractor. The smart contract will be programmed on a Blockchain that can run smart contracts, e.g. Ethereum. The smart contract could be written in a programming language called Solidity, which is a language similar to JavaScript. The smart contract will initially refer to the subcontracting agreement and its identical fingerprint. The original subcontracting agreement will form the basis for the smart contract. It is also important that the wallet addresses of persons between whom the contract is valid, in this case a contractor and subcontractor are stated in the smart contract. Furthermore, it should be stated when the smart contract comes into force and who will bear the responsibility as an oracle to communicate directly with the smart contract. After the basis of the contract has been established, the programmer will be able to start translating the agreed work or terms as agreed in the subcontracting agreement into smart contract code, see figure 11. It is important that when using smart contracts, it is already agreed in advance what will be paid after completion of each term. Each term will then be linked to these previously agreed fees in the smart contract. However, on a Blockchain it is not possible to pay with Euros or Dollars. For this crypto currencies are needed. Euros or dollars can be converted to crypto coins and these coins can be linked to different terms stated in the smart contract. The smart contract will then transfer the coins to the wallet of the subcontractor when clauses are satisfied. Now, the next phase of this process in which it will be explained how the coins should be sent to the address of a smart

contract and who should do this could be approached.

```

instantiateContract() {
  const contract = require('truffle-contract')
  const service = contract(ComcastVideoRental)
  service.setProvider(this.state.web3.currentProvider)

  this.state.web3.eth.getAccounts((error, accounts) => {
    if(error){
      console.error(error)
      return
    }
    this.setState({accounts: accounts})
    service.deployed().then((instance) => {
      let rentalServiceInstance = instance
      this.setState( {rentalServiceInstance: rentalServiceInstance} )
    })
  }).catch(error =>{
    console.error(error)
  })
}

onRentClicked(assetID){
  this.state.rentalServiceInstance.requestRental(assetID,
    {from: this.state.accounts[0], value: 0.1 * Math.pow(10, 18)}).then((result)=>{
      this.sendTransactionToServer(result, ()=>{
        window.location = "/paid"
      })
    })
}

```

Figure 11: Example of a smart contract created by software engineer (Source: Arpit Mathur, 2018)

6.2.4 Transaction to a Smart Contract

In order to make the smart contract actually work, there must be a balance on the smart contract and as explained in paragraph 6.2.3, in the form of crypto currency. The balance on the smart contract will be used to pay out the subcontractor after the oracle has confirmed that the certain condition in the smart contract has been met. For this, both the contractor and the subcontractor must have an address. To get an address both contractor and subcontractor could use a crypto wallet. A crypto wallet is a tool that allows users to interact with Blockchain networks. They are necessary when sending and receiving digital currencies.

Unlike the traditional wallets used in our daily life, crypto currency wallets do not really store your funds. In fact, the coins are simply part of a Blockchain system as pieces of data and the wallets serve as a means to access them. Technically speaking, most crypto wallets are able to generate one or more pairs of public and private keys. The public key is used to generate wallet addresses, which are needed to receive payments. The private keys, on the other hand, are used during the creation of digital signatures and verification of transactions. Private keys are confidential and should never be shared with anyone (Binance, 2020b). Furthermore, there could be made a distinction between two different types of crypto currency wallets; software and hardware wallets. Software wallets are the ones that are somehow connected to the Internet and, thus, are more susceptible to hacking attacks. Hardware wallets are the ones that generate keys without any Internet connection, which make them highly resistant to cyber attacks (Binance, 2020b).

After the wallets for both contractor and subcontractor have been created, the contractor can transfer crypto currency through a broker or exchange to his own wallet. What are often used as a currency to execute the contracts are the so-called stable coins. They are “backed” by Euros or dollars. Take for example Tether, which is a crypto currency linked to the value of the dollar. With this it is possible to transfer the same value as a dollar, but in a different currency. Hereafter, the intention is that (a part of) the contract sum in crypto currency is transferred to the address of the smart contract by the contractor. When the balance of the smart contract has been loaded and a payment can therefore be made immediately after completion of the agreed term and the associated activities, the smart contract is almost complete. The only thing missing is the approval of the subcontractor.

6.2.5 Digital Signature

The recipient of the coins, in this case the subcontractor, must have to sign the smart contract that has been drawn up on the basis of the subcontracting agreement. But before getting there, the subcontractor must be able to discuss with a software engineer whether the original subcontracting agreement corresponds to the smart contract code. After that, the subcontractor can sign a smart contract by making a transaction to the smart contract itself; this must be a transaction without a value. The subcontractor agrees to that which has been programmed by the software engineer and that if he meets the conditions, the smart contract automatically transfers the coins to the subcontractor's wallet address. This makes the smart contract complete and nothing can be adjusted anymore.

6.2.6 Oracle

After the subcontractor has completed the activities relating to the relevant payment term, he must request an inspection and approval of the work from the contractor. After this, a representative of the contractor will review and approve the work as explained in paragraph 6.1.4. In the current situation, the representative of the contractor gives a written approval of work. In the new situation where payments will be made via Blockchain, the representative communicates directly to the smart contract that the work has been completed. With this, the representative of the contractor who inspects and approves the work in the current situation will fulfill the roll of an oracle.

An oracle may be defined in multiple different ways, according to the context. Within the Blockchain context, an oracle is basically a data source that is used as a bridge between smart contracts and other external sources. More specifically, an oracle is an agent that not only communicates with external data sources but also verifies and authenticates that the data being provided is accurate. Thus, oracles are responsible for providing vital and reliable information to smart contracts, which in turn perform certain tasks (Binance, 2020a). The importance of oracles relies on the fact that Blockchain smart contracts are only able to access the data that is contained within their own digital network. Therefore, oracles are needed as a communication instrument that translates real world events to digital values that can be recognized by smart contracts. Most commonly used oracles are the software oracles. Software oracles retrieve online data from external programs and application programming interfaces (APIs) - such as market prices, flight status, and weather data and communicate this to the smart contracts to trigger the clauses (Binance, 2020a). However, in this case we are not dealing with a software oracle but with a human oracle.

Sometimes persons with specialist knowledge in a certain field can also be deployed as oracles. In the case of a construction project, it would be necessary to use a human oracle, because the inspection and assessment of work is now also done in this way and technology is not yet sufficiently developed to be able to take over this task from a human being. Human oracles are especially useful in decisions where subjectivity is involved (Garay, 2018). The way in which fraud can be prevented here is by verifying the identity of the human oracle using cryptography. With the use of cryptography it will be difficult to provide incorrect information to the smart contract.

After the representative of the contractor, the human oracle, has approved the work, he or she must communicate to the smart contract that the (relevant) conditions are met after which payment will automatically follow. After this, the amount due will be immediately visible on the subcontractor's wallet which completes the first term payment. The advantage of a smart contract is that it can also be programmed that the coins are transferred, for example, 20 days after confirmation by the oracle. As a result, payment terms can still be introduced to guarantee the liquidity of the contractor but the payment terms as agreed in the subcontracting agreement cannot be exceeded. In addition, after the completion of the work, no invoicing procedure will follow, leaving both the contractor and subcontractor only to focus on what really matters; to perform the work on the construction site as productively as possible.

6.2.7 Privacy

Before arriving at the diagram that shows the payment procedure through Blockchain in a construction project, a specific topic will first be discussed, namely the privacy when using a smart contract. The advent of smart contracts has opened up an entirely new avenue of applications. Ethereum, the leading smart contract platform, has facilitated the creation of compelling decentralized applications. However, the Ethereum Blockchain is completely transparent and data from any of these applications is accessible by anyone. This closes the door to an entire range of applications that rely on privacy. For example, both a contractor as a subcontractor would not appreciate it if other interested parties or outsiders have all the insights into the contractual terms drawn up in the smart contracts and the transactions that have taken place to and from the smart contract. Because of this, multiple teams have used different approaches to solve the privacy problem.

One of the solutions is using a zero-knowledge proof — a cryptographic technique used to prove the validity of any statement without revealing any other information. This technique is useful in private computations because it allows computing nodes to create verifiable proofs that they performed the computation honestly with the correct inputs, and hence the output must be correct (Koh, 2018). The only project which is working on this is Origo Network. In this protocol, all computing nodes are off-chain and must submit a zero-knowledge proof that they performed the program correctly. This allows the public to verify that computations were done correctly without any private data ever being on-chain. However, the criticism of the project is that it only minimizes the amount of private data being put on-chain, computing nodes can still see all the inputs and outputs. Furthermore, creating a zero-knowledge proof requires a trusted setup to be done beforehand. Performing a trusted setup for each different smart-contract is super expensive (Koh, 2018)

Another interesting development is that of the baseline protocol. EY is one of the frontiers when it comes to Blockchain technology evolution. They along with Microsoft and ConsenSys on March 4th, 2020, announced Baseline Protocol. It is a public domain Blockchain tool with which the enterprises can deploy and build business process security. It can also be used to create procurement processes and has the option of doing that privately (Singh, 2020). All of these can be done on the public Ethereum Blockchain. Currently, Baseline Protocol is being developed by EY in co-operation with Microsoft and ConsenSys. The first notable thing about Baseline Protocol is that it is open source. This means that it is free to use and offers businesses a low-cost adoption. The technology combines the best advancement in the field of Blockchain, messaging, and cryptography. All of these are done via the public Ethereum Mainnet (Singh, 2020). However, since it is still in development, it is useful to keep an eye on it to see what it can bring in the future.

6.2.8 Diagram of a payment procedure through Blockchain in a construction project

This brings us to the diagram showing the new payment procedure via Blockchain. This diagram also will only show the actions from a construction project that are directly or indirectly linked to a payment from contractor to subcontractor, but then using Blockchain as a payment tool instead of the current billing process

a number of accepted contract conditions for drawing up this diagram will be assumed:

- The contractor and subcontractor have agreed on payment in terms. Whereby each term is linked to a number of activities that must be carried out by the subcontractor before he can claim completion of the relevant term.
- The diagram will only show the course of the first term and the duration it will take before the contractor makes the first payment to the subcontractor.
- Hereby, we assume in the diagram that the activities linked to the first term are completed approximately 3 weeks after the start of the project
- the smart contract will transfer the coins to the subcontractor's wallet 20 days after confirmation by oracle
- Moreover, it is assumed that the project will start on Monday July 1, 2019.

This result in the following diagram, see figure 12:

Payment Procedure Through Blockchain

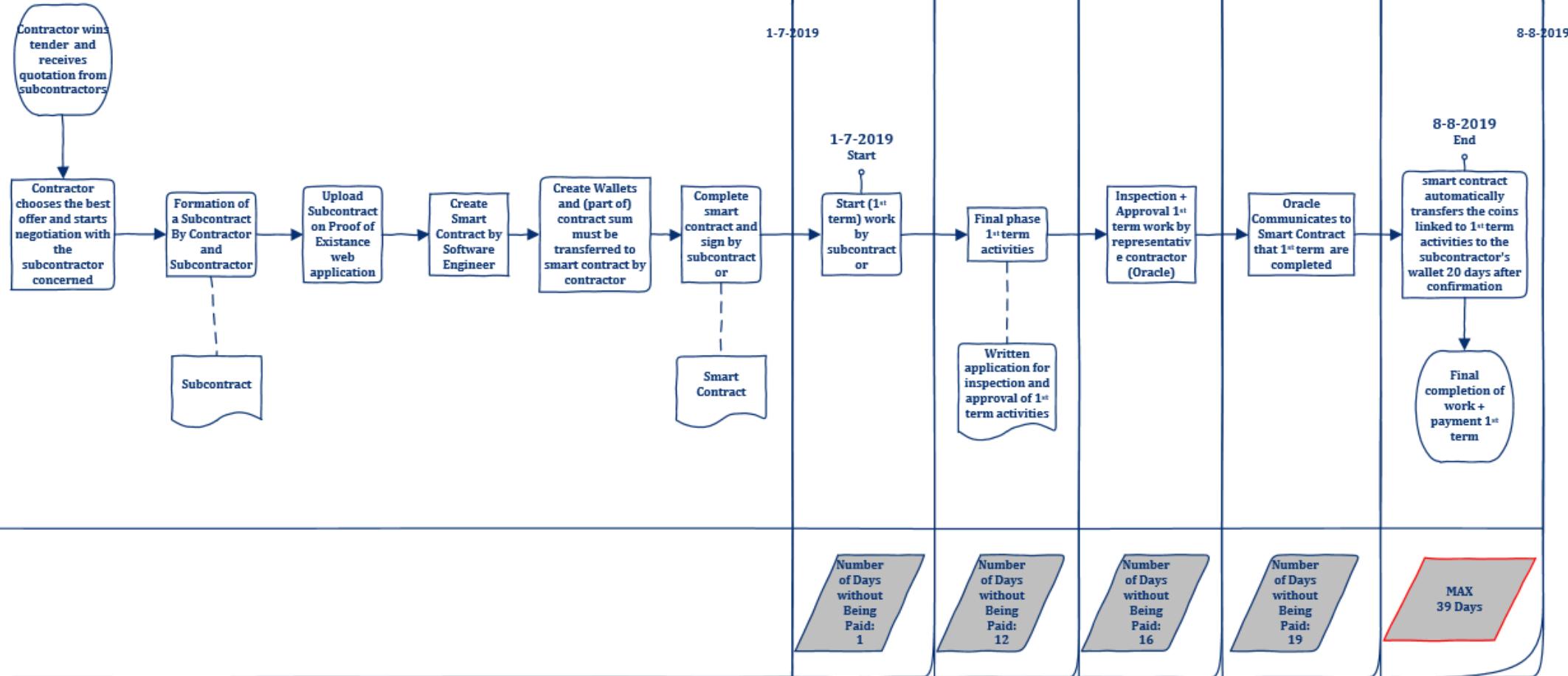


Figure 12: Diagram of a Payment procedure through Blockchain

VII. Validation

Chapter 6: Blockchain Solution explained what a current payment procedure in construction looks like and what the new procedure, which will involve payments via Blockchain, should look like. Before validating the Blockchain solution described in chapter 6, the advantages of the new payment procedure compared to the current payment procedure will be discussed in paragraph 7.1. In paragraph 7.2 the biggest limitations of the Blockchain solution will be mentioned, after which the Blockchain solution will be validated with the help of interviews with various experts in paragraph 7.3. The following two sub-questions will be answered in this chapter *To what extent can a Blockchain solution contribute to a better project outcome from a contractor's perspective? And What limitations does the Blockchain solution experience?*

7.1 Benefits of the Blockchain Solution

In addition to the most important feature; that the Blockchain solution could shorten the payment term and prevent nonpayment, there are several other advantages that were not initially reflected in the description and diagram shown in Chapter 6 Blockchain Solution. These benefits will be briefly explained in this paragraph to provide a better picture of the solution.

7.1.1 Trust and Transparency

In the initial phase of this research it is emerged that trust and transparency are a missing link between contractor and subcontractor. A result of this is that it is still necessary to work with bank guarantees and credit insurance these days. Paragraph 6.1.2 Bank Guarantees and Credit Insurance explain what influence both can have on the ultimate profit made by the contractor or subcontractor. Costs are incurred to take out insurance and bank guarantees and both the bank and the insurance company do not compensate the total damage if one of the two parties waives the contractual agreements. With the new system whereby payments will be made via Blockchain, both contractor and subcontractor will have a certain guarantee in the form of a smart contract. The subcontractor knows that if the contractual agreements are fulfilled by him, a payment will automatically follow. On the other hand, a contractor knows that if the subcontractor does not meet the condition as exactly described in the smart contract, nothing has to be paid. This offers both the contractor and the subcontractor a lot more certainty which will result in a relationship of trust between the contractor and the subcontractor and both parties will be transparent to each other. The introduction and proper application of the Blockchain solution could lead to a decrease in the urgency for bank guarantees and credit insurance in the future which could save considerable costs for both parties.

7.1.2 Pre-financing

In the construction industry it is known that in many projects the subcontractor has to pre-finance. A long period often elapses before materials purchased by subcontractors from suppliers are repaid by the contractor to the subcontractor. In the meantime, in addition to the supplier, the subcontractor has often also had to pay his own staff. When it is finally possible to invoice the contractor, a long payment term then applies, as shown in figure 8: Diagram of the current payment procedure. A major obstacle for the subcontractor is often the costs incurred to pre-finance. A common solution for this is taking out a loan with the bank to enable pre-financing. When taking out a loan, it goes without saying that interest is also involved. The interest that a subcontractor pays to the bank to enable pre-financing can be written off directly from the profit that will be made by the subcontractor. By using a smart contract, more specific contract conditions can be linked to payments. So that smaller amounts can be transferred more often and faster to a subcontractor's wallet after the subcontractor has performed his work correctly. With the smart contract, multiple small payments in addition to shorter payment terms could be created. With shorter payment terms and multiple payments, loans could be avoided which will directly affect the project outcome as a whole.

7.1.3 Tricks to delay payment

Earlier in this study it was also stated that in many cases the contractor performs tricks to delay payments. Take, for example, the trick that a large contractor in the Netherlands applies, whereby the payment term only starts from the 30th day of the month. This means that when a subcontractor submits an invoice at the beginning of the month, the payment term starts in the worst case 30 days later. This may mean that the contractor has 90 days the time after submitting the invoice by the subcontractor, to make the payment to the subcontractor. In addition, invoices are put "on hold" when there are small errors in the invoice, statements are missing, or statements are incorrect. Many large contractors in the Netherlands have several lawyers behind them, which makes it difficult to conduct a legal process for a smaller subcontractor. In addition, the distance between the administration department of the contractor and the subcontractors is large. Due to the great distance between office staff of the contractor and the subcontractors on the construction site many things go wrong in the field of processing the submitted invoice. This affects the relationship between contractor and subcontractor. With the Blockchain solution, the agreements are recorded in the smart contract in such a way that no discussion can arise about the contractual conditions at a later stage. The contract conditions and the payments that are linked to this must therefore be explained exactly and as specifically as possible in the smart contract, which will take a lot of effort. However, using Blockchain to make payments will reduce the possibilities to get out of a payment, which could prevent future conflicts between contractor and subcontractor.

7.1.4 Advantages from a contractor's perspective

Much of this research focused on the role of the subcontractor and the problems they experience that ultimately lead to conflicts between contractor and subcontractor. The solution was also aimed at solving a specific problem that the subcontractor experiences, namely the payment problems during construction projects. However, when describing the Blockchain solution, it was very important to consider how the Blockchain solution can also add something from a contractor's perspective. In order for the solution to work, the solution must convince the contractor in addition to the subcontractor.

The Blockchain solution described in chapter 6 will replace the actions related to submitting and processing an invoice, as shown in figure 8: Diagram of current payment procedure in the construction industry. Contractual agreements and the payments linked to this will be recorded before the start of the project, In Blockchain terms referred to as trust by design, in which the agreements based on mutual trust are laid down in advance. An advantage of recording payment agreements before the project starts prevents discussion or possible conflicts afterwards. Processing all kinds of invoices flowing in from different subcontractors and suppliers requires many administrative actions. By working with the described Blockchain solution, administrative efficiency is created because the billing process becomes redundant from then on. Administrative efficiency is directly linked to cost savings, which will benefit the construction project financially. An additional advantage for the contractor is the indirect influence on his reputation. In chapter 5 it was discussed that a research has shown that a large percentage of subcontractors will offer a discount on the work if the contractor can guarantee to pay on time. The Blockchain solution will increase status and could create a competition between subcontractors with the same specialism to carry out the work for the relevant contractor which could save money for the contractor. Overall, the effects for a contractor could with the right implementation be cheaper than actually implementing the Blockchain solution.

Moreover, another interesting point is liquidity. In the interviews conducted in chapter 4, it emerged twice that liquidity is the major cause of contractors delaying payments. Liquidity is the extent to which a company, in this case the contractor, can meet its current payment obligations. So when deferring payment obligations, the contractor prevent liquidity shortfall problems by holding the money longer. If shortages arise, loans have to be taken out at very high interest rates, which the contractor tries to avoid. In the current situation, they do this by being able to postpone payments with different tricks as explained in paragraph 7.1.3. In the new payment procedure, however, the tricks will no longer be possible, but the contractor's liquidity can still be guaranteed by also agreeing payment terms in the smart contract. It can be stipulated in the smart contract that after the oracle has approved the work and communicated this to the smart contract, the smart contract will, for example, proceed to payment 20 days later. This does not endanger the liquidity of the contractor, but it does give the subcontractor the certainty that he will receive the payment 20 days later after completion.

7.2 Limitations of the Blockchain solution

In addition to the benefits A Blockchain solution can bring to avoid the problems related to payments between contractor and subcontractor and thereby, reducing the number of conflicts with the effect of increasing productivity on the construction site, there are also limitations on the use of the Blockchain solution. The main limitations of the Blockchain solution will be briefly explained below.

7.2.1 Blockchain platform

The first limitation is the dependence on having to use a Blockchain platform that enables smart contracts. There is nothing wrong with the Blockchain platform or the technology, but unfortunately there are also restrictions on the use of a Blockchain platform. The largest Blockchain platform that enables smart contracts is Ethereum. In practice, the Ethereum network can only handle tens of transactions per second. This means that if a number of large companies' worldwide use the network, the network will slow down. With the digitization going on in the world, the demand for the use of smart contracts will most likely increase, but the platforms will not be able to cope. To be able to draw a comparison, we look at the well-known credit companies, visa and master card. At peak times, they process tens of thousands of transactions per second, while a Blockchain platform such as Ethereum can only handle tens of transactions per second. In addition, there is disagreement between developers about the further development of Blockchain platforms that make smart contracts possible which is detrimental to scaling up the number of transactions. Furthermore, costs have to be paid for almost every crypto transaction. This is called a transaction fee. A transaction fee is the fee that is paid for the execution of a transaction on a Blockchain network to, so-called miners. Miners add the transactions to a block, after which the block is added to the Blockchain, as explained in chapter 3. The use of smart contracts therefore entails costs. However, in general, the transaction fees for a crypto transaction are set as acceptable as possible so senders always accept them.

7.2.2 Legal status of a smart contract

In Chapter 6: Blockchain Solution, it is explained that the smart contract is legally binding by stating that the smart contract is drawn up based on the original subcontracting agreement and its identical fingerprint. However, there is a side note to this. The legal status of such smart contracts can be questioned with good reason, at least from the perspective of contract law. The extent to which smart contracts are legally binding or create valid commitments is a subject of discussion. On the one hand, it is stated that smart contracts somehow set the law aside, for example because the contracting parties agree that the contract law is not applicable and that their agreement is not binding, others believe that in a dispute about a smart contract the regular contract law that deals with such situations, is not applicable (Van Eersel and van den Bergh, 2017). However, Van Eersel and van den Bergh (2017) themselves expect that contract law (including the possibilities for settling disputes contained therein) will indeed apply. In their view, contracting via Blockchain is a form of electronic contracting that (Dutch) contract law has already partly provided for. Based on this, it can be concluded that the truth will be somewhere in the middle, which requires further research.

7.2.3 Implementation effort

The advantages of a smart contract, as mentioned several times, are highly attractive. The application of a smart contract can achieve great efficiency and possibly even prevent many conflicts between contractor and subcontractor. However, yet another issue remains. As in the current situation, the negotiation of the content and the clauses of the contract remain. Still, the involved parties need to agree on the contracts and the modalities considering the potentials of a decentralized execution infrastructure. Since the contract is represented as software code, the implementation effort must not be neglected. From an organizational point of view, the question arises, which persons have the required skills to implement a smart contract, i.e., translation into machine readable code. In addition, the machine readable code needs to be powerful enough to express the required norms with all necessary conditions, and in the same time it must be restricted to be robust against malicious behavior (Sillaber and Waltl, 2017). The ones who can write the program codes are the software engineers specialized in smart contracts. It will therefore be necessary for a contractor to approach a software engineer with specialist knowledge in the field of smart contracts to implement the smart contract. In addition to the high effort to implement it, costs will also be incurred to implement the smart contract. This could, unfortunately, be a major stumbling block for a contractor.

7.2.4 The Oracle Problem

In the description of the Blockchain solution, the term oracle has been mentioned several times, the oracle communicates to the smart contract that the condition has been met, after which the smart contract automatically pays the subcontractor the reward for completing the relevant condition. In the situation where the representative of the contractor fulfills the role of oracle, it can be stated that this representative has immense power over the smart contract. This is known as the oracle problem, which rises as a conflict of trust (Binance, 2020a). The representative of the contractor may, due to pressure from, for example, the construction management; choose to postpone communicating to a smart contract that the work has been completed. What will not benefit the payment term. Delaying communication to the smart contract can therefore be a new cause of conflict, or in the worst case, disputes. Although multiple oracles may present a possible solution, where multiple nodes therefore influence whether the correct information is communicated to the smart contract, there are still many challenges to be overcome; multiple oracles could also lead to more disagreements which does not benefit the positive features of a smart contract.

7.2.5 Crypto currency

Before going to paragraph 7.3 validation of the Blockchain Solution, there is a limitation that is not necessarily a limitation for the use of a smart contract or Blockchain since it makes the use of Blockchain and smart contracts easier, but can be experienced as a limitation by a contractor or subcontractor. That limitation is the use of crypto currency as a means of payment. The construction industry is a traditional industry, which could lead to a lot of resistance from both contractor and subcontractor if the trusted fiat currency has to be converted to crypto currency. There are options for any use of fiat currency if required. However, these solutions have not been worked out and are not considered in this study.

7.3 Validation of the Blockchain Solution

In the previous paragraphs, the benefits of the Blockchain solution and the limitations of the Blockchain solution have been discussed. In this paragraph the Blockchain solution will be validated by various experts. As stated before in chapter 3 Research Methodology, to validate the solution the results of the design-science research must be communicated effectively. A total of 3 different experts will be interviewed. Two of these were also interviewed in Chapter 4: Identifying bottleneck; the chairman of the Dutch Contractor's Federation that represents the interests of small and medium-sized construction companies in the Netherlands and subcontractor A . The third expert is a Blockchain specialist and will assess the technical feasibility of the solution.

Chairman Dutch Contractor's Federation (in Dutch: AFNL), see appendix D:

The Contractor's Federation is an umbrella organization of business organizations in the construction and infrastructure sector and represents the joint interests of the autonomous member associations and the construction and infrastructure industry. An important objective of the Contractor's Federation is to increase the market position of small and medium-sized contracting companies towards clients, such as national, provincial and municipal governments, water boards and housing corporations, and the same applies to large main contractors and private clients (AFNL, 2018). The Dutch Federation of Contractors believes that there is and should be much more space for small and medium-sized companies in the construction programs and infrastructure works. As an extension of the affiliated branches, the contractors' federation of the Netherlands advocates the common interests with governments, politicians, clients and third parties. This made it very interesting to have the Blockchain solution validated by the chairman of this large organization:

"Except that it takes a Software Engineer to implement it, this solution sounds like music to my ears"

The advantages and disadvantages of the Blockchain solution were discussed and the chairman was quite enthusiastic about the possibilities of the Blockchain solution, but he also made a comment:

"Its introduction will be more difficult, I fear. It is a development that will be met with particular suspicion by the major contractors"

In addition to the fact that the solution was primarily created from the interests of the subcontractor, the benefits the solution should bring from the contractors' perspective as described in paragraph 7.1.4 are also important. For the implementation of the Blockchain Solution, both parties, contractor and subcontractor, must be convinced, so there must be enough benefits of using the Blockchain solution for both of them. The chairman of the AFNL said the following about this:

"I think the Blockchain solution is good for the development of new digitization in construction. There are efficiency steps that have to be made, because indeed all unnecessary administrative costs that you can avoid, bank guarantees, long and high loans with associated interest costs, that is all profit and that will translate into productivity. Budgets will not be reduced if efficiency increases, which means that you can do more for the same money"

Subcontractor A, see appendix E:

For the second validation, a subcontractor with decades of experience in construction was approached to find out to what extent the Blockchain solution is suitable for use. It did not go into too much detail about how a smart contract is created, but the focus was placed on how a smart contract works and what the advantages and limitations of a smart contract are. It is not important to explain the problem in detail, since the interviews in round 1 have shown that the subcontractor is also experiencing the payment problems himself. After a brief repetition of the problem, we immediately switched to discussing the Blockchain solution:

"The solution sounds good if it can work. At the moment, contractors often hide by disapproving of everything in order to delay payments or even prevent them in some cases"

Blockchain Technology, as discussed earlier, is still under development. As a result, the trust and user-friendliness of Blockchain will eventually have to be increased to persuade parties to use a Blockchain platform. The subcontractor has been clearly explained that the step to applying smart contracts will be a big step into the digital world and that the traditional habits in the construction industry, that everyone is used to at the moment, will be lost. Contracts will be signed and viewed digitally, payments will be made digitally, digital wallets will have to be used, etc. It was important to find out whether subcontractors will also be willing to enter this world:

"The subcontractors have to participate in this, because I think that applying this solution in another way is not possible. We can already see that many things go digital and that many things require computers. In doing so, you can bypass all parties that help the subcontractors to make the contractors pay by applying this solution. In addition, it is a solution that will help the subcontractors, which could convince them more easily"

In addition to the subcontractor, the contractor must also go along with the application of smart contracts. With all the knowledge and experience of recent years, the subcontractor has been asked what the expectations will be if this solution is presented to a contractor.

"Convincing a contractor to use this form of contract will be very difficult. The point is that a contractor does not want to record payment agreements in this way because they want to be in control. So there will have to be a lot to do to actually persuade them"

Blockchain Specialist, See appendix F:

For the final validation of the Blockchain solution, a Blockchain specialist with over 30 years of experience in ICT and also co-founder of Fluidensity, a trademark of Scalart BV that uses Blockchain technology to collect and trade art in a safe, transparent and inclusive way was approached. First, Figure 8: Diagram Current Payment procedure in the Construction industry has been reviewed to clarify the problem. After this, the switch was made to critically discuss the Blockchain Solution

"The problem is clear; I just think the solution is a bit technical, where I still see some pitfalls. However, I understand the direction of the solution and also the choice why you want to solve it with Blockchain"

Based on that statement, the conversation turned to those pitfalls about which the Blockchain specialist said the following

"The smart contract must be drawn up by a software developer, but the person drafting the contract will also have to be a lawyer. The question is how will the contractor and subcontractor check whether all clauses are correctly included in the contract? "

Hereafter, the conversation elaborated on the role of the software developer in the implementation effort of creating a smart contract

"The software engineer has a crucial role. Finding a Blockchain software engineer is a problem here. Blockchain is a whole new technology that has not yet broken through. So right now the Blockchain programmers are the highest paid programmers because they are super scarce. Because you also need Blockchain programmers to validate the code, you create a lot of overhead costs"

Because of the overhead costs, it must remain profitable to actually apply the Blockchain solution, the advantage is that the value of a contract in construction is often very high, so it should be profitable enough. The Blockchain specialist was asked about the developments regarding the implementation of Smart Contracts and he said the following about this

"There are currently platforms under development in which, for example, a flow diagram can turn into a smart contract with the push of a button. This will be done with the help of a code generator, which will eventually also replace programmers in the future. All in all, that would be the ultimate solution"

The second pitfall that the Blockchain specialist noticed was the use of the crypto coins

"The ultimate scenario is that everyone switches to the use of crypto coins. However, the construction industry is quite traditional, so you could count on resistance from the contractor. I do think there is a solution to this by involving the banks in the smart contract. Some banks use APIs, so you can have the crypto coins replaced by fiat coins and the smart contract can use API to check whether the money has actually been transferred in time from the contractor's bank account to the subcontractor's bank account. You can also include penalty clauses in the smart contract if the bank has not confirmed that a transaction has taken place between contractor and subcontractor on time"

At the end of the validation, the Blockchain specialist gave a final opinion about the Blockchain solution as a whole

"I think the problem and the named solution to the problem are a good match. If you keep it all a bit more traditional, and I think there are possibilities for that, then the use case is just very good because you can offer the contractor and subcontractor trust by using Blockchain, while also making the payment terms shorter which will be good for everyone"

VIII. Conclusion and Discussion

In this research, Blockchain technology is proposed as a solution for reducing the conflicts between contractor and subcontractor during construction projects by improving the payment procedure. In this final chapter the conclusion of this research will be described and discussed by first answering the sub-questions based on the theoretical framework (chapter 2), the empirical findings (chapter 4), the design propositions and Blockchain solution (chapter 5&6), and the validation of the Blockchain solution (chapter 7). Based on the sub-questions and the validation, the main research question will be answered. In addition, the limitations of the research and recommendations for further research will be discussed in paragraph 8.2 and 8.3. The study ends with a discussion in paragraph 8.4.

8.1 Conclusion

The study starts with addressing a productivity problem in the construction industry, after which it has been found that the role of the subcontractor has always been out of debate when the productivity problems were discussed. Although they are largely responsible for the work on the construction site. It can even be argued that projects cannot be realized without subcontractors. After this, the focus was on the role of the subcontractors and what keeps them from being more productive on the construction site. Literature has shown that conflicts or disputes between contractor and subcontractor affect productivity on the construction site. In chapter 4 an attempt was made to identify a bottleneck that causes these conflicts by means of interviews, quantitative results and an in depth literature study. This has led also to requirements for a possible solution. Based on those requirements design propositions have been formulated using CIMO-logic. Chapter 6 describes a suitable solution that could solve this problem, after which this solution was validated in Chapter 7. During this process, several sub-questions were answered that will ultimately contribute to answering the main question that reads as follows:

To what extent can the potential of Blockchain Technology be applied to reduce the conflicts between contractor and subcontractor during construction projects?

In order to answer the main research question, the sub-questions formulated in chapter 1 will be answered first

Sub-question 1: How does the subcontracting process in the construction industry proceed, where contractor is responsible for subcontractor?

Before a contractor is appointed to execute a project by the client, a contractor requests various subcontractors for a quote. A contractor does this in order to be able to determine what the main contract sum will be. After the contractor has been appointed to actually execute the project, the contractor will select the subcontractors who can best carry out the work for them at that time. Incidentally, this does not have to be the subcontractors who were previously approached for a quote, but in many cases that is what happens. Chapter 2: Subcontracting in Construction Industry explains that a subcontractor for which a contractor is responsible is called a domestic subcontractor. The subcontracting agreement is based on what is included in the main contracting agreement. The aim of a domestic subcontractor is to perform all the works

stated in the subcontract in accordance with order from the main contractor (Lagiman, 2017). Depending on how the contract is drawn up, interim payments can be made. After the work is completed, the final payment will follow.

Sub-question 2: How are the contracts between contractor and subcontractor in a construction project structured these days?

A subcontract is a contract between contractor and subcontractor, which includes provisions that transfer certain responsibilities, obligations, and requirements from the contractor to the subcontractor. Subcontracts contain a detailed scope of work, the payment terms, provisions for changes, warranties, arrangements for temporary facilities and any other special subcontract requirements. In the Netherlands, the contractor and subcontractor usually contract on the basis of the law or on the basis of the UAV 2012. The latter conditions are bilateral and are widely applied in practice. In the Netherlands, a standard form or a domestic subcontract has not been published yet, however, various examples of contracts between contractor and subcontractor can be found.

Sub-question 3: What is a Bottleneck that causes the many conflicts during construction projects between contractor and subcontractor?

To determine the identified bottleneck causing conflicts between contractor and subcontractor, an empirical research tool, namely interviews, was used in combination with an in-depth literature study and reports with quantitative results from previous studies. After analyzing the interviews using coding, in combination with the new insights from the literature and the quantitative results, it was concluded that payment problems are a bottleneck that causes conflicts between contractor and subcontractor during construction projects. Based on this, the requirements have also been drawn up that a possible solution will have to meet to (partially) solve this problem.

Sub-question 4: What is Blockchain technology and how does it work?

Blockchain, a technology based on distributed ledger (shared database) technology (DLT), was first widely introduced in 2008 by Nakamoto (2008) as the underlying technology of Bitcoin to solve the double-spend problem by using a decentralized peer-to-peer Blockchain network without the need of a trusted third party. However, Blockchain has many other potential applications outside the world of digital currencies; a major advantage of the method used by Blockchain is the invalidity and immutability of the database. In fact, Blockchain serves as a database for registering transactions, but the benefits and possibilities of Blockchain technology go far beyond the traditional databases, therefore it is important to remind that Bitcoin and Blockchain are not the same. Blockchain provides the means to record and store Bitcoin transactions, but Blockchain has many uses beyond Bitcoin. IBM (2017) explained in their book Blockchain Technology as blocks that record and confirm the time and sequence of transactions, which are then logged into the Blockchain within a discrete network governed by rules agreed on by the network participants. Each block contains a hash (a digital fingerprint or unique identifier); time stamped batches of recent valid transactions and the hash of the previous block. The previous block hash links the blocks together and prevents any block from being altered or a block being inserted between two existing blocks. In this way, each subsequent block strengthens the verification of the previous block and hence the entire Blockchain.

Sub-question 5: What does a Blockchain solution that could reduce conflicts look like?

In Chapter 5 it was pointed out that Blockchain is the solution that can best solve the identified bottleneck, after which Chapter 6 describes the Blockchain Solution. The core of the Blockchain Solution is a smart contract. A smart contract is a computerized transaction protocol that implements the terms of the contract. The main advantages of using smart contracts besides traditional contracts are the efficiency of the contractual process. Contractual clauses that are embedded in smart contracts will be enforced automatically when a certain condition is satisfied. But in addition to the smart contract, the Blockchain solution consists of several steps.

In summary, the Blockchain Solution can be described as follows. First, the official subcontracting agreement must be uploaded to a web application called Proof of Existence which generates a digital fingerprint. A smart contract is drawn up on the basis of the official subcontracting agreement, with a reference to the digital fingerprint. At the same time, the contractor and subcontractor create a digital wallet with a public and private key, with which value can be sent and received. After the smart contract has been approved by a representative of both the contractor and subcontractor, both the contractor and subcontractor sign the smart contract by making a transaction to the contract using their private key. The contractor sends (part of) the contract price to the smart contract and the subcontractor signs by making a transaction of no value to the contract. The smart contract is now finalized and work can start. When the subcontractor meets one of the contract conditions, to which a payment is linked, he approaches the representative of the contractor (oracle). When the oracle approves the work, the oracle communicates, after verification using cryptography, to the smart contract that the contract condition has been met. From that moment on, the smart contract automatically makes the payment to the subcontractor's wallet within the agreed payment term.

Sub-question 6: To what extent can A Blockchain Solution contribute to a better project outcome from a contractor's perspective?

As stated at the beginning of the study, the focus is on creating higher productivity on the construction site by reducing contractor-subcontractor conflicts from a subcontractor's perspective. Ultimately, it is important that a contractor also participates in the solution, which means that the Blockchain solution must also be attractive from the perspective of a contractor. During the creation of the Blockchain solution, an attempt was made to take this into account, which led to the following arguments that a contractor could possibly persuade. Processing all kinds of invoices flowing in from different subcontractors and suppliers requires many administrative actions. By working with the described Blockchain solution, administrative efficiency can be created because the billing process becomes redundant from then on. Administrative efficiency is directly linked to cost savings, which will benefit the contractor financially. Furthermore, in chapter 4: Identifying Bottleneck it was mentioned that subcontractors will offer a discount on the work if the contractor can guarantee to pay on time. The Blockchain solution will therefore increase status and creates a competition between subcontractors with the same specialism to carry out the work for the relevant contractor. This could save also lot of costs. Moreover, payment terms may also be included in the smart contract to avoid liquidity problems for the contractor.

Sub-question 7: What limitations does the Blockchain Solution experience?

Several limitations emerged during the creation of the Blockchain solution. Limitations that make it more difficult to implement the solution and convince contractor or subcontractor to

apply the Blockchain solution. The first is the limitation of the current largest Blockchain platform that enables smart contracts. This platform is called Ethereum. Ethereum network can only handle tens of transactions per second. This means that if a number of large companies' worldwide use the network, the network will slow down. With the digitization and Blockchain developments that are now underway worldwide, the demand for the use of smart contracts will most likely increase, but the platforms will not be able to cope with this low speed of transactions. The second limitation has to do with legal status of a smart contract, there is still disagreement about the exact legal validity of a smart contract (in the Netherlands). This is largely due to the fact that smart contracts are still very limited in application in the Netherlands. Third limitation is implementation effort for creating the Blockchain solution; especially creating a smart contract. This requires a system engineer who is specialized in smart contract code and these are currently very scarce. Fourth limitation is the oracle problem. The oracle communicates to the smart contract that the condition has been met, in the Blockchain solution this oracle is the representative of the contractor. Partly due to influences from, for example, the construction management, the oracle could choose to postpone communication to the smart contract for as long as possible. The last limitation is the use of crypto currency in the Blockchain solution. That will most likely change in the future, but for now the use of crypto currency instead of fiat currency could cause resistance for both contractor and subcontractor for implementing the solution.

Main Research Question: To what extent can the potential of Blockchain Technology be applied to reduce the conflicts between contractor and subcontractor during construction projects?

The study starts with addressing a productivity problem in construction, where it is found that the perspective of a subcontractor is often lacking when it comes to problems that stagnate productivity in construction. Few studies have also paid attention to this while the subcontractors perform a large percentage of the work on the construction site. Based on this, it can be stated that without the subcontractor's specialism, a lot of work cannot be carried out on the construction site. It was therefore of great importance to this study to understand what problems subcontractors are experiencing and lead to stagnation of productivity on the construction site. The literature review has shown that this is (partly) due to the many conflicts that take place between contractor and subcontractor during construction projects.

The aim of the study was to determine to what extent the potential of Blockchain technology can reduce conflicts between contractor and subcontractor, so that indirectly productivity on the construction site will be increased. However, the causes of conflicts between contractor and subcontractor are varied. Based on the literature and databases in which disputes between contractors and subcontractors can be found, it can be confirmed that there are many causes for the conflicts. This is why the focus was placed, and the study was also immediately delineated, to identify a single bottleneck that causes conflicts between contractor and subcontractor. Based on an in-depth literature study, quantitative results from other research reports and empirical findings; it was then possible to confirm that payment problems are a bottleneck that causes conflicts between contractor and subcontractor. From there, payment problems have been raised as the field problem that needs to be solved in order to reduce conflicts during construction projects.

After identifying a bottleneck that causes conflicts between contractor and subcontractor, requirements have been drawn up and formulated on the basis of CIMO-logic into design

propositions. Based on design propositions, two different solutions could be identified as a possible solution for the identified field problem. Blockchain and a traditional database. The possibilities with Blockchain technology are diverse. In many studies, the focus is on finding a problem for a developed solution. The aim of this research has always been to raise a problem and to determine to what extent the potential of Blockchain technology could actually solve this problem. Ultimately, the two solutions, the use of a database and the use of Blockchain have been compared with each other. The aspect of trust, which is missing from a traditional database since it has always been managed by a DBA, has been decisive in further developing the Blockchain solution and to be designated as the most suitable solution. When a technology is used to solve a problem between two parties, it is important that both there are confidence in the technology but that the technology also creates trust between both parties. What is recorded on a Blockchain is indisputable, this means that once a contractual condition is included on a smart contract, it can no longer be revoked or changed. This avoids discussions afterwards about the contractual agreements made and therefore offers something that contemporary databases cannot offer. The described Blockchain Solution has attempted to apply the potential of Blockchain Technology to solve the problem raised and thereby reduce conflicts between contractor and subcontractor.

The main feature of the Blockchain solution is that exceeding payment terms and nonpayment is impossible because the payment agreements are unambiguously recorded and can no longer be manipulated by, for example, a DBA. If payment terms are no longer exceeded, or at best can even be shortened, provided the contractor's financial situation permits, the risk of a conflict related to a payment problem can be greatly reduced. It is also possible to multiply the number of payments in the smart contract by including multiple terms. The moment a subcontractor receives multiple payments in smaller quantities, the pre-financing problem experienced by subcontractors is (partly) tackled. Multiple payments in smaller quantities can also be very beneficial for the contractor's cash flow, which does not require large amounts to be transferred at once. Moreover, it was of great importance for this study that the solution can regain trust in a construction project between contractor and subcontractor. Chapter 6 explains in detail the reasons why bank guarantees and credit insurance policies are still applied today. With the use of the Blockchain solution it will become clear that when the subcontractor keeps to the contractual agreements, payment will follow automatically. The Blockchain solution will thus be able to contribute to trust, which will reduce the urgency of bank guarantees and credit insurance in the future. In addition, higher efficiency can be achieved. By using the Blockchain solution, paperwork and invoice processing will no longer be necessary. On the other hand, there are also limitations of the Blockchain solution. During the validation of the solution, it became clear that the implementation of the Blockchain solution can currently still cause high overhead costs because Blockchain software engineers are scarce. Furthermore, the application of crypto coins, despite the fact that the stable coins can be used, could provide resistance and deterrence from both contractor and subcontractor.

Coming back to the main research question of this study, *To what extent can the potential of Blockchain Technology be applied to reduce the conflicts between contractor and subcontractor during construction projects?* It can be confirmed that there is a great deal of potential to reduce the payment problems that lead to contractor-subcontractor conflicts with the use of Blockchain, provided that the technology continues to evolve at this rate and the major construction industry leaders are open for changes. The step for the application of the Blockchain solution as

described in chapter 6 will probably be too big for an industry where the image is that it is traditional, conservative and non-innovative. However, there are many developments going on with regard to Blockchain technology at the moment. Developers are working on code generators that can, for example, convert a flow diagram into smart contract code without the input of a Blockchain software engineer. And by involving the banks and Application Programming Interface (API), transactions in fiat coins can be made possible, which can remove the resistance to the use of crypto coins. Blockchain technology will not be able to resolve all conflicts linked to payment problems but it could, by alleviating concerns over payment by creating trust, substantially reduce the conflicts linked to payment problems and thereby increasing collaboration between contractor and subcontractors.

8.2 Limitation of the research

In this section, a number of limitations of this research will be discussed and further explained. Because there is a time limit for the research and it must be planned in advance in such a way which steps have to be taken on which data, it is important during the process not to deviate far from this and to make decisions at certain times. This has ensured that at certain times certain subjects could not be further investigated, otherwise planning would be jeopardized. Attempts have always been made to protect the reliability and quality of the research by substantiating the choices made during the research as much as possible.

First of all, the study started by pointing out that there is a productivity problem in the construction industry, and that various causes can be identified for this. An important link that does indeed influence productivity is the subcontractors, since it is common for the main contractors to subcontract 80% to 90% of the construction work to subcontractors (Kumaraswamy & Matthews, 2000). However, the voice of subcontractors has been entirely missing from the construction productivity debate (Loosemore, 2014a). The many conflicts between contractor and subcontractor can cause disputes to arise and work to come to a halt. In the worst case, this could jeopardize the delivery date. In chapter 4 an attempt was made to find out what bottleneck exist for the many conflicts between contractor and subcontractor during construction projects. However, insufficient research has been carried out into other possible causes that may cause conflicts between contractor and subcontractor. The interviews were used to find out whether payment problems are a bottleneck for the many conflicts between contractor and subcontractor, instead of finding out what they experience as problems and on this basis determine which cause is most experienced. The reason that during the interviews no questions were asked about what the subcontractors experience as the cause of the many conflicts is because a good conclusion could only be drawn if several interviews were conducted with different subcontractors. Since the goal of the study was to determine the extent to which Blockchain technology could reduce the number of conflicts, and taking interviews in combination with transcriptions and coding takes a lot of time, the number of interviews during this study has been limited.

The research method applied in this research is the Design Science Methodology (DSM), a research method with a goal to construct a new reality (i.e. solve problems) instead of explaining an existing reality, or helping to make sense of it (Iivari and Venable, 2009). A guideline for this research method is to describe several solutions after identifying a field problem, after which the best solution must be validated. Since it was initially determined that this study will examine to

what extent Blockchain technology can reduce the number of conflicts between contractor and subcontractor, it can be stated that the research method has not been fully applied in the way that it was initially intended. However, other possible solutions have indeed been studied and considered during the research and an attempt has been made to substantiate why Blockchain Technology is best suited to the identified field problem. Moreover, the research question was drafted in such a way that it also gave the opportunity to conclude that there are better solutions for the raised field problem and that Blockchain technology is not suitable for solving this problem.

The last limitation that will be discussed and further explained has to do with the detailed Blockchain solution in chapter 6. During the research, an attempt was made to explain in detail what the payment procedure will look like if Blockchain technology is applied and of this a diagram has also been drawn up. However, nothing tangible has been developed. An additional aim of the study was to program a piece of smart contract and to show what the functioning of a smart contract looks like. In consultation with my external supervisor and my first supervisor, it was then decided, partly due to the time limit of this research, not to further elaborate on this. The study also showed that the drawing up of a smart contract is currently only available to a limited number of software engineers and that it therefore takes a lot of time to specialize in developing a smart contract without any affinity. However, there are sufficient options to view the operation of a smart contract, for example on the Ethereum platform.

8.3 Recommendation for further research

In this paragraph, a number of recommendations will be explained for any further research based on experiences and insights that have arisen during this research. A distinction is made between scientific and practical recommendations.

In the limitations of the study it has already been mentioned that few respondents were consulted due to a limitation in time for the study. With the aid of external research reports and an in-depth literature study, it has been attempted to prove that the identified problem is actually a bottleneck that causes conflicts. However, multiple respondents would increase the reliability of the study and could lead to more varied requirements. With multiple respondents and more varied requirements, values can be linked to those requirements by, for example, looking at how often a particular requirement was mentioned during an interview. The solution that fulfills the most important requirements can then be further explained and validated. By using multiple respondents, the scientific level of the study increases and certain choices related to the Blockchain solution can be better substantiated.

Another important recommendation which will benefit the study has to do with the role of the contractor. In this research, the role and importance of the subcontractor has emerged several times and the solution has also been developed from an ideal perspective of a subcontractor. At various points in this study, it was also argued that the important role of the contractor in this solution cannot be disregarded. However, during the validation of the Blockchain solution, it emerged that the Blockchain solution could possibly count on resistance from various contractors. This has made it of great importance to also develop the Blockchain solution taking into account the requirements of the contractor. The requirements of the contractors can be

identified by submitting the problem, just like with the subcontractors, and discussing how they prefer to see the problem solved. Input from various contractors will benefit this study.

Another recommendation that could make a significant breakthrough in the use of Blockchain technology and specifically smart contracts is the legal validity of this form of contracting. Earlier in this study it was pointed out that in the Netherlands opinions differ about the legal status of a smart contract. An interesting study could be to investigate with the help of lawyers to what extent smart contracts are legally valid, or can be applied in a legally valid manner for problems as cited in this study.

In addition to the recommendations mentioned above, which can increase the quality and reliability of the study, there are also practical recommendations aimed at the described Blockchain solution. During this study, and especially during the validation of the Blockchain solution, a number of limitations have emerged where the current Blockchain solution can be improved. Based on these limitations, a number of recommendations can be made for a possible redesign of the Blockchain solution to resolve the bottleneck that has been raised.

During both the research and the validation of the Blockchain solution, it emerged that the use of crypto coins and a digital wallet could potentially lead to resistance from both contractor and subcontractor. There are a number of options for this, instead of using crypto coins, making the payment with the well-known fiat coins. One possible solution is to use the application programming interface (API). API is a software interface that allows two applications to communicate with each other. You could say the smart contract submits a request to the bank whether a certain transaction from contractor to subcontractor has taken place and then the bank provides feedback. The smart contract will therefore not make the payment itself, but will be able to check whether a payment has been made. The bank and the use of API play an important role in this solution. A challenge is to find out to what extent banks and the use of API can make the current Blockchain solution more user-friendly for both contractor and subcontractor.

Another recommendation for further research is directly linked to a limitation of the current Blockchain solution. A smart contract on an Ethereum network is transparent for everyone. This means that by translating a smart contract code, other stakeholders will have insight into possible details of the contract between contractor and subcontractor. At the time of writing this thesis, several developments are underway regarding safeguarding the privacy of a smart contract. A possible follow-up study could delve into these developments and elaborate how a private smart contract can be applied between contractor and subcontractor. Application of a private smart contract could reduce the chance of possible resistance to the implementation of the Blockchain solution. There are also developments going on with regard to code generators that can generate smart contract codes without programming knowledge. These developments can also be very interesting for further research.

In addition to the above recommendations, there is one final recommendation for the later future. This research was limited to only the conflicts between contractor and subcontractor. As a result, the solution for solving payment problems was also only focused on payments from contractor to subcontractors. However, payments are made throughout the whole construction chain. Earlier in the research it was pointed out that one cause of the late payments is the contractor's liquidity. By implementing Blockchain technology as a means to make payments

throughout the construction chain (i.e. from client to contractor to subcontractor to the supplier of the subcontractor), liquidity throughout the construction chain can be guaranteed, which will have a positive effect on every stakeholder who contributed to the construction project. A possible follow-up study is to investigate the extent to which Blockchain technology can be used throughout the construction chain as a means of making payments and thus increasing efficiency and productivity in the construction sector.

8.4 Discussion

As emerged from the validation, the identified field problem fits the developed solution, the Blockchain Solution. The research question was set up to find out to what extent Blockchain Technology could play a role in reducing conflicts between contractor and subcontractor and thus improve productivity in the construction sector. The results of the validation show that there are certainly opportunities for Blockchain technology to reduce the number of conflicts between contractor and subcontractor, on the one hand because the subcontractor and the chairman of the contracting federation were positive about the possibilities of the solution, on the other hand because according to the Blockchain specialist, it is technically feasible to actually develop the Blockchain Solution. However, a number of restrictions, as explained several times in this research, will have to be improved first.

The outcome of the validation is very interesting because the application of Blockchain technology can actually contribute something to the construction industry. This research addresses a problem that is still experienced these days in the construction industry worldwide. It has been pointed out that the payment problems have been going on for decades. Several attempts have been made to solve the problem, for example in the Netherlands attempts have been made to make the legislation regarding payment terms but this has hardly contributed to solving the identified field problem. According to the results of this research, Blockchain technology has the potential to change that. This ensures that the results of this research really matter.

On the other hand, insufficient research has been conducted into how contractors view this solution. Initially, this research was mainly focused on providing a solution to the conflicts between contractor and subcontractor from the perspective of a subcontractor. Taking into account the role of the contractor since the solution can only work if both contractor and subcontractor actually start to apply the solution in practice. However, when validating the solution, it becomes clear that the perspective of the contractor was not sufficiently taken into account. This was due to the fact that no interviews were conducted with contractors and therefore it was not possible to describe exactly what their requirements are for the solution. It is therefore expected that the solution could lead to resistance from the contractors when the solution may be implemented.

In order to find out what those requirements of a contractor are, it is very important that any follow-up study will be able to focus on a contractor's perspective to solve the problem. The requirements from both a contractor and a subcontractor can then be combined, after which design propositions can be drawn up on the basis of those requirements. Solution concepts can be derived from those design propositions and can lead to new insights. After this, a possible next step for the future could be to actually develop and test the solution in a real project.

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Appendix A: Transcript interview Chairman AFNL

Interview Voorzitter/directeur MKB INFRA

Philip van Nieuwenhuizen

1. Vorig jaar is er door staatssecretaris Mona Keijzer aangekondigd dat er een nieuwe wet zal worden ingevoerd m.b.t. het terugdringen van de betalingstermijnen voor MKB. Maar bijna een jaar later is deze wet nog steeds niet ingevoerd. Wat is uw mening over de huidige betalingstermijn van 60 dagen die gehanteerd mag worden, en over de gemiddelde betalingstermijn van 41,5 dagen in 2018?
 - Eigenlijk is elke termijn te lang, zeker voor het mkb. Door betalingstermijnen wordt financiering noodzakelijk. Dat betekent extra kosten (en verdiensten voor de banken, die toch al genoeg verdienen). Bovendien, als je een termijn stelt zullen veel debiteuren denken dat ze pas hoeven te betalen aan het eind van die termijn, terwijl de bedoeling is dat je z.s.m. betaalt. De termijn is er ooit gekomen omdat de rekening per post werd verstuurd en er bij de ontvanger een verwerkingsproces in gang moest worden gezet. Dat is in de huidige tijd echter iet meer zo en dus zijn termijnen achterhaald, zeker als de prestatie al is gevalideerd, dan kan de rekening direct bij ontvangst worden voldaan.
2. Wat zou volgens u een ideale betalingstermijn zijn om zowel de belangen van de betalende partij als de partij die de betaling ontvangt te behartigen?
 - Zie voorgaand antwoord. Hooguit een dag of 10 als de factuur nog door de hiërarchie heen moet, maar als er al een validatieproces voor heeft gezeten, dan gewoon omgaand.
3. Vindt u dat MKB genoeg mogelijkheden heeft lange betalingstermijnen vanuit te betalende partijen tegen te gaan/ te bestrijden?
 - Nee. Het mkb is zuinig op zijn klanten en grijpt niet snel naar incassomaatregelen.
4. Wat zou het volgens u voor effecten kunnen hebben indien de betalingstermijn bijvoorbeeld maximaal 30 dagen zal zijn en de betalende partijen zich hier ook aan zouden houden, voor in het bijzonder MKB?
 - Minder financiering nodig. Kosten gaan omlaag, product kan goedkoper.
5. Wat is volgens u de reden dat bijvoorbeeld een Hoofdaannemer liever de betaling zo lang mogelijk uitstelt aan een onderaannemer?
 - Liquiditeit, de onderaannemer wordt zo (mede-)financier van de hoofdaannemer. De smoes is, dat men zelf ook lang op de validatie en dan betaling moet wachten, wat bij overheidsopdrachten veelal flauwекul is.

6. Uit interviews met onderaannemers (bouwsector) is gebleken dat zij niet alle vertrouwen hebben in het invoeren van een nieuwe wet, zij vrezen dat grote aannemers andere manieren zullen vinden om de betalingen uit te stellen. De pilot toegepast door MKB infra in samenwerking met enkele gemeentes in 2015 had zeer positieve uitkomsten. denkt u dat we de oplossing in die hoek zouden moeten zoeken waarbij dus het gehele betaalsysteem toegepast in de bouw in infra omgegooid dient te worden, denk hierbij aan bijvoorbeeld het toepassen van technieken die betalingen automatisch zouden laten plaatsvinden binnen zoveel dagen na voltooiing werk?
 - Ja. Onze pilot bewijst dat er veel geld bespaard kan worden op deze manier. Die besparing betekent dat er meer geleverd kan worden voor hetzelfde gemeentelijke budget.

Appendix B: Transcript interview Subcontractor A

Interview Onderaannemer:

Wim Haverhals

Haverhals Metselwerken

Ik ben bezig met mijn afstudeeronderzoek en tijdens mijn onderzoek merkte ik dat er weinig aandacht is voor de conflicten die kunnen ontstaan tussen aannemers en onderaannemers tijdens bouwprojecten. Ik ben mij in de oorzaken van deze conflicten gaan verdiepen en één van de oorzaken is de problematiek rondom betalingen. Met in het bijzonder betalingen van aannemer aan onderaannemer. Over dit onderwerp ben ik in de COBOUW een artikel tegengekomen waarin u uw mening heeft gegeven over de betalingstermijnen in de bouw, graag zou ik u hier wat meer vragen over willen stellen.

1. Vorig jaar is er door staatssecretaris Mona Keijzer aangekondigd dat er een nieuwe wet zal worden ingevoerd m.b.t. het terugdringen van de betalingstermijnen tot 30 dagen. Klopt het dat deze nog niet is ingevoerd.
 - Dat Klopt. De wet was in eerste instantie een voorstel. Ik denk dat het op zeer korte termijn weleens ingevoerd kan gaan worden, maar het gros van de aannemers zal zich hier niet aan houden. De aannemers zeggen dat zij hun eigen betalingstermijnen aanhouden en de onderaannemers die maar hebben te accepteren
2. Hoelang zijn de betalingstermijnen gemiddeld op dit moment?
 - Binnen mijn bedrijf zit ik gemiddeld op 45 dagen. terwijl de meesten onderaannemers toch proberen in het contract te zetten om de landelijke trend van 30 dagen aan te houden wordt er hier toch niet aan gehouden door de aannemers. De betaling schuift steeds op, er wordt pas betaald nadat de onderaannemer twee of drie aanmaningen heeft gestuurd. Waardoor de contractuele afspraak als het ware niet wordt nagekomen.
3. Zou ik u mogen vragen hoeveel mensen u nu voor u hebt werken?
 - Totaal de ZZP'ers en met de mensen in loondienst heb ik ongeveer 65 mensen voor mij werken
4. Bent u als bedrijf weleens in financiële problemen gekomen doordat een hoofdaannemer van een project te laat of helemaal niet betaalde?
 - Ik ben er wel een aantal keer mee in de problemen gekomen, dat was dan voornamelijk in de tijd van recessie omdat er toen heel weinig marge zat tussen vraag en aanbod waardoor de betalingstermijnen weleens 60 dagen konden worden waardoor je als bedrijf in de problemen kunt komen

5. Zou u mij kunnen uitleggen hoe het in de praktijk precies werkt waardoor die termijnen zo hoog kunnen oplopen?
 - Wanneer wij het werk hebben afgerond wachten wij op de opdrachtbon. Op dat moment begint het uitstel van de aannemer al, op het moment dat de bon wordt ingeleverd stellen ze dat je over 7 dagen je tegen bon krijgt en na de ontvangst van de tegen bon treedt de afgesproken betalingstermijn in werking, dan pas kan er gefactureerd worden.
6. Dus zij geven henzelf een week extra de tijd om het werk te controleren?
 - Juist. In vele gevallen krijgen de uitvoerders van hun projectleider of in sommige gevallen zelfs van de directie te horen dat als een onderaannemer om een opdrachtbon vraagt, niet voor het einde van de week uitschrijven.
7. Dus eigenlijk zegt u dat ingevoerde wetten met betrekking tot betalingstermijnen op verschillende manieren omzeild kunnen worden.
 - Jazeker. Neem bijvoorbeeld de BAM, die houden zich aan de contractuele afspraak van een betalingstermijn van 30 dagen, maar dan wel vanaf de 30^{ste} van de maand. Dus stel dat men de 10^{de} van de maand klaar is, dan gaat de betalingstermijn 20 dagen later pas in gang wat dus in het ergste geval er zomaar voor kan zorgen dat je de betaling 2 maanden later ontvangt. Dus contractueel is afgesproken binnen 30 dagen, maar onder hun voorwaarde vanaf de 30^{ste} van de maand.
8. neemt u zelf dan nog wel werk aan van de BAM?
 - Nee. Daar begin ik niet meer aan. En dat heb ik ze zelf ook verteld ook
9. Wat zou voor u nou een ideale betalingstermijn zijn, waarbij u ook rekening houdt met de aannemer en u zelf niet in de problemen komt doordat u bijvoorbeeld u eigen personeel niet kan betalen?
 - Dan niet langer dan 30 dagen. Dus binnen 30 dagen maximaal betalen aangezien wij al een hoop voorfinancieren tijdens bouwprojecten. Ik heb in mijn eigen offerte een betalingstermijn van 21 dagen staan daar gaan aannemers alleen bijna nooit mee akkoord omdat ze een betalingstermijn van minimaal 30 dagen willen, maar hoger dan dat wil ik dan zelf niet gaan omdat ik weet dat ze die 30 dagen door verschillende foefjes kunnen omzeilen.
10. De aannemer eist dus vaak een betalingstermijn van minimaal 30 dagen, maar wat is volgens u de reden dat zij die betaling zolang mogelijk willen uitstellen?
 - Je moet het zo zien, de hoofdaannemers en dan hebben we het over de grote namen in Nederland, Heijmans, BAM, die hebben een winstpercentage van ongeveer 1-2%, dat is niet veel waardoor zij heel weinig kunnen hebben. Zij werken zelf met het geld waar zij de onderaannemer mee moeten betalen, dat kan gebruikt worden om andere projecten te ondersteunen maar ook om het personeel mee te betalen. Dus als zij de onderaannemer direct gaan uitbetalen moeten zij een kortlopende lening bij de bank nemen om hun eigen kosten te dekken. Op den duur komt het ook allemaal goed, maar het duurt gewoon veel te lang.

11. Maar het geld is er dus wel om de onderaannemer te betalen?

- Ja, alleen in sommige gevallen spreken zij termijnen af met de opdrachtgever. Dus bijvoorbeeld na afronden fundering ontvangt de aannemer eerste termijn, 1^{ste} verdieping als tweede termijn en de 2^{de} verdieping als laatste termijn. Als ik mijn werk heb afgerond en vraag om de opdrachtbon terwijl zij de termijn nog niet gehaald hebben, dus nog niet voldoen aan de eisen om de termijnbetaling te ontvangen, hebben zij ook het geld niet om de onderaannemer uit te betalen.

12. Werkt u in de contracten die u afsluit ook met termijnbetalingen?

- Ja, de eerste factuur dien ik meestal na ongeveer 10 dagen na start werk in. Ik ontvang de eerste betaling dan ongeveer 50 dagen na start van het werk, tot die tijd betaal ik al mijn personeel netjes op tijd. Ik heb het geluk dat ik het allemaal kan voorfinancieren, maar er zijn genoeg onderaannemers die dat niet kunnen en die hebben dan een probleem.

13. Want als je het niet zou kunnen betalen moet je simpelweg dus leningen afsluiten om voor te financieren met vele risico's die?

- Dat klopt inderdaad, in het ergste geval tot faillissementen aan toe. Want bij mij is het zo dat ik geen materialen hoef voor te financieren als metselbedrijf. Je hebt ook onderaannemers die materiaal leveren, dus die financieren zowel materiaal als personeel voor.

14. De bouw zit sinds na de recessie in een stijgende lijn, maakt u zich zorgen voor de toekomst indien er weer een dip zou kunnen ontstaan, denk bijvoorbeeld aan de problemen omtrent stikstof die op dit moment spelen?

- Ik maak mij daar best wel zorgen over ja. Ik heb laatst de cijfers van het EIB bekeken en die stellen dat de grote aannemers nog steeds geen vlees op de botten hebben. Nadat de recessie voorbij was is de vraag in de bouw gestegen waardoor de gespecialiseerde onderaannemers ook hun prijzen hebben opgevoerd. Dus dat het beter gaat met de bouw hebben de hoofdaannemers niet zoveel van gemerkt omdat zij ook meer moeten betalen voor het verwerken van hun producten.

15. Zou u zelf dan bereid zijn iets van de prijs af te halen indien een aannemer u kunt garanderen binnen bijvoorbeeld 2 weken na afronden werk tot betaling over te gaan?

- Nee, dat zou ik met de kennis die ik nu heb niet doen. Ik zie dat als onnodig cadeautjes weggeven. In het verleden hebben aannemers weleens gezegd dat zij het geld zouden overmaken indien nodig maar daarvoor wel een korting willen als tegenprestatie.

16. De reden waarom ik u dit vroeg is omdat ik uit een ander onderzoeksrapport heb gelezen dat onderaannemers in de verenigde staten zelfs bereid zijn om kortingen te geven op hun aanneemsom omdat de betalingstermijnen daar in sommige gevallen kunnen oplopen tot 120 dagen. Voor mijn onderzoek is het belangrijk dat ik van u de bevestiging heb ontvangen dat er een betalingprobleem is in de bouw. Nu ben ik benieuwd wat volgens u een geschikte oplossing zou kunnen zijn om het probleem met betrekking tot betalingen op te lossen
- Nee, daar heb ik zelf nooit over nagedacht. als straks de wet van een betalingstermijn van maximaal 30 dagen wordt ingevoerd dan moet iedereen daar zich ook aan houden anders krijg je dit probleem nooit opgelost. Aan de voorkant moet iedereen hier aan mee werken, dan gaat die trein vanzelf lopen. Dus als de opdrachtgever op tijd gaat betalen dan kan de Hoofdaannemer op tijd betalen en krijgt iedereen netjes zijn geld op tijd.
17. Dus als ik het goed begrijp geeft u aan dat het ergens in het betalingsproces vastloopt waardoor de partijen die als laatst betaald moeten worden, in dit geval de onderaannemers, hier dus een risico lopen?
- Ja, dat klopt. Je moet het zo zien, als ik een grote ploeg metselaars op een bouwplaats zet dan heb ik ongeveer €70.000,- aan kosten per week. Als ik dat dan vier weken moet voorfinancieren dan praten we over bijna €300.000,-. En dan moet je nog afwachten of de aannemer op tijd gaat betalen
18. Dat zijn grote bedragen voor een klein bedrijf, ik kan mij voorstellen dat u dan niet met iedere aannemer in zee gaat, hoe bepaald u met wie u wel en niet werkt?
- Ik schakel daarvoor een extern bureau in die de aannemer eerst voor mij screent alvorens ik met hen in zee ga. In sommige gevallen zie je dat een kredietmaatschappij maar tot €25000,- wilt verzekeren en de rest is dan eigen risico. Dat leg ik die aannemers dan ook netjes voor, dan vertel ik ze dat de kredietmaatschappij niet ver wilt gaan met het verzekeren en in sommige gevallen neem je dan nog wel het risico.
19. In het voorbeeld van net dat u weleens €300.000,- voorfinanciert is €25000,- niet veel. Kent u andere onderaannemers die hierdoor failliet zijn gegaan?
- Dat klopt inderdaad. Ja, ik heb wel een aantal bedrijven failliet zien gaan omdat de opdrachtgever failliet is gegaan. die waren dan met tonnen aan geld het project ingestapt en die haalden er dan helemaal niks meer uit
20. Ik zal u even een quote voorlezen: AFNL heeft in een artikel aangegeven dat de onderaannemers een mogelijkheid hebben om grote bedrijven te straffen als zij zich niet aan de betalingstermijn houden, maar daar wordt in de praktijk nauwelijks gebruik van gemaakt. Zij hebben de mogelijkheid om de organisaties die te laat betalen een renteboete op te leggen maar dat doen de meeste niet omdat het de relaties schaad, waarbij je een volgende opdracht dan wel kunt schudden. Heeft u zelf weleens gebruik gemaakt van deze methode ?
- Ik speel het via mijn kredietmaatschappij, die schrijven dan een aantal brieven en zetten er een advocaat op om tot betaling over te gaan, en dan komt meestal het geld ook wel binnen anders kun je overgaan tot beslaglegging en dat risico nemen ze niet.

21. Zonde eigenlijk dat we anno 2020 nog steeds met deze problemen kampen in de bouw industrie
- Ja, het gebeurd, en je moet dan ook echt in ogenschouw nemen dat het niet altijd leuk is
22. Maar is het dan zo dat u het dan gewoon accepteert zoals het nu gaat ?
- Ja, dat heb ik wel geleerd na al die jaren, gewoon accepteren zoals het nu gaat en ermee leren leven dat die problemen met betrekking tot betalingen er nou eenmaal zijn. Je moet heel alert zijn en gelijk er bovenop duiken als iets niet gaat zoals het zou moeten gaan, dat is de enige oplossing. Dus indien nodig gelijk een aanmaning sturen wanneer de betalingstermijn verlopen is en het geld nog niet binnen is, dan kun je in sommige gevallen nog weleens een boos telefoontje verwachten van de aannemer maar dat is dan maar zo.
23. Zijn er ook aannemers die het wel allemaal netjes op orde hebben, en wel altijd op tijd betalen zoals contractueel is afgesproken ?
- Ja, die zijn er ook. Voorbeelden zijn Heijmans en Dura Vermeer die betalen altijd netjes zoals afgesproken is. En als er dingen in de factuur staan waar zij het niet mee eens zijn dan lossen wij dat altijd samen op
24. De laatste vraag, Zou u straks ook bereid zijn om een oplossing voor dit probleem die ik in mijn scriptie ga beschrijven willen valideren ?
- Ja, dat zou ik heel leuk vinden, ik zit zelf in het bestuur van de aannemersfederatie en zit ook met dit probleem, jouw scriptie zou weleens interessant voor ons kunnen zijn.

Ik wil u hartelijk bedanken voor dit interview en uw tijd.

Appendix C: Transcript interview Subcontractor B

Interview Onderaannemer B: Veli Gultepe (Gultepe Sloopwerken)

Allereerst introductie over mijn afstudeeronderzoek

1. Voert u weleens klussen uit voor grote aannemers in Nederland ?
 - Ja. Tot voor kort heb ik voor hen gewerkt.
2. Heeft u toen weleens in de situatie gestaan dat er problemen waren rondom betalingen?
 - Ja altijd
3. Hebben deze problemen weleens tot conflicten geleid tijdens projecten
 - Ja, die hebben weleens tot conflicten geleid waarbij ik er zelfs over nagedacht heb om het werk tijdelijk stil te leggen
4. Zou u mij wat meer kunnen vertellen over de problemen die u hebt ervaren ?
 - In het contract worden vaak betalingen in termijnen opgenomen, wat de grote aannemers dan doen is de termijnen vasthouden. Ik probeer zelf meestal de termijnen zo in het contract te laten zetten dat ik ongeveer na 2 weken na start werk de eerste factuur op kan sturen. Dan is het weleens voorgekomen dat ik met mijn vijfde termijn bezig was en ik nog de betaling van de eerste factuur moet ontvangen
5. Dan praten wij dus over ongeveer een periode van 10 weken waarin er nog geen betaling heeft plaatsgevonden ?
 - Ja, en dat is gewoon te lang, echt te lang.
6. Is er een mogelijkheid om jezelf tegen deze lange betalingstermijnen te verdedigen ?
 - Ja, dat zijn een soort van verzekeringen waar ik van heb gehoord bij andere onderaannemers, zij sturen hun factuur naar die partij op en die betalen dan ook gewoon netjes, en zij factureren dan naar jouw klant
7. De kredietverzekeringen zoals ik dat heb begrepen, heeft u ook gehoord welk percentage zij daaraan verdienen ?
 - Ja, zij vertelde mij dat het je minimaal 5 tot 10% kost, maar dat is op basis van wat andere mij zeiden, ik heb dat zelf nooit gevraagd. Ik zelf vind 5 tot 10% veel en dat is ook de reden waarom ik er nooit achteraan ben gegaan.
8. Wat is volgens u de oorzaak dat er betalingsproblemen zich voordoen tijdens bouwprojecten tussen aannemer en onderaannemer ?
 - Ik denk dat de grote aannemers het geld bewust vasthouden, zodat zij op papier als financieel sterk bedrijf naar buiten toe kunnen treden. Ik heb voor de BAM verschillende klussen uitgevoerd, daarbij heb ik ook weleens met de projectontwikkelaar gezeten, zij hebben toen zonder dat er kosten waren gemaakt door de BAM, dus voor start van het project, al een groot bedrag over moeten maken naar de BAM

9. Dus eigenlijk verteld u mij dat het geld er wel is om de onderaannemers te kunnen betalen ?
- **Op de klussen waar ik ben geweest weet ik dat de opdrachtgever de termijnen op tijd betaald en dat de eerste termijn voor start werk ook al binnen was bij de aannemer**
10. Kan ik hieruit dan ook opnemen dat het probleem niet tot bij de opdrachtgever gezocht kan worden maar dat de aannemer om hun redenen het geld langer vasthouden en dat daar dus het probleem ligt ?
- **Ja, dat is wat ik heb ervaren**
11. Hoe groot is de impact op onderaannemers als er problemen zijn rondom betalingen.
- **Heel groot, Ik heb bij de BAM weleens meegemaakt dat een eigenaar van een voegbedrijf met volgens mij 20 of 25 jongens in vaste dienst een keer drie maanden na start werk aan het huilen was omdat hij zijn eigen personeel niet meer kon betalen.**
12. Dus die onderaannemer had na 3 maanden nog steeds geen betaling ontvangen ?
- **Nee, hij had na 3 maanden nog steeds geen betaling ontvangen terwijl al zijn kosten doorliepen. Op een gegeven moment kun je dat niet meer voorfinancieren**
13. Belanden zulke bedrijven dan ook vaak niet in de schulden door leningen die afgesloten moeten worden ?
- **Ja in sommige gevallen zelfs tot faillissementen aan toe.**
14. Heeft dit invloed op het vertrouwen dat onderaannemers nog hebben in aannemers wanneer zij aan een klus beginnen.
- **Ja, dat vertrouwen is er niet meer**
15. Als ik kijk naar mijn eerdere bevindingen van mijn onderzoek dan wordt er in de literatuur aangekaart dat een contract het vertrouwen zou moeten bieden aan een onderaannemer, hoe kijkt u naar de contracten tussen aannemer en onderaannemer ?
- **De contracten zijn heel erg eenzijdig in het voordeel van de aannemer. Eigenlijk wordt je bijna gedwongen met het contract. Kijk iedere grote aannemer heeft zijn eigen termijnen en voorwaarden. Ik heb weleens meegemaakt dat ik bij de BAM kwam voor het samenstellen van een contract waarbij ik aangaf dat ik een betalingstermijn heb van 30 dagen, dan vegen zij dat gelijk van tafel, die geven aan wat hun voorwaarden zijn en daar moet je het dan mee doen. Jouw eigen voorwaarden gelden dan niet meer.**
16. Wat is de reden dat een onderaannemer er op dat moment niet voor kiest om het werk dan niet uit te voeren, of na een late betaling het werk niet tijdelijk stil te leggen. Heeft dat te maken met een kans om bijvoorbeeld een toekomstige goede klus mis te lopen ?
- **Ja, dat houdt je ook in je achterhoofd. Plus vaak is het zo dat als jij eenmaal met een project bezig bent, dat je op dat moment al heel veel kosten hebt gemaakt en dan ben je eigenlijk gewoon bang om misschien wel helemaal niks te krijgen waardoor je bepaalde dingen gewoon makkelijker accepteert. De grote aannemers maken hierbij gewoon misbruik van hun machtspositie omdat zij ook weten dat zij veel werk**

hebben. Als jij personeel in dienst hebt die jij altijd door kan laten werken bij die grote aannemers dan wil jij zo een grote partij niet kwijt raken natuurlijk. En dat weten zij.

17. Heeft u weleens werk uitgevoerd voor overhedsinstantie ?

- Ja, ik heb voor verschillende gemeenten klussen uitgevoerd

18. Hoe verliepen de betalingen daar ?

- Ja, dat ging eigenlijk goed

19. Er zijn wetgevingen voor lange betalingstermijnen, denkt u dat die worden overschreden?

- Ja, er zijn wel meerdere wetten dat weet ik, maar ik heb weleens meegemaakt dat een andere onderaannemer de deur bij een aannemer heeft ingetrapt en vond dat hij werd belazerd waar hij bij stond.

20. U vertelde dat de voorwaarden van de aannemer meestal er doorheen gedrukt worden bij contractonderhandelingen. Waarop zijn de keuzes van een aannemer dan gebaseerd bij het kiezen van de juiste onderaannemer om de klus uit te voeren.

- In principe heeft dat allemaal te maken met net de juiste personen kennen en die jou het werk ook gunnen. Als jij dus de juiste mensen kent bij een Heijmans of Ballast dan krijg je eigenlijk automatisch het werk. Op het moment dat je een goede indruk achterlaat bij een van die grote bedrijven dan kun je het werk bijna allemaal van hun krijgen, maar wel allemaal onder hun voorwaarden en hun tarieven

21. Dus als ik het goed begrijp komt het voor dat een aannemer de aanneemsom voor de onderaannemer bepaald ?

- Ja, dat heb ik weleens meegemaakt, en dan moet je zelf uit gaan rekenen of het waard is om de klus uit te voeren of niet, daar is dan ook geen discussie over mogelijk.

22. Stel dat een aannemer u zou kunnen garanderen binnen 15 dagen of binnen 20 dagen na facturatie met zekerheid te betalen. Daartegenover staat wel een korting bieden van een aantal procent, zou u daar voor openstaan ?

- Ja, ik zou dat aantal procent korting geven als ik altijd op tijd betaald zou worden. En ik denk met mij heel veel onderaannemers. Ik heb het in het verleden ook weleens gehad dat ik zo een soort afspraak heb gemaakt, en zij kwamen dan ook hun betalingsverplichting na. Maar dat soort afspraken zie je vaker in de wegenbouw

23. Het zou voor een aannemer dan dus simpel gezegd eind van de streep financieel beter uit kunnen pakken als zij in ruil voor een korting de betaling op tijd verrichten ?

- Ja, dat lijkt mij wel, maar soms heb ik ook het idee dat de grote aannemers gewoon flink misrekenen, en op het moment dat zij misrekenen heb ik het idee dat zij hun fout proberen recht te breien op de rug van de onderaannemers. Dan zeggen ze bijvoorbeeld onze eigen timmerman is ook nog met jou werkzaamheden bezig geweest waarmee ze uren bij jou eraf kunnen schrappen.

Appendix D: Validation 1 Blockchain Solution

Transcript Validatie met Voorzitter Aannemersfederatie Nederland (AFNL): Philip van Nieuwenhuizen.

Onderwerp: Voortgang afstudeeronderzoek

In eerste instantie is er uitgelegd hoe de scriptie is opgebouwd en wat de exacte bedoeling van dit gesprek is: valideren van de Blockchain Solution

Onderwerp: Diagram huidige betalingsprocedure.

Vraag: wat vindt u van de opbouw van dit diagram, is dit ook daadwerkelijk hoe een huidige betalingsprocedure eruit ziet ?

Antwoord: de fatsoenlijker aannemers schakelen ook daadwerkelijk de onderaannemers in die in eerste instantie een offerte hebben gemaakt voor de te uit te voeren werkzaamheden, echter is dat niet vanzelfsprekend. Er zijn voldoende aannemers die een passende offerte ontvangen maar nadat het project is binnengehaald er alsnog voor kiezen andere onderaannemers te benaderen die de werkzaamheden eventueel goedkoper zouden kunnen uitvoeren. Verder wordt de goedkeuring van werkzaamheden in de praktijk ook wel prestatieverklaring genoemd.

Er wordt in het diagram nog een stadium overgeslagen, tegenwoordig wordt er veel gebruik gemaakt van back-to-back contracten, dit houdt in dat de onderaannemer pas kan factureren indien ook de prestatieverklaring van de opdrachtgever binnen is. In deze vorm moet er dus gewacht worden op zowel de aannemer als opdrachtgever voor een prestatieverklaring. Laat ik het zo zeggen, er is dus nog een erger scenario dan die jij nu hebt geschat in het diagram. En het grootste probleem hiervan is dat het moeilijk te controleren valt

Ik zal even een voorbeeld geven, ik ben pas een lid verloren, de man werkte vast voor een grote hoofdaannemer en deed ook vrij veel werk voor hen, op het moment dat de werkzaamheden exact waren zoals in de onderaannemingsovereenkomst is opgesteld, dan waren de betalingen altijd binnen 60 dagen afgehandeld, en werd de prestatieverklaring altijd op tijd aan de onderaannemer gegeven. Echter, als het meerwerk betrof dan vertelde de hoofdaannemer dat de procedure hiervan anders is (toevoeging auteur: anders dan de procedure waarbij een prestatieverklaring wordt opgevraagd voor de afgeronde werkzaamheden) omdat er intern meer administratieve stadia doorlopen moeten worden en bovendien moeten zij als hoofdaannemer wachten totdat de opdrachtgever het meerwerk gevalideerd heeft en daarmee liepen de betalingstermijnen uit naar vele maanden.

Vraag: Omschrijft u hier de welbekende pay-when-paid term ?

Antwoord: Juist dat is exact wat ik bedoel, ik probeerde je hiermee aan te geven dat de scenario's erger kunnen dan de 83 dagen zoals jij die hebt omschreven in jouw diagram

Onderwerp: Omschreven hoe de eisen van de Blockchain Solution tot stand zijn gekomen

Nadat het diagram van de huidige betalingsprocedure gevalideerd is door de voorzitter van de Aannemersfederatie is aan hem uitgelegd wat de eisen waren voor het opstellen van de oplossing voor dit probleem en hoe de oplossing uiteindelijk tot stand is gekomen. Dit bracht ons naar de volgende fase in het validatie gesprek, namelijk de Blockchain oplossing.

Onderwerp Blockchain Oplossing

In eerste instantie is kort uitgelegd dat voor de studie is gekeken naar een technische oplossing dat het probleem eventueel zou kunnen oplossen en dat hiervoor Blockchain Technology is toegepast.

Vraag: Zou ik u mogen vragen wat u al weet wat Blockchain Technology

Antwoord: Ik heb meerdere keren erover gehoord en heb toen ook zelf gekeken naar wat het was maar toen dacht ik al snel, daar verdiep ik mij ooit nog wel een keer in als ik daar wat meer tijd voor heb, het is als ik mij goed herinner een aaneen schakeling van digitale systemen waardoor processen versneld kunnen worden.

Hierna volgt een korte uitleg van wat Blockchain technology inhoudt door de auteur van dit onderzoek. En wordt de focus al snel gevastigd op de uitleg van Smart Contracts die mogelijk zijn gemaakt door Blockchain. Waarna het diagram waarin de betalingen via Blockchain verlopen getoond wordt en doorlopen wordt. Hierbij worden zowel de voordelen van het toepassen van Blockchain als middel om betalingen te verrichten in een bouwproject, als de beperkingen van Blockchain zo helder mogelijk uitgelegd.

Vraag: Wat vindt u van de Blockchain oplossing zoals ik hem net aan u heb beschreven ?

Antwoord: Goed, je geeft zelf aan dat de techniek nog in ontwikkeling is. Laat ik het zo zeggen, op het moment dat een contract wordt ingebracht dan moet je van beide kanten accorderen. Je geeft aan dat voor het opstellen van een smart contract een Software Engineer nodig is, het zou makkelijker zijn als dat door de boekhouders van beide contractpartners gedaan kan worden. Maar verder klinkt mij deze oplossing redelijk als muziek in de oren, het is een ontwikkeling die met name argwanend tegemoet zal worden getreden door de grote bedrijven. Grote bedrijven gebruiken nu nog verschillende trucjes om die betalingen uit te stellen dat moet denk ik langs de wetgevende weg afgedekt worden.

Het is nu zo dat er een wetsvoorstel ligt om de betalingstermijnen te verminderen naar 30 dagen. Echter zal een benadeelde onderaannemer ook met de invoering van deze wet de aannemer hierop niet aanpakken simpelweg omdat hij dan de volgende keer niet meer wordt gevraagd om het werk uit te voeren. Ze zijn nu druk bezig om te bekijken of er al dan niet een onafhankelijke toezichthouder erbij gezet moet worden. Ik verwacht dat dit tot nodige stof voor politieke discussie zal opleveren. Alle andere verzoeken die wij doen bijvoorbeeld op het gebied van aanbesteding, een aanbestedingsautoriteit, die zien wij afgewezen worden

Terugkomend op de Blockchain Solution, de invoering hiervan zal moeizamer worden vrees ik. Maar, ik denk dat het goed is hoe dan ook, in de ontwikkeling van nieuwe digitalisering in de bouw. Er zijn efficiency slagen die er gemaakt moeten worden, want inderdaad alle nodeloze administratieve kosten die je kunt vermijden, bankgaranties, lange en hoge kredieten met bijbehorende rentelasten, dat is allemaal winst en dat gaat zich vertalen in productiviteit. Budgetten zullen namelijk niet verlaagd worden als de efficiency hoger wordt, wat dus betekend dat je meer kunt gaan doen voor hetzelfde geld.

Appendix E: Validation 2 Blockchain Solution

Transcript Validatie met Haverhals metselwerken (onderaannemer): Wim Haverhals

Onderwerp: Voortgang afstudeeronderzoek

In eerste instantie is er uitgelegd hoe de scriptie is opgebouwd en wat de exacte bedoeling van dit gesprek is: valideren van de Blockchain Solution.

Onderwerp: Blockchain oplossing

De huidige betalingsprocedure is bij de onderaannemer bekend. Hierdoor is er direct overgeschakeld naar het valideren van de oplossing. Allereerst zijn de requirements voor de mogelijke oplossing toegelicht op basis van de kennis die ik heb opgedaan over het probleem. Hierna is in detail de werking van de Blockchain oplossing uitgelegd vanuit het perspectief van een toekomstige gebruiker, een onderaannemer. Daarbij zijn de technische kanten van de oplossing buiten beschouwing gelaten omdat die er simpelweg niet te doen voor een onderaannemer.

Vraag: wat vindt u van de Blockchain oplossing zoals ik hem voor u heb beschreven ?

Antwoord: De oplossing klinkt heel goed als het ook daadwerkelijk zou kunnen gaan werken. Op dit moment verschuilen heel veel aannemers zich ook achter het afkeuren van werkzaamheden van de onderaannemer om de betaling uit te stellen. Of een situatie waarin in eerste instantie een ondertekende bon wordt afgegeven en er in een latere fase wordt gezegd dat het niet gedaan had moeten worden waardoor ze de betaling vasthouden.

Vraag: voor mij is het interessant voor de validatie van mijn oplossing om u te vragen of u er ook voor open zou staan om het hele proces te digitaliseren en te werken met smart contract, of denkt u dat het op dit moment nog een stap te ver is voor de bouwindustrie en in het speciaal de onderaannemers?

Antwoord : Ik denk dat de onderaannemers wel mee zouden moeten bij het toepassen van de oplossing omdat het ook niet anders kan. Het is nu al in deze tijd dat alles digitaal en via computers verloopt. daarbij kun je alle partijen die nu helpen om de aannemers te laten betalen omzeilen door het toepassen van deze oplossing. Het spreekt in het voordeel van de onderaannemers wat hen dus makkelijker zou kunnen overhalen

Vraag: Klopt het dat u er zelf ook voor zou staan ?

Antwoord: Ja. Ik vind het ook wel goed wat je doet

Vraag: Mochten er bepaalde stappen nog te ingewikkeld zijn, zoals het gebruik van digitale munten dan kan dat met de nodige aanpassingen traditioneler gehouden worden. Daarbij verwacht ik dat de onderaannemers wel enthousiast zullen zijn over de oplossing maar mijn vraag aan u is wat verwacht u van de aannemer mocht ik deze oplossing bij hen voorstellen?

Antwoord: een aannemer overtuigen om dit type contract toe te passen zal heel moeilijk worden. Het punt is dat de aannemers zulke betalingsafspraken niet vast willen leggen, die willen toch de regie zelf in handen houden. Ik snap heel goed wat jij met de oplossing wilt bereiken maar ik verwacht dat de aannemers tot het laatste toe het geld zelf vast willen houden waardoor het moeilijk zal worden hen te overtuigen.

Vraag: Samenvattend kan ik dus stellen dat u verwacht dat de onderaannemers ondanks de grote veranderingen wel overstag zullen gaan maar dat er weerstand zal zijn vanuit de aannemer.

Antwoord: Ja, dat verwacht ik.

Vraag: Wat zou denkt u de aannemers wel kunnen overtuigen om zo een oplossing te implementeren of gewoon de betalingen op tijd te verrichten ?

Antwoord: Daar zijn wij al jaren tegen aan het boksen en wij zelf hebben daar ook nog geen oplossing voor. Ik geloof dat wel dat hetgeen wat jij nu aan het doen met die waterdichte contract een hele mooie oplossing zou kunnen zijn maar ik verwacht niet dat zij daar aan zullen meewerken. Ik vind het jammer hoe het nu gaat.

Appendix F: Validation 3 Blockchain Solution

Transcript Validatie met Co-founder Fluidensity & Madelin Twente B.V. (Blockchain Speciliast): Peter Langela

Peter Langela heb ik tijdens mijn afstudeer proces niet eerder gesproken daarom was het van groot belang goed uit te leggen wat ik voor mijn afstudeeronderzoek heb uitgevoerd en waarom ik hem heb benaderd om mijn oplossing te valideren. Peter Langela is mede-eigenaar van een bedrijf dat zich bezig houdt met de toepassing van Blockchain in de kunst wereld en weet wat op ieder vlak wat het vraagt om een nieuwe technologie als Blockchain toe te passen in een sector waar hier verder niks over bekend is.

Allereerst zijn de probleemstelling en onderzoeksvergroottekening toegelicht, hierna is uitgelegd hoe het knelpunt van dit probleem geïdentificeerd is en is in eerste instantie de betalingsprocedure in de huidige situatie met behulp van het diagram uitgelegd. Hierna is met behulp van het diagram waarin de betalingsprocedure via Blockchain zal verlopen gebruikt om de oplossing uit te leggen.

Vraag: Wat is uw eerste indruk van de oplossing ?

Antwoord: Ik snap het probleem, dat heb je goed uitgelegd. Ik snap ook de oplossing. Ik denk dat de oplossing misschien wat technisch in elkaar steekt, ik zie hier en daar nog wel wat valkuilen, maar ik snap wel de richting van je oplossing en ook je gedachte met hoe kunnen wij het probleem met Blockchain oplossen. De oplossing die je benoemd zou je bijvoorbeeld ook kunnen programmeren in Microsoft met een Oracle database. Maar met name het vertrouwelijke aspect, dat het onomstotelijk vastligt, dat is hetgeen wat vertrouwen gaan kunnen bieden. Het voordeel van een smart contract is dat het de contractvoorwaarden onconditioneel uitvoert, dus op het moment dat alle parameters waar zijn, het werk dus is uitgevoerd, de Oracle dus in dit geval de inspecteur zegt het is goed dan kan de aannemer niet meer voorkomen dat er betaald wordt. Dat is dus eigenlijk de kern van je oplossing.

Vraag: Exact, dat is hoe de oplossing kort gezegd in elkaar steekt...

Antwoord: En dat is een mooie oplossing, omdat je daarmee de discussie eigenlijk vermijd.

Vraag: U had het net over dat u een aantal valkuilen zag, wat zijn die valkuilen van deze oplossing?

Antwoord: Jij benoemde dat het smart contract wordt opgesteld door een software ontwikkelaar, maar degene die het contract opstelt zal nog steeds een jurist moeten zijn. Maar het contract wordt geprogrammeerd in code, dat is een javascript-achtige code als je met Ethereum werkt. Wie kan dat controleren? Hoe gaat een aannemer of onderaannemer controleren of alle clausules uit het originele overeenkomst daar goed instaan? dat is het ding waardoor het drempel verhogend werking heeft

Vraag: dat ben ik met u eens, aanvullend komt daarbij kijken dat als er een klein foutje in het contract staat en als het contract eenmaal op de Blockchain staat, het niet meer aangepast kan worden...

Antwoord: Exact, en dat kan onbewust gebeuren maar ook bewust natuurlijk. In deze oplossing wordt de rol van de programmeur of bureau die het contract gaat opstellen cruciaal.

Vraag: In de ideale situatie zouden de boekhouders van de aannemer en onderaannemer samen het smart contract in elkaar moeten kunnen steken, al is dat nu helaas niet mogelijk...

Antwoord: Nee nou ja, kijk, ik heb nu 5/6 generaties software ontwikkeling meegemaakt, en nu zit je gewoon met software ontwikkeling waarin je definiert wat je wilt hebben maar niet hoe

het moet. Dat zou je hier eigenlijk ook moeten uitzoeken, dat je op een administratieve manier gaat vastleggen hoe die flow van zo een contract moet zijn, en dat moet dan geïmplementeerd worden in een Blockchain smart contract. Ik denk dat als je zoiets voor elkaar zou kunnen boksen, dat je een heleboel problemen oplost. Er zijn nu accountant bureaus die de smart contract code kunnen valideren, dat zou je in deze oplossing kunnen toepassen maar daarmee creëer je een heleboel overhead. Dus de waarde van zo een contract moet wel heel hoog zijn om de oplossing op deze manier rendabel te kunnen maken.

Vraag: daarmee beantwoordt u ook gelijk deels mijn volgende vraag, want ik was benieuwd hoe het zit met de kosten van het creëren van zo een smart contract en in hoeverre zal de oplossing kosten kunnen besparen, door bijvoorbeeld administratieve efficiëntie te creëren, ten opzichte van de overhead kosten die een smart contract met zich meebrengt?

Antwoord: Ja dat is een vraag die nu ook in andere sectoren speelt en sowieso in de hele wereld van smart contract. Ik denk dat het heel interessant is als er een platform zal komen, die zijn nu ook in ontwikkeling, om het op een hele makkelijke manier vast te leggen. Dat als jij in Visio tekent dit is de flow met alle ja/nee en dan op een knop kunt drukken maak er maar een smart contract van, dan is dat natuurlijk een ultieme oplossing. En daar gaat het nu wel naartoe

Vraag: heeft u een voorbeeld van die ontwikkelingen die nu gaande zijn ?

Antwoord: nee niet zo uit mijn hoofd maar die zijn zeker te vinden, je ziet het nu ook in de software. Alle programmeurs worden langzaam maar zeker uitgevaagd door code generatoren. Ik heb zelf met 4^{de} generatie taal gewerkt waarin je aangeeft wat je wilt hebben maar niet hoe het moet en onderwater wordt dan een code gegenereerd. Het enige dat je moet weten is dat die code generator engine goed is, dan heb je eigenlijk je doel bereikt. Ik denk dat het een interessante richting zou kunnen zijn om dat verder te onderzoeken. Daar komt nog iets bij, het vinden van smart contract programmeurs kan ook nog een probleem zijn, die zijn op dit moment super schaars. En dat komt omdat Blockchain een hele nieuwe technologie is die nog niet doorgebroken is, dus op dit moment zijn zij ook de best betaalde programmeurs.

Vraag: Dat zijn wel nog een aantal belangrijke valkuilen waar rekening mee gehouden moet worden...

Antwoord: Ja, maar toch denk ik niet dat jij je eigen moet laten ontmoedigen en dat dit de juiste richting is waarin je naartoe moet gaan. Want zoals het nu gaat in de bouwsector is het gewoon niet goed, jij noemde een aantal scenario's die nog niet eens de slechtste scenario's waren. Het grote voordeel van wat de oplossing zal toevoegen is het stukje vertrouwen dat ontbreekt. Als iedereen het ermee eens is wat er in het smart contract staat dan gebeurd het ook en is er niets meer dat het tegen kan houden. En dat is ook gelijk de crux van Blockchain. Alles wat je benoemde kan ook met een database alleen het verschil is dat een systeem beheerde bepaalde afspraken kan blokkeren indien een van de partijen dat zou willen.

Vraag: er zijn inderdaad een aantal uitdagingen voor de oplossing, een ander voorbeeld is het Oracle probleem, de Oracle blijft de vertegenwoordiger van de aannemer en die kan ook de communicatie met het smart contract uitstellen indien hij bepaalde druk voelt van bijvoorbeeld een bouwdirectie. Een ander punt wat ik meerdere malen ben tegengekomen is de rechtsgeldigheid van een smart contract. In Nederland zijn hier nog twijfels over, weet u hier meer over ?

Antwoord: Ik ben zelf natuurlijk geen jurist maar ik snap je vraag wel. Als alle betrokken partijen afspreken dat dit het contract dan is dat naar mijn mening ook rechtsgeldig maar toch is daar discussie over. Misschien is het mogelijk dat nog te valideren bij een jurist. Maar zelf denk ik dat niet het grootste probleem is.

Vraag: in mijn scriptie kaart ik aan dat het Ethereum platform toegepast kan worden om de smart contract op te laten runnen, echter heeft het Ethereum platform ook een aantal beperkingen, namelijk dat het in vergelijk met bijvoorbeeld een Visa of Mastercard veel minder transacties per seconde aankan. Voor nu is dat geen probleem omdat smart contract nog niet in grote getallen worden toegepast alleen hoe kijkt u naar de toekomst indien grote bedrijven wereldwijd overstappen op het gebruik van smart contract ?

Antwoord: Ik ben er van overtuigd dat ze de prestaties van een Visa of Mastercard kunnen evenaren in de toekomst. Op dit moment zit Blockchain nog in een vroege fase. Maar daar zijn ook al nieuwe ontwikkelingen en protocollen mee bezig om dezelfde snelheden te behalen. Op het moment dat iets gaat doorbreken en de behoefte groter wordt dan gaat dat gepaard met heel veel ontwikkelingen. Het hoeft op dit moment niet sneller dus gebeurd het ook niet, maar op het moment dat die vraag groter wordt dan zal het vanzelf opschalen daar ben ik van overtuigd.

Vraag; zou u nog een eindoordeel kunnen geven over de oplossing in zijn geheel met alle besproken voor- en nadelen ?

Antwoord: Eigenlijk alle aspecten die wij genoemd hebben, dus het probleem en de oplossing passen goed bij elkaar. Dat het een uitdaging is om de contracten te maken, een andere uitdaging ligt in het converteren van echt geld naar cryptomunten, daar verwacht ik wel een hoge weerstand. Mijn vraag is dan ook is dat wel nodig. Je zou ook een smart contract kunnen maken waarin je het niet in geld uitdrukt maar in waarde. Dus dat je zegt op het moment dat dit waar moet je niet 10 Bitcoin overmaken maar gewoon €50.000,- Euro. En dat kun je ook automatiseren. Er zijn ook banken die API's hebben. Het gebruik van crypto is wel het ultieme maar ik denk dat je weerstand kunt verwachten op het gebruik van cryptomunten in met name de bouwwereld en dat probleem kun je best wel wegnemen. Ondanks dat Tether een stabiele coin is en zijn waarde vasthoudbaar kan ik mij voorstellen dat heel veel mensen het eng zullen vinden om gebruik te maken van cryptomunten. Daarvoor is het interessant om misschien wel uit te zoeken wat de mogelijkheden zijn om Fiat munten toe te passen. Ik denk dat als je de crypto betalingen zal vervangen door betalingen met fiat munten, en ik denk dat het kan, dan is de use case gewoon heel goed, omdat je dan met deze oplossing en vertrouwen biedt, de betalingstermijnen korter maakt en eigenlijk is dat voor iedereen goed.

Appendix G: General purchasing and subcontracting conditions

VOORWAARDEN

Algemene inkoop- en onderaannemingsvoorwaarden

Algemene inkoop- en onderaannemingsvoorwaarden van Heijmans N.V. en de ondernemingen die met haar in een groep zijn verbonden als bedoeld in artikel 2:24b BW.

Gedeponeerd op 15 december 2016 bij de Kamer van Koophandel.

I ALGEMEEN GEDEELTE

Algemeen

Artikel 1: Definities en toepasselijkhed

1.1 In deze algemene voorwaarden wordt verstaan onder:

- "de Opdrachtgever": Heijmans N.V. en/of één of meer van haar dochtermaatschappijen.
- "de Opdrachtnemer": elke natuurlijke of rechtspersoon met wie de Opdrachtgever over de totstandbrenging van een Overeenkomst onderhandelt en/of een Overeenkomst sluit.
- "de Principaal": de Opdrachtgever volgens de Hoofdaannemingsovereenkomst.
- "de Bouwdirectie": de directie volgens de Hoofdaannemingsovereenkomst.
- "Overeenkomst": elke overeenkomst tussen Opdrachtgever en Opdrachtnemer.
- "Hoofdaannemingsovereenkomst": de Overeenkomst tussen de Opdrachtgever en de Principaal.
- "het Project": de opdracht omschreven in de Hoofdaannemingsovereenkomst.
- "Werkzaamheden": alle werkzaamheden die door Opdrachtnemer in het kader van de Overeenkomst moeten worden uitgevoerd.
- "Levering van zaken": levering van zaken waaronder mede begrepen alle werkzaamheden en diensten, die verband houden met de levering van zaken, voor zover deze niet vallen onder "Uitvoering van werken".
- "Uitvoering van werken": het verrichten van ontwerp- en/of uitvoeringswerkzaamheden, waaronder het tot stand brengen van een stoffelijk werk, en/of het verrichten van diensten, al dan niet gepaard gaande met de levering van zaken, niet zijnde een arbeidsovereenkomst.

1.2 Indien de Overeenkomst betrekking heeft op de Levering van zaken is naast het bepaalde in het algemeen gedeelte (I) het bepaalde in het bijzonder gedeelte inkoopvoorwaarden (II A) toepasselijk. Ingeval van tegenstrijdigheid prevaleert in dat geval het bepaalde in het bijzonder gedeelte inkoopvoorwaarden.

1.3 Indien de Overeenkomst betrekking heeft op Uitvoering van werken is naast het bepaalde in het algemeen gedeelte (I) het bepaalde in het bijzonder gedeelte onderaannemingsvoorwaarden (II B) toepasselijk. Ingeval van tegenstrijdigheid prevaleert in dat geval het bepaalde in het bijzonder gedeelte onderaannemingsvoorwaarden.

Kernwaarden Heijmans

Artikel 2: Integriteit en duurzaamheid

2.1 De Opdrachtnemer, alsook de ondernemingen die met Opdrachtnemer in een groep zijn verbonden als bedoeld in artikel 2:24b BW, zijn medewerkers, alsmede door hem ingeschakelde onderaannemers, werknelmers en leveranciers zullen bij de uitvoering van de Overeenkomst de normen in acht nemen die zijn neergelegd in de vigerende Heijmans gedragscode ("Gedragscode") en handelen in overeenstemming met de in de 'Verklaring Duurzaamheid' opgenomen principes en eisen, beide te vinden op de website www.heijmans.nl, welke op verzoek zullen worden toegezonden.

2.2 Bij een ernstig vermoeden dat sprake is van gedragingen die in strijd zijn met de Gedragscode en/of de Verklaring Duurzaamheid is de Opdrachtgever gerechtigd een audit te laten uitvoeren door een onafhankelijke partij. De Opdrachtnemer zal hieraan zijn medewerking verlenen, alsook zorgdragen dat de in art 2.1 genoemde partijen en personen hun medewerking verlenen. Op het moment dat de conclusies van de audit met zich brengen dat de gedragingen in strijd zijn met de Gedragscode en/of de Verklaring Duurzaamheid, zal Opdrachtnemer direct zorgen dat Opdrachtnemer en/of de in art 2.1 genoemde partijen en personen weer handelen overeenkomstig de Gedragscode en/of de Verklaring Duurzaamheid, waarbij Opdrachtnemer eventuele schade voor zijn rekening zal nemen waaronder de kosten van voorname audit. Het handelen in strijd zijn met de Gedragscode en/of de Verklaring Duurzaamheid wordt beschouwd als een materiële tekortkoming.

Artikel 3: Veiligheid en milieu

3.1 Opdrachtnemer zal alles in het werk stellen om de veiligheid van projectmedewerkers, ketenpartners en de omgeving van het Project te waarborgen en het veiligheidsbewustzijn te vergroten. Tevens stimuleert Opdrachtnemer dat alle betrokkenen

proactief handelen ten aanzien van veiligheid. Opdrachtnemer zorgt dat Opdrachtnemer, zijn medewerkers, alsmede door hem ingeschakelde onderaannemers, werknelmers en leveranciers zich gedragen volgens de Heijmans houding- en gedragsregels en de veiligheidsregels zoals vastgelegd in het VGWM-handboek. Deze zijn te vinden op www.geenongevallen.nl.

- 3.2 Opdrachtnemer is verplicht de instructies, eisen en aanwijzingen van de Opdrachtgever, de Bouwdirectie of overheidsinstanties zoals de arbeidsinspectie, stipt na te leven.
- 3.3 De Opdrachtnemer verlaat in bezit te zijn van het certificaat "VCASM" of "VCA[®]". Kopie van dit certificaat dient voor aanvang Werkzaamheden in het bezit te zijn van de Opdrachtgever.
- 3.4 De Opdrachtnemer verzorgt of neemt deel aan toolboxmeetings (periodieke veiligheidsinstructies) en draagt zorg voor het uitvoeren en naleven van de regels en voorschriften welke voor het Project van toepassing zijn.
- 3.5 De Opdrachtnemer verlaat in het bezit te zijn van alle certificaten welke wettelijk en (indien van toepassing) volgens plaatselijke voorschriften vereist zijn voor het uitvoeren van de Werkzaamheden. Kopieën worden op eerste verzoek van de Opdrachtgever verstrekt.
- 3.6 De Opdrachtnemer is verplicht tot het nemen van zodanige maatregelen dat tijdens aan- en afvoer van materieel en/of materialen en tijdens de uitvoering van de Werkzaamheden op het bouwterrein geen bodemverontreiniging en/of milieuschade zal optreden. Mocht er echter toch bodemverontreiniging en/of milieuschade optreden dan verplicht de Opdrachtnemer zich tot het terstond nemen van passende maatregelen en het melden aan de Opdrachtgever van deze verontreiniging, alsmede het voor zijn rekening herstellen van de oorspronkelijke situatie. De Opdrachtnemer vrijwaart de Opdrachtgever voor aanspraken van derden ter zake.
- 3.7 Bij niet nakoming door de Opdrachtnemer van één of meer van de in de vorige ledien omschreven verplichtingen of gedragingen, heeft de Opdrachtgever het recht de persoon wiens gedragingen het betreft van het Project weg te sturen en hem verdere toegang te ontzeggen.

Overeenkomst

Artikel 4: Totstandkoming en inhoud van de Overeenkomst

- 4.1 De Opdrachtnemer doet zijn offerte gestand gedurende een termijn van 6 weken. In het geval de Opdrachtnemer zijn offerte uitbrengt in het kader van deelname aan een aanbestedingsprocedure door de Opdrachtgever, dan doet de Opdrachtnemer zijn offerte gestand tot een half jaar na de gunning van het Project door de Principaal aan de Opdrachtgever.
- 4.2 De Opdrachtnemer dient de hem toegezonden en in onderling overleg tot stand gekomen Overeenkomst ongewijzigd en ondertekend aan de Opdrachtgever te retourneren binnen 14 dagen na datum verzending van de Overeenkomst. Indien de Opdrachtnemer in gebreke blijft binnen de hierboven gestelde termijn de Overeenkomst te retourneren en binnen die termijn geen bewaar aan te kent tegen de inhoud daarvan, dan wel met de uitvoering van de Overeenkomst is begonnen, wordt de Overeenkomst geacht te zijn aanvaard op de condities als vermeld in de Overeenkomst en onder toepasselijkhed van deze algemene voorwaarden.
- 4.3 Op alle Overeenkomsten van de Opdrachtgever zijn van toepassing als waren zij daarin letterlijk opgenomen (met dien verstande dat voor "Principaal" moet worden gelezen "Opdrachtgever" en dat als Opdrachtnemer gezien dient te worden opdrachtnemer onder de Hoofdaannemingsovereenkomst):
 - a. alle op de Hoofdaannemingsovereenkomst betrekking hebbende technische en administratieve bepalingen van het toepasselijke bestek, proces-verbaal en/of staat van aanwijzing of soortgelijke bestekswijzigingen;
 - b. al het overige waardoer de Opdrachtgever uit hoofde van de Hoofdaannemingsovereenkomst tegenover de Bouwdirectie en/of de Principaal gebonden is, voor zover direct of indirect verband houdende met de Overeenkomst en indien en voor zover Opdrachtnemer daarvan kennis heeft kunnen nemen voorafgaand aan de totstandkoming van de Overeenkomst.Het bepaalde in de Overeenkomst prevaleert te allen tijde boven het gestelde onder lid a en b.
- 4.4 De in het kader van de Werkzaamheden van toepassing zijnde technische en administratieve bepalingen van het bestek en de daarbij behorende tekeningen, alsmede proces-verbaal en/of staat van aanwijzing, toelichtingen, aanvullingen en overige ter zake relevante beschrijvingen zijn voor de Opdrachtnemer bij de Opdrachtgever ter inzage beschikbaar. Desgevraagd zullen van deze stukken aan de Opdrachtnemer kopieën worden verstrekt. De Opdrachtnemer wordt geacht inzage in voorname stukken te hebben gehad en alle overige door hem gewenste inlichtingen te hebben verkregen.

Rechten en verplichtingen Opdrachtnemer

Artikel 5: Waarschuwingsplicht

- 5.1 Opdrachtnemer is verplicht Opdrachtgever schriftelijk te waarschuwen, indien inlichtingen, gegevens, planningen, werkwijzen, instructies, en dergelijke, verstrekt door of namens Opdrachtgever of beslissingen genomen door of namens Opdrachtgever, fouten bevatten of gebreken vertonen of hij vermoedt dat er sprake is van dergelijke fouten of gebreken. Indien Opdrachtnemer nalaat in de in de vorige volzin bedoelde schriftelijke mededeling te doen, is hij aansprakelijk voor de schadelijke gevolgen van zijn nalaten.

Artikel 6: Geheimhouding

- 6.1 De Opdrachtnemer verplicht zich tot geheimhouding tegenover derden over de inhoud van de Overeenkomst en alle informatie en zaken in dat kader ontwikkeld, constructies, schema's en andere bedrijfsinformatie en knowhow in de meest ruime zin des woords.
- 6.2 De Opdrachtnemer zal door hem bij de uitvoering van de Overeenkomst betrokken personeel en/of door hem ingeschakelde derden schriftelijk tot dezelfde geheimhouding verplichten.
- 6.3 De uit dit artikel voortvloeiende verplichtingen blijven ook na beëindiging van de Overeenkomst voortduren.

Artikel 7: Non-concurrentie

- 7.1 De Opdrachtnemer zal zich onthouden van het rechtstreeks doen van prijsopgaven en/of aanbiedingen aan de Principaal betreffende het Project waarvoor door de Opdrachtgever met de Principaal onderhandelingen worden gevoerd of een Hoofdaannemings-overeenkomst wordt of is aangegaan.

Artikel 8: Uitbesteding en intening

- 8.1 Zonder voorafgaande schriftelijke toestemming van de Opdrachtgever, aan welke toestemming voorwaarden kunnen worden verbonden, is het de Opdrachtnemer niet toegestaan de uitvoering van de Overeenkomst geheel of gedeeltelijk aan een derde uit te besteden ofwel gebruik te maken van ingeleaseerde werknemers.
- 8.2 Bij intening van werknemers als in het vorig lid bedoeld, is de Opdrachtnemer verplicht de voorwaarden zoals bedoeld in artikel 18 strikt na te leven om gevrijwaard te zijn tegen eventuele aansprakelijkstelling in het kader van de intendersaansprakelijkheid (artikel 34 Invorderingswet 1990). Te dezer zake geldt de vrijwarningsverplichting van de Opdrachtnemer als bedoeld in artikel 18.1.
- 8.3 Indien de Opdrachtnemer zijn Werkzaamheden, of een gedeelte daarvan, na verkregen toestemming opdraagt aan een ander, dient hij daarvoor onverwijld een schriftelijk contract op te stellen, waarvan de voorwaarden van deze Overeenkomst deel dienen uit te maken, in dier voegde dat de Opdrachtnemer daarin de rechtspositie inneemt van de Opdrachtgever en de leverancier/onderaannemer die van de Opdrachtnemer.

Artikel 9: Verzekering

- 9.1 De Opdrachtnemer is gehouden genoegzame verzekering(en), met een minimale dekking van € 2.500.000,- per gebeurtenis/aanspraak, ter dekking van zijn (ontwerp) aansprakelijkheid af te sluiten, bij gebreke waarvan Opdrachtgever gerechtigd is de Overeenkomst te ontbinden onvermindert de overige rechten van de Opdrachtgever. Verzekering van zijn aansprakelijkheid laat onverlet de aansprakelijkheid van de Opdrachtnemer op grond van de Overeenkomst of de wet.
- 9.2 Indien meerdere verzekeringen van toepassing zijn bij een schade gaat de (beroeps) aansprakelijkheidsverzekering van de Opdrachtnemer te allen tijde voor op andere verzekeringen.
- 9.3 Bij levering respectievelijk inzet van motorrijtuigen en ander rollend materieel dient de Opdrachtnemer het risico van aansprakelijkheid voor schade jegens de Opdrachtgever en/of derden te verzekeren overeenkomstig de wettelijke vereisten en met inachtneming van het van toepassing zijnde bestek en/of andere contractuele bepalingen. De verzekeringspolissen dienen onder meer te voldoen aan de navolgende voorwaarden:
 - a. de Opdrachtgever dient in verband met de Overeenkomst als medeverzekerde op de polis van de Opdrachtnemer te worden aangemerkt;
 - b. de motorrijtuigen- en werkmaterieelverzekeringen mogen geen uitsluitingen bevatten ten aanzien van het zogenaamde werkrisico en/of schade aan ondergrondse zaken, zoals maar niet beperkt tot kabels en leidingen.
- 9.4 Bij tegenstrijdigheid tussen de eisen die de Principaal stelt aan de inhoud van de verzekering van de Opdrachtgever en de daadwerkelijke inhoud van de verzekering van de Opdrachtgever prevaleert de laatste. Dat wil zeggen dat de Opdrachtnemer zich niet kan beroepen op de betreffende eisen van de Principaal.
- 9.5 De Opdrachtnemer is gehouden aan de polisverplichtingen zoals deze in de door Opdrachtgever en/of Principaal afgesloten verzekeringen zijn/worden vastgelegd. In geval de Opdrachtnemer tekortschiet in de nakoming hiervan is de Opdrachtgever gerechtigd om deze verplichtingen namens en voor rekening van de Opdrachtnemer na te komen.
- 9.6 Aanspraken op enige eventueel door de Opdrachtgever (of de Principaal) afgesloten verzekeringen ontstaan eerst door een daartoe strekkende verklaring door de Opdrachtgever (of de Principaal) aan de betreffende verzekeraars.
- 9.7 Het eigen risico van enige verzekering komt geheel voor rekening van de Opdrachtnemer voor zover schade voor rekening van risico van Opdrachtnemer komt.

Artikel 10: Certificaten

- 10.1 Indien in de Overeenkomst certificaten, attesten, garantiebewijzen en/of instructieboeken e.d. worden verlangd, draagt de Opdrachtnemer zorg, dat deze uiterlijk binnen twee weken na oplevering van de Werkzaamheden in het bezit van de Opdrachtgever zijn, tenzij in de Overeenkomst een eerder tijdstip is genoemd.

Artikel 11: Garantie & conformiteit

- 11.1 Onverminderd zijn aansprakelijkheid uit hoofde van de Overeenkomst of de wet garandeert de Opdrachtnemer gedurende de in de Overeenkomst te bepalen periode, bij gebreke waarvan een periode van vijf jaar geldt, dat de Werkzaamheden inclusief de daarvoor gebruikte zaken ten minste zijn:
 - a. van goede kwaliteit, zonder gebrek in ontwerp, constructie, montage en materiaal; en
 - b. in overeenstemming met hetgeen in de Overeenkomst (en de daarbij behorende bescheiden, waaronder die bedoeld in artikel 4.3 van deze voorwaarden) is bepaald en geschikt voor het doel waarvoor zij zijn bestemd en conform de eisen die daaraan in de Overeenkomst en door of vanwege de overheid zijn gesteld; en

c. van deugdelijk materiaal en goede uitvoering zijn, uitgevoerd door vakbekwame personen onder deskundige leiding, in alle opzichten overeenkomstig de tekeningen en specificaties en, indien van toepassing, ten minste gelijk zijn aan door de Opdrachtnemer aan de Opdrachtgever ter beschikking gestelde of getoonde monsters of modellen.

Het geleverde zal overigens volledig in staat zijn de beoogde prestaties te leveren, alsmede voldoen aan alle ten tijde van de totstandkoming van de Overeenkomst en ten tijde van de feitelijke levering (zodra het geleverde op de overeengekomen plaats van levering door de Opdrachtgever in ontvangst is genomen) geldende normen, keurkenmerken, wetten en overheidsvoorschriften.

- 11.2 Het bepaalde in lid 1 van dit artikel geldt met dien verstande dat, indien de Opdrachtgever vóór opdrachtverlening bekend maakt dat hij op grond van het van toepassing zijnde bestek jegens de Principaal gehouden is voor de Werkzaamheden een bepaalde garantie te verstrekken, de Opdrachtnemer verplicht is jegens de Opdrachtgever diezelfde garantie te verstrekken, tenzij de fabrieksgarantie uitgebreider is dan de hieroor bedoelde, in welk geval de fabrieksgarantie geldt.
- 11.3 De in leden 1 en 2 van dit artikel bedoelde garanties gelden (i) in geval van Levering van Zaken vanaf de dag van levering, (ii) in geval van onderraaneming, vanaf de dag van oplevering van het Project (dan wel deeloplevering van die Werkzaamheden) door de Opdrachtgever aan de Principaal en (iii) in geval van geleverde technische componenten en installaties in het bijzonder, vanaf de dag van ingebruikname of inbedrijfstelling. Onverminderd de overige aanspraken van de Opdrachtgever, zal de Opdrachtnemer alle tijdens de garantieperiode optredende gebreken voor eigen rekening op eerste aanzegging van en in overleg met de Opdrachtgever zo spoedig mogelijk herstellen.
- 11.5 Na vervanging of reparatie binnen de garantieperiode gaat voor het desbetreffende gedeelte van het geleverde de overeengekomen garantie opnieuw in.
- 11.6 De Opdrachtnemer is gehouden zijn organisatie zodanig in te richten en ingericht te houden dat van elk onderdeel en/of component van de levering de herkomst traceerbaar is op onder andere productie en herkomsthistorie.

Artikel 12: Prijs en hoeveelheid

- 12.1 Alle prijzen zijn vast, tenzij schriftelijk anders is overeengekomen. Geen verrekening vindt plaats wegens stijging van lonen, prijzen en andere kostenverhogende factoren, tenzij anders is overeengekomen.
- 12.2 Alle prijzen gelden voor levering van de zaken franco en zijn inclusief alle in- en uitvoerrechten en overige heffingen en belastingen en inclusief alle kosten van verzekering, echter exclusief B.T.W. Ook valutaverschillen (verschillen in wisselkoers tussen het moment van bestellen en leveren/factureren) hebben geen invloed op de prijs.
- 12.3 Tenzij in de Overeenkomst uitdrukkelijk is bepaald dat het gaat om verrekenbare hoeveelheden, zijn de in de Overeenkomst vermelde hoeveelheden zo nauwkeurig mogelijk opgegeven en dient zonder dat de Opdrachtnemer gerechtigd is prijsaanpassing per eenheid te verlangen, zoveel meer of minder te worden geleverd als het Project vereist.
- 12.4 De Opdrachtnemer komt uitsluitend een beroep op vergoeding toe wegens kostenverhogende omstandigheden, in geval en voor zover de Opdrachtgever dat beroep ook heeft op de Principaal.

Artikel 13: Facturering

- 13.1 De door de Opdrachtnemer aan de Opdrachtgever te verzenden facturen dienen te voldoen aan de eisen, gesteld bij of krachtens de Wet op de Omzetbelasting 1988.
- 13.2 Indien artikel(en) 34 en/ of 35 van de Invorderingswet 1990 van toepassing is/zijn dient de Opdrachtnemer op de gedagtekende en genummerde factuur tevens de volgende gegevens duidelijk en overzichtelijk te vermelden:
 - a. het contractnummer / SAP-nummer;
 - b. het Project en het projectnummer;
 - c. het tijdvak en de verrichte prestatie waarop de factuur betrekking heeft;
 - d. de omvang van de loonsom opgenomen in het gefactureerde bedrag;
 - e. naam, adres en woonplaats van de Opdrachtnemer;
 - f. BTW-nummer van de Opdrachtnemer;
 - g. een opgave of de verleggingsregeling (als bedoeld in artikel 24b Uitvoeringsbesluit Omzetbelasting 1988) al dan niet toepasselijk is. Bij toepasselijkheid met vermelding van "omzetbelasting verlegd". Indien niet toepasselijk met vermelding van het bedrag van de omzetbelasting;
 - h. het nummer van de G-rekening van de Opdrachtnemer als bedoeld in artikel 18.4 (Ketenansprakelijkheid/intendersaansprakelijkheid).
- 13.3 Facturen van de Opdrachtnemer moeten worden ingediend met vermelding van het door de Opdrachtgever aangegeven Project, project-/order- of contractnummer alsmede de datum van de opdracht. De factuur dient ingediend te worden bij de vestiging/het rayonkantoor van de betreffende dochtermaatschappij die optreedt als de Opdrachtgever, tenzij schriftelijk een andere wijze van facturering is overeengekomen.
- 13.4 De facturen dienen vergezeld te gaan van door gemachtigde van de Opdrachtgever voor akkoord getekende ontvangstbonnen, respectievelijk mandagenstaten, respectievelijk MUIS-inboeking.
- 13.5 De Opdrachtnemer is niet gerechtigd de factuur te verhogen met een zogenaamde kredietbeperkingstoeslag.
- 13.6 De Opdrachtnemer is verplicht de Opdrachtgever desgevraagd kosteloos alle inlichtingen te verschaffen voor zijn administratie of voor die van de Principaal.
- 13.7 De Opdrachtnemer zal op eerste verzoek van de Opdrachtgever de door deze verlangde zekerheid stellen.
- 13.8 Facturen die niet aan de in de voorgaande leden van dit artikel gestelde eisen voldoen, worden zonder in behandeling te worden genomen gereturneerd en niet betaald.

Artikel 14: Hulpmiddelen en Materialen

- 14.1 Tenzij schriftelijk anders wordt overeengekomen dient de Opdrachtnemer zelf zorg te dragen voor alle ten behoeve van uit te voeren Werkzaamheden benodigde

- hulpmiddelen en alle benodigd materieel, zoals steigers, hoogwerkers e.d. Alle transporten van materialen en materieel zijn voor rekening en risico van de Opdrachtnemer.
- 14.2 De Opdrachtnemer kan slechts met toestemming van de Opdrachtgever gebruikmaken van hulpmiddelen van de Opdrachtgever. Dat gebruik is voor rekening en risico van de Opdrachtnemer. De Opdrachtnemer zal de Opdrachtgever vrijwaren voor aanspraken van derden ter zake.
- 14.3 Indien en voor zover er voor de Werkzaamheden materialen benodigd zijn welke door de Opdrachtgever dienen te worden geleverd, zullen deze materialen op afroep aan de Opdrachtnemer worden geleverd. De zorg voor deze materialen is voor rekening en risico van de Opdrachtnemer. De Opdrachtnemer dient te zorgen voor een correcte ontvangst, opslag en transport van de materialen op het Project en voor eventuele retourzendingen.

Artikel 15: Vergunningen

- 15.1 De Opdrachtnemer zal zelf zorgdragen voor de vergunningen verbandhoudende met de uitvoering van zijn Werkzaamheden als opgenomen in de (Hoofdaannemings) Overeenkomst.
- 15.2 De Opdrachtnemer dient de voorschriften als gesteld in de voor het Project verleende vergunningen na te leven en in acht te nemen.

Artikel 16: Organisatie bouwplaats

- 16.1 De Opdrachtnemer is verplicht uitsluitend de door de Opdrachtgever gegeven orders en aanwijzingen op te volgen. De Opdrachtgever kan echter de Principaal (of diens gemachtigde) schriftelijk verzoeken na overleg met de Opdrachtnemer, diens orders en aanwijzingen rechtstreeks aan de Opdrachtnemer te geven.
- 16.2 Algemeen of ter plaatse van het Project erkende, of door overheid dan wel krachtens CAO voorgeschreven rust- of feestdagen, vakantie- of andere vastgestelde of vast te stellen vrije dagen, gelden ook voor de Opdrachtnemer en zijn medewerkers, die Werkzaamheden uitvoeren op het Project. Eventueel hieruit voortvloeiende meerkosten voor de Opdrachtnemer zullen niet op de Opdrachtgever verhaald kunnen worden. Dit laatste geldt eveneens indien door staking bij de Opdrachtgever of bij derden, daaronder begrepen de Principaal, niet van de diensten van de Opdrachtnemer gebruik gemaakt kan worden.
- 16.3 De door de Opdrachtnemer uit te voeren Werkzaamheden dienen binnen de op de bouwplaats geldende werktijden te geschieden, waarbij de Opdrachtnemer zich aanpast aan de vakantie-, werk- en schafttijden van de Opdrachtgever. Indien de Opdrachtgever verlangt dat gedurende het winterseizoen wordt doorgewerkt, is de Opdrachtnemer verplicht hieraan zijn medewerking te verlenen.
- 16.4 De namen (voorzien van BSN nummer, nationaliteit, ID nummer, soort ID en vervaldatum) van door de Opdrachtnemer op het Project tewerkgestelde werknemers dienen tijdig en voordat zij de bouwlocatie betreden aan de uitvoerder van het uit te voeren Project kenbaar te worden gemaakt. De Opdrachtnemer dient er zorg voor te dragen dat elke persoon wordt aangemeld. Opdrachtnemer ontvangt hiervoor (uiterlijk een week voor aanvang Werkzaamheden) een uitnodiging met bijbehorende link. Indien de registratie niet of niet volledig heeft plaatsgevonden zal de toegang tot de bouwlocatie geweigerd kunnen worden.
- 16.5 De Opdrachtgever heeft de bevoegdheid werknemers van de Opdrachtnemer de toegang tot de bouwplaats te ontzeggen en/of deze te laten verwijderen, wegens niet identificeren, ongeschiktheid, ordeverstoring, wangedrag etc.
- 16.6 Er dient tijdens de uitvoering van de Werkzaamheden steeds een persoon aanwezig te zijn namens Opdrachtnemer die de opdracht heeft orders en aanwijzingen van of namens de Opdrachtgever op te volgen en deze onverwijld aan de Opdrachtnemer over te brengen. De naam van deze persoon dient bekend te zijn gemaakt bij de uitvoerder van de Opdrachtgever en bij de eventuele Bouwdirectie ter plaatse. Deze persoon dient zich bij aanvang, onderbreking of beëindiging van de Werkzaamheden te melden bij de uitvoerder van de Opdrachtgever.
- 16.7 De Opdrachtnemer verleent zijn medewerking aan het schoonhouden van de bouwplaats. Met name is hij verplicht voor eigen rekening het bij zijn Werkzaamheden vrijgekomen puin en bouwafval, waaronder gebruikt verpakkingsmateriaal, gereedschappen en materieel, alsmede restant materiaal en verbruikszaakjes steeds op legale wijze en behoorlijk op te ruimen en conform de instructies met betrekking tot afvalscheiding die de Opdrachtgever specifiek heeft opgelegd. Opruiming van het vrijgekomen puin etc. geschiedt in containers van de Opdrachtnemer, tenzij schriftelijk anders is overeengekomen.
- 16.8 Eventuele parkeerkosten zijn voor rekening van de Opdrachtnemer.
- 16.9 Bij toepassing van zogenaamde wintervoorzieningen is de Opdrachtnemer verplicht tot medewerking aan verlet bestrijdende maatregelen conform het Bureau Weerlevertbestrijding van het Technisch Bureau Bouwnijverheid.

Artikel 17: Cessie en verpanding van vorderingen

- 17.1 Het is niet mogelijk voor Opdrachtnemer om vorderingen die de Opdrachtnemer ingevolge een Overeenkomst met de Opdrachtgever heeft of zal verkrijgen op de Opdrachtgever (waaronder het eventueel in de prijs begrepen verschuldigde bedrag aan premies sociale verzekeringen en loonbelasting, waarvoor de Opdrachtgever ingevolge de wet aansprakelijk is) aan derden te cederen, te verpanden of anderszins te bezwaren of over te dragen. De vorderingen van Opdrachtnemer op Opdrachtgever zijn zodoende goederenrechtelijk niet overdraagbaar, en daardoor tevens niet verpandbaar, in de zin van artikel 3:83 lid 2 BW, respectievelijk artikel 3:98 jo. 3:83 lid 2 BW.
- 17.2 Opdrachtnemer mag te allen tijde Opdrachtgever schriftelijk verzoeken om de goederenrechtelijke niet-overdraagbaarheid van een duidelijk bepaalde en gedefinieerde vordering c.q. vorderingen op te heffen. De niet-overdraagbaarheid van de duidelijk bepaalde en gedefinieerde vordering c.q. vorderingen is pas opgeheven nadat dit schriftelijk is bevestigd door Opdrachtgever.

Artikel 18: Diverse wet- en regelgeving

- 18.1 Opdrachtnemer is verplicht aan alle voorschriften te voldoen van de Wet arbeid vreemdelingen (Wav), de Wet allocatie arbeidskrachten intermediairs (WAADI), de Wet aanpak Schijnconstructies (WAS) en de Wet op de identificatieplicht (WID). Opdrachtnemer vrijwaart Opdrachtgever van enige boetes en/of sancties en/of schade (als inkomenserving van aanspraken van Principaal en/of derden) wegens overtreding van deze wettelijke voorschriften.
- 18.2 De Opdrachtnemer verplicht zich bij de uitvoering van de Werkzaamheden alle relevante normen en voorschriften na te leven en in acht nemen.
- 18.3 Opdrachtnemer garandeert de voor hem toepasselijke CAO's na te leven en aan zijn wettelijke verplichtingen tot afdracht van premies, sociale verzekeringen, alsmede van loonbelasting inclusief premies volksverzekeringen te voldoen (mede in het kader van de Wet Ketenaaansprakelijkheid).
- 18.4 In het kader van de naleving van de Wet Ketenaaansprakelijkheid en de intenders-aansprakelijkheid zorgt de Opdrachtnemer dat er te allen tijde een G-rekening beschikbaar is.
- 18.5 De verplichtingen van de Opdrachtnemer omvatten mede:
- a. het op verzoek van de Opdrachtgever tonen van zijn inschrijving in het Handelsregister, alsmede het opgeven van zijn BTW-nummer en van het nummer van zijn vestigingsvergunning, voor zover deze voor de uitoefening van zijn bedrijf vereist is;
 - b. het op verzoek van de Opdrachtgever, voordat medewerkers de Werkzaamheden aanvangen, overhandigen van een staat, bevattende de namen van alle werknemers die door hem direct of indirect te werk zijn gesteld;
 - c. het wekelijks verstrekken van een door de uitvoerder getekend mandageregister ter zake van de aan hem opgedragen Werkzaamheden. In geval van buitenlandse werknemers is de Opdrachtnemer verplicht voor iedere werknemer een Nederlandse BSN nummer aan te vragen en hiervan opgaaf te doen aan de Opdrachtgever indien in Nederland belastingplicht ontstaat;
 - d. het eenmaal per drie maanden, of zoveel vaker als de Opdrachtgever wenst, aan de Opdrachtgever verstrekken van een verklaring inzake zijn afdracht van loonbelasting en premies sociale verzekeringen. Indien de Opdrachtnemer is aangesloten bij de Stichting Normering Arbeid kan worden volstaan met een kopie van het meest actuele NEN-4400 certificaat;
 - e. het vrijwaren van de Opdrachtgever voor de aansprakelijkheid van de Opdrachtgever jegens en boetes opgelegd door de Principaal en/of derden wegens het niet naleven door de Opdrachtnemer van zijn verplichtingen ingevolge de Overeenkomst, dan wel ingevolge de wet;
- 18.6 De door de Opdrachtgever aan de Opdrachtnemer te verrichten betalingen zullen voorts gescheiden onder de voorwaarde dat voorafgaande aan tewerkstelling de Opdrachtgever op de hoogte wordt gesteld wanneer op het werk werknemers uit andere EU-landen dan Nederland te werk worden gesteld, onder vermelding van de namen en geboortedata van de desbetreffende werknemers en onder overlegging van bewijzen (zoals bijvoorbeeld een A1-formulier) waaruit blijkt dat de sociale verzekeringspremies voor deze werknemers voor de duur van de te verrichten Werkzaamheden in het desbetreffende andere EU-land worden afgedragen. Daarnaast dient, indien van toepassing, een kopie van het EHIC (European Health Insurance Card) te worden overgelegd op basis waarvan in Nederland medische zorg kan worden verleend.
- 18.7 Indien de Opdrachtgever redelijkerwijs tot het oordeel kan komen dat de Opdrachtnemer ter zake van de Werkzaamheden een hoger bedrag aan premies sociale verzekeringsswetten, loonbelasting en premies volksverzekeringen verschuldigd zal zijn dan het percentage dat in de Overeenkomst is vastgesteld, kan hij dat percentage wijzigen.
- 18.8 Indien op grond van de wet de Opdrachtgever aansprakelijk wordt gesteld en daardoor gehouden is niet betaalde (voorschot)premies, sociale verzekeringen en belastingen te betalen, heeft de Opdrachtgever verhaal op de Opdrachtnemer voor het gehele bedrag, te vermeerderen met wettelijke rente vanaf het tijdstip van betaling door de Opdrachtgever.
- 18.9 Indien de Opdrachtnemer zijn verplichtingen op grond van de voor hem toepasselijke CAO's jegens zijn werknemers niet nakomt en de Opdrachtgever aansprakelijk wordt gesteld deze verplichtingen na te komen, heeft de Opdrachtgever jegens de Opdrachtnemer verhaal voor het gehele bedrag te vermeerderen met wettelijke rente vanaf het tijdstip van betaling door de Opdrachtgever.
- 18.10 Indien de Opdrachtnemer en/of de door hem ingeschakelde derden niet meer aan hun betalingsverplichtingen uit hoofde van de wet kunnen voldoen, dient de Opdrachtnemer binnen vijf werkdagen vanaf de dag dat de betalingsomacht is ontstaan, de Opdrachtgever daarvan op de hoogte te stellen, bij gebreke waarvan de Opdrachtnemer jegens de Opdrachtgever van rechtswege in verzuim is. De Opdrachtgever is alsdan gerechtigd zonder dat enige ingebrekstellings of rechterlijke tussenkomst is vereist, de Overeenkomst geheel of gedeeltelijk ontbonden te verklaren, onverminderd zijn recht op schadevergoeding.
- 18.11 De Opdrachtnemer garandeert dat er tijdens de Werkzaamheden op het werk een persoon aanwezig is die zowel in het Nederlands als in de betreffende vreemde taal met de werknemers van de Opdrachtnemer kan communiceren.
- 18.12 De werknemers van de Opdrachtnemer dienen aan te tonen dat arbeid voor hen vrij is toegestaan of dienen te beschikken over een geldige tewerkstellingsvergunning wanneer zij niet beschikken over de Nederlandse nationaliteit, Zwitserse nationaliteit of de nationaliteit van een van de landen van de Europese Economische Ruimte (EER) met uitzondering van Kroatië.
- 18.13 De werknemers van de Opdrachtnemer dienen altijd (ook op de werkplek) een geldig identiteitsbewijs en, voor zover van toepassing, een geldige tewerkstellingsvergunning, te kunnen tonen. De Opdrachtgever kan hen hierop periodiek (steekproefsgewijs) controleren. Indien een vereist document ontbreekt, zal de Opdrachtgever hem de toegang tot het werk ontzeggen of van het werk verwijderen. Indien de Opdrachtgever hierdoor schade lijdt, zal deze schade volledig op de Opdrachtnemer worden verhaald.
- 18.14 De Opdrachtnemer zal op eerste verzoek van de Opdrachtgever ervoor zorgdragen dat alle documenten, waaronder ID's (indien vereist), waarvan de Opdrachtgever in het kader van de WID, WAV een afschrift verlangt, aan de Opdrachtgever worden overgelegd.

- 18.15 Opdrachtnemer legt alle arbeidsvooraardelijke afspraken ten behoeve van de uitvoering van de Werkzaamheden op een inzichtelijke en toegankelijke wijze vast.
- 18.16 Opdrachtnemer verschaft desgevraagd aan bevoegde instanties inzage in deze arbeidsvooraardelijke afspraken en werkt mee aan controles, audits of loonvalidatie. Indien uit de audit naar voren komt dat Opdrachtnemer niet aan de verplichtingen genoemd in bovenstaande leden voldoet, komen de kosten van de audit, alsmede bijbehorende kosten, voor rekening van de Opdrachtnemer.
- 18.17 Opdrachtnemer verschaft desgevraagd aan Opdrachtgever, dan wel aan een door Opdrachtgever daartoe gemachtigde, inzage in deze arbeidsvooraardelijke afspraken indien deze dit noodzakelijk acht in verband met het voorkomen van of de behandeling van een loonvordering aangaande verrichte arbeid ten behoeve van de Werkzaamheden alsmede bij het constateren van onregelmatigheden.
- 18.18 Opdrachtnemer vrijwaart Opdrachtgever tegen alle aanspraken van derden met betrekking tot loonbetaling die voortvloeien uit Werkzaamheden die zijn uitgevoerd in het kader van de uitvoering van de Werkzaamheden alsmede tegen eventueel aan de Opdrachtgever en/of derden opgelegde boetes als gevolg van overtreding van de WID en WAV.

Rechten en verplichtingen Opdrachtgever

Artikel 19: Compensatie

- 19.1 De Opdrachtgever is gerechtigd tot compensatie van de in verband met de Overeenkomst aan de Opdrachtnemer verschuldigde bedragen, met hetgeen hij zelf of één van de overige dochtermaatschappijen van het Heijmans concern, dan wel een minderheidsdeelname waarin een dochtermaatschappij uit het Heijmans concern deeltneemt, van de Opdrachtnemer te vorderen heeft, ook uit hoofde van enige andere Overeenkomst. De Opdrachtgever is daarbij niet gebonden aan de uit de Overeenkomst voortvloeiende verhouding tussen hetgeen op de G-rekening en hetgeen op de gewone rekening van de Opdrachtnemer gestort dient te worden en is mitsdien gerechtigd de in compensatie te brengen vordering geheel of in de door zijn gewenste omvang te compenseren met hetgeen hij ten gunste van de gewone rekening van de Opdrachtnemer verschuldigd is.
- 19.2 De Opdrachtgever bedingt bij wijze van derdenbeding ten behoeve van de ondernemingen die met hem in een groep zijn verbonden als bedoeld in artikel 2:24 BW, dat deze ondernemingen vorderingen van Opdrachtnemer op hen kunnen verrekenen met vorderingen die Opdrachtgever op Opdrachtnemer heeft.

Artikel 20: Opschortingsrechten

- 20.1 De Opdrachtnemer verklaart afstand te doen van zijn recht zijn verplichtingen ingevolge de Overeenkomst op te schorten.
- 20.2 De Opdrachtgever is, onverminderd de (opschortings)rechten die de Opdrachtgever op grond van de wet toekomt, gerechtigd zijn betalingsverplichtingen op te schorten indien de Opdrachtnemer tekortschiet, dan wel tekort dreigt te schieten in de nabkomming van zijn verplichtingen, ongeacht of deze tekortkoming toerekenbaar is.
- 20.3 De Opdrachtnemer doet uitdrukkelijk afstand van zijn retentierecht.

Artikel 21: Betaling en eindafrekening

- 21.1 Indien de Opdrachtnemer aan al zijn verplichtingen uit de Overeenkomst heeft voldaan, kan de Opdrachtnemer de overeengekomen prijs aan de Opdrachtgever factureren, waarna betaling door de Opdrachtgever zal geschieden binnen zestig (60) dagen.
- 21.2 Op het moment dat Opdrachtgever niet binnen zestig (60) dagen tot betaling overgaat van de in het vorige lid benoemde factuur, is Opdrachtnemer maximaal gerechtigd tot het vorderen van de wettelijke rente ex artikel 6:119 Burgerlijk Wetboek alsmede € 40,00 buitenrechte incassokosten.
- 21.3 De betalingen zullen gescheiden op basis van een overeen te komen termijnschema, en bij het ontbreken van dit termijnschema, na de laatste levering (ingeval Levering van zaken) c.q. na oplevering van zijn Werkzaamheden (in geval van Uitvoering van werken). De Opdrachtgever zal slechts betalen:
 - a. zodra de Werkzaamheden of het gedeelte waarop een (termijn)betaling betrekking heeft door de Opdrachtnemer naar genoegen zijn uitgevoerd;
 - b. na ontvangst door de Opdrachtgever van een factuur conform het bepaalde in artikel 13 (Facturering); en
 - c. nadat de Opdrachtnemer hem desgevraagd heeft aangetoond, dat hij de bij het Project betrokken werknehmers het hun toekomende heeft betaald, alsmede dat hij de voor deze werknehmers verschuldigde premies sociale verzekeringen en loonheffing heeft betaald.
- 21.4 De Opdrachtnemer is gehouden zijn eindafrekening binnen 4 weken na oplevering van zijn Werkzaamheden bij de Opdrachtgever in te dienen. Indien de Principaal en de Opdrachtgever een onderhoudstermijn zijn overeengekomen, dient de eindafrekening binnen 4 weken na afloop van die onderhoudstermijn te zijn ingediend.
- 21.5 Betalingen of factureringen kunnen onverminderd het bovenstaande eerst gescheiden, nadat de door de Opdrachtnemer ondertekende en ongewijzigde kopie van de Overeenkomst door de Opdrachtgever is terugontvangen.
- 21.6 Betaling door de Opdrachtgever voor de (gedeelten van) de Werkzaamheden ontslaat de Opdrachtnemer niet van enige garantie en/of aansprakelijkheid zoals deze voortvloeien uit de Overeenkomst of de wet.
- 21.7 Indien door in gebreke blijven of onvermogen van de Opdrachtnemer, de Opdrachtgever zijn Werkzaamheden geheel of gedeeltelijk uitvoert, of door anderen doet uitvoeren, heeft de Opdrachtgever het recht om voor rekening van de Opdrachtnemer rechtstreeks aan onderaannemers en leveranciers van de Opdrachtnemer een billijke vergoeding uit te keren voor de Werkzaamheden, waarvoor deze nog geen betaling heeft genoten. De Opdrachtgever gaat hiertoe niet over dan na de Opdrachtnemer ter zake te hebben gehoord. De betaling van Opdrachtgever strekt in mindering op de totaalsom.

Artikel 22: Inspectie en keuring

- 22.1 De Opdrachtgever en/of de Principaal en/of de Bouwdirectie hebben te allen tijde het recht de Werkzaamheden te inspecteren of te keuren. Alsdan zal de Opdrachtnemer zorgen voor zodanige faciliteiten als daarvoor redelijkerwijs kunnen worden verlangd.
- 22.2 De kosten van de inspectie en/of keuring komen ten laste van de Opdrachtnemer in geval de Werkzaamheden door de Opdrachtgever en/of Principaal en/of Bouwdirectie worden afgeweerd.
- 22.3 Inspectie of goedkeuring ontslaat de Opdrachtnemer niet van enige garantie of aansprakelijkheid, zoals deze voortvloeit uit de Overeenkomst of de wet.

Diversen

Artikel 23: Intellectueel eigendom

- 23.1 Alle (aanspraken op) bestaande en toekomstige intellectuele eigendomsrechten, in het bijzonder maar niet beperkt tot merkrechten, databankrechten, knowhow en auteursrechten (de "IE-rechten"), met betrekking tot enig resultaat voortvloeiende uit of ontstaan in het kader van de Werkzaamheden dan wel de Overeenkomst (het "Resultaat"), berusten bij Opdrachtgever. Opdrachtnemer draagt hierbij de (aanspraken op) de IE-rechten – voor zover nodig – (bij voorbaat) om niet over aan Opdrachtgever welke overdracht en levering Opdrachtnemer hierbij (bij voorbaat) aanvaardt.
- 23.2 Opdrachtgever en Opdrachtnemer erkennen uitdrukkelijk dat artikel 23.1 dient te worden gezien als de akte van overdracht van de (toekomstige) IE-rechten op het Resultaat. Voor zover de hiervoor genoemde overdracht niet resulteert in de overdracht van de IE-rechten aan Opdrachtgever (bij voorbaat), zal Opdrachtnemer op ieder eerste schriftelijke verzoek van Opdrachtgever onmiddellijk iedere handeling verrichten ten behoeve van de overdracht van de IE-rechten, waaronder maar niet beperkt tot het tekenen van een schriftelijke overdrachtsakte of enig ander document dat tot doel heeft dat de IE-rechten op het Resultaat worden overgedragen aan Opdrachtgever. In dit verband verleent Opdrachtnemer hierbij aan Opdrachtgever tevens een onherroepelijke volmacht om namens Opdrachtnemer al hetgeen te verrichten dat noodzakelijk is voor de overdracht van de IE-rechten op het Resultaat aan Opdrachtgever.
- 23.3 Opdrachtnemer doet afstand van zijn persoonlijkhedenrechten in de zin van art. 25 Auteurswet.
- 23.4 Ter verduidelijking, maar zonder daarmee enige beperking aan te brengen, verklaren partijen dat de overdracht krachtens artikel 23.1 meebrengt dat Opdrachtgever het Resultaat en de daarop rustende IE-rechten mag gebruiken respectievelijk (laten) exploiteren op welke wijze en in welke vorm dan ook, zonder dat daaraan enige beperking is verbonden.
- 23.5 De overdracht van de IE-rechten vindt plaats zonder dat Opdrachtgever daarvoor aan Opdrachtnemer enige vergoeding verschuldigd is. In het door Opdrachtnemer genoten vergoeding voor haar in opdracht van Opdrachtgever verrichte Werkzaamheden wordt de Opdrachtnemer voor deze overdracht geacht te zijn gecompenseerd.
- 23.6 Alle eigendoms- en IE-rechten op tekeningen, berekeningen, modellen, werkwijzen, computerbestanden en andere informatie(dragers) en bescheiden (al dan niet van elektronische aard) (het "Materiaal"), die de Opdrachtgever in het kader van de Overeenkomst aan de Opdrachtnemer heeft verstrekt, berusten bij de Opdrachtgever. Het materiaal dient op eerste verzoek van de Opdrachtgever aan de Opdrachtgever te worden gereturneerd, voor rekening van de Opdrachtnemer.
- 23.7 De Opdrachtnemer garandeert dat de uitvoering van de Overeenkomst geen inbreuk op enig IE-recht van derden zal opleveren. De Opdrachtnemer vrijwaart de Opdrachtgever zonder enige beperking voor aanspraken van derden wegens inbreuk op deze IE-rechten. De uit dit lid voortvloeiende verplichtingen van de Opdrachtnemer blijven ook na beëindiging van de Overeenkomst voortduren.

Artikel 24: Aansprakelijkheid

- 24.1 De Opdrachtnemer is aansprakelijk voor schade die Opdrachtgever of derden, daaronder begrepen de Principaal, lijdt c.q. lijden in verband met de uitvoering van de Overeenkomst.
- 24.2 De Opdrachtnemer is aansprakelijk voor administratieve boeten en/of andere strafmaatregelen die worden opgelegd aan de Opdrachtgever, de Principaal en/of derden ten gevolge van een doen en/of nalaten van de Opdrachtnemer.
- 24.3 Opdrachtnemer zal de Opdrachtgever vrijwaren voor aanspraken van derden ter zake en de Opdrachtgever zo nodig schadeloos stellen.

Artikel 25: Ontbinding / opzegging

- 25.1 Elke tussen de Opdrachtgever en Opdrachtnemer overeengekomen termijn voor de naboming door de Opdrachtnemer van zijn verplichtingen is een fatale termijn, tenzij schriftelijk anders is overeengekomen. Door het enkele verstrijken van een in de Overeenkomst genoemde termijn is de Opdrachtnemer in verzuim. Door de Opdrachtgever aan Opdrachtnemer gestuurde aanmaningen doen daaraan niet af.
- 25.2 In de volgende gevallen is de Opdrachtnemer van rechtswege in verzuim en is de Opdrachtgever gerechtigd, zonder dat enige ingebrekestelling of rechterlijke tussenkomst vereist is, de Overeenkomst geheel of gedeeltelijk ontbonden te verklaren of op te zeggen, zulks onverminderd zijn recht tot schadevergoeding en onverminderd de Opdrachtgever toekomende rechten op grond van de wet:
 - a. indien de Opdrachtnemer een of meer van zijn materiële contractuele verplichtingen niet of niet tijdig of niet volledig nakomt, of de Opdrachtgever uit een mededeling van de Opdrachtnemer moet afleiden dat deze in de naboming van zijn verplichtingen tekort zal schieten;
 - b. opzegging of ontbinding van de Hoofdaannemingsovereenkomst;
 - c. ingeval van (een aanvraag tot):
 - (i) faillissement,
 - (ii) (voorlopige) surseance van betaling,
 - (iii) (gedeeltelijke) liquidatie of
 - (iv) onder curatele stelling,

- van de Opdrachtnemer of van de (rechts)persoon die zich voor de verplichtingen van de Opdrachtnemer garant heeft gesteld of zekerheid heeft verstrekt;
- d. indien activa van de Opdrachtnemer onder bewind worden gesteld;
 - e. indien de Opdrachtnemer (onderdelen van) zijn onderneming of de zeggenschap daarover geheel of gedeeltelijk overdraagt, zijn onderneming geheel of gedeeltelijk stillegt, dan wel er anderszins sprake is van staking van de bedrijfsuitoefening;
 - f. indien op de zaken of een gedeelte van de zaken van de Opdrachtnemer conservatoir of executoriaal bestlag wordt gelegd;
 - g. indien de Opdrachtnemer zijn verplichtingen uit de Overeenkomst door overmacht niet kan nakomen;
 - h. indien de Opdrachtnemer komt te overlijden;
 - i. indien de Opdrachtnemer enig wettelijk voorschrift schendt, dan wel een boete of een andere maatregel opgelegd krijgt;
 - j. indien door Principaal is vastgesteld dat Opdrachtnemer niet (meer) aan de in het kader van de aanbestedingsprocedure van de Hoofdaannemingsovereenkomst gestelde geschiktheidseisen voldoet, dan wel sprake is van een uitsluitingsgrond.
- Tevens is de Opdrachtgever in genoemde gevallen gerechtigd de uitvoering van de Overeenkomst geheel of gedeeltelijk voor rekening en risico van de Opdrachtnemer aan een of meer derden op te dragen.
- 25.3 Indien een partij gebruik maakt van het in de voorafgaande ledien bedoelde recht, wordt de wederpartij schriftelijk in kennis gesteld van de gehele of gedeeltelijke ontbinding of opzegging van de Overeenkomst.
- 25.4 Bij (gedeeltelijke) ontbinding van opzegging heeft de Opdrachtgever, onverminderd zijn recht op vergoeding van schade en kosten het recht te zijner keuze:
- a. voor rekening van de Opdrachtnemer de reeds geleverde, maar niet (meer) te gebruiken zaken naar hem terug te sturen en/of het reeds uitgevoerde werk af te breken / en de voor deze Werkzaamheden reeds gedane betalingen terug te vorderen;
 - b. de Werkzaamheden zelf of door derden te laten voltooien, eventueel na schriftelijke kennisgeving, met gebruikmaking van de reeds door de Opdrachtnemer geleverde zaken en de door de Opdrachtnemer gebruikte materialen, materieel e.d. al dan niet tegen een achteraf overeengekomen redelijke vergoeding.
- 25.5 De vorderingen die de Opdrachtgever op Opdrachtnemer ten gevolge van de ontbinding of opzegging van de Overeenkomst moet hebben of verkrijgen, inclusief zijn eventuele vordering tot vergoeding van schade en kosten, zijn terstand en geheel opeisbaar.
- 25.6 De Opdrachtnemer is verplicht (een aanvraag van) faillissement en een (dreiging van) beslaglegging onverwijd schriftelijk aan de Opdrachtgever te melden.

Artikel 26: Geschillenbeslechting en toepasselijk recht

- 26.1 Alle geschillen – daaronder begrepen die, welke slechts door een der partijen als zodanig worden beschouwd – die naar aanleiding van de Overeenkomst of van overeenkomsten die daarvan een uitvoerisel zijn, tussen de Opdrachtgever en de Opdrachtnemer mochten ontstaan, worden beslecht op gelijke wijze als in de Hoofdaannemingsovereenkomst is voorzien. Indien de Opdrachtgever geen Opdrachtgever heeft, of indien tussen de Opdrachtgever en de Principaal geen geschillenregeling is overeengekomen, worden geschillen tussen de Opdrachtgever en de Opdrachtnemer, met uitzondering van de gewone rechter, beslecht door de Raad van Arbitrage voor de Bouw, met dien verstande dat de Opdrachtgever bevoegd blijft een geschil voor te leggen aan de volgens de wet bevoegde rechter.
- 26.2 De Overeenkomst wordt uitsluitend door Nederlands recht beheerst. Toepassing van het Weens Koopverdrag 1980 (CISG: Convention on the International Sales of Goods) is uitgesloten.

II A BIJZONDER GEDEELTE: INKOOPVOORWAARDEN

Artikel 27: Wijze van levering

- 27.1 Tenzij schriftelijk anders overeengekomen, geschiedt de levering franco werk. Het transport van de zaken vindt derhalve voor rekening en risico van de Opdrachtnemer plaats.
- 27.2 Breuk en/of beschadiging ontstaan bij het laden, transport en/of bij het lossen en tassen, zijn voor rekening van de Opdrachtnemer, tenzij Opdrachtnemer aantooft dat de schade is ontstaan door schuld van (werk)nemers van de Opdrachtgever.
- 27.3 Lossen en tassen buiten de normale werktijden van de Opdrachtgever kan alleen plaatsvinden na diens voorafgaande schriftelijke goedkeuring, tenzij bij Overeenkomst anders is bepaald.
- 27.4 De zaken moeten behoorlijk en milieuvriendelijk zijn verpakt. De Opdrachtnemer is aansprakelijk voor schade aan personen of zaken veroorzaakt door onvoldoende verpakking en/of beschadiging of vernieling van deze verpakking. De Opdrachtgever heeft te allen tijde het recht de (transport) verpakkingsmaterialen voor rekening van de Opdrachtnemer aan deze te retourneren.

Artikel 28: Plaats van levering

- 28.1 De Opdrachtnemer zal de zaken leveren op de plaats zoals vermeld in de Overeenkomst. Is geen zodanige plaats afgesproken, dan zal levering geschieden op de bouwplaats, waarbij de exacte plaats van levering op de bouwplaats wordt bepaald in nauw overleg met de Opdrachtgever.
- 28.2 Indien de Opdrachtgever vóór de levering verlangt, dat de zaken op een andere dan de overeengekomen plaats worden geleverd, zal de Opdrachtnemer gebonden zijn hieraan te voldoen voor zoverre dit redelijkerwijs van hem verlangd kan worden.

Artikel 29: Tijdstip van levering

- 29.1 De leveringen dienen op het in de Overeenkomst vastgestelde tijdstip te gescreiden/plaats te vinden dan wel overeenkomstig het door de Opdrachtgever vastgestelde schema. Bij overschrijding van de levertijd is de Opdrachtnemer zonder nadere ingebrekkestelling in verzuim en gehouden alle daardoor door de Opdrachtgever geleden schade op eerst verzoek te vergoeden.
- 29.2 De Opdrachtnemer is gebonden aan het in de Overeenkomst vastgestelde tijdstip van levering, dan wel het door de Opdrachtgever vastgestelde leveringsschema, met dien verstande dat de Opdrachtgever gerechtigd is het tijdstip c.q. het schema van levering nader vast te stellen door afroep en daarmee in te passen in de voortgang van het Project, zulks zonder dat dit de Opdrachtnemer aanspraak geeft op prijswijziging of enig andere vorm van vergoeding, tenzij een en ander onredelijk bewarend is voor Opdrachtnemer.
- 29.3 De Opdrachtgever is daarnaast gerechtigd indien de voortgang van het Project zulks vereist, de volgorde van de door de Opdrachtnemer te verrichten leveringen nader te bepalen, ook indien in de Overeenkomst een bepaalde volgorde is opgenomen.
- 29.4 Indien om welke reden ook de Opdrachtgever niet in staat is de zaken op het overeengekomen tijdstip via het vastgestelde schema in ontvangst te nemen, zal de Opdrachtnemer de zaken bewaren, beveiligen en alle redelijke maatregelen treffen om achteruitgang in kwaliteit te voorkomen, totdat zij geleverd zijn.
- 29.5 De Opdrachtnemer is jegens de Opdrachtgever aansprakelijk voor eventuele boetes of kortingen op de aanneemsom, die door de Principaal en/of de Bouwdirectie aan de Opdrachtgever worden gegeven wegens te late oplevering van (gedeelten van) het Project, ten gevolge van aan de Opdrachtnemer toe te rekenen vertraging.
- 29.6 Deleveringen zijn slechts toegestaan na schriftelijke toestemming van de Opdrachtgever.

Artikel 30: Eigendomsovergang; risico, aanvaarding, ter beschikking gestelde zaken

- 30.1 De eigendom van te leveren en/of te vervaardigen zaken wordt geacht over te zijn gegaan op Opdrachtgever op het moment waarop de zaken als zijnde bestemd voor de Opdrachtgever worden gesepareerd c.q. aangeduid dan wel op het moment waarop de Opdrachtgever aan zijn (gedeeltelijke) betalingsverplichting heeft voldaan. Het risico van de te leveren en/of te vervaardigen zaken blijft bij Opdrachtnemer tot het moment dat deze door de Opdrachtgever in ontvangst zijn genomen.
- 30.2 Door de Opdrachtgever ter beschikking gestelde zaken zijn en blijven onder alle omstandigheden eigendom van de Opdrachtgever en zullen als zodanig op voor derden herkenbare wijze door de Opdrachtnemer gekenmerkt en geïndividualiseerd worden; bedoelde zaken worden geacht in goede staat te zijn en conform de vereiste specificaties, tenzij de Opdrachtnemer binnen vier werkdagen na ontvangst schriftelijk heeft gecreameerd. De Opdrachtnemer zal op eerste verzoek van de Opdrachtgever de bedoelde zaken aanwijzen en die zaken aan de Opdrachtgever af- en overgeven.
- 30.3 In geval van afkeuring van de geleverde zaken door de Opdrachtgever blijven de geleverde zaken eigendom van de Opdrachtnemer en wordt ook het risico geacht bij de Opdrachtnemer te zijn gebleven en derhalve nimmer op de Opdrachtgever te zijn overgegaan. De Opdrachtgever is in dat geval niet gehouden zijn verplichtingen uit de Overeenkomst na te komen. De Opdrachtnemer zal de Opdrachtgever in dat geval crediteren voor reeds in rekening gebrachte bedragen en zal reeds door de Opdrachtgever betaalde bedragen onverwijd aan de Opdrachtgever terugbetaalen.

Artikel 31: Acceptatie en weigering

- 31.1 De levering wordt eerst geacht door de Opdrachtgever te zijn aanvaard, wanneer deze levering is goedgekeurd.
- 31.2 De Opdrachtgever en/of de Principaal en/of de Bouwdirectie hebben de bevoegdheid binnen een redelijke termijn het geleverde af te keuren, zodat alle andere termijnen waarbinnen moet worden gecreameerd, indien en voor zover deze door de Opdrachtnemer mochten worden toegepast, tegenover de Opdrachtgever niet gelden.
- 31.3 In geval van afkeuring zal de Opdrachtgever de Opdrachtnemer hiervan onmiddellijk in kennis stellen. De Opdrachtnemer zal afgekeurde zaken op eerste verzoek voor zijn rekening afvoeren. Bij gebreke van verwijdering van de afgekeurde zaken is de Opdrachtgever gerechtigd deze voor rekening en risico van de Opdrachtnemer te retourneren.

Artikel 32: Retourzendingen; emballage

- 32.1 Wanneer standaard handelszaken door wijzigingen in het bestek, of door andere buiten schuld van de Opdrachtgever liggende oorzaken overcompleet raken, moeten deze door de Opdrachtnemer tegen de gefactureerde prijs worden teruggenomen.

II B BIJZONDER GEDEELTE: ONDERAANNEMINGS- VOORWAARDEN

Artikel 33: Aanvang en oplevering van de Werkzaamheden: termijnen

- 33.1 De Opdrachtnemer zal met de uitvoering van de Werkzaamheden een aanvang nemen op het tijdstip, vermeld in de Overeenkomst. Indien in de Overeenkomst geen datum en/of tijdstip waarop de Opdrachtnemer met de Werkzaamheden zal aanvangen is vermeld, zal de Opdrachtgever deze bepalen. De Opdrachtnemer voert de Werkzaamheden uit

- overeenkomstig het van de Opdrachtgever ontvangen tijdschema en levert zijn Werkzaamheden op, op het tijdstip zoals vermeld in de Overeenkomst.
- 33.2 De Werkzaamheden wordt als opgeleverd beschouwd, indien het overeenkomstig het bepaalde in artikel 34 (Opneming en goedkeuring) is opgenomen en goedgekeurd.
- 33.3 De Opdrachtgever heeft het recht de volgorde van de uit te voeren Werkzaamheden te wijzigen ingeval hij dat wenselijk oordeelt in verband met de voortgang van de bouw, zonder deswege tot vergoeding van schade en kosten te zijn gehouden.
- 33.4 Indien de Opdrachtnemer zijn verplichtingen niet op het overeengekomen tijdstip dan wel binnen het overeengekomen tijdschema zal kunnen voltooien, is hij verplicht de Opdrachtgever hiervan onmiddellijk schriftelijk in kennis te stellen.
- 33.5 De Opdrachtnemer is jegens de Opdrachtgever aansprakelijk voor eventuele boetes of kortingen die door de Principaal en/of de Bouwdirectie aan de Opdrachtgever worden opgelegd wegens te late oplevering van (gedeelten van) de Werkzaamheden ten gevolge van een vertraging van Opdrachtnemer. De Opdrachtgever heeft het recht deze boetes en kortingen geheel (ook al betreft de tekortkoming slechts een gedeelte van de Werkzaamheden) te verhalen op de Opdrachtnemer, bijvoorbeeld door inhouding op de betalingen die de Opdrachtgever nog aan de Opdrachtnemer verschuldigd is.

Artikel 34: Opneming en goedkeuring

- 34.1 De Opdrachtnemer zal zijn Werkzaamheden uitvoeren naar de eisen van goed en degelijk werk, zoals deze door de Opdrachtgever en/of de Principaal en/of de Bouwdirectie zijn gesteld, en overeenkomstig hetgeen daarover in de Overeenkomst is bepaald.
- 34.2 Opneming van de Werkzaamheden geschieht op een – tot de Opdrachtgever – gerichte aanvraag van de Opdrachtnemer waarin de Opdrachtnemer aangeeft op welke dag de Werkzaamheden gereed zullen zijn. De aanvraag geschieht schriftelijk, tenzij anders overeengekomen.
- 34.3 De opneming geschieht zo spoedig mogelijk na de in lid 2 van dit artikel bedoelde dag. De dag en het tijdstip van opneming wordt aan de Opdrachtnemer zo spoedig mogelijk, zo mogelijk ten minste drie dagen voor de opneming kenbaar gemaakt. De Opdrachtgever kan verlangen dat de Opdrachtnemer of diens gemachtigde bij de opneming aanwezig is.
- 34.4 Nadat de Werkzaamheden zijn opgenomen, wordt aan de Opdrachtnemer zo spoedig mogelijk medegedeeld of deze al dan niet zijn goedgekeurd, in het laatste geval met opgaaf van redenen voor de onthouding van de goedkeuring. De mededeling geschieht schriftelijk, tenzij anders overeengekomen.
- 34.5 De heropneming na onthouding van goedkeuring geschieht conform bovengenoemde bepalingen.
- 34.6 De Opdrachtnemer zal de aangekeurde Werkzaamheden en/of onderdelen daarvan op eerste verzoek van de Opdrachtgever herstellen of vervangen, zonder dat de Opdrachtgever tot enige extra vergoeding gehouden zal zijn, onvermindert het recht tot ontbinding en schadevergoeding van hierdoor ontstane schade en kosten.
- 34.7 Opneming of goedkeuring ontslaat de Opdrachtnemer niet van enige garantie en/of aansprakelijkheid, zoals deze voortvloeien uit de tussen partijen gesloten Overeenkomst of de wet.
- 34.8 Bij afkeuring van de Werkzaamheden of een onderdeel daarvan heeft de Opdrachtgever voorts het recht de betaling van de op deze Werkzaamheden of onderdeel daarvan betrekking hebbende prijs op te schorten.

Artikel 35: Onderhoudstermijn

- 35.1 De onderhoudstermijn vangt aan de dag na oplevering van de Werkzaamheden door de Opdrachtnemer aan de Opdrachtgever en eindigt op het moment dat de onderhoudstermijn die voor het totale Project tussen de Principaal en de Opdrachtgever is overeengekomen eindigt, tenzij bij de Overeenkomst anders is bepaald. In het geval de onderhoudstermijn niet bij (Hoofdaannemings)Overeenkomst is overeengekomen, eindigt de onderhoudstermijn twaalf maanden na oplevering van het Project door de Opdrachtgever aan de Principaal.
- 35.2 De Opdrachtnemer is gehouden de gebreken die gedurende de onderhoudstermijn aan de dag treden op eerste aanzegeging van de Opdrachtgever voor eigen rekening tot genoegen van de Opdrachtgever en binnen een door de Opdrachtgever in billijkheid te stellen termijn te herstellen.
- 35.3 Na afloop van de onderhoudstermijn zullen de Werkzaamheden wederom worden opgenomen om te constateren of de Opdrachtnemer aan zijn verplichtingen heeft voldaan.

Artikel 36: Meer- en minderwerk

- 36.1 Meerwerk mag uitsluitend na goedkeuring door en na een schriftelijke opdracht van de Opdrachtgever worden uitgevoerd. De Opdrachtgever is slechts gehouden door hem schriftelijk opgedragen meerwerk te betalen. De verrekening van minderwerk wordt, tenzij schriftelijk anders overeengekomen, in onderling overleg bepaald.
- 36.2 In geen geval zullen als meerwerk of bijgekomen werk worden beschouwd en door de Opdrachtgever worden betaald, Werkzaamheden die redelijkerwijs moeten worden aangemerkt als tot de Werkzaamheden behorend, teneinde de Werkzaamheden overeenkomstig de aard en de bedoeling van de opdracht en overeenkomstig de aan deugdelijk werk te stellen eisen te kunnen opleveren.
- 36.3 Voor meer- en/of minderwerk gelden, onvermindert het overige in dit artikel bepaalde en tenzij schriftelijk anders overeengekomen, de voorwaarden van de Hoofdaannemingsovereenkomst.
- 36.4 De Opdrachtnemer heeft geen recht op betaling van meerwerk indien de Opdrachtgever dit meerwerk niet betaald krijgt van zijn Principaal.
- 36.5 De hoeveelheden zijn niet verrekenbaar, tenzij in de Overeenkomst uitdrukkelijk is bepaald dat het gaat om verrekenbare hoeveelheden. De in de Overeenkomst vermelde hoeveelheden zijn zo nauwkeurig mogelijk opgegeven en er dient, zonder dat de Opdrachtnemer gerechtigd is prijsaanpassing per eenheid te verlangen, zoveel meer of minder te worden geleverd als het Project vereist.