The Potential of Blockchain for Financial Control in Construction Supply Chains

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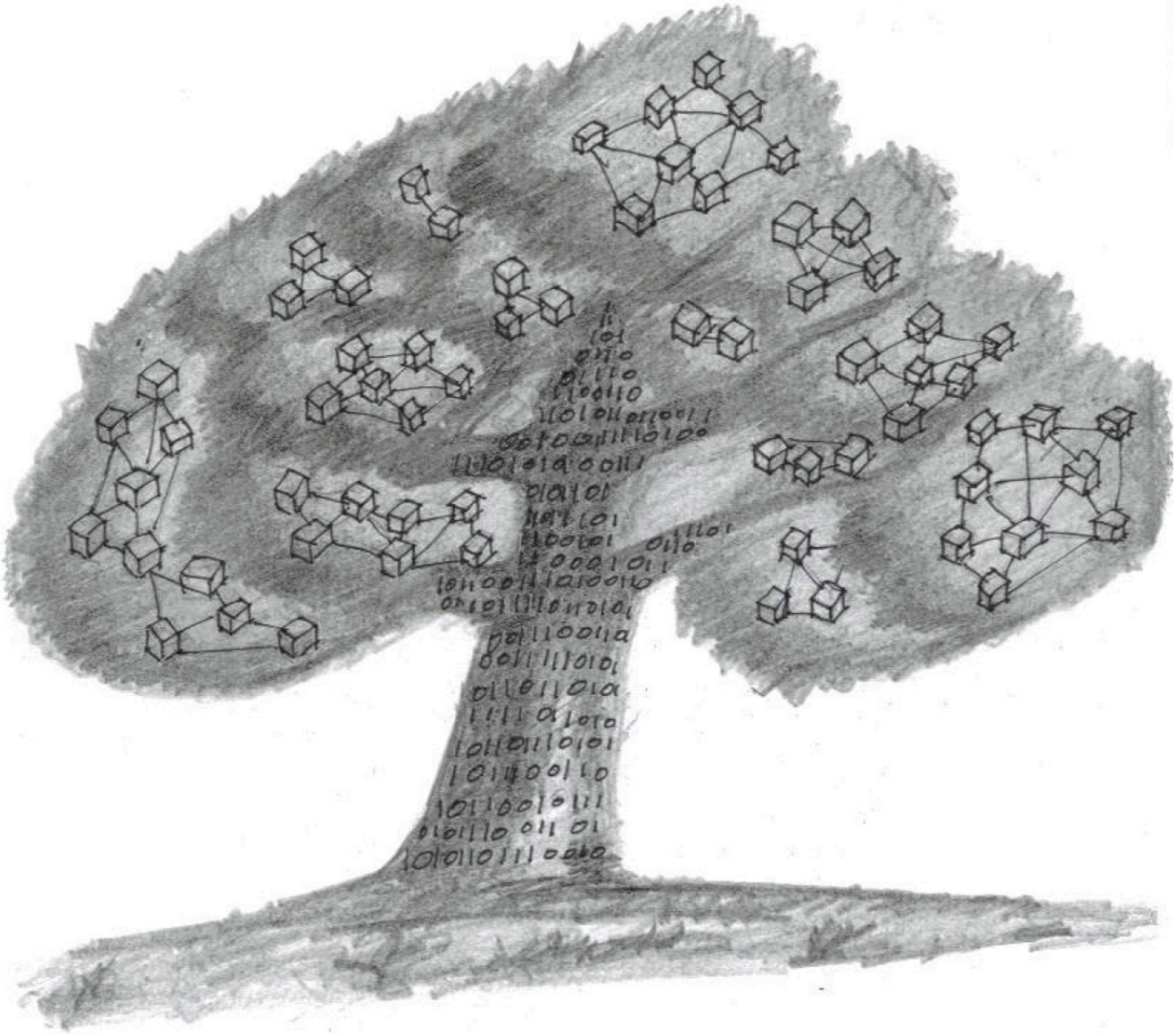

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A Little An(t)alogy

The tree on the cover represents an organic ecosystem that grows larger and stronger over the years. Thousands of little sub-processes are provided for by the tree and they all follow the basic principles of evolution. This comparison is sketched to introduce the inspiration behind this thesis. This research attempted to develop a technological alternative to provide such an organic ecosystem for building partnerships.

Ants, for example, are natures greatest builders. They're able to build the most amazing structures by using themselves as tools or structures in the process. They communicate through some kind of unity consciousness, which basically means that they have a shared mental model ingrained in their natural being. A software that's running in the background. Intuitively they make shared decisions and apply team learning behaviour through trail and error.

They strike partnerships with other animals and plants. The Croton is a plant that produces sweet fluids for ants to feast on. Caterpillars co-habit these plants and suck out the fluids, but also emit these through their own skin once saturated. It becomes easier for the ants to slurp up these fluids after its emitted by the caterpillars. In turn the ants protect the plants and caterpillars against predators and other threats. In this symbiotic partnership there is a mutual benefit in collaborating. By sharing these benefits they overcome the test of survival together.

What if people could emulate these kind of natural phenomena in their building practices?
By having a shared mental model that's running like software in the background.
Intuitively making shared decisions and applying team learning behaviour together.
By striking mutually symbiotic partnerships and sharing in all the benefits to survive.

People would be able to build even more fantastic structures!

Master Thesis

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Construction Management & Engineering

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In front of you is laying my final thesis report for the Master Construction Management and Engineering at Delft University of Technology.

I feel privileged to have had the freedom and opportunity to design this research completely from scratch. During my whole study career I've never experienced this level of commitment and passion for a project. I would like to thank Hennes de Ridder, Lex van Gunsteren and Ruud Binnekamp for their inspirational lectures which taught me the principles and philosophy behind dynamic project control and stakeholder oriented management.

This research wouldn't have been possible without the generous opportunity given to me by the contractor Huybregts Relou. I would like to thank Paul Uppelschoten and Mark van Diessen in particular for their hospitable attitude. For making time in their busy schedules, letting me participate in all their meetings, giving me access to all their resources and making it possible for me to work comfortably in a professional co-working office close to home.

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B.R.J. Visser
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Summary

Supply Chain Management (SCM) and Building Information Modelling (BIM) are seen as compatible innovations that can manage complexities in construction by focussing on integrating processes and products respectively. Combining these innovations could reduce fragmentation in the supply chain and offer a balanced attitude towards their implementation. The problem is that they are both still struggling with being adopted due to several financial, social, legal and technical constraints.

Blockchain technology is able to guarantee an immutable data record which could avoid disputes and litigations. It could also significantly reduce time and costs through process automation. The technology presents a potential solution for the many legal barriers in BIM, regarding ownership of information. This thesis will continue research based on these hypotheses by experimenting within a project transcending partnership in the Dutch social housing sector. For these partnerships alignment of business objectives and commercial interests is still lacking. An overarching goal through benefit-sharing agreements could be implemented by blockchain-enabled contract management. This could potentially result in better financial control and a lucrative business case, which are instrumental for actual adoption of new innovations. This is the focus for this thesis and therefore the research question is as follows:

How could blockchain offer more financial control in construction supply chains?

In order to present a satisfying answer to the main research question this thesis is embarking on a design problem. A preliminary design will be presented for the necessary software architecture to support the whole project cycle in guaranteeing financial control.

This software should provide the possibility to built a virtual company on top of the partnership. The current business-model, which is based on individual projects, has to evolve into one that suits better with the new project-transcending process. This requires a financial model that can accommodate the benefit-sharing agreements and is easily adaptable to changes. By offering real-time information the project can be steered adequately, which is governed through decisions made by the relevant stakeholders, resulting in the most ideal form of financial control. A simple virtual company environment is required to support intuitive decision-making. Blockchain will be able to guarantee the security and reliability of the data. This creates the possibility to safely automate the whole process, which would significantly improve the total efficiency.

The financial model and the virtual environment are the two key-components of the preliminary design. These are respectively tested through a case-study and a simulation. It is concluded that the proposed financial model, as an instrument, already improves the potential for more financial control significantly. But Excel is known for being time-consuming and prone to errors. In the further development it is recommended to keep the enabling potential of blockchain technology in mind. The results of the simulation are measured through a monitor which is specifically designed to measure supply chain collaboration and its effectiveness in the Dutch social housing sector. It is concluded that the proposed software architecture would have a considerable positive effect on the financial components of the monitor.

After this preliminary design it is recommended to continue the research by further refinement and optimization to develop a more detailed design. Possible improvements are presented and more specialized expertise would be necessary in disciplines of business information management and computer and software programming. The research scope could also be broadened, technically by including probabilistic network planning software and business-wise by exploring application strategies in concepts such as "Living Buildings" and "Buildings as a Service".

Contents

List of Abbreviations

Abbreviation	Definition
AEC	The Architecture Engineering and Construction industry
MBE	Management in the Built Environment (Master)
SCM	Supply Chain Management
SCP	Supply Chain Partnership
BIM	Building Information Modelling
SE	Systems Engineering
VPE	Virtual Private Environment
ERP	Enterprise Resource Planning
ERM	Enterprise Risk Management
WB	Wonen Breburg
HR	Huybregts Relou

Chapter 1

Introduction

1.1 Background

The construction industry has become known for adopting the “Hollywood business model” (Grantham, 2000) in its organization style. For each ”project” a unique set of contributors is assembled to work together and are dismantled at the end (Turk and Klinc, 2017). In her PhD research Papadonikolaki et al. (2016) describes the various challenges in the management of the Architecture Engineering and Construction (AEC) industry and particularly focusses on the issues of processual, technical, and organisational complexities, as well as the inherent and increasing fragmentation of the industry. Leading to a lack of effectiveness and productivity, making AEC one of the least performing industries (Koskela (1992); Botero et al. (2004); Jarkas (2010); Loera et al. (2013); Changali et al. (2015)).

The department of Management in the Built Environment (MBE) within the Faculty of Architecture at the TU Delft is doing extensive research in the practice of Supply Chain Management (SCM). This is suggested to be a more integrated approach to supply chain collaboration as a solution to the many problems and deficiencies existing in building. (Vrijhoef et al., 2014) ”The premise here is that the supply chain would function better when approached and re-conceptualised as a single entity, an extended enterprise or a single virtual organisation.” (Vrijhoef, 2011) ”Establishing trust and transparency is a major prerequisite, combined with the alignment of business objectives and commercial interests of the supply chain partners. Not only on a strategic and contract level, but also tactical/operational processes, procedures and systems must be aligned. In essence it is to think and act as one firm with everyone involved to be committed to add value to the supply chain. Besides it is important to take a multi-project approach to the business. Repetitive working must lead to strategic thinking , increased innovation and continuous improvement. This also enables to keep teams together for multiple projects, and to learn collectively as a result of continued work.” (Vrijhoef et al., 2014)

Supply Chain Management (SCM) and Building Information Modelling (BIM) are seen as innovations that can manage complexities in construction by focussing on integrating processes and products respectively. These two innovations have been considered compatible. ”A combined routine with both BIM and SCM could significantly promote SC integration, reduce its fragmentation and additionally offer a balanced attitude towards BIM implementation. Likewise, the BIM collaboration process could be greatly enriched from SCM” (Papadonikolaki et al., 2016).

1.2 Problem Statement

Due to SCM and BIM both being innovations. they are both, independently, still struggling with being adopted:

Challenges in Supply Chain Management

- The ultimate goal of SCM is to achieve a seamless and agile supply chain to meet the customers' needs at lowest cost. However, because of conflicting interests of various participants this goal is very difficult to achieve (Kopczak and Johnson, 2003).

- The traditional AEC industry involves trust issues in almost every aspect of daily activities (Johnston et al., 2004), especialy in a cross-disciplinary environment (Kadefors, 2004). The establishment of trust is one of the most critical factors that facilitates partnering success (Wong and Cheung, 2005).

- The other important aspect is related to information sharing, including the technology to support it, information content and information quality (Zhou and Benton Jr, 2007). It is necessary to have an established mechanism to identity false infromation and providing false information should be penalized (Wang et al., 2017).

Challenges in Building Information Modelling

- Also for BIM, information sharing is a source of many legals barriers. Several authors have identified legal issues to BIM technology adoption (Arensman and Ozbek (2012); Redmond et al. (2012); Thomas (2013); Eastman et al. (2011);Foster (2008)).

- Through interviews with Dutch experts in the field, it became apparent that the administrative systematics for making project-budgets is also a barrier for adoption. The current systematics on guidelines for writing budgets, by STABU in The Netherlands, is not yet compatible with the information models. STABU is currently working on a system that could support BIM, but the new codes have proved hard to be actually adopted by the budget writers.

- Experience, amongst experts, also shows that time pressure in the traditional approach of the AEC doesn't allow for enough time to develop the information models completely and benefit from their full potential. With a unique assembly of contributors for every project, the Hollywood model, to much time is lost by reinventing the organization for each project.

The implementation of SCM and BIM could benefit form each other, as stated by (Papadonikolaki et al., 2016). For example, strategic thinking, leading to innovation and increased improvement, could lead to improving budget systematics in a multi-project approach. Also, by having a guarantee that certain projects are going to happen long ahead of time, the SCP could start timely with building their information models. The combination of SCM and BIM, resulting in BIM-enabled SC-partnerships, is therefore a logical suggestion. Only, as long as the mentioned "technical" challenges; trust; information and legal barriers, are not resolved, an integrated implementation in the AEC industry is hard to deem realistic.

1.3 Research Objective

In the research of Wang et al. (2017) blockchain technology is presented as a potential solution for the trust and information security challenges in construction engineering management in general. The proposed blockchain-enabled applications by Wang can significantly avoid disputes and litigations due to the immutable data record. Time and cost can also be reduced through process automation. In the research of Turk and Klinc (2017) blockchain technology is presented as a potential solution for the many legal barriers with BIM. He states that further research is needed into smart contracts that would – as part of the blockchain – evaluate and respond to the state of the blockchain (state of the BIM database) and perform actions on it to check if the designer has performed the design task to a certain level of detail.

This thesis continues on the hypothesis by Wang regarding the immutable data record and reducing time and costs through process automation. As well as the requested further research by Turk on checking and evaluating design performances through smart-contracts. The multi-project approach in SCP creates the ideal environment to experiment with these kind of new innovations. The research gap this thesis will aim to fill is incorporating the made hypotheses by Wang and Turk to further investigate the potential of blockchain for BIM-enabled SC-partnerships.

Through interviews with experts in the field it also occured that challenges exist regarding the "business"-part of SCM and BIM. Meaning that the traditional business model for construction projects doesn't seem to be lucrative for SCP. The Construction Industry Institute Australia (CIIA 1996) and Larson and Drexler (1997) suggested that next to developing trust relations, effective communication and a competent management team also a fair benefits-sharing formula is critical to the success of project partnering. An example of benefit-sharing can be seen in the Dutch Talentgroep, which is a collaborative alliance between the construction company Strukton, the installation firm Imtech and the facility manager ISS. A legal entity for the Montaigne College construction contract was set up on the basis of equity participation by all partners. The equity positions of partners were supplemented by further rules for profit sharing which ensured that each would obtain a reasonable profit margin. The partners' equity positions can determine their influence on decision-making, but, while formal procedures exist, decisions are typically reached in an atmosphere of unanimity and consensus (De Man and Roijakkers, 2009). With this example it is shown that competing goals can be reduced significantly on the basis of equity participation by all partners. Through creating such an overarching goal the needs of all the various relevant organizational constituencies are increasingly satisfied.

Contractual safeguards and trust are important control mechanisms that reduce risk and facilitate cooperation in a partnership (Lui and Ngo, 2004). Trust is the key feature of blockchain technology. If the construction business or activities are executed on a blockchain system, participants involved don't need to have an established trust relationship if they trust the blockchain itself (Wang et al., 2017). An overarching goal, through an equity-alliance, could be implemented by blockchain-enabled contract management. Profit-sharing arrangements would enable a reasonable profit-margin. This could potentially result in better financial control and a lucrative business case for SC-partnerships. In this way, blockchain technology could contribute to solving both the technical as business challenges to realistically implement BIM-enabled SC-partnerships. Getting the AEC industry one step closer to becoming more effective and productive.

1.4 Research Questions

A potential new technology may have no obvious business model, and in such cases technology managers must expand their perspectives to find an appropriate business model in order to be able to capture value from that technology. The root of tension is the conflict between the business model established for the existing technology, and the business model that is required to exploit the emerging, disruptive technology. (Chesbrough, 2010). The purpose of this research is to explore how blockchain could present a solution to the current challenges that are withholding SCM and BIM to live up to its full potential. The focus will be on financial control and a sound business-model since that's the key to real adoption of new innovations. Thus, the main research question is:

How could blockchain offer more financial control in construction supply chains?

The example of Talentgroep is meant to introduce how an overarching goal can be created through an equity alliance. More attention would have to be spent on the different possible variations of creating such an overarching goal and how this could result in driving down costs and making projects more lucrative. Leading to the following sub-question:

1. **How can the business model ensure higher profit margins for the whole SCP, without compromising on effective collaboration?**

   The way budgets are traditionally composed will have to change in order to make the budgets work for a BIM-enabled SC-partnership. Leading to the following sub-question:

2. **What could a financial model look like for an BIM-enabled SC-partnership?**

   Attention will be spent to the use and potential of blockchain-technology and how this can help in offering real-time financial information, to adequately steer and control a project, and contribute to higher revenues Leading to the following sub-question:

3. **How could the administration for this financial model be automated by blockchain?**

   All partners would have to contribute in an integrated manner to the new budget. Leading to the following sub-question:

4. **How would the administration have to be organised at all the different partners?**

   Financial control is necessary throughout the cycle of the whole project. This would require a standardized approach, ideally supported with software. Leading to the following sub-question:

5. **How could the organization of the whole project cycle be supported with software?**

   Results have to be measured in order to make a valid justification for the proposed solution. Leading to the following sub-question:

6. **How could results be demonstrated and measured?**

1.5 Methodology

"Scientists study the world as it is, engineers create the world that never has been."
Theodore von Karman

This research is dealing with operations related research questions; "How could ...", which are of a typical engineering nature. Involving the application of science and technology to create useful products and services for the whole community, within economic, environmental and resource constraints. This is why this thesis is dealing with a design problem, creating an artefact that does not yet exist. For this a design-process cycle can be applied as shown in figure 1.1.

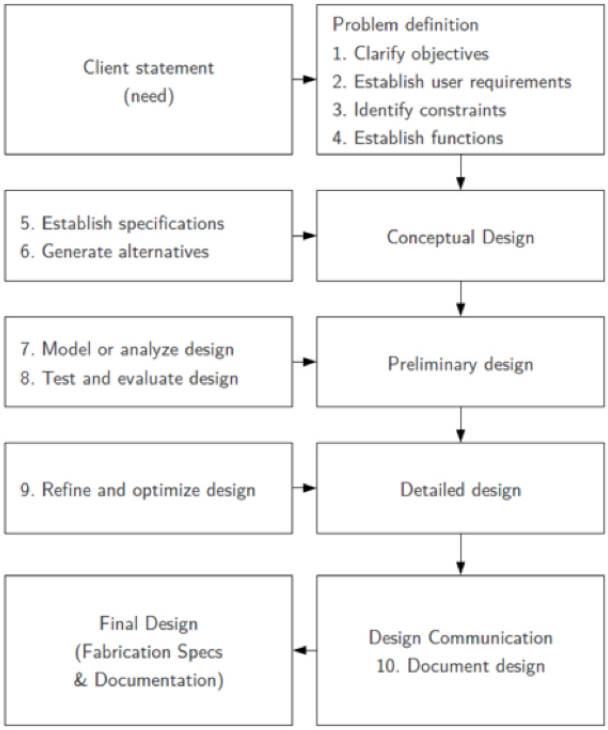

Figure 1.1: Design-Process Cycle (Dym et al., 2009)

In order to present a satisfying answer to the main research question this thesis is embarking on a design problem. Developing the necessary software architecture, based on blockchain, to support the whole SCP project cycle in guaranteeing financial control. Developing this software architecture is a greenfield project, lacking constraints imposed by prior work. Due to the limited time available for a master thesis research it has been agreed that the design process will be executed until the preliminary design step.

In a field study on project team level factors Koolwijk et al. (2015) state that many different studies approach SC-partnerships as a technical-managerial problem. Mainly involving the application of appropriate tools and techniques (Venselaar et al., 2015). By implementing these tools, it is thought that professionals will start to perform in line with the intended strategies. They've found that much more attention should be given to the project team; to the people that have to work together in a new setting. There are many different team related variables that can hinder a project team in reaching its goals. In addition, its known

that if the human factor is ignored the impact of tools that are intended to motivate people to work together might be compromised (Rose and Manley, 2010).

Such projects are deemed as higher risk, as they are often for new infrastructure, new customers, and even new owners. For this reason, agile software development is often deemed the best approach, as it proposes how to handle those risks by developing small slices of complete functionality and getting them in the hands of customers (internal or external) quickly for immediate feedback. Agile software development describes an approach under which requirements and solutions evolve through the collaborative effort of self-organizing and cross-functional teams and their customer(s)/end user(s) (Collier, 2012). Information is gathered through collaboration with a project-team consisting out of employees of the housing association Wonen Breburg and the contractor Huybregts Relou. This SCP has been experimenting with the practice for over five years.

1.6 Thesis Structure

This thesis answers the central research question through the next six chapters. These chapters are based on the steps in the design process cycle shown above. After each chapter the corresponding sub-questions are answered and in the final conclusion the main research question is answered.

Chapter 2, The Problem, focusses on the problem definition by clarifying the objective, establishing the user requirements, identifying the constraints and establishing the functions. This will cover answering the first sub-question.

Chapter 3, The Architecture, focusses on the conceptual design by establishing the specifications and generating possible alternatives. Based on the experiences of the collaboration with the SCP choices will be made between the possible alternatives and a conceptual model will be designed. This will basically cover the sub-question two to five.

Chapter 4, The Back-end, will discuss the preliminary design by analysing the software that would be running in the background. The focus will be on the financial model which basically is the back-bone of the software architecture.

Chapter 5, The Front-end, will discuss the preliminary design by analysing the intuitive user experience that's necessary to make the software accessible for all different kinds of users. This will be done by organising an experiment in the form of a simulation. Evaluating these results will cover answering the final sub-question.

Chapter 6 draws conclusions on the preliminary design and the main research question. Recommendations will be made on how to further execute the last three steps of the design process cycle. It will also be attempted to extrapolate the results for more general applications in the AEC industry.

Chapter 2

The Problem

The housing association Wonen Breburg (WB) and the contractor Huybregts Relou (HR) have been experimenting with SCP and are looking for new insights to guarantee a lasting collaboration with their project-team while maintaining a competitive edge as a company. Throughout my research they offered me the opportunity to join their evaluation meetings. This SCP is linked to the MBE department of the TU Delft. A view on the Dutch social housing sector and the trend towards supply chain collaboration is discussed by Vrijhoef et al. (2014). The objectives, constraints and functions are generalized as much as possible. The user requirements will be aimed in particular on SCP's with Dutch housing associations, since this is where the data is gathered from. At the end of this chapter answers will be presented to the relevant sub-questions.

2.1 Clarifying Objectives

In clarifying the objectives and establshing the requirementrs the guidelines of Enserink et al. (2010) are followed. This book is part of the study material for the course Policy Analysis of Multi-Actor Systems (EPA1124). In paragraph 1.2, the fundamental objective is stated as "making BIM and SCM adoption more realistic". The challenges, preventing these innovations to be fully adopted, are stated in that paragraph as well. In paragraph 1.3, possible solutions to these challenges are touched upon. Figure 2.1 summarizes this in a clear means-ends diagram, which should be read from top-to-bottom by asking the "how" question. Starting with "how can we make BIM and SCM adoption more realistic", and so on. The diagram can be read from bottom-to-top by asking the "why" question.

As stated in paragraph 1.4, the focal objective is having a more suitable business model for the BIM-enabled SC-partnership. The equity alliance of the Talentgroep consortium, mentioned in paragraph 1.3, is an example of how an overarching business model could be designed, but unfortunately the organisation and social cohesion within the consortium were sub-optimal as stated in the master thesis of Dalen (2007). In this research it is also stated that the eventual quality for the end-user didn't meet the initial requirements, which are both undesired side-effects. This results in the following problem statement, which is also the first research question:

"How can the business model ensure higher profit margins for the whole SCP, without compromising on effective collaboration?"

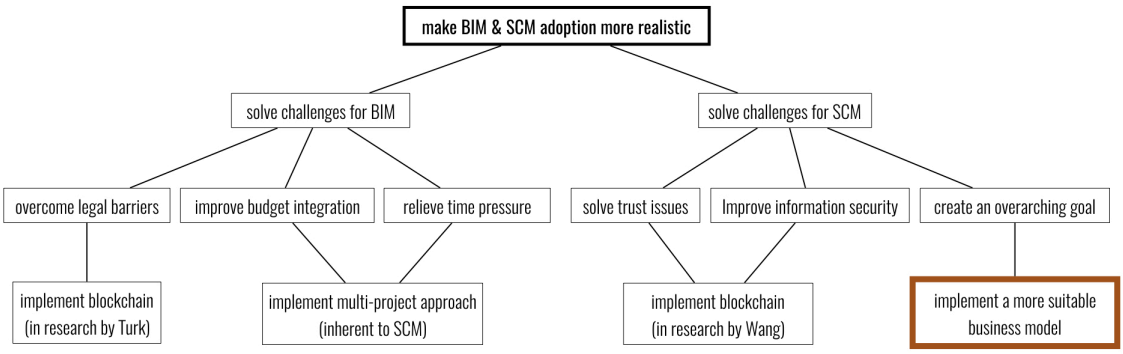

Figure 2.1: Means-ends diagram (by guidelines of Enserink et al. (2010))

Figure 2.2 shows the resulting objectives tree from this statement. The first level underneath the focal objective is the made through dissecting the problem statement. The levels underneath should be read in the same fashion as the means-ends diagram. The interpretation of this objectives tree compiles a set of criteria by which the effectiveness of a solution can be measured. These established criteria will function as the user requirements.

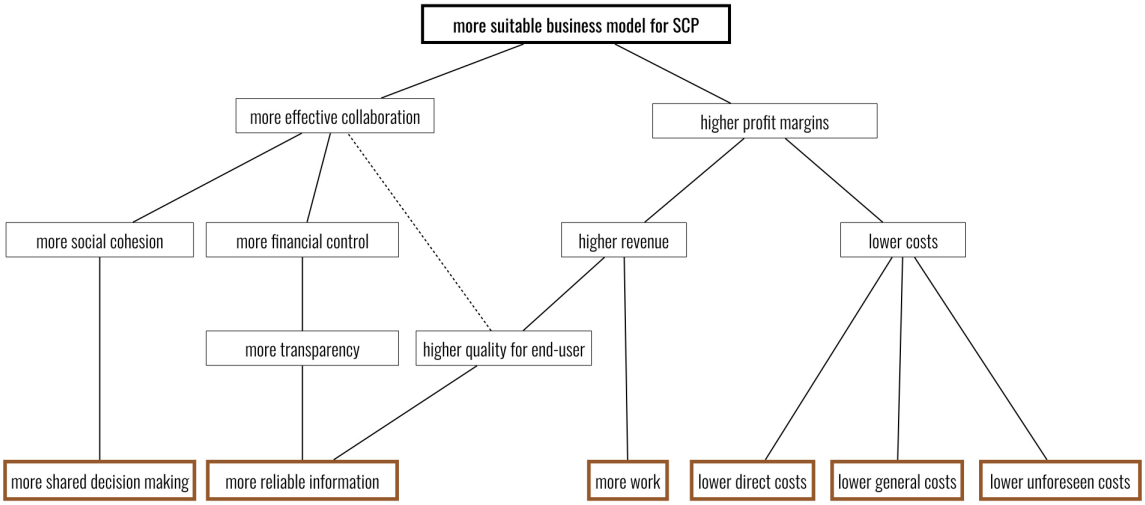

Figure 2.2: Objectives tree (by guidelines of Enserink et al. (2010))

2.2 Establishing User Requirements

To effectively control a project a firm goal is absolutely necessary. The main parties involved in a project have different goals and associated different interests. The main consequence is that they cannot work together in a collaborative way without sharing formulas for the benefits, also discussed in the lectures of prof. dr. H.A.J. de Ridder. With the equity alliance of Talentgroep this was ensured with rules for profit sharing that would obtain a reasonable profit margin for each partner. Through this mechanism each partner could be incentivised to deliver the highest possible quality for the lowest possible cost, while collaborating as effectively as possible. Part of this is taken care of by earning a decent profit, but the other, just as important, part is about team level factors such as everybody understanding their role and responsibilities, building a shared mental model, trust and psychological safety (Koolwijk et al., 2015).

2.2.1 Effective Collaboration

The left half of the objective tree concerns **more effective collaboration**, which is realised through **more social cohesion** and **more financial control**. More social cohesion is achieved through a shared mental model, trust and psychological safety. Activities that help building such a model are; setting clear project team goals, planning the design phases as a team, discussing what needs to get done, why and who it can be done in the best way (Koolwijk et al., 2015). In order to achieve successful results in complex projects it was concluded that, in addition to a redundancy of capable people and other resources, the style of management is of paramount importance. The essence of the prevailing management style should take the interest of all stakeholders as a basis of decision-making in all issues that arise (Gunsteren, 2011). Which results in the criteria **more shared decision-making.** When construction projects become large and complex many relevant matters are reflected neither in the contractual specifications nor in the budget or the network planning of the project. As a result, functionality suffers under the traditional management approach (Gunsteren, 2011). This explains how **higher quality for the end-user** is realised through more effective collaboration in figure 2.2.

More financial control is established through **more transparency** in financials, roles and responsibilities. For example, back-door dealing is a relational risk which is present in every partnership were turnover and profit can be hidden in the direct cost and external control is lacking (Koolwijk et al., 2015). This is why the criteria of having **more reliable information** is important for having more transparency. This criteria is also valid for achieving **higher quality for the end-user** since you want to focus on realizing quality as required by functionality, not only as specified in contracts, and consider cost and time of completion as outcomes of a process, which can only indirectly be controlled (Gunsteren, 2011).

Waste is defined as "anything that is not required to create value for the client or end-user" (Mossman, 2009). Waste also includes: transportation, overproduction, waiting time, inventories, too much machining, moving, and making defective parts and products (Koskela, 1992). Waste and non- value adding activities must be regarded as unnecessary costs (Aziz and Hafez, 2013). Decreasing these unnecessary costs could all result in even higher profit margins, which is why it's all indirectly connected to the objective of having a more suitable business model.

2.2.2 The Profit Margin

The right half of the objective-tree concerns **higher profit margins**, which is realised through generating **higher revenues** and/or **lowering costs**. Higher revenues can be achieved through creating **higher quality for the end-user**, which will result in a higher value end-result for the commissioner, and/or having the obvious criteria of creating **more work**.

Lower costs can "theoretically" be achieved in three ways. The first way is **lowering the direct costs**. These costs include all costs for production, procurement, installation, testing and commissioning plus the general costs for the construction site (ABK in Dutch). Although this is a criteria, it will be hard to actually lower these costs since they depend on the external market. The second possibility is **lowering the general costs**. These costs concern overhead and other indirect costs which are usually a percentage of the direct costs. The last possibility is **lowering unforeseen costs**. These costs are a result of unexpected risks that are occurring, such as removing asbestos in unexpected places.

2.3 Identifying Constraints

2.3.1 Financial Constraints

The total price of the project is traditionally made up out of the direct costs (DK in Dutch), general costs (AK in Dutch), profit and risk. The biggest part of the direct costs, about 80%, consists of purchases from sub-contractors and is usually translated in prices per unit. These prices are shown in an "open-book" administration, without any explanation regarding the relation between costs for labour, material, coordination, business management and such regarding the concerned disciplines. This is in fact a vague and diffuse process, because business continuity in the construction companies is mainly realised through (hidden) percentages over purchase of material and services, percentages over percentages and budgeting disproportional buffers. This makes it almost impossible to influence these costs. This is the often mentioned opaque marketplace in the construction industry, which is causing a lot of frustration in SCP (N.en partners (2016)). In the five-year of experience with SCP between WB and HR it's been proven that de-buffering the cost-price turns out to be problematic.

2.3.2 Social Constraints

In general people are very aversive to risk and therefore change. Especially in the building industry you have to collaborate with all kinds of different people, who might not see the need in changing their way of doing things. This makes managing the transition extra complex. That's why its important in the beginning to start experimenting and that all people, within the project-team, are on the same wave- length. This goes for both the client and the contractor, as well as for the contractor and sub-contractors. Within Huybreghts-Relou they call this their "DNA". All the actors within the partnership need to have the same DNA in order to make a smooth collaboration possible. The company is trying out new ways to design a selection procedure for this.

2.3.3 Legal Constraints

In his paper Giancaspro (2017) describes that as early as 1994, American computer scientist Nick Szabo proposed what was then a fanciful notion of 'smart contracts'; computerised transaction protocols which execute the terms of a contract (Tapscott and Tapscott, 2016). At that point in time, the existing economic and communications infrastructure was insufficient to support such protocols (Omohundro, 2014). Thanks to blockchain technology, the requisite infrastructure is available and smart contracts are increasingly being developed, tested and implemented across a variety of industries the world over. (A introduction to blockchain technology is added in Appendix A). Fundamentally, a smart contract is a computer program which verifies and executes its terms upon the occurrence of predetermined events. Once coded and entered into the blockchain, the contract cannot be changed and operates in accordance with its programmed instructions (Giancaspro, 2017).

Smart contracts have the potential to increase commercial efficiency, reduce transaction and legal costs, and facilitate transparent and anonymous transacting. There are, however, questions surrounding the legal enforceability of smart contracts; it is uncertain whether they will easily adapt to current legal frameworks regulating 'conventional' contracts across jurisdictions (Giancaspro, 2017). With the AEC industry it's foreseeable that many problems would occur due to the incompatibility between smart contracts and the current contract law. For example the incompatibility with the DBFM contracts. As time progresses, and smart contracts become more widely used and applied in a greater variety of commercial contexts, it is essential that the law keeps pace (Giancaspro, 2017).

2.3.4 Technical Constraints

Wang et al. (2017) states that blockchain technology is without a doubt a disruptive innovation that has the potential to revolute thecurrent practice of construction engineering management. However, there are still lots of challenges when implementing it into real construction projects. The blockchain technology is still in the early stages of development and faces a number of technical limitations such as throughput (a theoretical maximum number of transactions per second), latency (the time it takes to process a transaction), and size and bandwidth (time needed to download the entire blockchain). Detailed information can be found in Swan (2015). Companies in the construction sector got accustomed to maintaining their business activities in their own ledger in the last many centuries. It is very hard to change the way to a distributed ledger. Lack of awareness and understanding prevents the diffusion of this technology. There are many issues to be resolved before individuals would feel comfortable storing their personal records in a decentralised manner (Wang et al., 2017), which is indirectly also another social constraint.

2.4 Establishing Functions

Functionalities will be established based on the above mentioned user requirements and constraints. The distinction will be made between social functions, regarding the objective of achieving more effective collaboration, en financial functions, regarding the objective of achieving higher profit margins.

2.4.1 Financial Functions

The way of budgeting as described above is unnecessarily frustrating when its attempted to work in a company transcending organisation as with SCP. In the context of attempting to plan and organise optimally, it doesn't help to constantly discuss about the fact if company costs are covered or not. N. en partners (2016) states that the way out of this discussion is relatively clear:

- Work with an unambiguous set of rules for structuring the budget for the partners that oversee the largest part of activities.
- Manage and guarantee joint financial awareness and transparent steering from the start. This must have absolute priority and determines the go / no-go for each milestone in the project.
- Don't offer any ingrained uncertainty. Explainable expenses get covered for everybody, provided that these are actually transparent and there is proof of continuous effort to improve.

These assumed functions connect well with the shift of project-management to process-management. Project-organisation, information facilitation, quality and risk control are more emphasized with integrated process-management, instead of just steering on time and costs.

2.4.2 Social Functions

The collaboration amongst participants and stakeholders becomes the core focus. Koolwijk et al. (2015) perfectly sum up all of the team level factors that help or inhibit a construction project team to perform. A team communicating about its goals, tasks, working relationships and situations and discussing how the different team members understand them will build a shared mental model (Mathieu et al., 2008). Shared mental models help team members to predict what their team-mates are going to do and facilitate coordinating actions between each other (Harbers et al., 2012). All types of knowledge about tasks, working relations and so on need to be shared and understood adequately in order for teams to become effective (Mohammed and Dumville, 2001). The following distinction in shared mental models is assumed necessary for this:

- The choice for a particular project-team member is mainly determined on the type of work that needs to be preformed and the expert knowledge that is required to make the design or to identify and manage potential risks (Koolwijk et al., 2015). So a mental model is required per project and its associated partners.

  It is inferred that building a shared model takes experience and that having experience in traditional projects is not enough to do it right the first time in a SCP setting.

- Team learning behaviour can help the team to explore its capabilities and to structure the work faster and to come up with new ideas and smart design solutions (Koolwijk et al., 2015). So the project-transcending approach lifts the management approach up to a meta-level where it shifts into managing a process. This requires a shared mental model on it's own for the SCP process as well.

Examples of team learning behaviour have to do with speaking up, communicating openly about concerns and errors, evaluating different opinions and views, openly discussing opinions, adjusting processes on team members behaviours (Edmondson, 2004). Before people

are willing to perform such learning behaviour an environment is required in which this behaviour is accepted by the team and where people feel psychologically safe to really speak up (Edmondson, 2004).

2.5 Conclusion

RQ #1 - How can the business model ensure higher profit margins for the whole SCP, without compromising on effective collaboration?

It is concluded that due to the multi-year approach, which transcends over multiple projects, the SCP organisation shifts to a meta-level which has to be managed like a process. The current business-model, which is based on individual projects, also has to evolve into one that suits better with the new project-transcending process. The consequence is that each "project" becomes a sub-process of the overall SCP. It has been shown how more effective collaboration contributes to decreasing unnecessary costs. The financial and social functions should support project-organisation, information facilitation, quality and risk control. A shared mental model is required for both the individual projects and the overarching process of developing the SCP.

In the next chapter, designing the architecture, we will attempt to determine which business-model would be best suiting for the SCP process. Supported with a virtual environment that could accommodate for transparency, trust and psychologically safety.

Chapter 3

The Architecture

In order to converge to an suitable design for the software architecture its necessary to start with describing the process for which the architecture will be necessary. Through the accompanied evaluation meetings it turned out that there was no unanimous consensus over what the process actually looked like. Throughout the gatherings an attempt was made to generate a shared mental model on the SCP process per "project". The outcome will be presented first. After that clarification it will become possible to establish the right specifications, generating different alternatives to meet these specifications. Eventually the chosen architecture will be explained.

3.1 The Supply Chain Process

The organisation of the SCP, and its projects, knows four organs: the management team, the work-group, the steering group and the the project-team. The Management team and the work-group exist to further develop the SCP. The steering group and project-team are responsible for steering and organizing the SC projects. Figure 3.1 shows an overview of how these organs relate to each other.

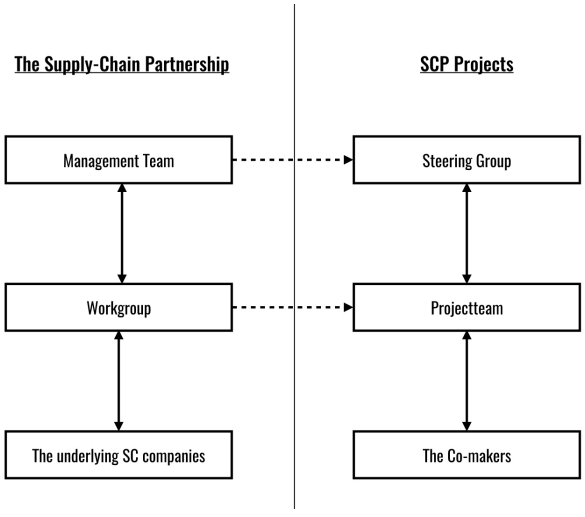

Figure 3.1: Supply Chain Partnership - Organisation

The SCP is formalized through a memorandum of understanding, a collaboration agreement and a shared vision-document.

Generally, in construction projects, the phases of design, build and maintain can be distinguished, with slight adaptations for different kinds of projects. In traditional housing-renovation projects four different phases are known; the initiation phase, the design phase, the building preparation phase and the realisation phase. Figure 3.2 shows how these phases relate to the general phase distinction, with their accompanied milestones.

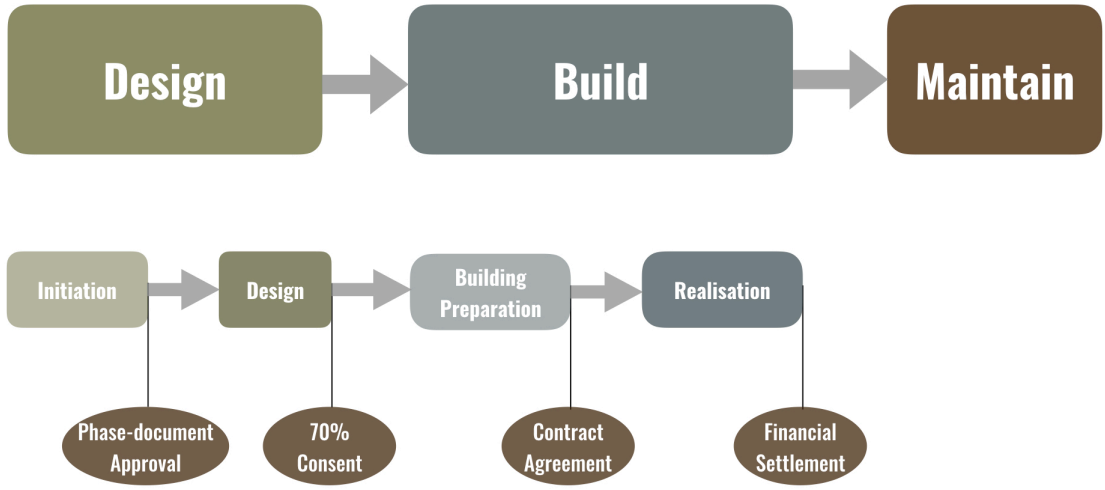

Figure 3.2: The Supply Chain Process

The SCP approach requires a more integrated collaboration amongst all relevant parties from the very start of the project. The steps differ slightly from the traditional approach as a result of this early involvement of all participants. The most recent shared model of the steps taken in this phase is shown in figure 3.3. The mentioned building preparation phase has an overlap from the point of executing the pilot in the design phase until the end of the "warm recordings" in the realisation phase. This overlap, and the "70% Consent" milestone, creates some vagueness in the current practice, which is one of the improvements they are working on. The "70% Consent" milestone is the point that 70% of the residents have given their consent for renovating the interior of their houses.

The initiation and design phases could be seen as an adaptation of the "double diamond" design process model The double diamond is formed from four distinct phases. These are Discover, Define, Develop and Deliver (Council, 2007).

In the design phase it's important to minimise the margin of uncertainty as much as possible. This requires that all involved parties are in full agreement about the budget, planning and risks before the contract is signed. KPI's will be determined in order to measure the status and it will also be decided when and how checks will be preformed during the realisation phase. After several projects together initial uncertainties will become easier to identify. This will make the decisions in the design phase more reliable and more efficient over time.

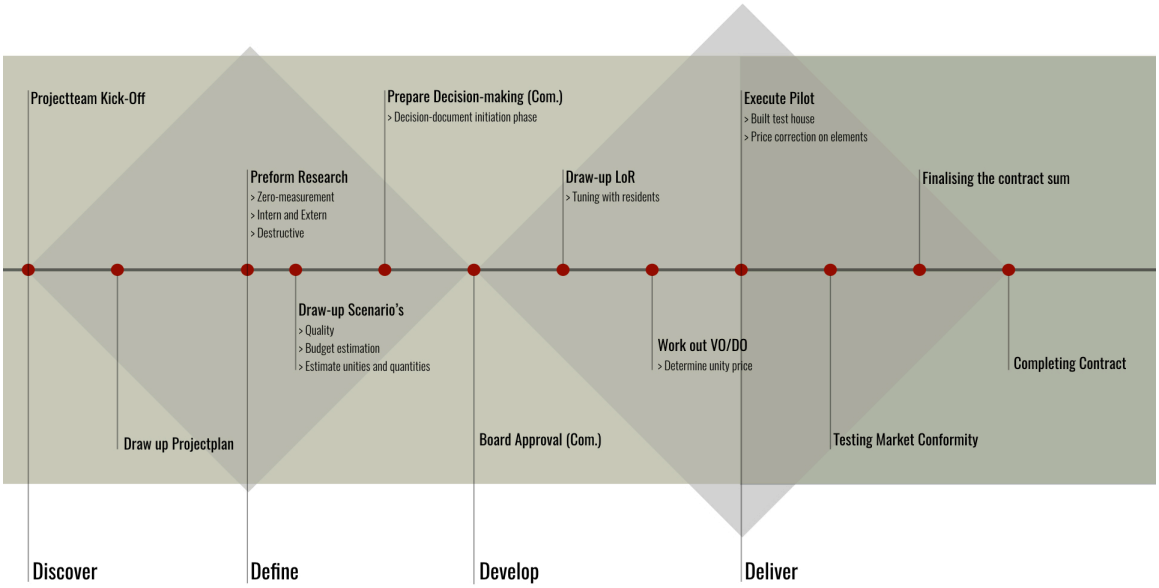

Figure 3.3: The Design Phase

The realisation will be done, as much as possible, according to the agreed upon plan. The steps shown in figure 3.4 don't look very complex at first sight, but unexpected situations and occurring risks or opportunities are unavoidable. This requires quite some iterations throughout the realisation phase. Dealing with these deviations has proven to be quite problematic in the past. Therefore, this is the main specification the architecture should account for.

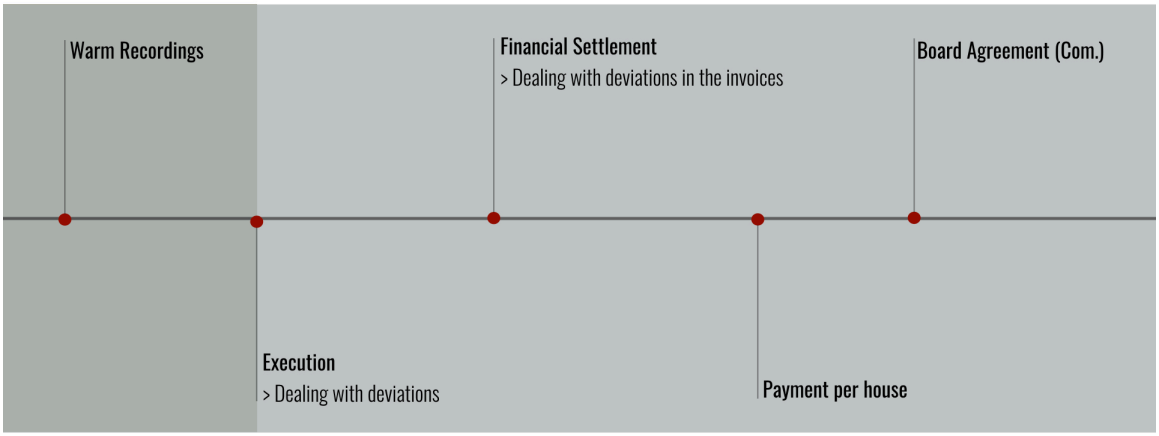

Figure 3.4: The Realisation Phase

3.2 Establishing Specifications

Several things are necessary in order to adequately respond to changing situations. At the core a financial model is required that supports an overarching goal and easily allows for changes in quantities. This should be obviated by the financial specifications. At the surface an environment is necessary which presents reliable information and makes shared decision-making, based on this information, possible. This should be obviated by the social specifications. The right technology is necessary to make it all work which is the basis for the technical specifications.

3.2.1 Financial specifications

A project can be controlled dynamically in the case there is a common goal: all parties are interested in, and benefit from, enhancing the difference between the project output and the project input. This common goal can only be achieved by sharing formulas for the benefits. This is the first specification a financial model would have to satisfy (1).

Enhancing the difference between the project output and the project input means that you either/or generate higher revenues and either/or lower costs (see figure 2.2 Objective Tree). With the covered financial constraints, covered in paragraph 2.3, it would seem, in first instance, that it would be easier to not burn our hands again on lowering direct and general costs. This is why we should first focus on maxing out all the potential gains in creating more work, higher quality and less unforeseen and unnecessary costs. Which covers the next two specifications; Increasing coordination to guarantee more work and deliver higher quality (2), to generate a higher value output, and less unforeseen and unnecessary costs (3), to decrease input.

Currently all key-partners keep track of their administration and bookkeeping in their own way. This requires a clear understanding of what kind of administrative information is needed from each involved party. Once there would be one standard for the whole SCP, it would become easier to incorporate budgets into information models. One standard for structuring the budget with an unambiguous set of rules would be the fourth specification (4).

To manage and guarantee joint financial awareness and transparent steering it is necessary to increase reliable and transparent financial information (5).

3.2.2 Social specifications

As mentioned in paragraph 2.5; a shared mental model is required for both the individual projects and the overarching process of developing the SCP. Their should be an intuitive and psychologically safe social environment that would offer the possibility of shared decision making. The results of this decision-making should be seamlessly integrated with the development of the shared mental model of the SCP process, as well as the joint financial awareness and transparent steering (6).

3.2.3 Technical Specifications

Blockchain has to be viewed in a similar way as the internet. Few people know exactly how internet works form a technical viewpoint, but we massively use it for almost all of

our daily practices. Internet is making a lot of our daily activities very easy and over time many applications have been built on top of it. It completely revolutionized the way we communicate and do things. Blockchain basically is an internet 2.0, adding a business upgrade, which will unlock an entire new range of possibilities. For example, blockchain provides internet the possibility to build virtual companies with complete transparency and trust by design. A virtual company running its governance and administration on software instead of human management. Without any paperwork and no limits to its growth.

A smart contract is expressed as a software code which is unambiguous and predictable when compared with the traditional contracts. Massive time in terms of contract registration, monitoring and updating can be saved because of the automated process and tamper-proof system (Wang et al., 2017). By supporting a financial model with smart contracts on the blockchain it will become possible to automatically update the model and receive real-time financial information (5).

Tracking reputation scores from all key-partners would also become possible with this technology. These scores could keep track off everything. Did the sub-contractor accomplish its activity as agreed upon? Did he finish it in time? Did the main-contractor pay in time? Does everybody present valuable contributions to occurring problems? The reputation score could increase or decrease your weight in the voting processes. This would create an incentive for proper behaviour and will stimulate a psychologically safe environment for everybody to speak up, without any financial triggers. Besides supporting integrated shared decision-making (6), such a reputation based system could also contribute to creating more social cohesion in other ways. Think of gamification to improve for example; user engagement, organizational productivity, flow and team learning behaviour.

Wang et al. (2017) states that payments withheld or not paid are a serious problem in the current industry, and has been highlighted as the main cause of business failures and escalating disputes. With a smart contract, the funds can be embedded into the contract against the insolvency of the late payments so as to protect general contractors, sub-contractors and suppliers. Moreover, these smart contracts can be interlined with each other to create a web of payments. For instance, when a construction project achieves a payment milestone, such as completing the renovation of a house-block, the main-contractor will get an automated payment through the smart contract with the project client. This event will also automatically activate all the related payments, such as the smart contracts between the general contractor and their subcontractors or suppliers, based on the contract conditions. Such an automated billing solution could drastically decrease administration costs (3).

In order to support all these prior specifications the right blockchain application has to be determined, since there are multiple alternatives for such as system configuration (7).

Other Potential (outside of scope)

With the increased complexity of the construction projects, there is a large demand of using heavy equipment to help deliver their jobs such as cranes, compressors, excavators, and loaders. Due to the high cost of these heavy equipment including maintenance and repairing cost, most of the construction contractors face financial constraints to purchase. Therefore, instead of making huge investments in buying them, leasing is a lucrative option for both large and small contractors to cut down their expenses on construction projects. A conventional leasing process is time-consuming and inefficient, which includes lengthy negotiation cycles, insurance quoting procedures, burdensome financing applications, and

reams of paper documents need to be signed and maintained. With blockchain all of the above processes will take a mere matter of minutes (Wang et al., 2017).

Together with sensing technologies, the operational status can be tracked and recorded in the blockchain such as abnormal breakdown events, daily lifting load and frequency, and electricity consumption. These sensing technologies, Internet of Things, could also be applied in the housing-stock that would be renovated. This will give more accurate and reliable information for maintaining the real-estate, which is called precision maintenance.

SCP forms an ideal breeding ground for new innovations, due to its multi-year approach, but once these blockchain applications grow more mature it could start to find its way in other approaches as well. Wang et al. (2017) states that the cost of building trust among different parties in a construction project is very high because every project is one-off and the project team is always temporary. In the traditional way (the Hollywood-business model), construction lawyers play a key role in creating and managing the enforcement of many of business rules through contracts and litigation. To maximise their profits in a real project, corporations rely on in-house lawyers or large firms to help them stay on the right side of the law and execute their contracts appropriately. Blockchain makes it easier for two parties to trust each other without a third-party enforcer. The blockchain-enabled contract can be stored in a non- editable format. Together with the self-executing codes, neither party has the upper hand to tamper or prevent the execution of the contract. With right code and secure code executing across a peer-to-peer network of databases, the "trust" function that a legal team currently plays becomes redundant, which can lead to significant time and cost savings.

3.2.4 List of specifications:

1. Guarantee benefit-sharing
2. Guarantee more work and higher quality (higher output)
3. Guarantee less unforeseen and unnecessary costs (lower input)
4. One standard budget-structure
5. Guarantee more reliable and transparent financial information
6. Integrated shared decision-making
7. An appropriate blockchain system configuration

3.3 Generating Alternatives

For each of the established specifications different alternatives could be thought of to achieve the objective. In this paragraph these alternatives are discussed. In the paragraph after this one, modelling the design, the choice of each alternative per specification will be substantiated.

3.3.1 Guarantee benefit-sharing

"The best result would come, when everyone in the group is doing what's best for himself AND the group."

John Nash - Mathematician & Founder of Game Theory [1]

It is stated that all players in the SCP have to work together towards a common goal. Different approaches could be thought of in order to determine a fair way of sharing in the benefits. Benefits don't necessarily limit themselves only to profit. Also sharing in certain risks is a good way to make partners liable for their responsibilities and forcing more commitment. The project-commissioner would for example be more involved in the project once bearing responsibility in reducing the risk of finding asbestos in unexpected places.

Profit-sharing

- Brandenburger and Stuart Jr (1996) states how cooperative game theory could provide the underpinning for value-based business strategies. In a cooperative situation, game theory can tell you how to be fair in allocating pay-offs (a primer on game theory can be found in Appendix B). The contribution of each player is determined by what is lost or gained by removing them from the game. This is called their marginal contribution. The Shapley value assigns a unique distribution (among the players) of a total surplus generated by the coalition of all players. The set-up is as follows: a coalition of players cooperates, and obtains a certain overall gain from that cooperation. Some players may contribute more to the coalition than others or may possess different bargaining power (for example threatening to destroy the whole surplus). The Shapley value provides one possible answer to how important each player is to the overall cooperation, and what pay-off can he or she reasonably expect. De Clippel and Rozen (2013) research the fairness through the lens of cooperative game theory.
- A lighter variant could also be possible for determining a pay-out allocation key. This allocation key would be based on each of the key-partners contribution with the costs they are making. Based on the fact that removing a key-partner from the game would mean that the project can not be completed and all would be lost. The profit pay-out that would be allocated then consists of the difference between the price, paid for by the commissioner, and the total costs, made by all the contractors.

Risk-sharing

- A separate pot could be created from which occurring risk would be covered. This could be made up from completely de-buffering the risk in your cost-prize, and all the extras that are usually incorporated.

[1] A Beautiful Mind, Ron Howard, 2001.

- A separate risk-pot could also be filled with drawing up an unforeseen budget. Based on a risk inventory, a financial amount could be estimated per risk. Once the amount is agreed upon by the SCP this money will be paid up-front. Throughout the project an transparent book-keeping could be held on what is spent, or not, per risk. This extra, or less, work could be balanced out throughout the project with a clear final balance sheet at the end of the project. At the end there would exist a surplus or deficit in the balance sheet. A surplus would be paid back to the commissioner and a deficit would be paid out of the profit-pot. This could be completely automated with blockchain technology.
- Risks could also be managed by deriving a risk based Shapley value, as done by Jin et al. (2017), or a less complex ratio, determined through consensus, to share the costs of the risk after its occurrence.

3.3.2 Guarantee more work and higher quality (higher output)

The whole point of SCP is about striving to improve the integration amongst all stakeholders in the supply chain. With trying out this new approach, experience has shown that roles and responsibilities starts to shift. More interaction with the residents became necessary because of the social-housing context. The residents are generally poorly-educated with a low income, struggling with many financial and health issues. These residents require a careful approach in order to prevent unrest in the neighbourhood. These projects are organized in such a way that the construction activities on the outside and inside of the building are separated. The work outside is obligatory, but the residents can chose themselves which parts they want to have renovated inside the house. The SCP wants to perform as much work as possible because it will generate more income. This requires the help of external companies, which are specialised in communication, in order to convince residents to give their consent. The whole SCP could even contribute in creating more consent. For example, by letting the sub-contractors help in the communication with the residents. Residents will be more inclined to trust the people that actually execute the work, then the men in suits from the housing association or main contractor.

New roles and shifting responsibilities appear in order to generate more work and insure higher functional quality and satisfaction. This is why more transparency is also required, next to financial transparency, in roles and responsibilities. This needs to be accounted for in a shared mental model. All types of knowledge about tasks, working relations and so on need to be shared and understood adequately in order for teams to become effective (Mohammed and Dumville, 2001).

3.3.3 Guarantee less unforeseen and unnecessary costs (lower input)

"There are known knows. These are things we know that we know.

There are known unknowns. That is to say, there are things that we know we don't know.

But there are also unknown unknowns. These are the things we don't know we don't know."

Donald Rumsfeld - Former American Secretary of Defence

Unforeseen costs are born out of risks called "unknown unkowns", the things we don't know we don't know and therefore are not accounted for in our budgets. When these risks occur they can result in financial disappointments. Due to the inherent risks that come along with construction projects there will always exist a degree of uncertainty in the actual activities that will be faced during the realisation phase. Its a growing common practice that coordinated team learning focusses on keeping track of the occurring risk. But actually implementing this with financial control is not being done in the housing renovation projects of WB and HR and they are probably not the exception.

Unnecessary costs are covered by Vrijhoef (2016). His paper aimed at improved organization and performance of production in housing renovation projects. With the purpose to explore and demonstrate the potential of lean work organization and industrialized product technology to improve work-flow and productive time. He concludes that both concepts could be rejoined into one probably. Because apparently both concepts have taken another route towards the same effects and aims. This would strengthen both concepts, in practice as well as conceptually and theoretically, and their effect on such issues as work-flow and productivity which is linked to reducing unnecessary costs. Both concept would be perfectly based in SCP since they have the same kinds of effects and aims.

3.3.4 One standard budget-structure

In order to have one standard budget it is required that all information, from all different parties, is integrated in a clear and structured way. As mentioned in paragraph 2.4, it's necessary to work with an unambiguous set of rules for structuring the budget for the partners that oversee the largest part of activities and to manage and guarantee joint financial awareness and transparent steering from the start.

In his master-thesis Hoeber (2012) concludes that the Systems Engineering (SE) process, in the construction industry, can be improved by using BIM. BIM can help with visualising the SE requirements and interfaces to proof that they are properly captured and structured. This helps with simplifying the verification and validation phase.

The element method is a qualification method, in line with the SE process, which is meant to be used for design, realisation and maintenance of construction projects. This method structures objects in six different levels, to create transparency about products from suppliers and to group financial information in a clear way. The six different levels are defined as follows:

1. Element-groups (not official) - to distribute over different professional disciplines (architecture, mechanical etc.). (e.g. Finishing)

2. Elements - are building parts with an independent function inside, or outside, the construction. Depending on form, construction-style and material choice. (e.g. Ceiling finishes)

3. Variant-elementgroups - are a collection of (variant)-elements that have common characteristics. (e.g. Lowered Ceiling)

4. Variant-elements - are elements that have one or more characteristics in common. (e.g. Suspended ceiling)

5. Sub-elementgroups - are a collection of breakdowns of variant-elements to mainly function. (e.g. Prefab)

6. Sub-elements - concerns the breakdown of the variant-elements to mainly function. (e.g. Mineral wool plates)

A budget can be based on this distribution, which would be made up by the total of the costs on (sub)element level. The element-method is useful for minimising the complexity of a project and to create a structured overview that can integrate all the information; costs, planning, risks and involved stakeholders. But in order to determine reliable costs estimates it's still necessary to apply a suitable approach.

N. en partners (2016) states that Activity Based Costing (ABC) seems to be ideally suited to the shift from project to process-management. ABC is an approach which can be used to look for causal relationships between the way companies use people and resources for activities that create products and services. This approach makes it possible to improve all costs relations with work, material, coordination and business-management of all involved parties. Given that all the key partners are willing to give full transparency in there own indirect costs and optimize them.

The Element Method will be complementary with the ABC-costing method. By determining a price on a specific elemental level it can easily be used to adapt to changing circumstances. If for example more kitchens are required to be renovated then initially established, the price per kitchen, and involved sub-contractors, will make it easy to calculate the new financial situation and consequences to the planning.

It was mentioned in the problem statement, paragraph 1.2, that the administrative systematics for making project-budgets is a barrier for adoption. The current systematics on guidelines for writing budgets, by STABU in The Netherlands, is not yet compatible with the information models. STABU is currently working on a system that could support BIM, but the new codes have proved hard to be actually adopted by the budget writers. Two alternatives exist for dealing with this situation.

- The most promising developments are made by Systhema with their web-based budget-software. This should allow different parties to work on the same element-budget at the same time, just as with shared documents in Google Drive. Such software would potentially open-up the way to actually start working as one company, since the administration will get standardised for the whole partnership.

- Traditionally the budgets, made by the main-contractor, are based on work-types and not elements. There exist recent developments within administrative software that allow for a conversion from work-types to elements, but this has to be kept in mind from the very beginning of writing the budget. Even when this is done from the beginning, the existing element systematics are not ideal. This is why some contractors, in collaboration with their architecture-partner, have developed their own systematics to work around this obstacle. This "in-house" solution was necessary in their increasing work related to housing renovation. So it works for them, but it's not standardized.

3.3.5 Guarantee more reliable and transparent financial information

By basing your system on blockchain technology, the system will be trustworthy and transparent by design. There is no alternative to blockchain technology that would come with as much added value and future potential. There are however different blockchain software

configurations, but these alternatives will be covered later. The key for every model is the principle of "garbage-in garbage-out". So this specification would focus on collecting the most accurate input information. A clear stepwise plan needs to be executed during the preparations in the design-phase. These steps must have absolute priority and determine the go or no-go for each milestone in the project. These steps, tasks and goals all contribute to building a shared mental model, which links this specification also with the next one.

3.3.6 Integrated shared decision-making

Nobody likes tedious, long and ineffective meetings with many people, but SCP's seem very susceptible to them. Certainly in the early stages where everybody has to get used to a new way of working. It's required that making decisions is done as effective as possible. This is were social cohesion is created, by building empathy and understanding, but can only be done under proper leadership and dedication. Facilitating this is difficult on its own, but can be supported with software tools. These tools can help with making decisions between meetings, approve resolutions and minutes, keeping everything in one place, increase transparency, giving all people a voice, increasing accessibility and diversity. Such software-tools, for example Slack, are used mainly in unprofessional environments, too my knowledge, which doesn't make them reliable enough for professional companies. Such professional software will have to be developed, which could be done following the agile software development approach. This is exactly what the design problem of this research is focussed on.

3.3.7 An appropriate blockchain system configuration

Developing such software from the ground-up is in this case not a bad thing, because now it can be developed on top of an appropriate blockchain software infrastructure.

Turk and Klinc (2017) state that the nature of transactions in collaborative building projects, as well as legal consequences in case of project failures, constitute an ideal use case for the application of blockchain technology. Due to requirements regarding the control over individual data and privacy over individual / all parts of the resulting models it fits well to the description of a hybrid blockchain, as seen in figure 3.5. More information on a hybrid blockchain can be found through the first video in Appendix A.

- We do need a database (of building information).
- Shared access is required.
- Writers are well known but it's unclear whether they can be trusted.
- Writers interests are not unified.
- We don't want to use a trusted third party, because they're not common in construction projects.
- We need control functionality.
- Transactions should not be public.
- Consensus is determined inter-firm.

Turk and Klinc (2017) identify four different alternatives for managing building information with blockchain.

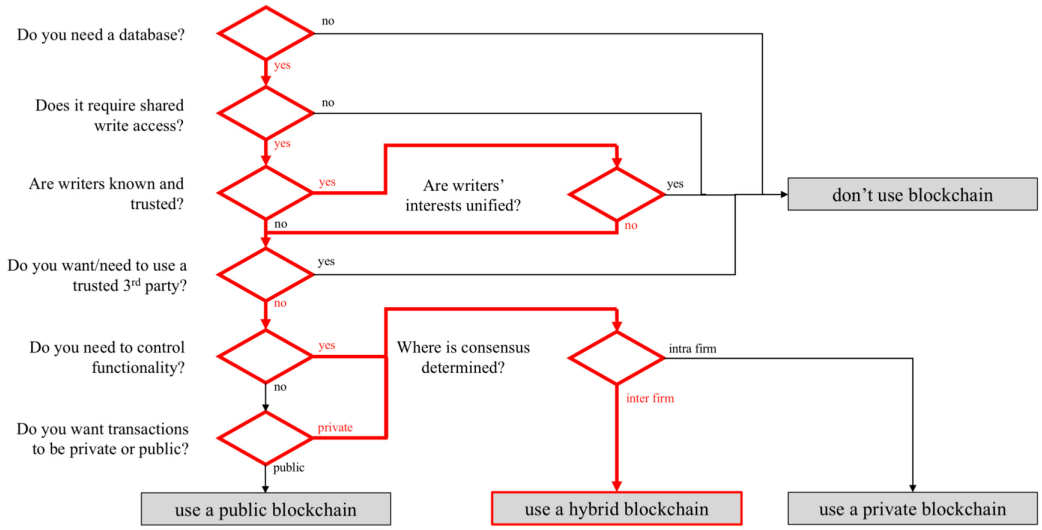

Figure 3.5: What kind of blockchain to use (Turk and Klinc, 2017).

1. **Chained and very decentralized** - building information is copied into the blockchain. Blockchain is copied across workstations of participants. An operating system plugin presents it very much like a shared Dropbox folder, the exception being that all versions of all files are preserved and that a valid "last" version of every file is maintained.

   The main problem of the chained scenario is that the size of the blockchain would soon grow very large and would exceed the capacity of individual workstations..

2. **Chained and slightly decentralized** - The solution would be to distribute the blockchain across a few key partners in the project but to offer just a "wallet software" to the clients on the workstations. It would appear to the client that a file is local while in fact it would be pulled from the blockchain and cached locally if and when needed. At least one project partner would need to host the blockchain and every project partner that would want to have it could have it.

3. **Unchained** - The unchained scenario does not store the files themselves in the blockchain but just their fingerprints and perhaps the metadata. The files are stored in the cloud or on a file management server. All members of the project could have a copy of the blockchain, proving that a certain file existed at some point. They would also need to have a possibility to prove that the file is the one whose fingerprint is in the blockchain.

   It would be left to other software to guarantee that all the files, mentioned in the blockchain, would be preserved somewhere.

4. **BIM server integration** - is an implementation of the unchained architecture with BIMserver.org's open source BIM server and open source blockchain services.

3.4 Modelling the Design

3.4.1 Guarantee benefit-sharing

Profit-sharing - the discussion regarding the opaque marketplace, mentioned in the financial constraints (paragraph 2.3), has to be avoided. If profit pay-out consists of the difference between the price and the total costs, the contractors will have an incentive to start lowering its costs as much as possible. Determining an allocation-key based on cost-input seems like a good starting point.That would be the price minus the profit and risk margin. All these margins could be used to fill the profit-pot, so in theory partners would only have more to gain. Strategic thinking will start forcing sub-contractors to improve all costs relations with work, material, coordination and business-management. Eventually the true essence of ABC costing will hopefully come in to existence.

Game theory is also known as the mathematics of strategy, which would be compatible with information science and computer technology and thus blockchain. At this point in time it is just not realistic yet to apply such complex mathematics. The lighter variant would be a good starting point to start experimenting with.

Risk-sharing - It got concluded that by completely de-buffering risks out of the cost-price the whole principle of being a contractor is endangered. As a contractor you want to maintain a hard line, because there will always be an inherent risk to construction projects. While making up an inventory of the risks, and their associated costs, it's hard to draw this line of where to stop.

The other two other alternatives could actually complement each other, based on what kinds of risks your dealing with. For example, the likelihood of risk occurrence could be a threshold to decide which alternative to take. If the likelihood of occurrence is high it could be budgeted in an unforeseen post. If a certain risk is very unlikely to happen it makes less sense to account for it in the budget, so then a sharing ratio could be established between the relevant parties.

3.4.2 Guarantee more work and higher quality (higher output)

Two alternatives for this specification have been mentioned but the truth is that as many alternatives as possible are welcome. With each project it would be good to experiment with adding one new social innovation at a time. This way the SCP can start to grow used to them one by one, instead of getting overwhelmed by trying everything at once. The choice would be determined by priority and could be left to the SCP itself.

3.4.3 Guarantee less unforeseen and unnecessary costs (lower input)

Unforeseen costs - the ways you can deal with these are mentioned under risk-sharing.

Unnecessary costs - coordinating the innovations mentioned by Vrijhoef (2016) could be supported with the specification on integrated shared decision making.

3.4.4 One standard budget-structure

The "in-house" developed solution for the budget structure would be an ideal starting point as a financial model. At this point it is not standardised and couldn't be integrated with BIM, but that's ideal because the whole blockchain architecture has to be designed from scratch anyway. It is important, for further development, that this is professionally coordinated with an official organ like STABU.

3.4.5 Guarantee more reliable and transparent financial information

In the design-phase it's important to minimise the margin of uncertainty as much as possible. This requires that all involved parties are in full agreement about the budget, planning and risks before the contract is signed. KPI's will be determined in order to measure the status and it will also be decided when and how checks will be preformed during the realisation phase. After several projects together, in the same strategic partnership, initial uncertainties will become easier to identify.

The design-phase plans will largely be done in collaboration with the commissioner, the main-contractor and their consulting parties. With real substantive and technical affairs the sub-contractors will also be involved in this stage. The consulting parties will require relatively small fees, so these parties will not be involved in the sharing ratio's and paid for at the end of the design-phase. Creating the Element/ABC-budget determines the share of contribution of all the sub-contractors. These shares will be fixed in the contract and saved onto the blockchain. The main-contractor will perform an open bookkeeping on all the interim paid-for costs.

This open bookkeeping could be linked to a dashboard to show the paid-for costs, and the remaining budget, so it will be visible to all. The effects of the decisions on the planning could also be shown in such a dashboard. At the point that the entire project is realised to all parties satisfaction, and this is agreed upon, the profit-pot will be divided through the most up-to-date allocation key.

3.4.6 Integrated shared decision-making

The virtual environment for integrated shared decision-making has to be developed from scratch. Loomio is an open-source software project that has the exact aim of providing a platform for the required kind of decision-making. This online-tool is used by thousands of groups around the world to increase transparency and inclusion, decrease meetings and emails, and make better decisions together. This tool is a good starting point but it probably needs to be redesigned in order to be integrated with all the other required financial and technical specifications:

- Within this virtual environment a real-time status of the whole project will be have to be made visible. On this dashboard an overview of all financial information regarding paid and unpaid costs, planning and risks could be shown and for all stakeholders to see. The realisation will be done, as much as possible, according to the agreed upon plan, but unexpected situations, risks or opportunities, are off course unavoidable. The consensus and voting mechanisms, provided by the virtual environment, will be used in order to determine how to deal with these situations. In most cases it should be possible to deal with such situations through these mechanisms, if it really requires a

fundamental change in the cost-structure, affecting the share ratios, the contract will be updated and the consequences will be shown on the dashboard.

- Technical concepts like reputation tracking and gamification could also be incorporated.

  Game theory is also an appropriate approach for decision making in construction engineering and management processes to solve different problems from real life Kapliński and Tamošaitiene (2010). It can recognize and clarify the behaviors of parties involved in the project and describe how interactions of different parties such as stakeholders (client), main contractors or subcontractors can lead to project evolving Barough et al. (2012). Selection of variables, like with multi-criteria analysis could also be supported with game theory (Peldschus, 2008). So there exists at lot of potential innovation but, as mentioned before, these additions are to complex for the current situation.

3.4.7 An appropriate blockchain system configuration

The BIM server integration is probably the way to go in the long-term future. But also for this it would be preferable to start in the least complex way, in order to minimise the potential of failure. An unchained architecture would therefore be preferred. The only part in the software were blockchain technology is essential is with updating the contracts. By doing this in the "unchained" way the blockchain component would only make up a small part of the entire architecture. All the other software modules just need to make sure that they communicate with the blockchain component accordingly.

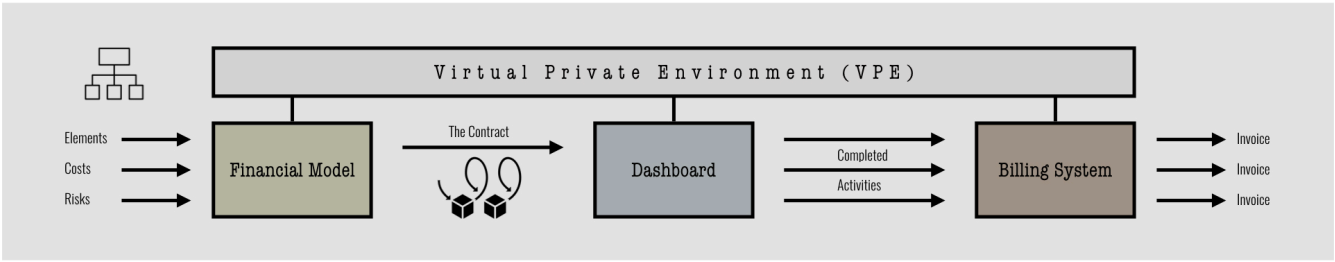

Figure 3.6: The Software Architecture

3.5 Conclusion

RQ# 2 - What could a financial model look like for an BIM-enabled SC-partnership?

The financial model should be structured in such a way that it can be parametrized. By changing certain parameters, like element quantities, the consequences for the budget should be calculated instantly. This would make the budget easily adaptable to changes, so that it can evolve with the project over time. The element-method makes it possible to integrate all the information per element regarding costs, determined with ABC, planning, risks and involved stakeholders. Dealing with deviations, during the realisation, would just become a matter of adjusting the parameters. How to deal with these adjustments will be decided by the relevant parties. Therefore, all this information has to be gathered and integrated in the design-phase as complete as possible and presented in a clear and intuitive way, preferably with BIM,

RQ #3 - How could the administration for this financial model be automated by blockchain?

Blockchain could make many valuable additions, but the one focussed on in this research is securing reliable information which has to be transparent to everybody in the SCP. By offering real-time information the project can be steered adequately which is governed by decisions made by the relevant stakeholders, resulting in the most ideal form of financial control. Every time a decision is made to adjust certain parameters in the budget these changes can be incorporated in the financial model. This will calculate a new contract instantly and by matching digital "fingerprints" the blockchain will recognise that it has to be updated and will do so.

RQ #4 - How would the administration have to be organised at all the different partners?

The most up-to-date version of the contract will communicate with the dashboard so that everybody in the SCP can see it. This means that each partner can keep their administration in the way that they are used to, as longs as they're able to provide the necessary and reliable information for filling the financial model to prevent "garbage-in garbage-out". In the beginning they could suffice with just presenting their cost-price (= price minus profit and risk percentage), but eventually strategic thinking will hopefully start forcing all partners to improve all costs relations with work, material, coordination and business-management. This will eventually require the partners to arrange their administration differently, because they will be incentivized with higher profit margins.

RQ #5 - How could the organization of the whole project cycle be supported with software?

A concept of the software architecture is graphically presented in figure 3.6. The VPE is the interactive part (front end) which should work as simple and intuitive as possible, since all types of people would have to work with it. All the other software-components would just have to run automatically in the background (back end), governed by the decisions made in the VPE. This should be possible when the structure of the budget is based upon the element system, with ABC costing, and the overarching goal is ingrained through the right kind of profit and risk-sharing agreements. The smart contracts that make up the web of payments should be linked to the determined KPI's and milestones by the SCP, so that once certain milestones are reached everybody will be paid accordingly.

Chapter 4

The Back End

In the coming two chapters preliminary concepts are analysed that together would make up the two key components of the software architecture. These are the financial model that would run in the background, back-end, and the VPE that would make up the user experience, front-end.

In this chapter the underlying financial model will be introduced which is done by empirically analysing a SCP project. This financial model functions as the backbone of the developed software architecture and It will be explained, in a qualitative manner, how blockchain is going to support the financial model. Specifically in order to safeguard the most efficient and effective financial control.

4.1 Testing the Design

For designing and developing the software architecture an agile approach is preferred. This approach is described by evolving requirements and solutions through the collaborative effort of self-organizing and cross-functional teams and their end user(s) (Collier, 2012). For this it is not necessary to re-engineer massively or disruptively to gain benefits, because the very nature of agile structuring supports graceful, incremental migration. Agility is about effective change management (Dove, 2005a). Agility can be used in many different contexts, in this research it's used to described both the approach as the type of system that will be developed.

As CIO of a semi-conductor foundry start-up, Dove was concerned with the development of an agile enterprise-IT infrastructure. A principle concern was to break the rigid lock that Enterprise Resource Planning (ERP) systems traditionally imposed on evolving business process and business strategy. He wanted to leverage the possibilities of the internet and web-browser information access, build unprecedented transparency into the heart of the operating philosophy and culture, and facilitate an aggressive growth strategy with rapid integration of new-plants, acquisitions, and outsourced semi-conductor packaging firms.

Dove (2005b) works with ten underlying design principles for agile systems and the results suggest that employment of these principals can increase the predictability of major software projects and the responsiveness to change. He defines agile systems as software systems that are concerned with *response ability* - for both reactive and proactive responses needs and opportunities - when these are unpredictable, uncertain, and likely to change.

The principles discussed in figure 4.1 were developed from analysis of systems exhibiting agile characteristics of good reactive and proactive response to unpredictable events in uncertain environments (Dove (2002), Chapters 5 and 6). These principles are intended as root-level principles, which may instantiate in different ways by different practitioners. They are meant as underlying first-thought modes, Above all, they are meant to guide the construction of agile systems - not all systems.

Principles enabling reusability
Self-Contained Modules. Modules are distinct, separable, self-sufficient units cooperating toward a shared common purpose.
Plug Compatibility. Modules share defined interaction and interface standards; they are easily inserted or removed.
Facilitated Reuse. Modules are reusable/replicable; responsibilities for ready reuse/replication and for management, maintenance, and upgrade of component inventory are specifically designated.
Principles enabling scalability
Evolvable Framework Standards. Frameworks standardize inter-module communication and interaction; define module compatibility; are monitored/ updated to accommodate old, current, and new modules; they are minimized (parsimonious).
Redundancy and Diversity. Duplicate modules are employed to provide capacity right-sizing options and fail-soft tolerance; diversity among similar modules employing different methods is exploited, with attention to requisite variety.
Elastic Capacity. Module populations may be increased and decreased widely within the existing framework.
Principles enabling reconfigurability
Flat Interaction. Modules communicate directly on a peer-to-peer relationship; parallel rather than sequential relationships are favored.
Deferred Commitment. Module relationships are transient when possible; decisions and fixed bindings are postponed until immediately necessary; relationships are scheduled and bound in real-time.
Distributed Control and Information. Modules are directed by objective rather than method; decisions are made at point of maximum knowledge; information is associated locally, accessible globally, and freely disseminated.
Self-Organization. Module relationships are self-determined; component interaction is self-adjusting or negotiated.

Figure 4.1: Fundamental Agile Design Principles (Dove, 2005a)

The primary lesson-learned by this author, from the management transition, was the need for continued value-propositioning and culturally-embedded value-propositioning skills - as a corner-stone of agile systems that are to remain agile through time (Dove, 2005a). Plain and simple, the value proposition for enterprise agility is rooted firmly In risk management - more specifically enterprise risk management (ERM). The purpose of agility is to maintain both reactive and proactive response options in the face of uncertainty. This is in line with the design decision made in paragraph 3.4.1 regarding risk-sharing.

The development and testing of the software architecture, presented in the previous chapter, will follow the design principles from figure 4.1. It's not necessary to fully develop this software-system, with all its components, in order to start testing certain key functionalities.

The answer to RQ#2, regarding the financial model and what it would suffice to, exists out of the following aspects:

- It has to be parametrized to easily adapt to changing circumstance.
- Based on an element model to clearly incorporate all relevant information.
- With the prizes determined by ABC-costing to easily determine the benefit shares.

4.2 Case-Study: Lindeplein

Huybregts-Relou has now been experimenting with strategic partnering for about 5 years. In this chapter we will discuss the previous project called Lindeplein, because a lot can be learned from this specific case and it was used in the evaluation-meetings. Throughout these meetings the causes were analysed that resulted in exceeding the budget. These sessions were conducted by trained professionals (certified six-sigma coaches). The results of these meeting are used here complemented with my own insights.

The goal of the project was to perform major maintenance on 81 households in the social-housing residential block Lindeplein, Breda. This was the fourth consecutive project performed with the same SCP. In the first three projects the SCP experimented with ABC-costing, but struggled too much with the identified constraints described in paragraph 2.3.1. For this reason the SCP decided to experiment with a prize-book, but they experienced a mis-match between this prize-book and the partners. As a result the discussion focussed again on money instead of quality, which created friction amongst the partners.

In order to analyse this case the following research questions are formulated:

1. How much did the after-calculation deviate from the budget?
2. How much would it deviate if the proposed blockchain-solution would be applied?

   The answer to this question is best divided in three separate parts. First it should be clarified what the core-causes and the corresponding sub-causes are. Second the counter-measures should be explained per cause. The last part covers how the financial model, supported by the proposed blockchain-solution, is going to contribute to these measures. The causes and measures are covered per stage in the building process, respectively design, build and the financial settlement.
3. How could this effect be demonstrated?

Q#1 - How much did the after-calculation deviate from the budget?

Major maintenance SCP-projects are very different from regular new-construction projects based on the Hollywood business-model. This innovative way of working requires a different approach in keeping administration. Professional administrative software, ERP-systems, for these type of projects don't exist yet. At this point, project managers have to rely on excel spreadsheets which can become messy and are prone to errors. For the Lindeplein project this was the case as well.

Another cause of problems was the absence of clear process-steps. Due to the novelty and the hands on approach of the SCP they started the projects in a traditional fashion and came up with solutions for the problems at hand, without having a clear idea of the long-term consequences. This is exactly the kind of mindset that's needed to innovate and learn, which is why the SCP started an evaluation trajectory in search of the source-causes of their previous budget exceedance.

Eventually the financial administration kept by the main-contractor (HR) and the one kept by the housing-association (WB) differed considerably. Internally the exceedance-percentage for WB amounted to 5% and for HR it was 11%, but the difference in actual costs compared with each other was about 3%. So it can be concluded that the administration on both sides became quite messy and eventually didn't add up correctly. One of the causes for the

difference in actual costs could be that the project leaders from both sides played around a bit with the numbers in order to justify the loss to the board.

Q#2 - How much would it deviate if the proposed blockchain-solution would be applied?

Causes

Design-Phase

The core cause in this phase comes to be through the vague 70% milestone, discussed in paragraph 3.1, this is the point that 70% of the residents have given their consent for renovating the interior of their houses. After they've given their consent recordings will be made regarding the actual state of the elements that will be renovated, these are called warm recordings ("warme opnames" in Dutch). During the Lindeplein-project this was a vague milestone, because the building activities had already started before all the recordings were finished and there didn't exist a proper approach to actually translate the results of the recordings into financial consequences. This made it practically impossible to present a new financial prognosis after the recordings were finished and at that point the building activities were already full steam ahead.

The sub-causes are based on the multiple aims that are currently attempted to be satisfied with these recordings and the way they are executed. Because besides the fact of checking the state of the elements it's also meant as a moment of getting to know the residents and explaining the plans. In this social encounter it's easy to lose track of time and lose sight of the initial priorities if there is no unambiguous check-list. The check-list is most of the time not filled out correctly, which also begged the question if the list is actually drafted in a way that the output can not be interpreted in a different way then it's meant to be. Next to that, there also is no clear agreement on which party is actually responsible for properly executing these recordings (the commissioner or the main-contractor). Then there's also the common problem with such old buildings that original information about them is often not well documented.

Build-Phase

The core cause in this phase builds on the existing deviations in the elements, which come to be through the self performed alterations on the interior by the residents. These are supposed to be inventoried with the warm-recordings but, as discussed, the actual financial translation is missing during the execution of the building activities. Following on this, agreements are missing amongst the SCP on how to deal with these deviations, how they are documented and what the possible differences are amongst them. For example when deviations are structural or incidental and how to deal with them respectively.

Currently there exists a list which hangs in the fuse-box closet of each house ("meterkast-lijst"). All sub-contractors are supposed to note their activities and work-hours on this list, which then should be included in the administration by the project leader. In reality this doesn't actually happen the way it's supposed to, because there again is no clarity on who is actually responsible for making sure these lists are accurate and included in the financial administration. The consequence is that there's no reliable notion of how the execution activities effect the project financials.

Financial Settlement

If there's no clear approach to translating the actual situation towards a financial prognosis, and no clarity on how to document and deal with deviations during the execution, it's obvious that the project can not be steered during the execution. That's why in the end it's inevitable to have disagreements amongst the partners on the financial settlement. All these disagreements have to be straightened out after the fact resulting in many discussions, payment delays and friction amongst the partners. This leads up to high administrations costs due to sending incorrect invoices and the necessary man-hours for drafting and evaluating them.

Measures

Design-Phase

A clear planning should be devised with milestones and unambiguous requirements. The whole project could, for example, be divided in sub-systems and the recordings per subsystem have to be finished before building activities can start. The minimum requirement of 70% consent has to be guaranteed before this, which also has to be incorporated in the planning. This could for example be done by campaigning in the residential block, organised by communication specialists.

The state of the interior has to be recorded in an unambiguous way, which could be done by creating a clear check-list standard that requires all the essential information necessary to build a reliable prognosis of the work. This moment of recording should have the clear goal of only gathering the necessary information about the elements. Distribution of general information regarding the project and getting familiar with the residents could be done through an independent event near the beginning of the execution.

Build-Phase

A new financial model is required to deal with the administration of the SCP-projects. A concept for such a model is sketched in the answer of RQ #2, in the conclusion of chapter three, and a prototype has been developed by an experienced project leader of Huybregts Relou. This model will be the backbone for guaranteeing financial control throughout the project. Rules have to be devised in order to fill the model with reliable data, to prevent "garbage-in garbage-out". A timetable should be determined upfront, based on the milestones and related payments as discussed in the answer of RQ #5.

With a clear check-list which is seamlessly suited to the required input for the financial model, the recordings could be translated into a prognosis of what the eventual work would amount to ("Prognose Einde Werk" P.E.W.) it would become possible to gain more financial control and steer the project adequately during the activities. Based on such a P.E.W., rules could be formulated on how to fill the model and how to act upon it.

Deviations can be dealt with as discussed in paragraph 3.4.1, under risk-sharing. By using an element-model many different types of information, including documenting deviations, could be incorporated in order to replace the flawed fuse-box list. Capturing and covering the financial consequences of the deviations can be pre-determined with the unforeseen post. By having such an element-model and such a financial model, ideally communicating with each other, and clear guidelines for documenting and dealing with deviations it should be possible to constitute a prognosis of the overall financial situation, transparent to the whole SCP.

Financial Settlement

The financial model should be structured in such a way that it can be parametrized per household. By changing certain parameters, like element quantities, the consequences for the budget should be calculated instantly. Deviations on the elements should be categorized as structural or incidental and for each of the general deviations risk-sharing agreements can be established. All these deviations should be documented structurally, so an overview can be created per household showing the used unforeseen budget. For each household it will differ how much of the post will actually be used, for some the budget may be exceeded and for some less work will be necessary, which can be used to balance the expenses (in Dutch this is also known as "Meer en Minder werk" - MM)

In this way a financial overview can be created per household, partly based on the standard elements and partly on the extra/less work. This overview could be dissected into the contributions of all the different sub-contractors which would easily create the basis for an invoice. This would be an invoice from the sub-contractor directed to the main-contractor, which makes it possible for both parties to incorporate them into their own general company administration.

List of measures

1. Concrete milestones and associated requirements
2. Clear functions and responsibilities
3. A well structured element model
4. Unambiguous check-list, for recordings, with a singular aim
5. Pre-determined agreements on how to deal with structural and incidental deviations
6. Effective documentation of work and deviations
7. A parametrized financial model with the ability to show a prognosis of the total work and automated billing.

IT-Support

Establishing the first two measures would not necessarily require additional software support as they are a matter of reaching consensus amongst the SCP. Though, reaching consensus could be supported by a VPE, as discussed in paragraph 3.4.6., and the files could be stored in a shared cloud system, like Docstream, for everybody to access. Such a cloud application could also be integrated with the VPE. Clear functions and responsibilities should be established within the SCP. Accounts of participants, in the VPE, could be used to show what the functions and responsibilities are of everybody. The tracking of reputation, proposed in paragraph 3.4.6. as well, could potentially also be implemented here.

BIM essentially aims to serve the measure of having a well structured element model, but is currently not used in major maintenance projects. This is because it will take to much time to simulate the entire residential block in an information model. A lighter and more accessible substitute for building an element model would be ideal for documenting all kinds of relevant information regarding deviations, residents, building activities and finance. For example, Kumu is a data visualisation platform that helps organizing complex information into interactive relationship maps. Ideal to visualise the project as an element system.

Executing unambiguous recordings of the interior requires a well drafted check-list aimed on gathering only the required information for the financial prognoses. These check-list could be programmed as such they're usable with tablets and the results get automatically stored in the right place, ideally interacting seamlessly with the element-model and the financial model.

During the construction activities its inevitable that changing circumstances occur. If unpredicted changing circumstance arise during the execution, only the actual relevant stakeholders will be able to adequately decide how to deal with them. This will become possible through specific decision-making tools in the VPE. The element model, as discussed above, would be a simple way of documenting them and the discussed unforeseen posts should be included in the financial model so the consequences can be translated financially and incorporated in the prognosis. A billing system could be programmed in such a way that it would automatically dissect the performed activities per household into an invoice per sub-contractor.

The financial model could potentially be filled out and updated manually in excel, by for example the project leader, but this can be very time consuming and prone to errors. Certainly if there's a large amount of houses to be renovated. This is why it would be more efficient if the financial model could be automated and that everybody can see the actual prognosis in real-time. If changing circumstances occur and a consensus is reached within the SCP on how to deal with them, the financial translation of the decision will be made through the financial model and projected into an updated prognosis that would be visible to all partners in a dashboard. Each updated state of the budget and prognosis can then be stored on the blockchain to secure the data and nobody can mess with it. This will guarantee that there will always be reliable information, agreed upon by the whole SCP, to base future decisions on regarding controlling the project.

Q#3 - How could this effect be demonstrated?

An real-time overview of the financial status, with a prognoses of the end-result, makes it possible to steer the project. The model is designed to present insight in the difference between initial budget, agreed upon contract, state after recording and the eventual actual costs. In the beginning this is based upon the most actual data at that point in time and these are extrapolated in order to predict, give a prognoses, of the financial end-result. At the start these are mostly estimates but overtime, while activities proceed and are paid of, the financial status will gradually become more definite.

The prototype is currently built with an Excel spreadsheet and automated as much as the program allows. Unfortunately it was not possible to apply the latest model on the Lindeplein case, since the information during the execution was not ideally documented and eventually got slightly manipulated by both parties. A quantified fictitious example is presented in figure 4.2 to demonstrate how the prognoses could have developed over the course of the projects.

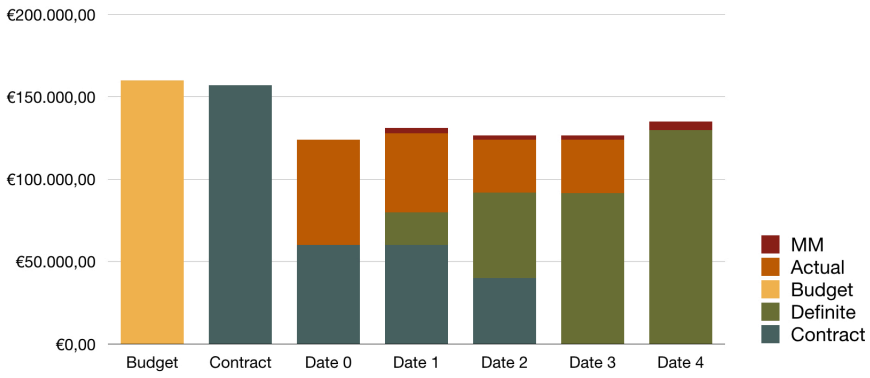

Figure 4.2: Fictional Prognoses Overview

Column 1 shows the available budget that is agreed upon by the commissioner, this also accommodates the unforeseen posts. Column 2 is the agreed upon prize in the contract with the SCP, which is a more detailed number and in this case a little less then budgeted. Date 0 signifies the moment were the warm recordings are finished for the first houses, the actual costs after recording is shown in orange. At Date 1 the first houses have been finished and the definite prize for those houses are shown in green, the eventual balance of extra/less work is added on top with the red bar. Overtime all houses will be recorded and more houses will be finished, as shown in the column of Date 3. At the end all the houses are finished and the definite situation is shown in column of Date 4. In this fortunate scenario the definite costs are considerably smaller than the initial contracted prize, this means that the surplus gets divided according to the pre-determined benefit-sharing formulas and each partner ended up with a good profit-margin.

4.3 Conclusion

It will still be the case that the after-calculation can deviate from the initial budget, but with the proposed solution there will be one transparent administration for the project which is continuously agreed upon by all the partners. This means that the administration of the commissioner and main contractor can not deviate, as was the case with the Lindeplein project. By having this kind of financial control it is strived for that all partners are continuously agreeing with the current situation so its impossible to have a disagreement concerning the end-result.

It's perfectly possible to manually create the financial prognoses, as shown with the quantified example in figure 4.2. But the problem would still be that only the project leader will be filling the model and he would still be prone to making human errors, accidentally or on purpose. Blockchain will be able to guarantee the security and reliability of the data. This creates the possibility to safely automate the whole process, which will significantly improve the total efficiency. By digitising the construction process in this manner the door will also be opened to other information technologies, that would all contribute to higher productivity.

Chapter 5

The Front End

This chapter will focus on the VPE that would make up the user experience, front-end. In order to test this a simulation was organized amongst the SCP of WB and HR. It'll be explained how the simulation was organized and the results will be analysed to evaluate the design. These results, together with the results of the previous chapter, are measured through the Supply Chain monitor, developed by the MBE department, in order to make a valid justification for the proposed solution.

5.1 Simulation: Virtual Private Environment

As discussed in the answer of RQ#5, the key functionalities of the VPE consists out of the following parts:

- The "Virtual Private Environment" (VPE) is the interactive part which should work as simple and intuitive as possible, since all types of people would have to work with it. All the other software-components would just have to run automatically in the background, governed by the decisions made in the VPE.
- Next to this an information model should be build and maintained with all the reliable and necessary information present to base the decision-making on.

Organizing a simulation of a virtual company environment seemed realistic with the help of two existing web applications, respectively to the required key functionalities above:

- Loomio as a starting point for integrated decision-making in a VPE. In order to satisfy the objective of more effective collaboration supported with appropriate decision-making tools.
- Kumu will be used as a lighter substitute for building an element model, since BIM would be too extensive and complex to use as a shared information model.

The case for the simulation was based on the renovation project of 't Ven in Eindhoven, since this SCP-case was also studied throughout the research. The simulation had to mimic working in a virtual situation in which everybody could participate from the comforts of their own working environment. Spending about 15 to 30 minutes a day, spread over their working day, over the course of a week. The simulation was organized in three rounds of which each round was based on a phase in the SCP process. The simulation limited its

scope on the kitchens. This way it was kept relative simple and enough information could be gathered to gain insight on the desired requirements.

Round 1 - Design Phase

During a previous similar project it became clear that there was a lot of uncertainty regarding the changes residents made themselves in the interior. Together it has to be decided how they're going to handle this uncertainty. This way certainty can be created on how to deal with uncertainties. The SCP would have to decide for themselves what the best trade-off would be between proactive and reactive options. This would follow the specification of guaranteeing benefit sharing, with the focus on dealing with uncertainty and lowering unforeseen costs.

Round 2 - Realisation Phase

Asbestos has been discovered in some unexpected places during the construction activities. This has created a lot of problems in previous projects. Panic could occur amongst the residents if this situation is not controlled quickly. This could result in reduced consent from residents to renovate their kitchens. The consequence would be that the profit margin for the whole partnership gets endangered. The consequences for the profit margin were based on consent-scenarios. These scenario's would forecast the profit-margins for each partner in the cases of 70%-80%-90% and 100% of the residents given their consent to perform the renovations on the inside. These scenarios were developed in the design phase. This would follow the specification of guaranteeing benefit sharing, focussing on generating more work.

Round 3 - Billing Phase

This is not really a round. It's just to show how invoices could be automated. Automatic invoices will be sent to the right parties after it has been agreed, within the virtual environment, that activities are completed.

The participants shouldn't have to be bothered with the technical details of the blockchain software. They just need to be able to use it in an intuitive manner. The simulation is organised in such a way that the participants have all the necessary information, and the right environment, to make sensible decisions. The results of their decisions would be implemented by myself, in the way the software-system would organically steer, and the consequences would also be communicated by me through the VPE.

The participants consist of the actual members in the SCP.

- The projectleader of the housing association Wonen Breburg.
- The projectleader of the main contractor Huybregts Relou.
- The plumber (employee of Huybregts Relou).
- The electrician (employee of Wonen Breburg).

Measuring Results

The 'believers' in supply chain integration are convinced of the possible improvements in the process. Housing associations in general, however, still need to be convinced by actual facts and figures on what process changes really are effective (Vrijhoef et al., 2014). The purpose of his research was to develop a model of organisational effectiveness that:

a) is applicable across a broad group of different types of construction project organisations;

b) defines the characteristics of different organisation forms (with a focus on those characteristics that distinguish supply chain collaboration from other forms);

c) measures the output and outcomes generated by these organisations for different stakeholders.

It needs to be kept in mind that a prognoses of the work (PEW) doesn't exist yet for SCP projects within HR, so internally they are also still struggling with benching-marking (financially comparing) their SCP projects. This is why the components of the SC-monitor are mainly used to evaluate the results (the whole model can be found in Appendix C).

The relevant components, table 5.1, are chosen by aligning them with the list of user-requirements/criteria deduced in chapter 2:

- More shared decision-making (indirectly lower unnecessary costs) - aligns with the variables systems/procedures, collaboration and project goals (shared mental model).
- More reliable information (indirectly lower unnecessary costs) - aligns with the variable transparency.
- More work - aligns with the finance variables.
- Lower direct costs - aligns with the finance variables.
- Lower general costs - aligns with the finance variables.
- Lower unforeseen costs - aligns with the finance variables

Screen-shots of the executed rounds and its related discussions, decisions and outcomes can be viewed in Appendix D

Table 5.1: Relevant parts of the Supply Chain Monitor by Vrijhoef et al. (2014)

Components	**Variables**	**Subjects**, questions asked within the components [a]
Processes	Transparency	Level of accessibility of financial and additional information between client, contractor and subcontractors, and vice versa (o).
	Systems/Procedures	Use of joint information sharing (c), joint risk management (c), joint planning i.e. lean planning (c), joint decision making and evaluations (c), joint quality assurance (c)
	Collaboration	Use of team building and joint training of the project team (c), purpose of training (c)
	Finances	Use of financial incentives (risk/reward) (c), level of joint purchasing (c), level of project risk sharing (c).
Output	Project Goals	Areas of goals formulated (c), level of formulation of goals (o), level of goal achievement (o).
	Finance	Ratio between cost estimate(s), awarded bid and final costs of construction, and total investment costs (r), reasons for changes in cost (c).
Outcomes	Project manager (client) satisfaction	Opinion about the project team (o), effort of team members (o), responsibility taken by team members (o), involvement of team members (o), performance of team (o), view on the collaboration (o), chances of repeating this way of collaboration (o).
	Project manager (main contractor) satisfaction	Same as above row of client's project manager.
	Team satisfaction	Opinion about team atmosphere (o), Fun working in the team (o), Room for new ideas (o), attitude among team members (o), efficiency of the team (o), transparency amongst team members (o), involvement of team members (o), room for improvement of team functioning (o), pride in working for the team (o), self- esteem (o).

[a]The type of scales used to measure the variables are codes as follows: continuous (con), interval (int), categorical (c), nominal (n), ordinal (o), interval (i) or ratio (r)

5.2 Analysing Results

The results and lessons [1] will be covered variable by variable based on the results of performing the case-study in chapter 4 and the experiment in this chapter.

Processes - Transparency The level of accessibility of financial and additional information between client, contractor and subcontractor was improved with the shared information models, both with the element and financial model.

While preparing the element-model in Kumu it became clear that such a model can incorporate many different types of information. If implemented successfully it could help with showing and tracking all the activities, which could replace the fuse-box list which is currently not functioning in the most ideal way. It can also be used to document social factors per household that should be taken into account, such as violent residents, special handicaps or behaviour etc. This would generate a clear picture for each specific household regarding the work to be done, the progress and the extra and less preformed work, which could be viewed and complemented by all partners to have full transparency.

[1]These lessons are already incorporated in earlier parts of this thesis, but it was through this experiment that they actually came to be.

All the information about the elements could be incorporated (cost, planning, risks and involved stakeholders) as well as relevant information per household, such as health issues or violent behaviour. By setting up this element model it became clear that this tool can also function as a substitute for the "fuse-box list", as discussed in paragraph 4.2 (causes - build phase) .

A real dashboard with KPI's, milestones and financial information was not fully possible yet. This would require more information on the activities and planning. Visualizations were created of how the allocation-key and consent scenarios could be used to show the real-time status. These can be found in Appendix D This would ensure access to the open-book accounting.

Possible improvements:

- This model should be filled to the best of everybody's ability during the design phase. Keeping track of relevant information in the model could be incentivized by reputation rewards. More on that will be covered under the "Outcomes" component.

Processes - Systems/Procedures To reduce the margin of uncertainty it's necessary to start with reducing the complexity of a system. It has been shown that this can be achieved with the element-method. This created a structured overview of all the work that has to be done, who is responsible for what and it can be conveniently complemented with the ABC costing method. This guaranteed the use of joint information sharing, as seen in Appendix D (Chapter - Element model in Kumu).

By learning from previous projects you can document all the unexpected developments. Turning the "unknown-unknowns" into "known-unknowns". By knowing the unknowns, such as the variability on the standard element package, you can plan on how to deal with them in advance. The partnership did this in round 1. They negotiated an unforeseen post in the budget. This post would become the risk-pot. Per kitchen it could be tracked how much is spent from the unforeseen post. Which can easily be tracked for the whole project by balancing the extra and/or less work per kitchen. The remains of the risk-pot will eventually be returned to the commissioner. If the pot is exceeded the money will have to come from the profit-pot of the partnership. This represents the definition of joint risk management done through shared decision-making and evaluation. In round two the asbestos risk was also managed through shared decision-making and coordinating new responsibilities amongst the sub-contractors. The plumber and electrician agreed that they would help to communicate with the residents in order to gain their trust, which will contribute to the costumer satisfaction. Their opinion was also taken into account to completely remove all the asbestos for long term benefits, ensuring joint quality assurance.

As mentioned in paragraph 3.4.3, joint planning (i.e. lean planning) is perfectly based in SCP and could ideally be supported with integrated shared decision making, but this is besides the scope of this research.

Possible improvements:

- As mentioned in the previous chapter, by Dove, the purpose of agility is to maintain both reactive and proactive response options in the face of uncertainty. For every project the unforeseen post can be fine-tuned to improve the proactive response. For every project more unknown-unknowns will become known-unknowns, but the SCP will always have to be cautious for black swans. For such exceptions reactive response

could be negotiated in the future by establishing risk-sharing ratios for the relevant parties.

Processes - Collaboration The evaluation meetings preceding the simulation ensured a shared mental model on the steps taken in the SCP projects. This could be perceived as a joint training of the project-team, because they're training themselves in becoming more effective. The execution of the simulation was perfectly timed in the regard that we finished determining the critical-points and potential sources for problems in the current process.

Processes - Finances Through execution of the simulation two important lessons got learned regarding the potential rules for profit and risk sharing.

Risk-sharing

Through the guided discussion and the shared decision-making in round 1 the strategy for dealing with risk got established as discussed in 3.4.1. This is based on the likelihood of occurrence. If the likelihood is high it will be accounted for in the unforeseen post and if the likelihood is low it will be covered with a cost-sharing formula (e.g. 40% commissioner - 60% main-contractor).

Profit-sharing

In preparing round 2 the realisation dawned that its not necessary to be concerned with the internal cost mechanisms at this point. The coordinated effort could just start to focus on generating more work by creating as much consent amongst the residents as possible. This resulted in the consent scenario's that were used in the experiment. With more interiors to be renovated more revenue will be generated. The whole partnership can contribute to creating more consent, as seen throughout round 2 on the simulation. For example, by letting the sub-contractors help in the communication with the residents.

Possible improvements:

- The level of project risk sharing could be improved as discussed earlier under the Systems/Procedures variable.
- Joint purchasing was not accounted for in this simulation, because it wasn't thought of. But it could be tested in the future since it would also be an ideal way to avoid the discussion regarding the opaque marketplace.

Output - Project Goals The preparation of the SCP project organized by housing association 'Thuis in Eindhoven was already coordinated by R. Vrijhoef. This made it and ideal case to base the simulation on, because all the state-of-the-art knowledge regarding SCP was incorporated. In the project description all goals were formulated clearly and the the SCP management team was in the process of determining the KPI's to measure them. These were not incorporated in the simulation since it fell outside of the financial scope of this research.

Output - Finance The ultimate ratio between cost estimates, awarded bid and final costs of construction and total investment costs was not possible to determine. But as shown in chapter 4, with the developed financial model it is possible to generate a prognosis on this information. Furthermore, the specifications will contribute to decreasing uncertainty and

driving down the differences between costs estimates and the final costs, as well as decreasing the, reasons of changes in costs.

Plus, administration costs will be cut drastically by automating the billing system, as described in paragraph 3.2.3 and attempted to show in round 3 of the simulation. Driving down unnecessary costs and/or adding to the fact that more money can be invested in houses to guarantee a higher quality. In the future a lot more financial gains can be made by applying blockchain technology for leasing-schemes, sensing technologies and driving down legal cost.

Possible improvements:

- It would be best to generate real quantitative proof on the effect of such a private blockchain environment as soon as possible to present more convincing facts and figures on its effectiveness.

Outcomes - participants satisfaction The execution always differs from how it's envisioned in the preparation. The participants seemed to be quite busy, so close before holidays. Despite the fact that some were already on their vacation, the participants did seem to have fun with the exercise. They usually responded during the evening.

In round 1 the participants had to get used to the whole virtual environment and it required some steering in the right direction from my part. The project leader from the main-contractor, started of by acting a bit "old-skool" following the traditional approach where each party tries to satisfy only its own goals. The project leader of the housing association addressed this mindset in a joking fashion, but it didn't change his action of blocking the proposal. In finalizing the outcome of round one I decided to punish such undedicated behaviour by subtracting a significant amount from his fictional reputation score. It was interesting to see how his behaviour changed notably during round 2. So even with a fictional reputation score the psychological effects were noticeable, proving it to be a successful social stimulus for creating psychological safety. The other team members picked up on this fun and became more engaged in their act throughout round 2. Room to speak-up and present new ideas by the sub-contractors was intentionally facilitated through my way of steering the discussions. The members also created a what's-app group out of themselves to communicate off-topic. Personal events were shared in this group which created a stronger inter-personal bond.

From the start it was clear that the electrician was not very enthusiastic about this new digital approach. The plumber, on the other hand, was quite curious and even printed all of the context information before hand. Eventually both of them contributed and gave valuable input in the discussions. This shows how different attitudes can co-exist but its clear that a lot of friction would come from trying to implement these kind of innovations.

5.3 Conclusion

RQ #6 - How could results be demonstrated and measured?

Results on the key-functionalities are generated through executing both a case-study, for the financial model, and a simulation, for the Virtual Private Environment. Measuring these results has been done in several ways. Empirical results from the case-study are discussed along the research questions in chapter 4 and empirical results from the simulation are discussed along the relevant parts of the Supply Chain Monitor.

The purpose of the Supply Chain Monitor is to measure supply chain collaboration and its effectiveness in the Dutch social housing sector, in order to present more actual facts and figures on what process changes really are effective. Vrijhoef et al. (2014) also states in his research that the external validity of the monitor still needs more attention and will be discussed in future papers. Analysing the results through the SC-monitor shows how the key-functionalities of the proposed software architecture would have a considerable positive effect on some of the key-components, with the emphasis on financial control. Possible improvements to keep an eye on in the future were also identified.

As concluded in chapter 4, the proposed financial model as an instrument already improves the potential for more financial control significantly. But Excel is known for being time-consuming and prone to errors. This is why it's necessary that this prototype gets developed into more professional administration software. As shown in the software architecture, figure 3.6, the financial model is only one of the software modules. This means that it would be convenient to keep the interfaces with the other modules in mind while professionally developing the software, as well as the enabling potential of blockchain technology.

Chapter 6

Conclusion

The relevant sub-questions are answered per chapter and the main research question will be answered here.

Main RQ - How could blockchain offer more financial control in construction supply chains?

Throughout this thesis it's substantiated how controlling both the financial and social aspects of supply chain collaboration more effectively will indirectly lead to better financial project results. Dynamic control of a project can only be done once there exists an overarching goal for the entire partnership. This is what the business model for the multi-year SCP-process should accommodate and that's why this research proposes a business model based on benefit sharing. The mathematical discipline of game theory shows how to be fair in allocating pay-offs in a cooperative situation, based on the contribution of each participant. Throughout this research it's attempted to apply this theory, to the best of my ability, in determining the best strategy of constituting the right balance for all the partners to share in the potential benefits. Blockchain could make many valuable additions, but the one focussed on in this research is securing reliable information which has to be transparent to everybody in the SCP. By offering real-time information the project can be steered adequately, which is governed through decisions made by the relevant stakeholders, resulting in the most ideal form of financial control. The combination of this new business model and blockchain technology could meet the prerequisite of establishing trust and transparency, combined with the alignment of business objectives and commercial interests of the supply chain partners.

A preliminary design is developed for the agile software architecture that would incorporate this business model and the enabling capabilities of blockchain technology. The functionalities were based on the user-requirements and constraints mentioned in chapter 2. It's substantiated in chapter 3 how the proposed system will contribute to this new business model by decreasing unnecessary and unforeseen costs, combined with increasing the potential amount of work and quality for the end-user. The performed simulation, discussed in chapter 4, showed how the key-functionalities would have a positive effect on the relevant components of the supply chain monitor, which measures supply chain collaboration and its effectiveness in the Dutch social housing sector.

6.1 Recommendations

As stated in Chapter 1, this thesis will embark on a design problem until the point of developing a preliminary design, because at this stage enough information can be gathered to draw sensible conclusions and answers for the presented research question. In order to take this research further a refinement and optimization of the design would be necessary to develop a more detailed design. The following three recommendations can be made:

1. A good starting point for optimization would be the identified possible improvements in paragraph 4.2.2..
2. Further along the road it would become essential to apply information strategies, business analytics and more knowledge about platform ecosystems. This would require more specialized expertise in business information management.
3. Refinement can be performed on the different software modules presented in figure 3.6 and their interfaces. This would require more specialized expertise in computer technology and software programming.

Next to refining and optimizing, the research scope could also be broadened. The following recommendations could be made for this:

- On the technical side, planning aspects could be included to connect determined milestones and corresponding KPI's. Potential interesting applications to explore are combinations with probabilistic network planning software, as developed by R. de Graaf, R. Binnekamp and G.A. van Gunsteren. Overtime this would present potential compatibility with big-data and artificial intelligence, due to the large amounts of information on activities that will be generated within the virtual companies.
- On the business side, the scope could be broadened to concepts as "living buildings" and "Buildings as a Service". Through interviews with experts in the field and attended conferences I learned that such concepts are very popular, but ideas are lacking on how to make sense of them business-wise. The proposed business-model for the multi-year SCP in this research would provide a sensible business-strategy, since the established partnership could stay the "owner" of the building over it's whole life-cycle. Maintaining and managing these assets would become the responsibility of these virtual companies. Revenue from rent and usage of the building could be automatically divided through the established benefit-shares in the smart-contracts.

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Appendices

Appendix A

An Introduction to Blockchain

This appendix presents an info-graphic about blockchain technology, developed by the consultancy company Price Waterhouse Cooper. The most common application of the technology is currently focussed on transactions of cryptocurrencies, like bitcoin. As described in the third step of the flowchart: "A verified transaction can involve cryptocurrencies, **contracts, records or other information**". This thesis focusses on these last three types of transactions. However, the principle for handling these transactions is similar as with cryptocurrencies.

The concept of the technology seems complex in the first instance. To really get the potential of this abstract principle it's recommended to consult several different sources and use-cases. Here are two video's that could help:

- What is BLOCKCHAIN? The best explanation of blockchain technology
- NOS - Wat is de blockchain? En wat kan je ermee?

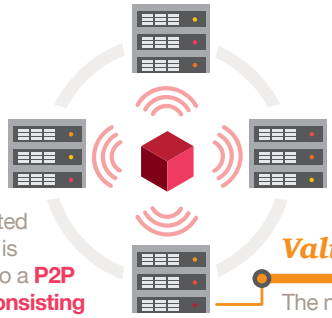
A look at blockchain technology

What is it?

The blockchain is a decentralized ledger of all transactions across a peer-to-peer network. Using this technology, participants can confirm transactions without the need for a central certifying authority. Potential applications include fund transfers, settling trades, voting, and many other uses.

How it works:

Someone requests a transaction.



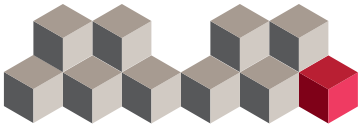
The requested transaction is broadcast to a **P2P network consisting of computers, known as nodes.**

Validation

The network of nodes **validates the transaction and the user's status using known algorithms.**

A verified transaction can involve **cryptocurrency,** contracts, records, or other information.

The transaction is complete.



The new block is then added to the existing blockchain, in a way that is permanent and unalterable.

Once verified, the transaction is combined with other transactions **to create a new block of data for the ledger.**

Benefits

- **Increased transparency**
- **Accurate tracking**
- **Permanent ledger**
- **Cost reduction**

Unknowns

- **Complex technology**
- **Regulatory implications**
- **Implementation challenges**
- **Competing platforms**

Cryptocurrency

Cryptocurrency is a medium of exchange, created and stored electronically in the blockchain, using encryption techniques to control the creation of monetary units and to verify the transfer of funds. Bitcoin is the best known example.

Has no intrinsic value in that it is not redeemable for another commodity, such as gold.

Has no physical form and exists only in the network.

Its supply is not determined by a central bank and the network is completely decentralized.

Potential applications

Automotive

Consumers could use the blockchain to manage fractional ownership in autonomous cars.

Financial services

Faster, cheaper settlements could shave billions of dollars from transaction costs while improving transparency.

Voting

Using a blockchain code, constituents could cast votes via smartphone, tablet or computer, **resulting in immediately verifiable results.**

Healthcare

Patients' encrypted health information could be shared with multiple providers without the risk of privacy breaches.

Sources:
"Money is no object: Understanding the evolving cryptocurrency market," PwC, 2015
"A Strategist's Guide to Blockchain," strategy+business, January, 2016
"How Blockchain Technology Is Disrupting Everything," TechDay, 2016

pwc

Appendix B

An Introduction to Game Theory

This appendix presents a paper from the University of California which gives a brief and clear introduction to Game Theory. This is shared to give a sense of what this mathematical discipline is about and how it could contribute determining the best partnering strategies.

GAME THEORY

Thomas S. Ferguson
University of California at Los Angeles

INTRODUCTION.

Game theory is a fascinating subject. We all know many entertaining games, such as chess, poker, tic-tac-toe, bridge, baseball, computer games — the list is quite varied and almost endless. In addition, there is a vast area of economic games, discussed in Myerson (1991) and Kreps (1990), and the related political games, Ordeshook (1986), Shubik (1982), and Taylor (1995). The competition between firms, the conflict between management and labor, the fight to get bills through congress, the power of the judiciary, war and peace negotiations between countries, and so on, all provide examples of games in action. There are also psychological games played on a personal level, where the weapons are words, and the payoffs are good or bad feelings, Berne (1964). There are biological games, the competition between species, where natural selection can be modeled as a game played between genes, Smith (1982). There is a connection between game theory and the mathematical areas of logic and computer science. One may view theoretical statistics as a two person game in which nature takes the role of one of the players, as in Blackwell and Girshick (1954) and Ferguson (1968).

Games are characterized by a number of players or decision makers who interact, possibly threaten each other and form coalitions, take actions under uncertain conditions, and finally receive some benefit or reward or possibly some punishment or monetary loss. In this text, we present various mathematical models of games and study the phenomena that arise. In some cases, we will be able to suggest what courses of action should be taken by the players. In others, we hope simply to be able to understand what is happening in order to make better predictions about the future.

As we outline the contents of this text, we introduce some of the key words and terminology used in game theory. First there is the **number of players** which will be denoted by n. Let us label the players with the integers 1 to n, and denote the **set of players** by $N = \{1, 2, \ldots, n\}$. We study mostly two person games, $n = 2$, where the concepts are clearer and the conclusions are more definite. When specialized to one-player, the theory is simply called decision theory. Games of solitaire and puzzles are examples of one-person games as are various sequential optimization problems found in operations research, and optimization, (see Papadimitriou and Steiglitz (1982) for example), or linear programming, (see Chvátal (1983)), or gambling (see Dubins and Savage(1965)). There are even things called "zero-person games", such as the "game of life" of Conway (see

Berlekamp et al. (1982) Chap. 25); once an automaton gets set in motion, it keeps going without any person making decisions. We assume throughout that there are at least two players, that is, $n \geq 2$. In macroeconomic models, the number of players can be very large, ranging into the millions. In such models it is often preferable to assume that there are an infinite number of players. In fact it has been found useful in many situations to assume there are a continuum of players, with each player having an infinitesimal influence on the outcome as in Aumann and Shapley (1974). (Incidentally, both authors were later to win Nobel Prizes in Economics.) In this course, we take n to be finite.

There are three main mathematical models or forms used in the study of games, the **extensive form**, the **strategic form** and the **coalitional form**. These differ in the amount of detail on the play of the game built into the model. The most detail is given in the extensive form, where the structure closely follows the actual rules of the game. In the extensive form of a game, we are able to speak of a **position** in the game, and of a **move** of the game as moving from one position to another. The set of possible moves from a position may depend on the player whose turn it is to move from that position. In the extensive form of a game, some of the moves may be **random moves**, such as the dealing of cards or the rolling of dice. The rules of the game specify the probabilities of the outcomes of the random moves. One may also speak of the **information** players have when they move. Do they know all past moves in the game by the other players? Do they know the outcomes of the random moves?

When the players know all past moves by all the players and the outcomes of all past random moves, the game is said to be of **perfect information**. Two-person games of perfect information with win or lose outcome and no chance moves are known as **combinatorial games**. There is a beautiful and deep mathematical theory of such games. You may find an exposition of it in Conway (1976) and in Berlekamp et al. (1982). Such a game is said to be **impartial** if the two players have the same set of legal moves from each position, and it is said to be **partizan** otherwise. Part I of this text contains an introduction to the theory of impartial combinatorial games. For another elementary treatment of impartial games see the book by Guy (1989).

We begin Part II by describing the **strategic form** or normal form of a game. In the strategic form, many of the details of the game such as position and move are lost; the main concepts are those of a strategy and a payoff. In the strategic form, each player chooses a strategy from a set of possible strategies. We denote the **strategy set** or **action space** of player i by A_i, for $i = 1, 2, \ldots, n$. Each player considers all the other players and their possible strategies, and then chooses a specific strategy from his strategy set. All players make such a choice simultaneously, the choices are revealed and the game ends with each player receiving some payoff. Each player's choice may influence the final outcome for all the players.

We model the payoffs as taking on numerical values. In general the payoffs may be quite complex entities, such as "you receive a ticket to a baseball game tomorrow when there is a good chance of rain, and your raincoat is torn". The mathematical and philosophical justification behind the assumption that each player can replace such payoffs with numerical values is discussed in the Appendix under the title, **Utility Theory**. This

theory is treated in detail in the books of Savage (1954) and of Fishburn (1988). We therefore assume that each player receives a numerical payoff that depends on the actions chosen by all the players. Suppose player 1 chooses $a_1 \in A_1$, player 2 chooses $a_2 \in A_2$, etc. and player n chooses $a_n \in A_n$. Then we denote the payoff to player j, for $j = 1, 2, \ldots, n$, by $f_j(a_1, a_2, \ldots, a_n)$, and call it the **payoff function for player** j.

The **strategic form of a game** is defined then by the three objects:

(1) the set, $N = \{1, 2, \ldots, n\}$, of players,

(2) the sequence, $A_1, \ldots, A_n$, of strategy sets of the players, and

(3) the sequence, $f_1(a_1, \ldots, a_n), \ldots, f_n(a_1, \ldots, a_n)$, of real-valued payoff functions of the players.

A game in strategic form is said to be **zero-sum** if the sum of the payoffs to the players is zero no matter what actions are chosen by the players. That is, the game is zero-sum if

$$\sum_{i=1}^{n} f_i(a_1, a_2, \ldots, a_n) = 0$$

for all $a_1 \in A_1$, $a_2 \in A_2$,..., $a_n \in A_n$. In the first four chapters of Part II, we restrict attention to the strategic form of finite, two-person, zero-sum games. Such a game is said to be **finite** if both the strategy sets are finite sets. Theoretically, such games have clear-cut solutions, thanks to a fundamental mathematical result known as the **minimax theorem**. Each such game has a **value**, and both players have **optimal strategies** that guarantee the value.

In the last three chapters of Part II, we treat two-person zero-sum games in extensive form, and show the connection between the strategic and extensive forms of games. In particular, one of the methods of solving extensive form games is to solve the equivalent strategic form. Here, we give an introduction to Recursive Games and Stochastic Games, an area of intense contemporary development (see Filar and Vrieze (1997), Maitra and Sudderth (1996) and Sorin (2002)). In the last chapter, we investigate the problems that arise when at least one of the strategy sets of the players is an infinite set.

In Part III, the theory is extended to two-person **non-zero-sum** games. Here the situation is more nebulous. In general, such games do not have values and players do not have optimal strategies. The theory breaks naturally into two parts. There is the **noncooperative theory** in which the players, if they may communicate, may not form binding agreements. This is the area of most interest to economists, see Gibbons (1992), and Bierman and Fernandez (1993), for example. In 1994, John Nash, John Harsanyi and Reinhard Selten received the Nobel Prize in Economics for work in this area. Such a theory is natural in negotiations between nations when there is no overseeing body to enforce agreements, and in business dealings where companies are forbidden to enter into agreements by laws concerning constraint of trade. The main concept, replacing value and optimal strategy is the notion of a **strategic equilibrium**, also called a **Nash equilibrium**. This theory is treated in the first three chapters of Part III.

On the other hand, in the **cooperative theory** the players are allowed to form binding agreements, and so there is strong incentive to work together to receive the largest total payoff. The problem then is how to split the total payoff between or among the players. This theory also splits into two parts. If the players measure utility of the payoff in the same units and there is a means of exchange of utility such as **side payments**, we say the game has **transferable utility**; otherwise **non-transferable utility**. The last chapter of Part III treat these topics.

When the number of players grows large, even the strategic form of a game, though less detailed than the extensive form, becomes too complex for analysis. In the **coalitional form** of a game, the notion of a strategy disappears; the main features are those of a **coalition** and the **value** or **worth** of the coalition. In many-player games, there is a tendency for the players to form coalitions to favor common interests. It is assumed each coalition can guarantee its members a certain amount, called the value of the coalition. The coalitional form of a game is a part of cooperative game theory with transferable utility, so it is natural to assume that the **grand coalition**, consisting of all the players, will form, and it is a question of how the payoff received by the grand coalition should be shared among the players. We will treat the coalitional form of games in Part IV. There we introduce the important concepts of the **core** of an economy. The core is a set of payoffs to the players where each coalition receives at least its value. An important example is two-sided matching treated in Roth and Sotomayor (1990). We will also look for principles that lead to a unique way to split the payoff from the grand coalition, such as the **Shapley value** and the **nucleolus**. This will allow us to speak of the power of various members of legislatures. We will also examine cost allocation problems (how should the cost of a project be shared by persons who benefit unequally from it).

Related Texts. There are many texts at the undergraduate level that treat various aspects of game theory. Accessible texts that cover certain of the topics treated in this text are the books of Straffin (1993), Morris (1994) and Tijs (2003). The book of Owen (1982) is another undergraduate text, at a slightly more advanced mathematical level. The economics perspective is presented in the entertaining book of Binmore (1992). The New Palmgrave book on game theory, Eatwell et al. (1987), contains a collection of historical sketches, essays and expositions on a wide variety of topics. Older texts by Luce and Raiffa (1957) and Karlin (1959) were of such high quality and success that they have been reprinted in inexpensive Dover Publications editions. The elementary and enjoyable book by Williams (1966) treats the two-person zero-sum part of the theory. Also recommended are the lectures on game theory by Robert Aumann (1989), one of the leading scholars of the field. And last, but actually first, there is the book by von Neumann and Morgenstern (1944), that started the whole field of game theory.

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Appendix C

Supply Chain Monitor

This appendix presents the entire Supply Chain Monitor by Vrijhoef et al. (2014), in order to show which other aspects are also measured with this tool.

Table C.1: Supply Chain Monitor by Vrijhoef et al. (2014)

Components (dependency)	**Variables**	**Subjects**, questions asked within the components [a]
Project	Project characteristics	Name, type and location of project (c),Construction phase (c), Function (c), type of contract and delivery method (c), floor surface (con), amount of floors (con), technical complexity (o)
(independent)		
Resources	Project managers	Age (con), Education (c), Gender (c), employers' company name
(independent)	(client, contractor)	
	Organisations involved	Roles of project team (c), phase in which involved (c), names and addresses of team members.
	People involved	influence of each team member (o), selection criteria used to select team members(o), methods used to compose the team (c), team procedures (o), joint location for the team (c), joint history of the team (0), level of support from management (o)
	Past and (potential) future involvement	Extent of previous collaboration in single or multiple projects (o), intentions or agreement for future collaboration in single/multiple projects (o)
Processes	Transparency	Level of accessibility of financial and additional information between client, contractor and subcontractors, and vice versa (o).
	Systems/Procedures	use of joint information sharing (c), joint risk management (c), joint planning i.e. lean planning (c), joint decision making and evaluations (c), joint quality assurance (c)
	Collaboration	Use of team building and joint training of the project team (c), purpose of training (c)
	Finances	Use of financial incentives (risk/reward) (c), level of joint purchasing (c), level of project risk sharing (c).
	Design	Use of BIM (c), purpose of BIM (c), use of design concepts of references(c), use of prefab (or similar) solutions (c), use of maintenance history (c)
	Logistics	Use of BIM (c), purpose of BIM (c), use of design concepts of references(c), use of prefab (or similar) solutions (c), use of maintenance history (c)
	Health and Safety measures	Involvement of team in H&S plans during design (n), safety measures taken (c), level in which H&S plans were usable during construction (o), amount of safety visits (by authorities) (con), scores given by authorities (int), use of accident records (o)

[a]The type of scales used to measure the variables are codes as follows: continuous (con), interval (int), categorical (c), nominal (n), ordinal (o), interval (i) or ratio (r)

Output	Project Goals	Areas of goals formulated (c), level of formulation of goals (o), level of goal achievement (o).
	Finance	Ratio between cost estimate(s), awarded bid and final costs of construction, and total investment costs (r), reasons for changes in cost (c).
	Planning	Ratio between estimated duration at the definition and design phases, and actual duration at the end of the project (r), reasons for changes in duration(c).
	Quality	Amount of defects (con), defects that postponed the final completion of project (con), working days used to solve defects (con and r, when divided by total construction time), outcome of air permeability test (o), outcome of ventilation performance test (o), outcome of thermo graphic inspection (o)
	Sustainability	Ratio between planned label (BREEAM, GPR or EPA energy label) at the end of definition and design vs achieved label after construction (r).
	Health and safety	Amount of accidents leading to a non-attendance longer than 1 day (con), amount of people sent away because of violating H&S codes (con), project manager's view on H&S (o), amount of effort needed to get achieve H&S goals and attitude (o).
Outcomes	User satisfaction	Opinion about the project team (o), effort of team members (o), responsibility taken by team members (o), involvement of team members (o), performance of team (o), view on the collaboration (o), chances of repeating this way of collaboration (o).
	Project manager (client) satisfaction	Method used to measure user satisfaction (type), Score of user satisfaction versus average of previous projects (o).
	Project manager (main contractor) satisfaction	Same as above row of client's project manager.
	Team satisfaction	Opinion about team atmosphere (o), Fun working in the team (o), Room for new ideas (o), attitude among team members (o), efficiency of the team (o), transparency amongst team members (o), involvement of team members (o), room for improvement of team functioning (o), pride in working for the team (o), self-esteem (o).

Appendix D

Simulation Screenshots

This appendix presents screenshots of the simulation that is organized as the experiment for chapter 5. This is done to give a feel for how such an virtual company environment might look like.

Project Description

This is a description of the context for the case.

WonenBreburg

HUYBREGTS RELOU

Simulatie

-

Werken als één virtueel bedrijf

Inleiding
320 sociale huurwoningen in woonwijk 't Ven zijn toe aan groot onderhoud. Een flink aantal bouwtechnische gebreken moeten worden aangepakt. De woonstichting wil ze duurzaam maken en tegelijkertijd betaalbaar houden.

Bewoners, gemeente en de "binnen-de-wijk-actieve" instellingen hebben met elkaar een gezamenlijk doel:
In 2020 willen het Wijkoverleg 't Ven en de wijkpartners samen bereiken dat 't Ven een vitale wijk is die in staat is een eigen koers te kiezen en te varen.

Voor het project is gestart met een ketensamenwerking waarbij alle partijen, vanuit een gezamenlijke verantwoordelijkheid, vanaf het begin aan tafel zitten en als het ware werken als één virtueel bedrijf. Verantwoordelijkheden worden laag in de organisatie neergelegd. Er is een duidelijke en op maat gesneden projectorganisatie, waarbij alleen medewerkers die toegevoegde waarde leveren aan tafel zitten. "Los-laten" is een van de belangrijkste succesfactoren. Hiermee wordt getracht de discussie te focussen op kwaliteit in plaats van geld.

De wijk
Het is een groene en aantrekkelijke wijk waarin het aandeel bijzondere doelgroepen hoog is en sterk toeneemt. Van de bijna 500 sociale huurwoningen zijn 364 woningen vroeg naoorlogs (1948). In de complexen wonen veel laagopgeleide mensen. Met regelmatig stevige problematiek achter de voordeur, op het vlak van onder andere financiën en gezondheid. Het aantal laag opgeleide bewoners met een laag inkomen, die afhankelijk zijn van de Wet Werk en Bijstand, groeit. De bewoners, in de sociale huurwoningen, hebben onderling niet veel contact.

Middels een fors investeringstraject wordt er met alle betrokkenen een "energie-impuls" aan de wijk gegeven. Dit betekent dat samen met de bewoners de handschoen wordt opgepakt. Duidelijk is dat met onderhoud alleen niet volstaan kan worden. Er is gekozen voor écht verduurzamen van de woningen. Dit gaat gefaseerd waarin in 2017 de kleine woningen aan de beurt zijn geweest (ong. 40). Nu volgen de 320 woningen in de periode 2018/2020.

Voor veel bewoners is het 'hun huis en hun wijk' en dat moet zo blijven. Een gevoel dat proactief ondersteunt moet worden. Met een maximale uitgaven van 100.000 euro per woning gaat het tegelijkertijd om een substantieel project in de bestaande bouw. De volgende twee ambities moeten hierbij gerealiseerd worden:

Ambitie 1: De woningen in 't Ven zijn binnenkort energie-neutraal en hebben 50 jaar geen onderhoud meer nodig.

Ambitie 2: Werken met een allround ketensamenwerking die technisch en sociaal de lead kan nemen in het gehele proces.

Rendementssturing van totale investeringskosten en exploitatielasten
Door te sturen op rendement, totale investeringskosten en exploitatielasten ontstaat in de ogen van de woonstichting de mogelijkheid om de meest optimale oplossingen toe te passen. Zo zal een hogere investering op voorhand mogelijk zijn als dit tot voldoende en aantoonbare verlaging van de lasten leidt gedurende de exploitatie.

Plan van aanpak
De huurder en het woonplezier hebben de hoogste prioriteit. Hiervoor wordt een KPI van >8 gebruikt voor de bewoners-tevredenheid. Hierover wordt maandelijks gerapporteerd.

De woonlasten worden terug gebracht tot € 0,- aan energieverbruik-lasten (NOM). Resulterend in een flinke besparing. De streefhuur blijft onder de eerste aftoppingsgrens.

Aan de hand van een zogenoemde menukaart met diverse mogelijkheden kan de bewoner zelf keuzes maken voor zijn woning. De communicatie-partner en de huurders-coach organiseren een verstaanbare en begrijpbare communicatie met de bewoners. Zij zijn de oren en ogen in de wijk en koppelen deze signalen terug naar het projectteam. Zij zoeken de bewoners op om te komen tot een samenspel. De woonstichting en de ambassadeurs in de wijk gaan campagne voeren voor het minimale draagvlak van 70% van de bewoners maar liefst nog meer!

Gezamenlijk met de bewoners worden keuzepakketten in binnenrenovatie, flexibiliteit in planning en omgang met Zelf Aangebrachte Voorzieningen (ZAV's) ontwikkeld. De aanpak is erop gericht dat de bewoners thuis kunnen blijven wonen gedurende de werkzaamheden. Er worden leuke mogelijkheden aangeboden voor overdag. Nuttig ingevuld met aangename activiteiten en participatiemogelijkheden in het renovatieproject.

In de projectrealisatie zijn de buiten en de binnenrenovaties twee op zichzelf staande bouwstromen. De binnenrenovaties worden op afroep van de bewoner uitgevoerd, zolang we in de wijk bezig zijn en als deze maar voorafgaande aan de buitenstroom plaatsvindt. Er wordt gewerkt volgens de lean methodiek en met principes van serie van 1 los van de buitenschil.

Duidelijke afspraken worden gemaakt middels een digitale scheurkalender op maat. Met inzage waneer wat gebeurt in de woning en met zekerheid op naleving. Waarmaken van planning is ook een KPI.

Eerst wordt een demowoning gemaakt om de techniek uit te testen en te evalueren. Vervolgens wordt op een bewoond blok de methode verder geoptimaliseerd. Bestrating rondom de woning gaan z.s.m. weer dicht, om overlast voor de bewoners te beperken. Bouwlogistiek zal via de steigers plaatsvinden om zo min mogelijk in de woning hoeven te zijn.

Element Model in Kumu

This is the link that will bring you to the actual information model online:

't Ven - Element Model

't Ven

Deze map bevat een selectie van het elementen systeem voor het groot onderhoud van de woonwijk 't Ven.

Onderverdeling

Voor deze simulatie is het systeem beperkt gehouden tot één woning. Bij het verder uitwerken van het project zou het systeem per woning uitgekristalliseerd kunnen worden. Zodat je precies kan bijhouden wat de situatie is per woning.

Navigatie

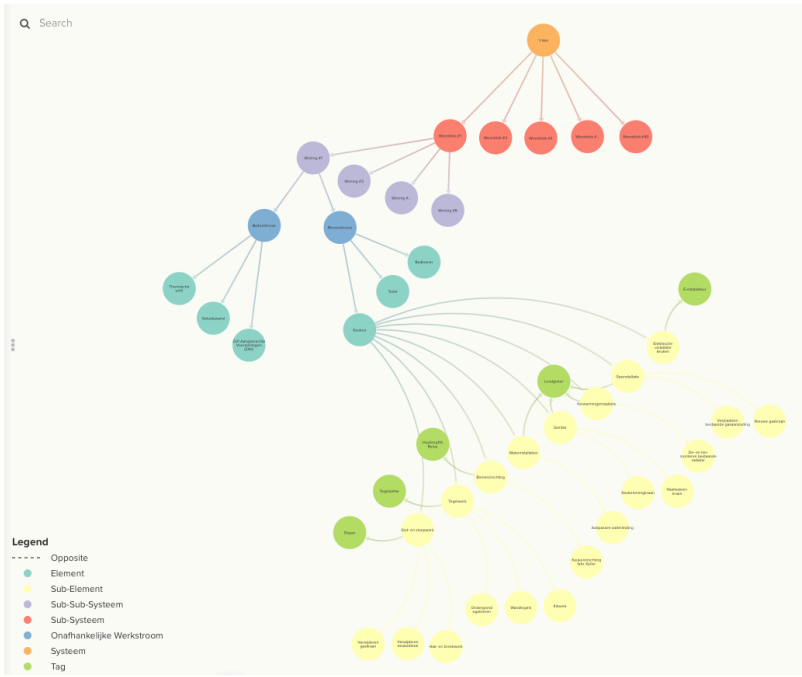
Je kunt op de map klikken en hem rond bewegen. Door te scrollen kun je in en uit zoomen. Je kunt hiervoor ook de knoppen aan de rechterkant van het scherm gebruiken.

Zoeken

Met de zoekfunctie kan er gezocht worden naar een specifiek element. Je kan hier ook op een link klikken naar iedere woning.

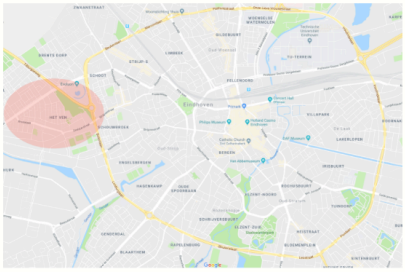
Woning #1

#t-ven | permalink



't Ven

SYSTEEM

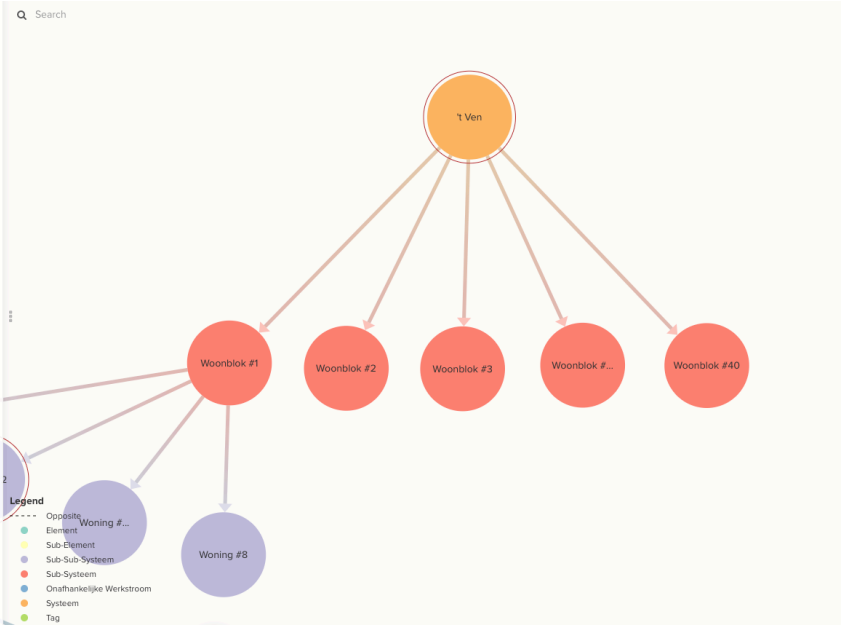


ADD TAG

DIRECTE KOSTEN http://www.wijkhetven.nl

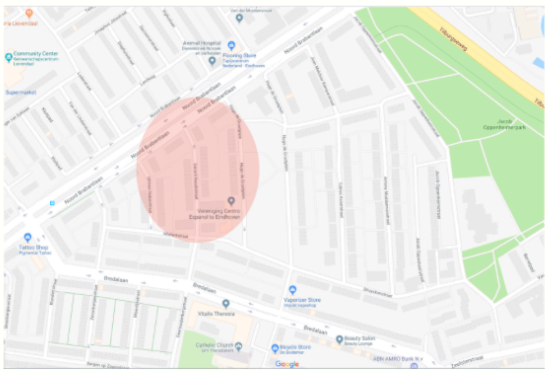
+ New field

#t-ven/t-ven | permalink



Woonblok #1

SUB-SYSTEEM



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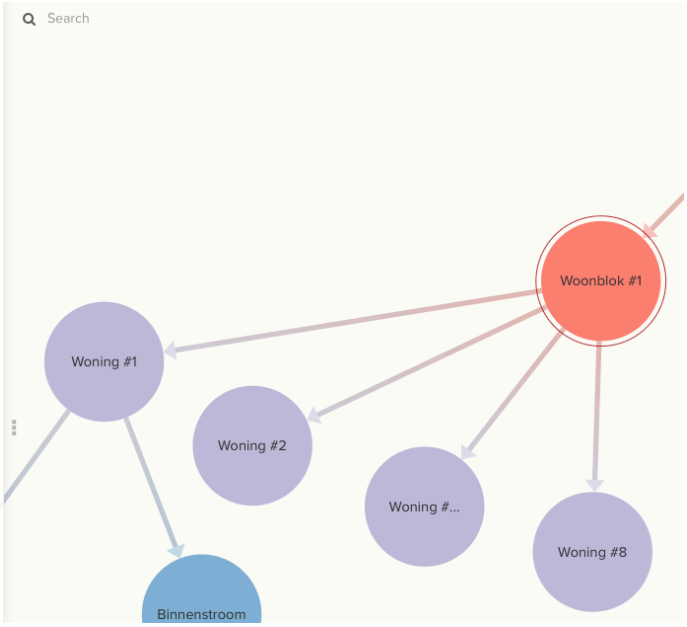

Woning #1

SUB-SUB-SYSTEEM

Adres en relevante bewoner informatie

ADD TAG

DIRECTE KOSTEN ADD DIRECTE KOSTEN

+ New field

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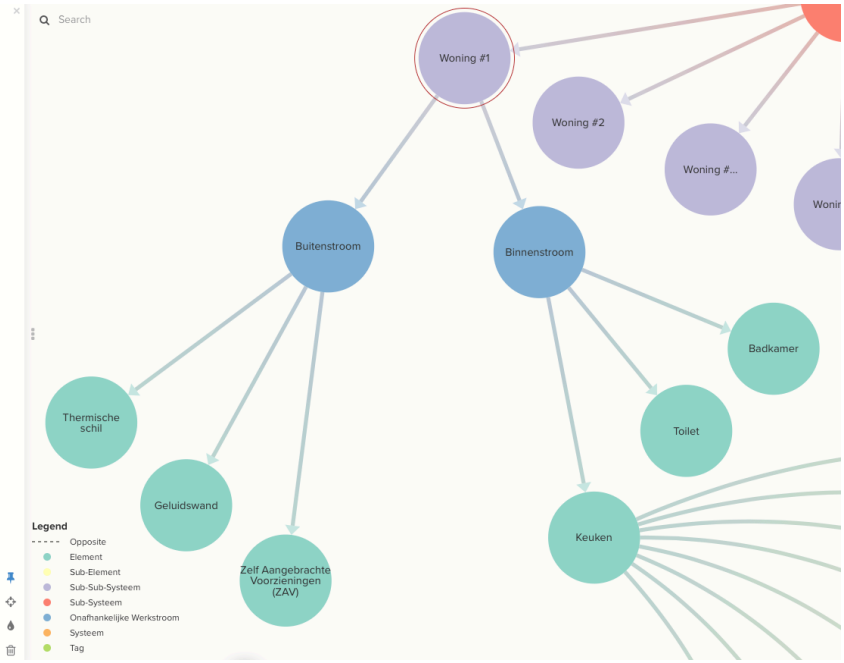
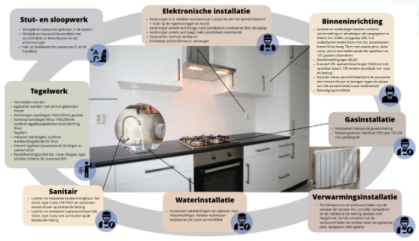


Keuken

ELEMENT

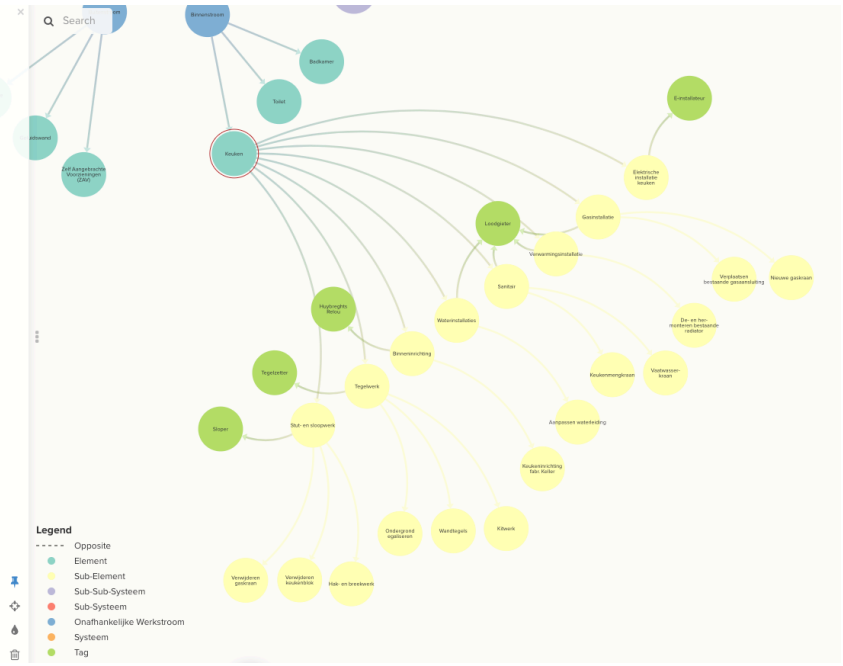


ADD TAG

DIRECTE KOSTEN ADD DIRECTE KOSTEN

+ New field

#t-ven/keuken | permalink



Tegelwerk

SUB-ELEMENT

Voorstrijken wanden

Egaliseren wanden met cement gebonden mortel

Aanbrengen wandtegels 150x200mm gelijmd

Aankoop wandtegels Mosa 150x200mm conform tegelkeuzepaketten woonstichting 'thuis

Tegellijm

Inwassen wandtegels, conform standaardtegelcollectie 'thuis

Kitwerk tegelwerk (wand/wand), leidingen en aanrechtblad

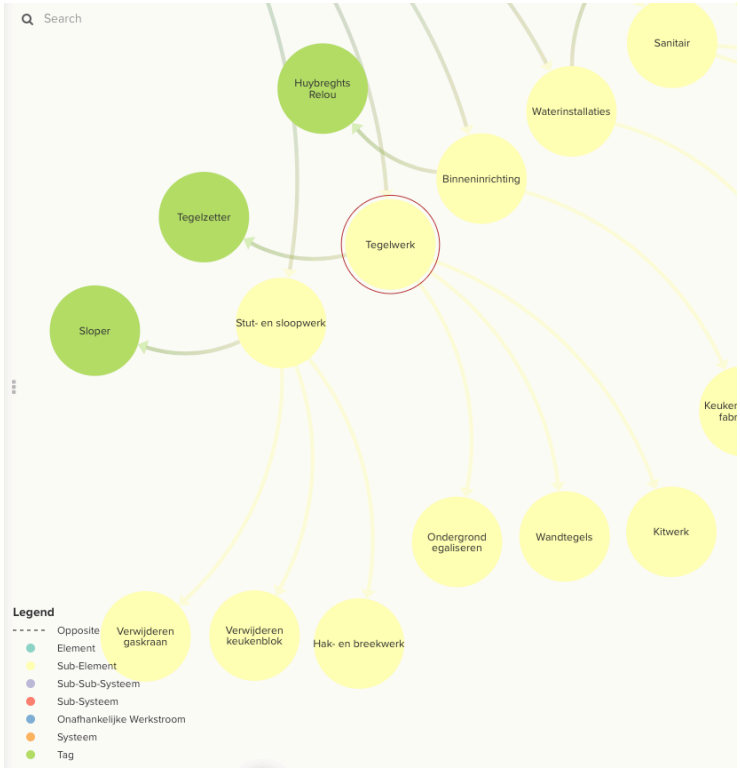
Randafwerkingsprofiel fair. Ceves Vergeet, type Schülter-Schiene EB, materiaal RVS

Tegelzetter

DIRECTE KOSTEN 477,67 euro

+ New field

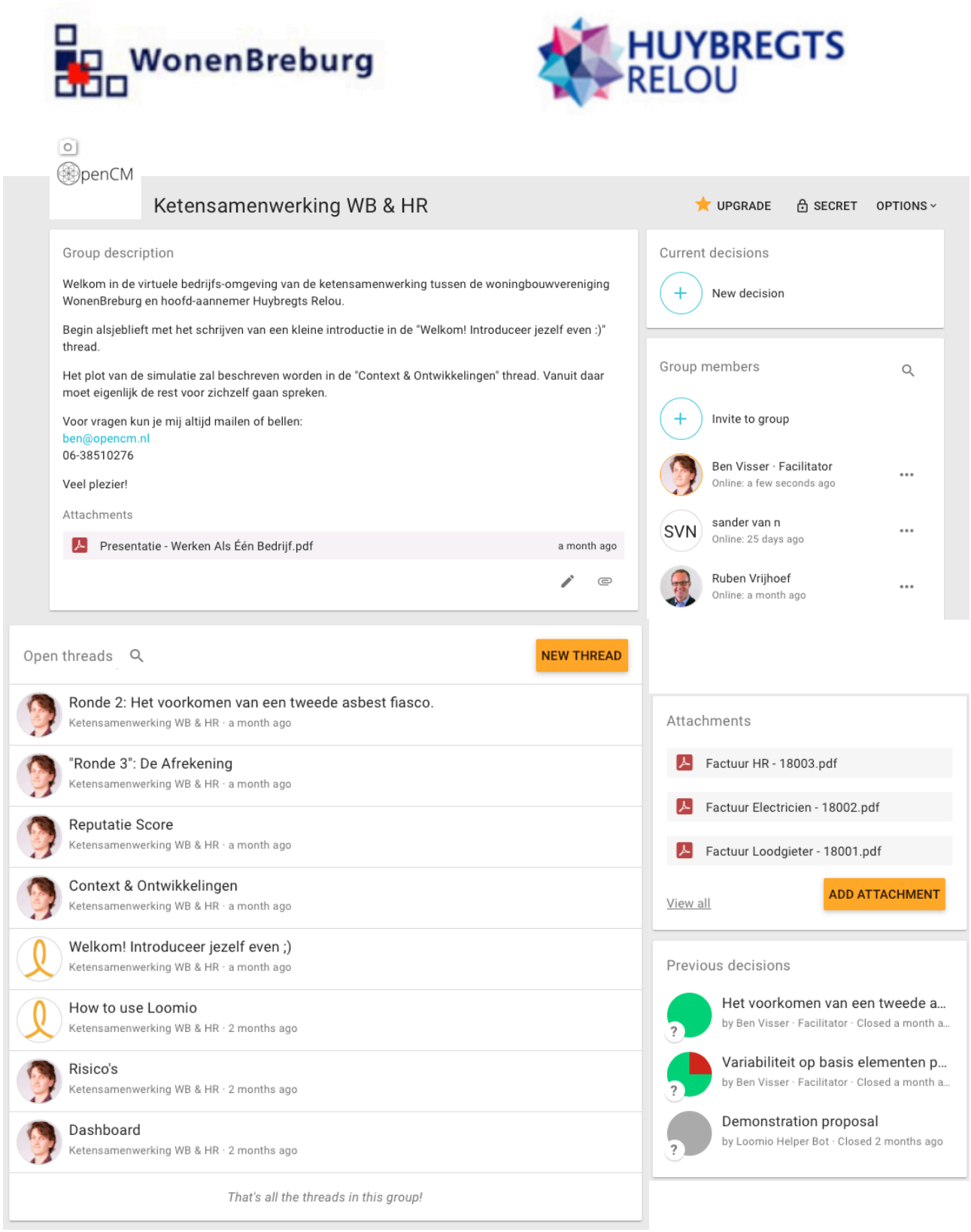
#t-ven/tegelwerk | permalink



Simulation Rounds in Loomio

Here you can see how consensus was reached in the different rounds of simulation.

Start Screen



Dashboard

Ben Visser · Facilitator · 2 months ago · Private · Seen by 5

Hier wordt de real-time status van het situatie weergegeven.

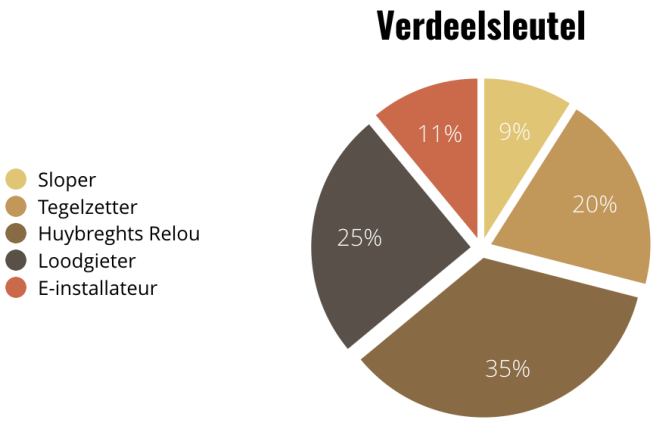
Gedurende de ontwerpfase is er getracht de onzekerheids-marge zo klein mogelijk te maken over het budget, de planning en de risico's. Hiervoor is een elementen-systeem uitgewerkt. Per element zijn de relevante partners en de Directe Kosten (DK) bepaald. Het DK-aandeel per partner bepaalt de verdeelsleutel.

- Elementen systeem: https://kumu.io/benvisser1/t-ven-element-systeem
- Verdeelsleutel (bijgevoegd)
- Planning (valt buiten de scope van deze simulatie)

Toelichting:
Om tot de verdeelsleutel te komen is uitgegaan van de Directe Kosten (DK) in de tabel. Er is helaas geen financiële informatie beschikbaar op een gedetailleerder element-niveau.

(Deze verdeelsleutel zal met name relevant zijn gedurende de tweede ronde van de simulatie.)

Elementenlijst deelbestek C3: keuken	
STUT- EN SLOOPWERK (SLOPER)	€ 225,00
Verwijderen gaskraan	€ -
Verwijderen keukenblok	€ -
Hak- en breekwerk	€ -
TEGELWERK (TEGELZETTER)	€ 477,67
Ondergrond egaliseren boven bestaand tegelwerk	€ -
Wandtegels	€ -
Voorstrijken wanden (in prijs aanbrengen wandtegels)	€ -
Voegafwerking (in prijs aanbrengen wandtegels)	€ -
Kitwerk	€ -
Randafwerkingsprofiel t.p.v. aansluiting deurkozijn (in prijs aanbrengen jolly profiel)	€ -
BINNENINRICHTING	€ 853,75
Keukeninrichting fabr. Keller	€ -
WATERINSTALLATIES (LOODGIETER)	€ 596,88
Aanpassen waterleidingen	€ -
SANITAIR (LOODGIETER)	?
Keukenmengkraan	€ -
Vaatwasserkraan	€ -
GASINSTALLATIES (LOODGIETER)	?
Verplaatsen gasaansluiting	€ -
Nieuwe gaskraan	€ -
VERWARMINGSINSTALLATIES (LOODGIETER)	?
De- en hermonteren bestaande radiator	€ -
ELEKTROTECHNISCHE INSTALLATIES (E-INSTALLATIE)	€ 266,50
Elektrotechnische installatie keuken	€ -



Risico's

Ben Visser · Facilitator · 2 months ago · Private · Seen by 6

In de ontwerpfase zijn de hoofden al bij elkaar gestoken om een risico en kansen matrix op te stellen. Het resultaat daarvan is hier bijgevoegd.

Lees deze goed door voordat er een voorstel of besluit gemaakt wordt over het delen van de risico's in ronde 1!

Attachments

Risico-_en_Kansenmatrix.pdf a month ago

Ronde 1

Context & Ontwikkelingen

Ben Visser · Facilitator · 2 months ago · Private · Seen by 8

De beschrijving van de case is hier bijgevoegd. Deze beschrijving geeft de context voor de simulatie weer.

In totaal zal de simulatie plaatsvinden in drie verschillende rondes. Iedere ronde sluit aan bij een fase in het ketensamenwerking-process.
Ronde 1: Ontwerp-fase
Ronde 2: Realisatie-fase
Ronde 3: Afrekening

De beschrijving van het probleem bij iedere ronde zal tijdig bekend gemaakt worden.
Ronde 1 zal plaatsvinden vanaf dinsdag 3 juli t/m donderdag 5 juli.
Ronde 2 vanaf vrijdag 6 juli t/m zondag 8 juli.
Ronde 3 vanaf maandag 9 juli t/m dinsdag 10 juli.

Het kan zijn dat deze tijden herzien moeten worden. Maar dat kijken we gedurende de simulatie wel aan.

Attachments

Projectbeschrijving.pdf — a month ago

Ben Visser · Facilitator · a month ago

Ronde 1: Uitzondering op de elementen.

Uit de eerste 40 woningen, in fase 1, is gebleken dat de standaardkosten per keuken ongeveer € 2500,-.
Bewoners hebben zelf veranderingen aangebracht in hun keukens, zoals een bar, verhogen/verlagen van het plafond, type deuren. In sommige situaties heeft dit zelfs geleid tot ondeugdelijke elektra. De variabiliteit op het basispakket is dermate groot dat de onvoorziene kosten per keuken kunnen oplopen tot gemiddeld € 750,-

Opdracht:
Tussen de OG (Wonen Breburg) en ON (Huybregts Relou) zal besloten moeten worden hoe met deze variabiliteit op het basispakket omgegaan zal worden.

De afweging hiervoor is dat je de warme opname naar een hoger niveau brengt en daardoor eerder de variabiliteit kan afprijzen, maar dat dit veel tijd en energie kost. Hierover zal een beslissing gemaakt moeten worden, gebaseerd op een onvoorzien-stelpost per keuken en risico-deling.

Dus als de OG veel zekerheid wil hebben over de situatie dan kan hij dit door de ON laten doen in ruil voor een kleinere onvoorzien-post. En/of een kleiner aandeel in het opdragen voor de kosten in het mogelijke scenario dat de onvoorzien-post overschreden wordt.
En vice versa, een grotere stelpost en/of groter risicoaandeel als de OG het minder dringend vindt om van te voren meer zekerheid te hebben.

De aftrap:
De projectleider van de ON (Mark) zal moeten beginnen met het maken van een voorstel. Op basis van wat hem een schappelijke afspraak lijkt. Daarna kunnen de andere ketenpartners hierop reageren. Er kan, als het nodig is, gebruikt gemaakt worden van de "Decision tools" aan de rechterkant van dit scherm.

Tip:
Bestudeer eerst de Risico- en Kansen matrix goed.
https://www.loomio.org/d/wmVgR8zB/risico-s

Als meer informatie nodig is om een beslissing te maken hoor ik het graag.

Succes!

MMR **MIster MvD ready to play!** · a month ago

Hoi allemaal, ten eerste de excuses dat ik niet eerder heb gereageerd, echter het is nogal druk zo vlak voor de vakantie :)
Als ik het goed heb begrepen is onderstaande voorstel ter beoordeling van jullie:
We hebben de eerste 40 woningen opgenomen en we zouden komende week aanvangen met de uitvoering. Als we de eerste woningen uitvoeren als nu bedacht geven we € 750,- per woning meer uit. In de wijk geldt dat wat we bij de eerste bewoner uitvoeren moeten we bij alle uitvoeren daar de wijk extreem homogeen is. Aangezien we kort voor start werk zitten kunnen we in tijd gezien niet anders dan rekening houden met 320won*750*70%deelname extra budget. Lijkt me niet zo'n probleem wel??
O'ja heb ff een rondje gebeld naar de onderaannemers. Die geven aan dat als het werk doorschuift ze dan meteen 6 weken doorschuiven ivm de drukte. Vooral de Electricien had hiermee een probleem. Gevolg is dat we dan door de bouwvak heengaan in 2019, waardoor de oplevering 10 weken doorschuift. De bouwplaatskosten van € 9.000,- p/w moet ik dan doorberekenen over deze periode. Graag jullie akkoord opstart en het extra budget voor de keukens. Anders de goedkeuring voor de € 90.000,- aan ABK.

Ben Visser · Facilitator · a month ago

Het totale budget voor de keukens is op dit moment (320x0,7x2500=) 560.000,- euro.

Gebleken is dat onvoorziene kosten, door uitzonderingen op het basis elementen pakket van de keukens, kunnen oplopen tot gemiddeld 750,- euro per keuken.

Mark vraagt hiervoor in totaal om (320x0,7x750=) 168.000,- euro extra budget op het totale budget voor de keukens.

Dit weegt op tegen de situatie dat als er meer tijd besteed zal worden aan warme opnames, om meer zekerheid te hebben over daadwerkelijke extra kosten, daarmee de planning in totaal 10 weken opschuift. Resulterend in 90.000,- euro extra ABK.

Voordat er over dit voorstel gestemd kan worden, moet Wonen Breburg een reactie geven over deze afweging. Zijn zij het eens met dit extra budget? Wat dus gegarandeerd betaald zal gaan worden. Of willen zij hier op een andere manier mee omgaan? (tip: lees nogmaals de afweging in de opdracht goed door)

Nadat er een compromis gevonden is tussen WB en HR kan er gestemd worden samen met de onder-aannemers of dat iedereen het met de eind beslissing eens is.

FK **Feicko Kooistra** · a month ago

We gaan toch starten. Wel gaan we meteen starten met te komen tot een ontwerp, waarbij de kosten voor de keuken binnen budget kunnen blijven. In die tijd gaan we ook door met warme opnames om zo snel mogelijk inzichtelijk te hebben of de aantallen te vervangen keukens mogelijk bijdragen aan de oplossing. Dit geheel is er dus op gericht om wantrouwen bij bewoners te voorkomen over afstel, een slimme vervolgaanpak om wantrouwen te voorkomen over verdunning binnen het project.
Vervolgens moeten we kijken in hoeverre we de bouwplaatskosten slim binnen de perken kunnen houden door of niet uit te lopen of door alleen uit te lopen in afgeslankte vorm. Op voorhand al akkoord te gaan met uitloop doet voor mijn gevoel absoluut geen recht aan de gedachte van taakstellend werken in de keten. (Dus snagger, niet te kort door de bocht, hihi)

Ben Visser · Facilitator started a proposal: Variabiliteit op basis elementen pakket keukens. · a month ago

Started by Ben Visser · Facilitator · Closed a month ago

Stemming alleen bedoeld voor:
Mister MvD Ready to Play, Feicko, Bram en Rob

Komen tot een ontwerp om toch binnen budget te blijven is lastig gebleken bij de eerste 40 woningen. Door de hoge variabiliteit in zelf aangebrachte veranderingen. Waardoor op zijn minst een onvoorzien-pot gebudgetteerd zal moeten worden.

Voorstel:

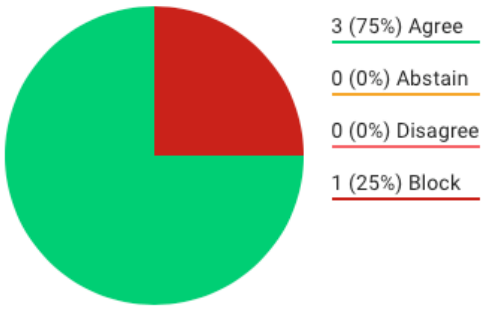
De onvoorzien-pot wordt gebudgetteerd voor (320x0,7x750=) 168.000,-. Het geen dat overblijft zal terug betaald worden aan WB. Via de gedigitaliseerde meterkast-lijst (in Kumu) kan precies bijgehouden worden hoeveel van de onvoorzien-post besteed is.

Let wel!
Dit is enkel voor 70% instemming. Als het draagvlak stijgt blijft deze totale onvoorzien-post gelijk.

Er zal direct doorgegaan worden met de extra warme opnames waardoor geen extra vertraging op gelopen wordt voor de keten-partners. Dus dit zal wat extra mankracht vereisen. Hierbij zouden de loodgieter en elektricien kunnen inspringen. Als zij dit komen doen zal er een betere band gecreëerd worden met de bewoners en dus minder wantrouwen ontstaan over astel.

Bonus!
Door deze persoonlijke aanpak van de keten-partners is de kans groot dat het draagvlak binnen de wijk vergroot zal worden. Meer taart dus voor iedereen!

Results



31% of members have stated their position (4/13)

Votes

Newest first

BS **Bram Staals** Agree

Zie bovenstaande tekstblok.

FK **Feicko Kooistra** Agree

R **Rob** Agree

MMR **MIster MvD ready to play!** Block

Wij kunnen er niets aan doen dat de huurders zo'n hoop ellende hebben gebouwd. Gaat dan toch niet af van ons resultaat! (old skool!)

Variabiliteit op basis elementen pakket keukens.

Outcome

By Ben Visser · Facilitator a month ago

👏 De eerste ronde is tot een einde gekomen! 👏

Bedankt allemaal voor jullie bijdragen. In de ketensamenwerking gedachte is het voorstel omtrent de "variabiliteit op basis elementen pakket" gehonoreerd. 🤗

Het blokkeren van de stemming door Mister MvD Ready to Play (AKA snagger) heeft ernstige twijfel teweeg gebracht omtrent zijn toewijding tot de ketensamenwerking. Dit leidt dan ook tot een flinke reputatieschade. 🤤

Feicko heeft na deze momentopname de hoogste reputatie score. Vanwege het feit dat hij Mark ook nog even aangesproken heeft op zijn mentaliteit. Wat ook effect heeft gehad. De onvoorzien pot is teruggebracht naar 350,-. 🤓

In de volgende ronde is er natuurlijk nog volop kans om eventuele achterstand in te halen. 🤞

Jullie kunnen de instructies voor de tweede ronde deze middag verwachten.

Reputatie scores 1.1.jpeg a month ago

Ronde 2

Ronde 2: Het voorkomen van een tweede asbest fiasco.

Ben Visser · Facilitator · a month ago · Private · Seen by 9

Gefeliciteerd!
Dankzij de persoonlijke behandeling van de E&W-installateurs is het draagvlak voor de binnen-pakketen gestegen naar 85%.

Tijdens de voorbereiding zijn er draagvlak scenario's ontwikkeld voor de verschillende situaties dat er 70%, 80%, 90% of 100% draagvlak is voor de binnen-paketten (zie bijgevoegde afbeelding). Hierin is het budget opgebouwd uit de Directe Kosten, Algemene Kosten en Winstmarge. Daarnaast bestaat de risico-pot uit 350,- euro per keuken, zoals die in ronde 1 geaccordeerd is. Op het moment begeven we ons dus in scenario 2.

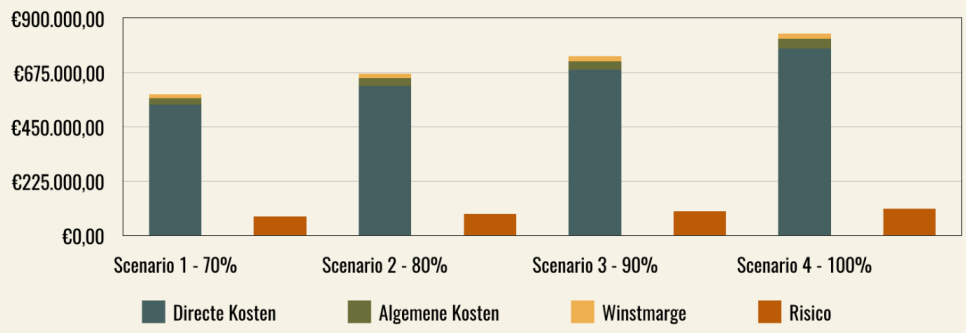
Via de gedigitaliseerde meterkast-lijst wordt per keuken bijgehouden hoeveel van deze pot nodig is: https://kumu.io/benvisser1/t-ven-element-systeem
Hetgeen dat overblijft uit deze pot wordt terugbetaald aan de OG (WB). Bij overschrijding wordt dit betaald vanuit de winstpot van de ketensamenwerking. (Risicodeling)

Ontwikkeling:
Rob, de elektricien, heeft tijdens een van zijn warme-opnames asbest ontdekt op onverwachte plekken. De hele ketensamenwerking heeft nog steeds nachtmerries over het asbest-fiasco in 2013:
http://www.omroepbrabant.nl/?news/1957901073/Buurt+boos+asbest+in+huizen+Vestingstraat+Breda,+WonenBreburg+doet+voorlopig+niets.aspx
Daarom heeft hij dit nog niet aan de bewoners gemeld. Het gevaar heerst dat er weer een paniek-golf kan uitbreken. Daarmee zou het draagvlak onder de 70% kunnen raken. Dit zou betekenen dat de winstmarge voor de hele ketensamenwerking in gevaar komt.

Opdracht:
Samen zal er besloten moeten worden hoe met deze situatie omgesprongen wordt. Op basis van die beslissing zal een nieuwe winst-status bepaalt worden.

Aftrap:
Hopelijk is er binnen WB geëvalueerd op het vorige het asbest-fiasco van 2013. Daarom zal Feicko deze ronde moeten aftrappen met een voorstel. Wellicht kan het bestuur van WB hier ook wat in betekenen.

Draagvlak Scenario's



Winstdeling					
Ketenpartner		Scenario 1	Scenario 2	Scenario 3	Scenario 4
Sloper	9%	€1.463,50	€1.672,57	€1.881,64	€2.090,71
Tegelzetter	20%	€3.252,21	€3.716,81	€4.181,41	€4.646,02
Huybregts Relou	35%	€5.691,37	€6.504,42	€7.317,48	€8.130,53
Loodgieter	25%	€4.065,26	€4.646,02	€5.226,77	€5.807,52
Electricien	11%	€1.788,72	€2.044,25	€2.299,78	€2.555,31

FK **Feicko Kooistra** · a month ago

Veilig wonen eist dat bewoners geen risico's lopen met asbest. We gaan er dus voor zorgen dat we de risico's voor bewoners voorkomen. We moeten weten welke risico's bewoners op dit moment lopen en daar ons crisisteam (management en communicatie) asap over informeren.
Voordat ik met de vraag om aanvullend budget naar het bestuur ga wil ik wel graag antwoord kunnen geven op de volgende vragen die we kunnen verwachten:

1. Kunnen we het asbest naast verwijderen op duurzame manier afschermen voor de bewoners en welk verschil betekent dit in de kosten?
2. Als we het asbest duurzaam afschermen wat betekent dit dan voor de waardeontwikkeling van het vastgoed op de termijn, rekening houdend met het risico dat het asbest onder strengere wetgeving alsnog verwijderd moet worden?
3. Welke fouten zijn er gemaakt tijdens inventariseren, waarom, wat hebben we daarvan geleerd, en hoe kijken we als keten tegen de verdeling van de kosten als gevolg van deze fouten.

MMR **MIster MvD ready to play!** · a month ago

Het blijkt dat de asbest zit onder het plafond van de keuken, daar waar de bewoners het toen nog niet hadden weggehaald, ongeveer 50%. In een eerdere onderhoudsronde is het restant afgetimmerd met plastic schroten. Het plafond is nu afgeschermd en direct gevaar is geweken, echter vanuit rookontwikkeling dienen de schroten te worden verwijderd.

- Keuze is nu schroten en asbest eruit. Hierdoor kan de electra ook worden aangepast. (asbest incl nieuw plafond 2250,- p/w)
- Of nogmaals overlagen met gipsplaten. (350,- p/w)

Voorstel is om daar waar de elctra (10% van de 50%) niet voldoet eea te verwijderen overige beter af te schermen.

R **Rob** · a month ago

Vanuit elektricien is veilig werken belangrijk, dus bij elke oplossing die wordt gekozen is dit voor ons van het grootste belang. Feicko vraagt of er fouten zijn gemaakt bij opnames asbest, maar dit is niet het geval. Het heeft meer te maken met keuzes van WBB in het verleden, dus extra kosten zijn voor de opdrachtgever. Mijn advies zou zijn: doe het nu goed, dus volledig verwijderen van asbest. De beste oplossing voor de lange termijn.

BS **Bram Staals** · a month ago

Ik adviseer om alle asbest volledig te verwijderen:
Alleen saneren waar dit voor de elektra of loodgieter werkzaamheden nodig is, is niet verstandig. Dit roept veel vraagtekens op bij de bewoners en kan invloed hebben op de het scenario. (Gelijke behandeling voor bewoners)
Ik vind ook dat de extra kosten voor WB zijn, omdat het te wijten is aan nalatige registraties in het verleden. Dit kan niet ten koste gaan van de winstpot van het bouwteam.

Ben Visser · Facilitator started a proposal: Het voorkomen van een tweede asbest fiasco. · a month ago

Het voorkomen van een tweede asbest fiasco.

Started by Ben Visser · Facilitator · Closed a month ago

Stemming alleen bedoeld voor:
Mister MvD Ready to Play, Feicko, Bram en Rob

Antwoorden op geanticipeerde vragen van het bestuur:

- Kunnen we het asbest naast verwijderen op duurzame manier afschermen voor de bewoners en welk verschil betekent dit in de kosten?

Antwoord:
De onder-aannemers geven aan voor de lange termijn oplossing te gaan.

- Als we het asbest duurzaam afschermen wat betekent dit dan voor de waardeontwikkeling van het vastgoed op de termijn, rekening houdend met het risico dat het asbest onder strengere wetgeving alsnog verwijderd moet worden?

Antwoord:
N.v.t. vanwege de keuze voor de lange termijn oplossing.

- Welke fouten zijn er gemaakt tijdens inventariseren, waarom, wat hebben we daarvan geleerd, en hoe kijken we als keten tegen de verdeling van de kosten als gevolg van deze fouten.

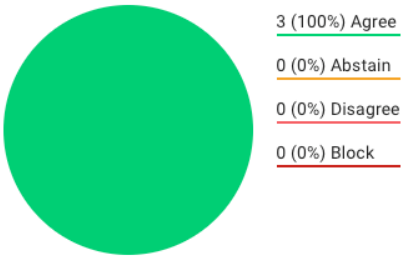
Antwoord:
Doordat de bewoners zelf aanpassingen gemaakt hebben aan de woning is het overzicht over waar zich asbest begeeft verloren geraakt. Wel was na 2013 bekend dat dit een bestaand risico is. Door lering van het asbest-fiasco in 2013 heeft WB daarom over de afgelopen 5 jaar een asbest pot opgebouwd. Om voorbereid te zijn op dergelijke ontwikkelingen. De keten heeft ook laten weten dat dit niet ten kosten kan gaan van hun winstpot. De kosten worden dus opgevangen door WB.

Ontwikkeling:
Nu dat de bewoners gehoord hebbend dat al het asbest verwijderd zal worden is het draagvlak omhoog geschoten naar 95% (scenario 3)!

Voorstel:
Blijkbaar heeft 50% van de woningen het asbest in het plafond. Dit komt neer op (320x0,95x0,5=) 152 woningen. Voor 2250,- euro p/w zou dit neerkomen op (2250x152=) 342000,- euro. (Mark, is dit de kale kost prijs?)

Door "Agree" te stemmen stemt de keten ermee in dat de sanering kan gescheiden tegen kale kost-prijs. Dit zou een mooi gebaar zijn naar WB. Ook omdat met deze afhandeling de te verdelen winstpot vergroot wordt!

Results



23% of members have stated their position (3/13)

Votes — Newest first

BS **Bram Staals** Agree

Lijkt me een goed voorstel.
Doet me goed dat MmvdRTP tegen kostprijs wil werken ten behoeve van de gehele keten 🙂

Of zou het nodig zijn dat we hem om een spacificatie van de € 2.250,- vragen? 🤔

R **Rob** Agree

Aangezien het asbestsanering betreft, heeft dit geen financiële consequenties voor ons als elektriciën. Als ik asbestsaneerder zou zijn, dan zou ik het niet reëel vinden om alleen de kale kostprijs door opdrachtgever te laten betalen.

MMR **MIster MvD ready to play!** Agree

Voorstel klinkt aannemelijk

Ronde 3

"Ronde 3": De Afrekening

Ben Visser · Facilitator · a month ago · Private · Seen by 8

Vrees niet! De rondes waar jullie input voor nodig is zijn afgerond. Dit is dan ook enkel om iedereen te laten zien hoe de geautomatiseerde facturering in zijn gang zou gaan.

In principe zou het dus zo moeten zijn dat alle activiteiten per woning zichtbaar zijn. Bijvoorbeeld met behulp van een programma als Kumu: https://kumu.io/benvisser1/t-ven-element-systeem

Dit zou dan ook de meterkast-lijst vervangen. Waardoor per woning te zien is hoe ver de werkzaamheden zijn. Hierdoor kan het systeem maandelijks controleren welke werkzaamheden er precies afgerond zijn. Op basis van de afgeronde elementen wordt dan automatische een factuur gecreëerd. Deze wordt dan ook door het systeem verzonden naar de juiste partij. Dat zou er dan uitzien zoals de bijgevoegde facturen. (Hier is nog geen Meer of Minder Werk post in opgenomen)

Dat geldt dus voor de tussentijdse betalingen, bijvoorbeeld op maandbasis. De winstpot wordt pas helemaal aan het einde van de rit verdeeld. Gebaseerd op de meest actuele verdeelsleutel. Die gedurende het hele project automatisch up-to-date is gehouden. Het project is officieel afgelopen als iedereen aan zijn verplichtingen voldaan heeft, iedereen zijn geld ontvangen heeft en iedereen akkoord is met het eind-resultaat

Uiteindelijk zou het zo moeten kunnen zijn dat het overeengekomen budget aan het begin op een derdengelden-rekening gestort wordt. Waar de maandelijkse betalingen automatische uit worden gedaan. De figuurlijke stok achter de deur die de aannemer nu heeft om onder-aannemers in het gareel te houden, door middel van financiële prikkels, wordt in dit systeem vervangen met sociale prikkels. Bijvoorbeeld door middel van het reputatie-systeem.
Het zou dan voor de hoofd-aannemer geen probleem meer moeten zijn om te werken met een derdengelden-rekening. Hiervoor moet het gehele systeem wel vlekkeloos werken. Dus dit zal voorlopig nog niet aan de orde zijn. Ik meld dit slechts om een toekomstbeeld te schetsen.

Attachments

- Factuur HR - 18003.pdf — a month ago
- Factuur Electricien - 18002.pdf — a month ago
- Factuur Loodgieter - 18001.pdf — a month ago