KLEISSEN BOUWMANAGEMENT EN ADVIES

#HOUDBAREHUISVESTING

Setting up circularity objectives to structurally implement circular construction

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Preface

Dear reader,

This thesis concludes my Bachelor Industrial Engineering and Management at the University of Twente, Enschede. As well sustainability as construction always sparked my interest. I was fortunate to work on a project that included both. During the past months, I have executed a research project at Kleissen & Partners Oost B.V. in Hengelo. The project's goal was to make a first step towards structurally implementing circularity in their construction projects. The process of managing construction projects of this size with all kinds of parties and unforeseen risks involved makes me enthusiastic. The assignment was interesting, exciting, and educational. I would like to thank Kleissen to work with them and gain insight into the world of managing residential and utility construction projects.

First, I would like to thank my company supervisor Eugenie Knaap for her guidance in the overall process. She always took the time to advise and help me. Together we narrowed the scope and determined the goal of the research. Furthermore, I would like to thank all my colleagues at Kleissen for providing me contacts and information when needed. I appreciated the open and helpful atmosphere at Kleissen. It made me feel welcome from the beginning. Everyone at Kleissen gave me the feeling that they were interested in my research and willing to contribute. Since I had no construction experience, the first plan was to follow up with a project manager to get known with the process. However, due to COVID-19, this was not allowed, which took me some extra time to get a clear picture of the process. Kleissen gave me a workplace in the office, which enabled me to work efficiently and interact with my colleagues.

From the University of Twente, I would like to thank my first supervisor Devrim Yazan, for the open and relaxed meetings and for providing me with valuable feedback. Also, I would like to thank Luca Fraccascia for being my second supervisor. Furthermore, a special thanks to my friend and buddy Dennis Zuidema helped me well during the research process.

Janos van Galen, 01-09-2020

Management summary

Problem identification

This research starts with a problem of Kleissen & Partners Oost B.V. Kleissen is a construction management agency that advises its clients on construction projects and processes. The company currently counts 16 employees. Kleissen wants to be progressive on all sustainability aspects, which is why they have set up the label called #HoudbareHuisvesting. The label contains sustainability objectives that can be implemented in a construction project. Following Kleissen, these sustainability aspects include circularity aspects. The label should be part of the working method of a project manager. However, the experienced problem is that Kleissen does not structurally and consequently implement the label's sustainability objectives. For Kleissen, it is unclear how to approach clients to introduce objectives to start implementing sustainable construction. Also, the interests of architects and contractors regarding circularity are unknown. Since the label is not structurally applied for every project, circular construction is currently only occasionally and unorganized implemented in projects. Kleissen wants to focus more on circular construction. This research investigates the possibility of setting up circularity objectives and find out the stakeholders' interests regarding circularity. This way, a first step should be made towards structurally implementing circular construction in projects.

The main research question that is answered in this thesis is:

''What are the circularity objectives that form a method to implement circularity in construction projects structurally?''

The selected core problem is:

''There is a lack of a method containing circularity objectives based on the interests of Kleissen's stakeholders.''

Method

To identify a way of structurally implementing circular construction in projects, several stages have passed. The research starts with setting up a theoretical framework on circular construction. This framework is based on literature and interviews with circularity experts and forms the research's starting point.

The first step in assessing the current situation of Kleissen starts with the label #HoudbareHuisvesting. The label is compared to the theoretical framework to check whether it contains all the circularity aspects. Kleissen's prescribed working method and way of tendering are analyzed regarding circularity implementations. Also, a visualization of the supply chain of Kleissen is made to understand the construction management process of Kleissen thoroughly. The flowchart will later support in finding out where and how to implement the circularity objectives.

Through interviews and a survey, the interests of stakeholders are assessed. The stakeholders are architects, contractors, and clients. Exploratory research on the survey's output is conducted to find patterns in the data that could indicate possible relations in the respondent's choices. These relations and patterns can tell more about the stakeholders' interests than only the survey results. The findings can later be used to specify the circularity objectives.

Finally, based on the theoretical framework, the main objective and sub-objectives are given. The circularity objectives will support implementing circular construction. In order to achieve the circularity

objectives efficiently, a change of the current working method is recommended. By refining the circularity objectives based on the stakeholders' interests, stakeholders can be more effectively approached to implement circular construction. Any project manager on different projects can apply the circularity objectives.

Solution

The solution consists of circularity objectives that can be applied by any project manager on any type of project. The circularity objectives consist of a main objective and sub-objectives. Achieving sub-objectives will get us closer to achieving the main objective.

The main objective of circular construction is: **protect the material sources**. Circular construction should have the objective of protecting the sources of materials. This objective can be achieved by achieving the sub-objectives:

- **Reuse materials when managing a construction project.** In a construction project, a distinction must be made between renovation and new construction. During the renovation, a search must be done for materials that can be reused per material category. In the case of new construction, there must be a local search for secondary materials per material category.
- **Design for disassembly when managing a construction project.** In a construction project, dry connections between materials should be designed and constructed. Materials can be easily and cleanly detached, which simplifies the reuse of materials when the building enters its ending phase. Also, this makes it possible to easily change buildings in function and size.
- **Use circular materials when managing a construction project.** This means that in a construction project, the focus should be on using materials that come from sources that can recover fast. Per the material category, materials that are exhaustive for the earth should be replaced by these circular materials.

Motivating the stakeholders to construct circular is important to achieve the sub-objectives. For this reason, the interests of the stakeholders were analyzed. Stakeholders can be approached with circularity objectives that fit their interests. This will result in a greater chance that sub-objectives will be achieved, and hence circular construction will occur. These circularity objectives are not mentioned in this section because they are based on conceptual interests, which is explained in section 6.3.

The solution involves a change in the current working method. Without a change, there is little chance that the circularity objectives will lead to structurally implementing circular construction. The following adjustments and additions to the current working method have been proposed to start constructing more circular:

- Integrate circular construction as an action in every phase of the phase plan. The project manager has to discuss the circularity objectives in every phase with the client;
- Make circular construction part of the transition document. After every phase, the current status of the circularity objectives is checked;
- Include the circularity objectives as requirements in the request of a tender. Architects and contractors will be stimulated to think along and come up with circular solutions;
- Report the used circularity objectives and applications. A database containing this information will contribute to improving the circularity objectives.

Table of content

1. Introduction

To finish my bachelor Industrial Engineering and Management at the University of Twente, research has been conducted at Kleissen & Partners Oost B.V. to find an optimal way of structurally implementing circular construction in their projects. This chapter is an introduction to the research. Section 1.1 introduces the company and the company structure. Section 1.2 identifies the action problem, whereas section 1.3 focuses on the identification of the core problem. The research design is elaborated in section 1.4, after which the main deliverables are described in section 1.5

1.1 Company information

Kleissen is a process- and project- construction management agency situated in Hengelo with currently sixteen employees. This company gives advice and guides clients through the whole design and construction process of residential and utility construction. This can be done from the first idea until the delivery of the building. With their label '#HoudbareHuisvesting', Kleissen wants to make (existing) housing ecological, social, and dynamically more sustainable. Kleissen focuses on five work fields: education, care, residential, culture, and business accommodations. Most projects are currently in the education, care, and residential work field. Through advising and managing projects, Kleissen relieves the client of the heavy task of managing a construction project. However, the client is still responsible for making key decisions.

1.2 Problem introduction

The law already covers other sustainability requirements, but there are no requirements on circularity yet. Circular construction is becoming an increasingly important topic. The Ministerie of Infrastructuur and Waterstaat (2019) explains that The Netherlands has to use 50% less primary raw materials by 2030. By 2050, the Netherlands wants to have a fully circular economy (Ministerie van Infrastructuur en Waterstaat, 2019). The Dutch Ministry of Infrastructure and Water Management (2019) sees this as an economy without waste, where everything revolves around reusable raw materials. Kleissen wants to be a forerunner and be experienced regarding circularity instead of waiting for the government to set regulations on circularity in construction. Following Kleissen, their label called #HoudbareHuisvesting contains circularity aspects. However, every project manager has to fulfill the concept of #HoudbareHuisvesting by themselves. This leads to no circularity implementations or implementations based on the project manager's own interpretation and circular construction knowledge. The company wants to know how they can structurally make their projects more circular.

According to Kleissen, the problem is that circularity is not structurally implemented in construction projects they manage. There are no clear circularity objectives that form a standard for every project.

Their problem is mainly caused by the fact that there is no standard work method containing circularity objectives to efficiently approach clients to implement circularity. When project managers can convince clients in a way that circular construction is interesting for them, clients would be more likely to cooperate.

1.3 Problem identification

We discern a core problem to (partly) solve the presented problem. This is done by using a problem cluster and criteria that core problems should satisfy (Heerkens & van Winden, 2016). We shortly analyze the core problem to determine the current and desired state. Finally, we derive a research question from the core problem to clarify the goal of this research.

1.3.1. Problem cluster

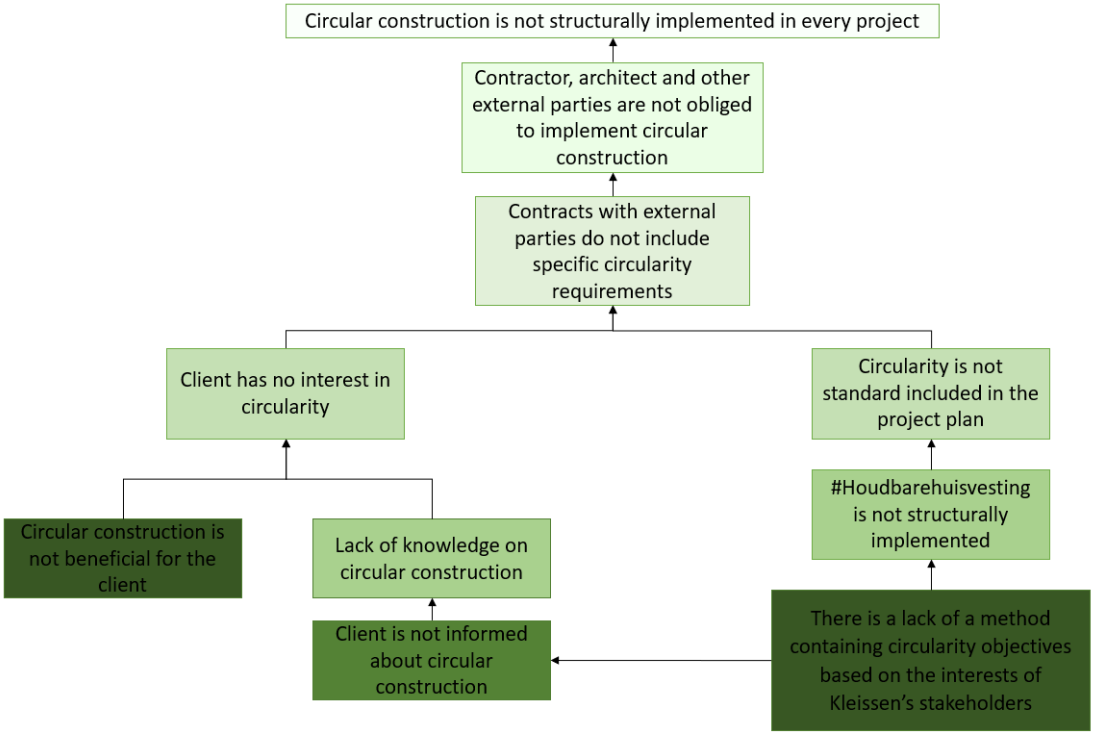


Figure 1: Problem cluster

The problem that Kleissen explained is formulated as 'circular construction is not structurally implemented in every project.' Kleissen wants to be a forerunner in implementing circular construction instead of waiting for the government to set up regulations. The problem explained by Kleissen is the largest encountered problem, so it is placed at the top of the problem cluster (Figure 1). Starting with this problem, we can further discuss the problem cluster. This problem cluster describes the problems Kleissen faces, linked with the provided problem. A problem connected to a problem from a higher layer (lighter color in Figure 1) means that the problem from the lower level (partly) causes the upper problem. Starting with the presented problem at the top, each problem is researched to find potential causes. One problem causes the presented problem. This problem is that external parties are not obliged to implement circular construction. This problem is caused by other problems and so on (see figure 1).

In the fourth layer (up to down) of the problem cluster, two problems cause the upper problem. The two problems causing the upper problem are 'client has no interest in circularity' and 'circularity is not standard included in the project plan.'

The left problem in the fourth layer, called 'the client has no interest in circularity,' can be caused by the fact that circular construction is not beneficial for the client. The client has no interest because it does not bring the client anything. There is no other problem causing this problem. Another problem that can cause the client to have no interest in circular construction is a lack of knowledge about circular construction. The client does not know what it means, which makes the client decide to ignore circular construction and put no effort into understanding it. A problem causing a lack of knowledge about circularity is that the client is not informed about circular construction.

The right problem in the fourth layer is called 'circularity is not standard included in the project plan.' When circularity is not standard included in the project plan, this is due to not structurally implementing the label #HoudbareHuisvesting. With this label, Kleissen focuses on applying sustainability, including circularity.

The circularity part of this label is not structurally implemented because there is no method containing circularity objectives that are based on the interests of the stakeholders. A method with objectives regarding circular construction can support a project manager to start structurally implementing circularity in projects.

The procedure used in the problem cluster led to two problems without causes. A problem with no causes (not linked to another problem downwards) is considered as a possible core problem. Solving a core problem leads to solving the upper problems as well. The following two problems remain (from left to right in figure 1):

1. Circular construction is not beneficial for the client;
2. There is a lack of a method containing circularity objectives based on the interests of Kleissen's stakeholders.

The two problems must be reduced to one core problem. This project is entirely focused on finding a solution to this problem. First, the chosen core problem should be influenceable by the problem solver (Heerkens & van Winden, 2016). Problem one cannot be influenced by the problem solver. The client decides for itself whether circular construction is beneficial or not. This problem, therefore, no longer belongs to possibly being the core problem. Problem two is influenceable by the problem owner and also influences two upper problems in the problem cluster. Furthermore, the problem appears to be solvable in ten weeks by means of the methods learned in the IEM program.
To solve problem two, Kleissen needs a clear approach of implementing circular construction and find out all stakeholders' interests. Therefore, the chosen core problem is:

''There is a lack of a method containing circularity objectives based on the interests of Kleissen's stakeholders.''

1.3.2. Action problem

Since we distinguished the core problem, we can now derive an action problem. An action problem describes the current and desired state of a certain problem. Our core problem describes the lack of a method containing circularity objectives based on the interests of Kleissen's stakeholders. From the problem cluster (Figure 1), we derive that Kleissen needs to have circularity objectives to structurally implement circularity in projects.

The action problem has been determined as the following:

''The implementation of circularity in projects is unorganized, this should be improved by setting up circularity objectives that can be adopted in project plans.''

1.3.2.1. Reality

Reality describes the current situation. The reality of this action problem is the fact that circularity is not implemented or implemented based on project managers' or clients' interpretation of circular construction. Kleissen has created the label #HoudbareHuisvesting. The label explains objectives regarding sustainability. Following Kleissen, circularity is included in the label. However, the label is not structurally and standard disseminated in every project. Furthermore, Kleissen's prescribed working method does not contain actions to approach stakeholders to implement circular construction effectively. Also, tender requests do not contain specific requirements for circular construction. There is a lack of a clear method with objectives to implement circular construction. To implement circularity, Kleissen must verify their interpretation of circular construction. Therefore, a theoretical framework on circular construction is made and checked with the concept #HoudbareHuisvesting. In order to set up an advised method and circularity objectives, the interests of stakeholders need to be found. This research describes the steps taken to improve the current situation.

1.3.2.2. Norm

The norm gives the desired situation. In the problem at hand, the norm represents a method that project managers of Kleissen support to more structurally implement circular construction. Kleissen explained that circularity objectives that fit the stakeholders' interests would help them in (partly) solving the encountered problem. Based on the ten weeks of this project, we collectively decided to set up circularity objectives that will support protecting the material sources. To achieve the circularity objectives, a change of the current working method is advised.

1.3.3 Research question and goal

A research question is needed to solve the previously introduced action problem. This entire project aims to answer this question and solve the action problem. The solution to this problem lies in setting up circularity objectives that can be adopted in the project plan. The research question is formulated as follows:
The main research question is:

''What are the circularity objectives that form a method to implement circularity in construction projects structurally?''

The goal of the research is to answer this question. In other words, circularity objectives will be set up to enable Kleissen to more structurally implement circularity in projects. Setting up circularity objectives can support in convincing clients to implement circular construction and stimulate contractors and architects to come up with circular applications. Kleissen can choose for themselves whether they are going to incorporate (some of) the objectives.

1.4 Problem approach

A problem-solving approach is formulated in this section using the defined problem and research question. This approach is designed through the MPSM and the 'Do, Discover, Decide' principle (Heerkens & van Winden, 2016). The different knowledge questions form the fundament for the approach. The research design describes all activities involved per knowledge question. The answers to each of these knowledge questions serve to eventually answer the research question.

1.4.1. Knowledge questions

To be able to identify a way of structurally implementing circularity in projects, knowledge questions are answered.
The following knowledge questions guide through the research:

- How can circular construction be formulated?
- How is circularity currently implemented in projects of Kleissen?
- How does the current supply chain of Kleissen's construction management process in general looks like?
- What are the interests of the company's stakeholders, and how do they interpret circularity in construction?
- What circularity objectives do other organizations operating in residential and utility construction set in their project plan?
- What should be the main and sub-circularity objective(s) for Kleissen?
- What are the conceptual circularity objectives that are in the interests of the stakeholders?

1.4.2. Research design

In this section, the knowledge questions are more deeply elaborated. The main steps, activities, and purpose per knowledge question are given.

1.4.2.1 Literature research and circularity experts interviews

First, literature research is conducted to find out more about circular construction. The literature research shows what the current knowledge and solutions for circular construction are. Interviews with circularity experts are conducted to gain insight into the current practical execution of circular construction. The most important facts found about circular construction in the literature and interviews are then summarized as key findings for this section. A clear formulation of circular construction is needed to be able to relate and motivate every action taken. A theoretical framework is set up based on the key findings of this chapter. This framework will later support in setting up questions for the second round of interviews and the survey. The second round of interviews will be conducted with stakeholders. The theoretical framework answers the following question:

- **How can circular construction be formulated?**

1.4.2.2 Kleissen case study

After the literature research and interviews with circularity experts, Kleissen's current situation is assessed. The case study shows that the problem can be justified. First, the label called #HoudbareHuisvesting is checked whether it contains the aspects of circular construction mentioned in the theoretical framework. Kleissen provided a phase plan of how projects are managed. They also provided access to transition documents, tender guidelines, and other project-related documents. The documents are analyzed to determine the current implementation of circular construction. The problem can be justified by conversations with project managers. The first question that is answered in this chapter is:

- **How is circularity currently implemented in projects of Kleissen?**

As mentioned, a phase plan of how projects are managed was provided. Using a tool, the supply chain of Kleissen's construction management process, in general, is visualized to better understand the process. The visualization of the supply chain is based on the phase plan and conversations with project managers and project coordinators. This gives an insight into when stakeholders are involved and how or where the solution should be implemented. The second question that is answered in this chapter is:

- **How does the current supply chain of Kleissen's construction management process, in general, look like?**

1.4.2.3 Stakeholders' interests

To find the company's stakeholders' interests, interviews with clients, architects, and contractors were conducted. This is the second round of interviews in this research. Furthermore, a survey was sent to stakeholders containing questions where the respondent has to rank the importance of different aspects of a construction project. The interviews and survey should indicate to what extent circular construction currently plays a role for the stakeholder and to what extent stakeholders are open to it. The survey results are used to conduct exploratory research to find patterns that can indicate a relation between some interests. This chapter focuses on answering the following question:

- **What are the interests of the company's stakeholders, and how do they interpret circularity in construction?**

1.4.2.4 Circularity approach at other organizations

In this chapter, desk research and the third round of interviews are conducted to find circularity objectives or certain approaches of other organizations. In case other organizations already clearly stated circularity objectives in their project plan, Kleissen could learn from these objectives and might adopt them. A number of organizations that proclaimed they focus on circular construction were asked

for an interview. Only two organizations were open to an interview. This chapter is centered around the following question:

- **What circularity objectives do other organizations operating in residential and utility construction set in their project plan?**

1.4.2.5 Objectives

The circularity objectives will be fully based on the findings of this research. Based on the theoretical framework of circular construction, the main circularity objective is found. The main objective is supported by three sub-objectives that are based on the strategies mentioned in the theoretical framework. The sub-objectives form the base of the solution since these objectives should be achieved to implement circular construction. The first question that is answered in this chapter is:

- **What should be the main and sub-circularity objective(s) for Kleissen?**

Through exploratory research on the survey's output, the interests of the stakeholders are analyzed to set up possible circularity objectives. The possible circularity objectives are based on relations found in the output of the survey. The project managers should be able to convince the client to cooperate and achieve the objectives. These objectives can be used as examples of a way on how to formulate the interests as objectives. The second question that is answered in this chapter is:

- **What are the conceptual circularity objectives that are in the interests of the stakeholders?**

1.5 Deliverables

The goal of this project is to formulate circularity objectives that make Kleissen structurally implement circular construction in their projects. The objectives should enable an efficient way of approaching clients with circular construction. Thereby, it should also give an insight into how the current working method should be adjusted in order to achieve the circularity objectives.

1.5.1. Flowchart

The first deliverable is a visualization of the supply chain of the general construction management process of Kleissen. This flowchart gives insight into how projects are managed and when certain stakeholders are involved. Two visualizations are made, a specific model and a simplified model. The specific model shows all details and the actions per stakeholder. The simplified model only describes the most important actions of a project manager in a construction project. Kleissen can also use these flowcharts themselves to create more overview.

1.5.2. Circularity objectives and recommendation

The main deliverables are the circularity objectives accompanied with an advised change of the current working method. The circularity objectives are centered around the theoretical framework of circular construction and form a method for every project manager to efficiently approach clients to implement circular construction. Also, the interests of stakeholders and examples of objectives based on these interests are given. The recommendation describes the advised method of approaching clients to make the first attempt towards circular construction.

1.5.3. Report

The last deliverable is this report. It provides readers with the needed knowledge to understand the project and the procedures in the correct way. The goal of the report is to clarify the overall process during the research, the choices, the outcomes, and the assumptions that are made.

2. Literature research and interviews

In this chapter, we discuss the literature research and conducted interviews with circularity experts. This chapter is divided into different sections. In section 2.1, we discuss the literature on circular construction. This regards how circular construction is currently defined by literature and an independent platform. In section 2.2, interviews with circularity experts are discussed. Interviews are conducted to obtain information from the people that handle circular construction on a day-to-day basis. Section 2.3 explains the theory of the CB23' platform. This platform currently develops a way to measure circularity. Section 2.4 shortly concludes the findings of the literature research and the interviews with circularity experts. In section 2.5, a theoretical framework on circular construction is set up. The framework is based on desk research and interviews with experts. This framework forms the fundament of the research since this is the optimal way of interpreting circular construction. This chapter focuses on answering the following question:

- How can circular construction be formulated?

2.1 Desk research circular construction

The first part of the research focuses on literature research on circular construction. The goal is to gain more knowledge about circular construction and find different circular solutions. The literature research shows that recently more and more researches about the interpretation and execution of circular construction are conducted. The second part investigates the information provided by the CB23' platform. Together with all types of organizations, this platform is currently setting up a way to measure circularity. The focus of this section, in its entirety, is on finding definitions and solutions of circular construction.

2.1.1 Literature research circular construction

Literature research is executed to find a gap in the literature to justify the research question. Also, the literature research will be used to set up a theoretical framework. The framework will later assist in coming up with a solution and act as the optimal interpretation of circular construction.

Useful articles related to the research question are found. In particular, recent articles can be found for circular construction. Little has been written about circular construction in the distant past. By searching for circular solutions, literature will provide current interpretations of circular construction and how to execute it. When literature explains how circular solutions can be achieved, then this will theoretically support in answering the research question of this project. If not, it shows that there is a gap in the literature, and we are still in a phase of defining circular construction.

For the literature research, an article by Gallego-Schmid, Chen, Sharmina, and Mendoza (2020, p. 121115) is used as a starting point. This is the most recent article consisting of a literature review about all kinds of circular economy solutions in the construction environment. From this starting point, every circular economy solution is analyzed, and different articles are assessed.

During construction, 10-15% of the building materials are wasted, and 54% of demolition materials are landfilled because they are unsuitable for reuse due to their toxicity (Gallego-Schmid, Chen, Sharmina, & Mendoza, 2020, p. 121115). As mentioned in the article by Gallego-Schmid et al. (2020), all recent circular economy solutions in construction are mentioned and reviewed based on their impact on greenhouse gas reductions. The circular economy solutions are not selected based on a relation to greenhouse gasses.

The first circular economy solution found is slowing resource loops. This solution is devised by Eberhardt, Birgisdóttir, and Birkved (2018, p.670) and consists of reusing at the product level, reusing

at the sector level, refurbishment, and durability. Following Eberhardt et al. (2018), reusing at the product level is most efficient when products are designed for disassembly to facilitate the reuse of materials. Reusing at the sector level means that materials will be reused at a sector-wide perspective, including business model and policy considerations. Refurbishment in construction is seen as extending the lifespan of buildings by making small adjustments to the building. Durability is explained by research from Campbell (2019) on mass timber. The research explains that durability consists of four approaches: modify less, increase adaptability, loop (increase inner circles), and sell a product as a service.

The second circular economy solution is closing resource loops (Gallego-Schmid et al., 2020, p. 121115). Closing resource loops is considered upcycling. This solution is devised by Sung (2015) and defines upcycling as a recycling process in which used materials are converted into something of the same or higher value/quality in their second life. For example, Hertwich, Ali, Ciacci, Fishman, Heeren, Masanet, and Wolfram (2019, p.43004) show that new methods to upcycle hydrated cement waste into new cement help reducing CO2 emissions by 30%.

The third circular economy solution in the built environment is narrowing loops. Narrowing loops are all about material optimization and material substitution. Gallego-Schmid et al. (2020) consider material substitution and design optimization as the main parts of narrowing resource loops, assuming that the new material choices are less material- and/or energy-intensive. In other words, fewer sources or other sources are used on the product- or design level. Hertwich et al. (2019) show in their research that material substitution in new buildings is considered as product-light weightings, such as replacing steel and concrete with wood.

Three circular solutions in a construction environment are mentioned. All solutions are defined as loops. The circular economy in construction is about slowing, closing, and narrowing the loops of materials. The solutions are summarized in table 1. Gallego et al. argue that the circular economy solutions in the built environment do not always result by default in emission reductions because, in order to carry out some solutions, emissions will be released again. However, all studies show that emission reductions can be achieved at the product level. Studies about slowing resource loops have demonstrated that substantial greenhouse gas savings can be achieved (up to 99%) per functional unit (Gallego-Schmid et al., 2020). The most promising circular economy solution for reducing greenhouse gasses is material reuse. Design for disassembly plays a key role in achieving separate material streams for further reuse and recycling when materials can no longer be reused in construction. For closing loops, reviewed articles show substantial reductions (between 30% and 50%) in greenhouse gas emissions for some recycled construction materials compared with virgin materials. However, quite a few studies agree that the level of emission reductions can be affected by the logistics of delivering recycled materials. Besides, virgin materials could become a lower carbon option if transportation is emission-intensive. For narrowing loops as a circular economy solution at a construction level, several articles show a significant impact of solutions such as design optimization or material substitution. However, there are barriers to the development of these solutions. The barriers to these solutions are high initial costs, limited information and public awareness about their benefits and expenses, and limited political support.

In conclusion, studies thus show that depending on the solution and functional unit considered (e.g., a component, building square meter, a product, or an entire infrastructure), emissions can drop by 5% up to 99% (Gallego-Schmid et al., 2020). Also, effectively combining circular economy solutions contributes to a higher drop in emissions. This indicates that every step towards a circular economy, such as refurbishment, reuse, and materials upcycling in the construction environment, yields a positive contribution to environmental and greenhouse gas savings. Still, it is important to keep in mind

that manufacturing more recyclable or reusable versions of construction products can lead to higher emissions than non-recyclable or non-reusable versions of the same products, particularly if the more circular versions are not reused and recycled at the end-of-life. This is why Campbell (2019) emphasizes that a cradle-to-grave life cycle perspective considering the embodied emissions of the materials is crucial for analyzing the effects of circular economy solutions that change how construction materials are designed, sold, used, and treated at the end of life.

Table 1: Circular economy solutions in a built environment

	Short explanation	Examples of the solution	Examples of greenhouse gas savings	Possible disadvantages
Slowing resource loops	Extending a product's useful life	Reuse of materials (at the product level and sector-wide); design for disassembly; refurbishment	Reuse of materials: up to 99%	Use of virgin materials cheaper than secondary materials
Closing resource loops	Upcycling of materials	Converting secondary materials to the same or higher value/quality their 2nd life	Upcycled construction materials: between 30% and 50%	Logistics of delivering recycled materials highly affect emissions
Narrowing resource loops	Using fewer sources per product	Design optimization; material substitution	Design optimization: reductions of up to 9.23 Mt CO2 eq. for years 2023-2027 in the UK. Material substitution: reductions of up to 19.82 Mt CO2 eq. for years 2-23-2027 in the UK	High initial costs, limited information, and awareness about the benefits and expenses, limited political support.

2.2 Interviews circularity experts

In this section, the first round of interviews is described. Interviews with circularity experts have been conducted to approach the problem also from a practical point of view. The interviews aim to determine how circularity experts define circular construction and how it should be implemented. Besides, the interviews will support in setting up interview and survey questions for stakeholders. This way, the questions are not only based on literature findings of this chapter but also on practical knowledge.

The experts have a lot of information and experiences in the field of circular construction. In this section, the answers of the experts are summarized, and their interpretations of circular construction are pointed out. Four circularity experts are interviewed. By the duty of confidentiality, only their titles within their organization are mentioned.

We refer to the experts through four letters:

- W: Sustainability manager at a circular consultancy that is affiliated to a contractor;
- X: Architect of a progressive architectural firm;
- Y: Product owner and co-founder of sustainable services;
- Z: Director at a circular consultancy that is affiliated with a contractor.

According to W, circular construction starts with using materials that can easily be reused and substituting traditional materials with materials that are (more) environmentally friendly. Products that have to burn in their end-of-life are part of the so-called linear materials. These materials have to be out banned. As an example, W mentions PIR panels, used as isolation material. This is a material that, in its end-of-life, only can be burned. This means that in this material's end-of-life, greenhouse gasses are released. If this product is replaced by a circular material, the product can be reused multiple times and environmentally friendly, degraded in its end-of-life. Following W, the optimal way of implementing circularity in construction would be to only use environmentally friendly materials that can be reused, constructing detachable buildings, and making agreements with suppliers about picking up the materials at their end of life.

At the beginning of the interview with X, X first mentions the importance of understanding the goal of circular construction. Following X, the goal of circular construction is all about protecting the sources of materials. From this perspective, every building should be constructed. Protecting the sources of materials goes hand in hand with reducing CO2 emissions. CO2 can also be considered as a source. Too much of this source causes environmental damage. When we look at the starting point of circular construction mentioned by W and assess it from X's perspective, the starting point of W can be seen as a method to protect sources and reduce CO2 emissions. Using circular materials means that materials from sources are used that can recover fast and can be environmentally degraded. Also, constructing detachable makes buildings easier to disassemble. This stimulates the reuse of materials. Reusing materials supports the material's source to have more time to recover. X explains that buildings should be constructed in a way that they are future-proof. This means that buildings should contain enough beauty and be adaptive in use. When a building contains enough beauty and fits in its environment, it is most likely that people feel connected to the building and want to keep it in their environment. Depending on the location and function of the building, the building should be built detachable. Before applying a method to protect sources, X emphasizes that keeping in mind the embodied energy of materials is very important. Embodied energy can be defined as the energy consumed in life cycle stages other than the operation, such as the processing and transportation of materials (Dixit, Culp, & Fernández-Solís, 2013, p. 160). When circular methods result in high embodied energies, it must be considered whether a more traditional way could be better.

Y emphasizes that when circular construction ambitions are too high, not all organizations can go with the flow. To slowly take a step towards a circular economy together, organizations must be given time to gain experience in circular construction. In other words, the tender requests should not contain specific circular requirements right now. Organizations should currently be offered space to let them come up with circular solutions by themselves. Y also mentioned the importance of requesting a material passport. A material passport makes a building a material depot. All materials used are documented, which simplifies reusing materials. Following X, full circular construction is not possible today. The tax system must change for this, less tax on labor, and more on environmentally harmful materials. Z confirms this with his experience and mentions that circular construction is currently more expensive than traditional construction. Z explains that purchasing circular materials is becoming cheaper. However, reusing materials is, most of the time, quite expensive and not wanted. There is a low chance that materials can directly be reused. Often the materials have to be processed before they

can be reused. Besides, clients are not always willing to use secondary materials in their building because the building has to look brand new.
If we link and summarize the experts' experiences and knowledge, it can be said that to make steps towards circular construction, the tax system is not ready for it. However, the focus should be on making small steps because this gives a higher chance of all organizations being able to shift towards circular construction. These small steps should be focused on protecting the sources of materials. From this starting point, circular methods should be implemented, but keep in mind the embodied energy of materials.

2.3 CB23' platform

During the interview with circularity expert Y, the advice was given to read the documents of CB23'. This is a Dutch platform that aims at drawing up broad agreements concerning circular construction in the national construction sector. CB23' stands for 'Circulair Bouwen 2023', which can be directly translated to 'Circular Construction 2023'. CB23 aims to create and share knowledge, inventorying and scheduling obstacles, and drafting construction wide agreements (CB23, 2019). CB23' consists of all types of members, from universities to construction companies, with a total of around 140 organizations.

In the document called 'measuring circularity,' CB23' presents a first approach to measuring circularity in construction. An action team set up this approach through cooperation with the members of CB23'. This document points out the factors that currently measure circularity in a construction project and how different circular construction terms should be defined. CB23' mentions that the core measurement for circularity in construction should focus on the following three circular construction goals (CB23, 2019):

1. Protecting material stocks;
2. Protecting environmental quality;
3. Protecting existing value.

For all three goals, different circular strategies divide their impact differently over time. For example, adaptive construction often requires a greater investment of materials in the realization phase but saves additional material use during a renovation (CB23, 2019). CB23 (2019) mentions that to compare all circular strategies, it has been agreed that the extent to which an initiative contributes to circular construction should be determined by the impact on these goals throughout the entire life cycle. Discarding a (partial) object for fulfilling its current function is seen as the end of a life cycle.

The action team of CB23 distinguishes two types of indicators in the currently available methods for measuring circularity: process indicators and impact indicators. Process indicators are indicators that measure the extent to which certain circular strategies have been applied. Impact indicators focus on quantifying the effects of using these circular strategies. A widely supported starting point for the core measurement method for the degree of circularity in construction is that this core measurement method should focus exclusively on formulating impact indicators that indicate to what extent a construction-related activity contributes to the three core objectives of circular construction: protection of material stocks, environmental quality, and existing value.

The core measurement method's input consists of a list of all information (origin, lifespan, quantity) about all materials used, information about adaptivity aspects, an MPG- or MKI calculation, and data for performing value retention calculations and loss of value. Per impact, indicator calculation rules are given. If all information is present, circularity can be measured. However, how heavily the different indicators weigh in relation to each other is still a matter of its own. This means that the same input can give a different output when different weightings per indicator are used.

2.4 Key findings of the desk research and interviews with circularity experts

Based on the desk research and the interviews with circularity experts, the key findings on circular construction are summarized. First, the key findings of the literature research and CB23's platform are given. This explains whether the research question can be justified and the most effective ways of implementing circular construction. This is followed by the key findings of the interviews with the circularity experts. This part explains the most important practical experiences from experts.

This section explains the key findings of the desk research and interviews with circularity experts. Table 2 summarizes the key findings for as well the desk research as the interviews.

The research question of this project is justified by the literature. There is no study that explains an effective way or method to construct circular. In addition, the found circular solutions do not explain how to implement them or execute them. The articles show that although the term 'circular construction' becomes more and more popular, we are still in a phase where circular construction is being defined. This also emerges from CB23's study. The platform is setting up a way to measure circular construction for one year. A next step would be to provide organizations a plan and objectives to start constructing circular.

Following the literature, quantifying the greenhouse gas emissions per construction project is an intensive and underdeveloped process. This makes applying (some) circular economy solutions based on their emission reductions very hard. However, certain methods are already proven to be always effective when it comes to greenhouse gas emissions. For example, both reusing materials and design for disassembly are methods of slowing resource loops that will always reduce emissions. Combining such methods will be even more effective in reducing greenhouse gas emissions.

Every step towards a circular economy in the construction environment yields a positive contribution to environmental and greenhouse gas savings. Still, it is important to look at every circular strategy from a cradle-to-grave life cycle perspective (Campbell, 2019). From this perspective, the materials' embodied emissions are crucial for analyzing the effects of circular economy strategies that change how construction materials are designed, sold, used, and treated at the end of life.

CB23' explains that the measurement of circular construction should focus on three circular goals:

1. Protecting material stocks;
2. Protecting environmental quality;
3. Protecting existing value.

By achieving these goals, full circular construction is best approached.

The interviews with circularity experts show that small steps towards circular construction should be made. The starting point of implementing circularity in construction should be based on the goal of circular construction. The goal is to protect the material sources. Sources are protected if they are not used and have time to recover. As mentioned by W, linear materials should be out banned and replaced by circular materials. Furthermore, the detachability of a building is important but should only be implemented in certain sizes based on the building's location and function (mentioned by circularity expert X). The experts experience reusing materials as an expensive method because there is a low chance that materials can directly be reused. Besides, the tax on labor is currently too high to process secondary materials instead of buying new materials.

Table 2: Key findings of the desk research and interviews with circularity experts

Key findings	Desk research	Interviews with circ. experts
1.	Reusing materials reduces emissions	The goal of circ. construction is to protect material sources
2.	Design for disassembly reduces emissions	Linear materials should be banned and replaced
3.	Embodied emissions of materials are crucial to analyze the effects of circ. strategies	Focus on detachability depending on the building's location and function
4.	Full circ. construction can be approached by CB23's three circ. goals	Reusing materials is experienced as an expensive method

2.5 Theoretical framework

Based on the literature, CB23's platform, and the interviews with circularity experts, a theoretical framework is drawn up to define circular construction. The framework answers the knowledge question of this chapter by formulating the main goal of circular construction and strategies to achieve this goal.

2.5.1. Goal of circular construction

Combining the literature research and knowledge of the experts, a currently applicable theoretical framework on circular construction can be drawn up. Before looking at strategies to implement circular construction, it is important to have a goal to base these strategies on. As mentioned by CB23, their future goal on circular construction consists of protecting material stocks, protecting environmental quality, and protecting existing value. The extent to which a circular strategy contributes to circular construction should be determined by its impact on these goals throughout the entire life cycle. To determine the impact on a goal, a goal should be able to be measured. Following the literature, it is quite hard to measure the protection of environmental quality. Most of the time, this is based on greenhouse gas reductions. Calculating these reductions per construction project is an underdeveloped and time-intensive process. Protecting material stocks amounts to the same as protecting materials' sources mentioned by X. This is a goal that can logically be substantiated. Every circular strategy that lowers or stops the use of a source or gives a source more time to recover contributes to protecting material sources. Protecting existing values means expanding the life of buildings and materials. This goal is already covered if the main focus is on protecting material sources. Protecting material sources includes protecting all sources of materials used in a building. By expanding the life span of a building, the sources will have more time to recover.

Even though it is hard to measure greenhouse gas reductions for circular economy solutions in construction projects, it is important to keep in mind the cradle-to-grave life cycle perspective (Campbell, 2019). Embodied emissions of the materials are crucial for analyzing the effects of circular economy strategies. Since CO2 is a source and should also be protected by not having too much of it in the atmosphere, the goal of circular construction is best described by protecting material resources. Hence, based on the above reasoning, the current goal to make small steps towards circular construction is formulated as: 'protecting material sources.'

2.5.2 Strategies of circular construction

The strategies to implement circular construction are be based on the aforementioned goal. The most effective strategies that protect resources and reduce greenhouse gas emissions are chosen based on literature, the CB23 platform, and the interviews with circularity experts. The strategies are focused

on lowering or stopping the use of material sources or giving a material source more time to recover. Three strategies form the fundament of protecting material sources: reusing materials, design for disassembly, and using circular materials.

2.5.2.1 Reusing materials

Literature shows that reusing materials has the highest impact on reducing greenhouse gasses (Gallego-Schmid et al., 2020). However, experts tell that currently reusing materials is often too expensive to apply in a construction project. Reusing materials in construction supports the source of a material to have more time to recover since the period of use is extended. The possibility of reusing materials depends on the location of the building and the type of construction. Construction types like renovation and construction at the site of a to be demolished building makes reusing materials possible. In the case of new construction, materials can be reused from other buildings that will be demolished in the area. It is important to keep in mind the costs and embodied energy of materials when focusing on reusing materials. Reusing materials can require extra time and labor to process the materials and make them meet the current construction requirements. If reusing materials causes a high embodied energy, it can be less environmentally beneficial than using virgin materials. In conclusion, reusing materials is an effective strategy. Every type of implementation will protect the material sources and have a significant impact on greenhouse gas savings provided that the embodied energy of reused materials are lower than virgin materials.

2.5.2.2 Design for disassembly

Next to reusing materials, design for disassembly is a circular economy solution that positively impacts greenhouse gas savings (Gallego-Schmid et al., 2020). However, CB23 (2019) claims that adaptive construction often requires a greater investment of materials in the realization phase. Design for disassembly is a strategy that supports the protection of material sources and is most effective when it is combined with the other strategies. A building that is designed for disassembly facilitates the reuse of materials. In case of renovation or demolishing the building, materials can easily be detached and reused. Furthermore, the building is adaptive in its type of use. When a building has to be changed for another type of user, adjustments can easily be made. The longer the building can be used, the more time the materials' sources have to recover. In conclusion, despite the expected extra costs, every implementation of design for disassembly will protect the material sources and is even more effective combined with other strategies.

2.5.2.3 Using circular materials

The substitution of linear materials by circular materials is mentioned in literature as part of the narrowing resource loops solution. Literature shows that material substitution results in substantial greenhouse gas reductions. W emphasizes the importance of banning linear materials. Currently, more circular materials are produced, which reduces the price (mentioned by circularity expert Z). However, traditional materials are, most of the time, still cheaper (mentioned by circularity expert Z). By substituting linear materials with circular materials, buildings will be constructed with materials from sources that can recover fast. In conclusion, despite the expected extra costs, every implementation of circular materials will protect the sources and reduce greenhouse gas emissions.

3. Kleissen case study

In this chapter, we discuss the current situation of Kleissen. This needs to be done thoroughly, as this is the situation we endeavor to improve. The chapter is divided into five sections. Section 3.1 addresses the first step in understanding the current situation. The section assesses Kleissen's label called #HoudbareHuisvesting. Furthermore, in section 3.2, the analyses of the current phase plan and the transition document is explained. This section describes whether circular construction is part of their prescribed working method. Section 3.3 describes the current tender procedure and how circularity is included in the tender. Section 3.4 goes deeper into the prescribed working method. Based on the phase plan, the process of construction management is visualized and explained by flowcharts. Finally, in section 3.5, a conclusion on the current situation is given. This chapter focuses on answering the following questions:

- How is circularity currently implemented in projects of Kleissen?
- How does the current supply chain of Kleissen's construction management process in general looks like?

3.1 #HoudbareHuisvesting

To start familiarizing ourselves with the current situation, we first discuss the sustainability label of Kleissen. #HoudbareHuisvesting is a method of Kleissen to give meaning to sustainable construction. The method focuses on three sustainability aspects (Kleissen & Partners Oost B.V., 2020):

1. Ecological sustainability: self-sufficient housing by making fewer claims on raw materials and energy is pursued. As a result, housing can provide for its own renewable energy, and no raw materials are used that deplete the earth.
2. Social sustainability: user-friendly housing with the result that the user is happy with pleasant learning, working, and living environment in a building that facilitates, communicates, and interacts with the environment and its users is pursued.
3. Dynamic sustainability: flexible and modular or future-proof housing, adaptable in functions, and size is pursued. Buildings that are demountable, reusable, and transformable so that we extend the life cycle because they are not designed for just one function.

Kleissen's method of giving meaning to sustainability already covers some parts of circular construction. The first aspect, 'ecological sustainability' and the third aspect, 'dynamic sustainability,' contain elements that align with the goal of circular construction and circular strategies mentioned in the theoretical framework in chapter two. The elements that align in aspect one are 'making fewer claims on raw materials,' and 'no raw materials are used that deplete the earth.' The circular strategy of reusing materials aligns with the element of making fewer claims on raw materials. If you want to use less raw materials, secondary materials have to be used. The circular strategy of using circular materials aligns with the element of not using raw materials that deplete the earth. If you do not want to use raw materials that deplete the earth, you have to use materials from sources that will not (easily) deplete. The element that aligns in aspect three of the label is 'flexible and modular or future-proof housing, adaptable in functions and size.' The circular strategy of design to disassemble mentioned in the theoretical framework aligns with this element of dynamic sustainability. If you want to build flexible and modular or future-proof housing, adaptable in functions, and size, you have to make sure that materials can easily be detached from each other.

Since these elements of #HoudbareHuisvesting align with the circular strategies of chapter two. It can be said that these elements also have the goal of protecting material sources. This indicates that Kleissen already wants to implement circular construction in their construction projects through their

label. The circularity objectives are hidden in their label and still too vague to approach clients efficiently. Besides, there is no underlying method or more specific objectives that support the project managers to structurally implement the label's objectives. This leads to the main problem mentioned in chapter one.

3.2 Phase plan and transition document

In this section, Kleissen's current way of managing construction projects is assessed. Here, the integration of circularity in Kleissen's working method is analyzed. In other words, this section explains how Kleissen currently carries out its label #HoudbareHuisvesting. An internal document, called the phase plan, contains all the steps that a project manager makes in a construction project. The phase plan can be seen as Kleissen's prescribed working method for managing construction projects. This phase plan consists of different phases containing all actions that a project manager goes through when managing a project from the start until the building's delivery and aftercare. In practice, a project manager does not use this phase plan continuously. It is more used as general guidance or a way to check whether all actions have been carried out.

The phase plan consists of the following phases:

1. General (concept);
2. Initiative and feasibility;
3. Project definition;
4. Structure design;
5. Preliminary design;
6. Final design;
7. Technical design;
8. Price- and contract formation;
9. Execution and execution-ready design;
10. Execution and management;
11. Use and exploitation.

To understand the meaning of every phase and the project management process of Kleissen thoroughly, a flowchart is made. This flowchart serves as a visualized representation of the construction management process and aids in advising on implementing the circularity objectives. An elaborated description of a detailed and simplified flowchart can be found in section 3.4. This section will extensively describe the current implementation of circularity and the label #HoudbareHuisvesting in the phase plan.

For every phase, actions for the project managers are listed that can be checked by a checklist. After finishing a phase, the project manager has to write a transition document for the client. Before sending the transition document to the client, the director of Kleissen will check the document and give feedback. After the approval of the director, the document is sent to the client. The client needs to make choices, provide clarity, and approve this document before the next phase can be entered. The transition document consists of:

- Informing the client about what has been achieved in the underlying phase, in terms of money, organization, time, information, and quality.
- Choices the client has to make.

A project can start from every phase, depending on when a client needs the service of Kleissen. Every phase roughly consists of actions related to money, organization, time, information, and quality. The concept of #HoudbareHuisvesting is executed by the action called 'sustainable construction' in the

phase plan. Sustainable construction refers to implementing the aspects of #HoudbareHuisvesting. The action 'sustainable construction' only comes forward in phase two (see detailed flowchart section 3.4). This means that if Kleissen enters a construction project from a phase after phase two and the project manager follows the phase plan's actions, there is a high possibility that sustainable construction will no longer be discussed.

As mentioned, money, organization, time, information, and quality are the main aspects of all phases. Since these are the main aspects in all phases, they are covered in every transition document. The transition document does not contain any aspects of sustainable construction. If sustainable construction were covered in the transition document, the implementations of circularity (and other sustainable objectives) would be checked and continuously discussed. Since this is not the case, circular construction is currently only mentioned in phase two and does not necessarily have to be checked. It depends on the project manager whether sustainable construction is discussed more often and adopted in (some) transition documents. In conclusion, as long as sustainable construction is not a section in the transition document, it is not checked in every phase and will not make part of the project manager's standard work method.

3.3 Tendering

When constructing a building, the client needs external parties, such as contractors, architects, and several advisors, to execute the project. Depending on the size of the assignment, the client can be obliged to submit a tender. If not, the client is allowed to choose a party by themselves. In most cases, a party enters the construction project through a tender procedure. A tender is a procedure in which an external party is selected, and the price (the contract price) for the assignment is established. In construction, strict procedures apply. Proper execution of the tender is very important. As stated by Mohemad, Hamdan, Othman & Maizura (2010), the successful execution of a construction project is heavily impacted by making the right decision during tendering processes. In case Kleissen enters the construction project before other parties are involved, then Kleissen supports, guides, and advises the client during the tendering procedures.

For every tender, tender guidelines are set up. These guidelines include the wishes and requirements stated by the client and are adopted in the project plan. Kleissen supports the client in setting up the tender guidelines. The assignment will be released following a strict procedure. Several parties are allowed to make an offer. The registrations of the parties are often assessed by the BPKV (previously called EMVI) assessment model. Other models are 'lowest price' and the 'life cycle cost model.' The lowest price speaks for itself. Parties are only assessed by their submitted price. The life cycle cost model is a complex model based on the harmfulness of materials to the environment and is rarely used (Rick Brouwer, tender manager at Kleissen, 2020). BPKV stands for 'Beste Prijs Kwaliteit Verhouding, ' which can be translated to 'Best price-quality ratio.' With quality, mainly public orientation, sustainability, and risk management are meant (Rijkswaterstaat, 2020). Kleissen uses the BPKV model to enable the client to assess the registrations fairly. A specification of the criteria in the BPKV model is based on the tender guidelines; in other words, the requirements of the client. The assignment is awarded to the tenderer whose tender meets the client's wishes best. Most of the time, this is the party that has the highest score in the BPKV assessment model. However, the client can also choose one of the other parties, but this choice should be very well motivated. The winner agrees with the client. The project plan also is part of the contract signed by the winner.

Sustainable construction is one of the criteria that, most of the time, count in the assessment of the registrations of the parties during a tender. However, in none of Kleissen's construction projects' tender guidelines, specific circular construction criteria have been requested. Parties are asked for their ambition or interpretation of sustainable construction. Since the tender guidelines and project plan do not contain specific requirements, the external party is even after the agreement free to give

its interpretation of sustainable construction. In the worst case, this could mean that the party decides not to give substance to sustainable construction after the agreement. In the best case, it could lead to new sustainable applications in a construction project. As mentioned in section 3.1, sustainable construction also covers a circular construction. This means that in the worst case, circular construction will not be honored. Suppose there are no specific requirements in the tender guidelines or the project plan, and there is a party involved that does not take sustainability seriously. In that case, there is a risk that circular construction will be neglected. Besides, the weightings per criteria in a BKPV assessment can also differ per tender. The client determines the weighting of criteria based on its wishes, general standards, and advice from Kleissen. For some clients, it is more important to have a party that focuses on sustainability. For these clients, the weighting for sustainability will be higher, leading to bigger sustainability efforts by the registered parties.

In conclusion, Kleissen currently stimulates clients to assess tenders on sustainability. However, due to the lack of clear requirements on sustainable construction in the tender guidelines, parties are free to give their interpretation of sustainable construction. This can lead to positive or negative events. Besides, every tender weighting per criterion can be divided differently.

3.4 Supply chain

A flowchart of the supply chain is needed to understand the construction management process of Kleissen thoroughly. The flowchart serves as a visualization of the construction management process of Kleissen. The goal of making a flowchart is to check the current implementation of circularity in the prescribed working method and find out where and how Kleissen could implement the circularity objectives. In this section, the second question mentioned at the beginning of this chapter is answered:

- How does the current supply chain of Kleissen’s construction management process, in general, look like?

Kleissen delivers different services, but for this research, the focus is only on the construction management service. Furthermore, the choice is made to base the visualization on the construction method called ‘bouwteam.’ Bouwteam can be translated to ‘construction team.’ Compared to the traditional form of tendering, the contractor is involved in an earlier stage of the project instead of simply executing the architect's design. There is a contractual difference between the traditional tendering and construction team. For the construction team, there is a construction team agreement in which the implementing party makes an effort to create a design together in a team. If the client and contractor agree on the work's quality and price, a building contract can be concluded. If the parties do not agree, the agreement states that the parties say goodbye to each other with some conditions. For example, the client pays the design work to the executing party, and the client is given the right to use the design documents. However, in this visualization, we assume that the contractor that enters the construction team also executes the construction project.

The choice to base the flowchart on the method ‘bouwteam’ is motivated by the fact that most of Kleissen’s construction projects are managed this way. Besides, the flowchart is largely based on the phase plan. The phase plan contains all actions in an order when ‘bouwteam’ is applied.

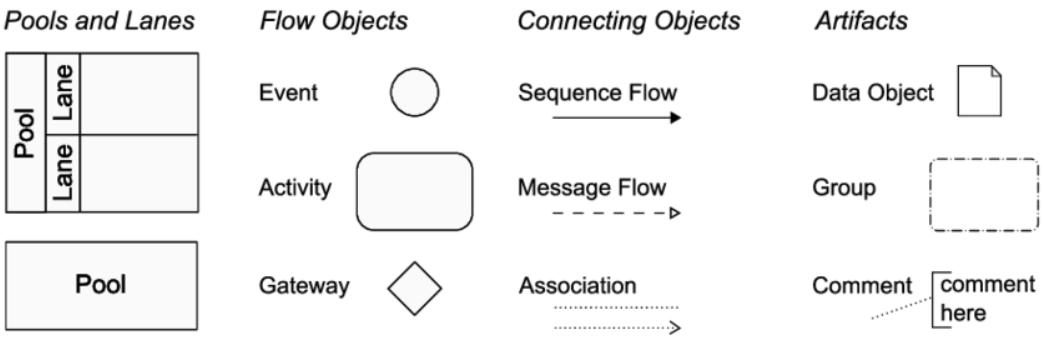
First, a detailed flowchart is discussed to get familiar with the process entirely. This version is subsequently simplified. In the second, more simplified version, the irrelevant steps are left out, and the chart is focused on the core of the process. Phase 0 (general) of the phase plan is not included in the flow charts. This phase includes all actions before the cooperation with the client is set up. For implementing circularity objectives, we only focus on the process of construction management. Thus all actions before are not included. Information needed for the flowchart was retrieved via internal documents (a.o.t. the phase plan) and conversations with Thijs Stroot (project coordinator at Kleissen).

3.4.1 Detailed flowchart

As mentioned, first, a detailed flowchart of the construction management process is discussed. The flowchart can be found in appendix B. The phases of the phase plan mentioned in chapter 3.2 form the basis of the detailed flowchart. The detailed flow chart is designed around all actions, a project manager takes at the start, during, and at the end of a phase. The detailed flowchart is designed as a swimlane diagram. This adds accountability and clarity to the chart. The swimlanes contribute to visualizing clearly who is responsible for what task. In this detailed flowchart, every actor in the process has its own lane. Particular actors that perform certain activities are placed in the corresponding. Kleissen, in its entirety, is represented as a pool. The different lanes of Kleissen's pool that represent a department or employee are placed inside this pool. All external parties have a separate pool or lane.

Not just the pool and lane symbols are used, a lot of other symbols as well. For this flowchart, the pool, lane, event, activity, gateway, message flow, sequence flow, association, and data object symbols are used (Figure 20). The meaning of most of the symbols is quite straightforward. All events represent occurrences that start or stop the flow, an activity describes an action, and a gateway splits the process into multiple possibilities. The connecting objects can connect all the previously mentioned objects, and the data object visualizes that data is stored or used.

Figure 2: Bizagi symbols



The detailed flowchart is split up into two schedules because of its size (Appendix B). The first schedule consists of phases one to five and the second schedule of six to ten. In this flowchart, as soon as a client's project is received, the process can start from different phases. The project manager determines which phase to start. In all phases, the project manager has an important task of continuous coordination between all parties and collecting all client wishes and requirements. As mentioned, every phase consists of actions related to money, organization, time, information, and quality. Although the detailed flowchart does not show to which subject every action is divided, the actions can be traced back to this.

3.4.1.1 Phase one

To clearly walk through the process, the flow chart is explained from phase one to ten. Going through these phases in real-time can be a process of years. Phase one starts with actions for the project manager to determine the client's requirements and wishes. The actors that are mainly involved in this phase is the client and the project manager. When the project manager executes all needed actions of this phase, the project manager sets up the transition document. The document is sent to the client and the director of Kleissen. After every phase, the project manager has a meeting with the director to discuss the project's progress and bottlenecks. If the transition document is approved by both the client and director, the project manager can move on to the next phase. If the client or director does not approve the transition document, the project manager should first improve the document before moving on to the next phase.

3.4.1.2 Phase two

The second phase, which can thus also be accessed from the moment a client asks for Kleissen's service, is all about defining the project. In phase 2, only the project manager and the client are involved. The project manager will set up the project plan based on the client's choices. The building type and a concept of the building will be set up. Aspects of sustainable construction and the project lead time will be discussed. Furthermore, the project manager will set up an SKO. This is the 'StichtingKosten Overzicht' and means that a cost estimation will be drawn up. If phase 2 is finished, the transition process starts. The project manager has a meeting with the director, and as soon as the client approves the transition document, the next phase will be entered.

3.4.1.3 Phase three

From phase three, more parties will be involved. This phase is all about setting up the structure design of the building. This includes activities such as setting up the program requirements, selecting advisors, and receiving an integral sketch design. In this phase, there is a lot of coordination and consultation with the client about their wishes and requirements. The general matters of the client are included in the plan of approach. One of the first actions of this phase is selecting advisors. The group of advisors mainly consist of an installation advisor, BBA advisor, constructor, and architect. Depending on the amount of money for a task, some tasks will be subject to tender. Other parties can be selected by a negotiated tender. The project coordinator can support in setting up the selection guide, and the tender expert makes sure that any tender follows the correct rules. The client determines the content of the selection guide and the selection weightings. Also, the client determines which parties to work with. The detailed flowchart shows that the advisors that applied for the task also will be the advisors executing the task. In real-life, when tendering, several parties apply for a task, and only one will get the task. To keep the flowchart clear, this is visualized with only one party per swimlane. During this phase, the project coordinator can support the project manager in several actions, such as keeping track of incoming invoices, setting up and adjusting a planning or meeting. As soon as the advisors are selected, they will deliver concepts of their advice to the project manager. The concepts of their advice are based on the requirements and wishes of the client. Eventually, after some meetings with all parties and the client has taken place, the architect has set up an integral sketch design. The project manager adjusts the project definition if needed. If phase 3 is finished, the transition process starts. The project manager will meet the director, and when the client approves the transition document, the next phase will start.

3.4.1.4 Phase four

In phase four, together with the client, the plan of approach will be further elaborated, and more external parties will join the process. The phase starts with selecting the contractor and installer. These two parties are visualized as two different lanes since, in most cases, the installer is not subject to the constructor. In some cases, other parties such as a painter or an infrastructure constructor are also not subject to the contractor. To keep the schedule as clear as possible, only these two lanes are chosen. As soon as the contractor and installer have been selected, they will join the design team. Together they form the construction team and sign a construction team agreement. Later, in phase 7, the contractor and installer will sign a building contract. In this phase, the contractor and installer will advise on the preliminary design that is made by the architect. Furthermore, the architect has to make the first application for an environmental permit at the construction site. The project manager ensures that the permit is set up by the architect. If the project manager is very busy, the project coordinator is sometimes given the responsibility to communicate with the municipality and architect about the permit. The project coordinator or project manager will communicate with the architect about the requirements of the permit. When phase 4 is finished, the transition process starts. As mentioned, the

project manager has a meeting with the director to discuss the progress and bottlenecks of the project. When the transition document is approved by the client, the next phase can be entered.

3.4.1.5 Phase five

Phase five is all about setting up the final design of the building. The project manager reviews the program requirements, receives advice on the construction and installations, and receives a final design of the building from the architect. Before advice and a final design are delivered, a lot of communication with the client takes place. All actions have to be in line with the requirements and wishes of the client. Suppose the needs of the client change, the plan of approach has to be adjusted. The architect also sets up the V&G plan consisting of an explanation of how the employees can work safely at the construction site. Later the contractor will take over the responsibility of the V&G plan. The project coordinator assists the project manager by checking contracts with the municipality and other parties, keeping track of invoices, and setting up a planning or meeting. When phase five is finished, the transition process starts. After the project manager has met the director and the client approves the transition document, phase six is ready to start.

3.4.1.6 Phase six

From phase six, the flowchart continues in the second scheme. The goal of this phase is to set up the technical design of the building. Again, the project manager reviews the program requirements. The project manager goes through actions such as setting up the scope of statements for architectural, interior, construction, and installations. The scope of statements is set up in cooperation with the construction team and the client. The project manager integrates all scope of statements in one document. In this phase, good coordination and communication with the customer about all decisions are very important. During this phase, the architect will apply for an environmental permit at the municipality. The municipality can either approve or deny the permit. Besides the project coordinator's common tasks, the project manager can give the coordinator the responsibility to ensure that the environmental permit is submitted. When the technical design is created, phase 6 ends. As mentioned, the transition process will start. When the client approves the transition document, the next phase can be entered.

3.4.1.7 Phase seven

The goal of phase seven is to set up the prices and contracts before starting the construction. At the start of this phase, parties are selected that will be responsible for the interior and the landscape around the building. The architect will set up all architectural, landscape, and interior costs. This is a negotiated tender most of the time, which means that known parties are contacted and mainly selected based on their price. These parties have little contribution to the overall construction process. They simply execute the given plans. This is why the detailed flowchart does not include these parties in a separate swimlane. The contractor and installer are already selected, but an exact price will now be determined. Negotiations between the client and the executing parties will start. The contractor and installer will set up detailed costs for executing the construction project. After the price determination and all parties agree with the prices, the contractor and installer will sign the building contract, which means that they will have to execute the building's realization. When the negotiations get stuck, the client has to find other parties that will execute the construction project and keep the rights to everything established in the design phase. This is included in the construction team agreement. The event that parties could separate in this phase is not included in the flowchart. This event does not occur often, and it makes the flowchart complex. In phase seven, the environmental permit has to be approved to start the construction. The project coordinator executes the same tasks as in the other phases. When all actions are executed, phase seven is finished. Before entering the next

phase, the transition process starts, and the transition document has to be approved by the client to move on to the next phase.

3.4.1.8 Phase eight

In phase eight, supervisory contracts are set up. The project manager sets up an architectural, interior, landscape, and construction execution documents. To determine the construction site's situation before the construction starts, the contractor conducts a null measurement and checks the nuisance for the environment. The project manager will supervise proper construction preparations. Furthermore, the V&G plan is executed. The contractor and installer have set up their execution documents. The project manager assesses these documents and approves them if they are ready for execution. The project coordinator executes its common tasks and supports the project manager. If all documents are ready for execution, phase 8 is finished, and the transition process starts.

3.4.1.9 Phase nine

Phase nine is all about executing the construction plan. In most cases, the project manager is assigned by the client as the construction site manager and supervises measurements of building physics, acoustics, and geotechnics. Furthermore, the project manager provides integral supervision at the construction site. For every construction project, there is a manager and a supervisor. The manager can be the client or a person appointed by the client. A supervisor monitors the progress of the construction project and the quality of the building. The supervisor reports this to the manager. The manager is the person who is authorized to make decisions. The detailed flowchart assumes that the project manager is appointed as the manager by the client. Depending on the importance of the decisions, the project manager has to make decisions in the client's hands. The client can also appoint a supervisor. However, in most cases, when the project manager of Kleissen is appointed as manager, the supervisor is appointed by Kleissen. In the flowchart, the supervisor and manager's actions are taken together and seen as actions for the project manager. During the construction, the advisors will do inspections to hand out certificates. The project manager will direct the inspections. When the construction is almost finished, the architect, contractor, and installer sets up revision documents. The project manager checks the documents. When phase nine is finished, the last transition starts.

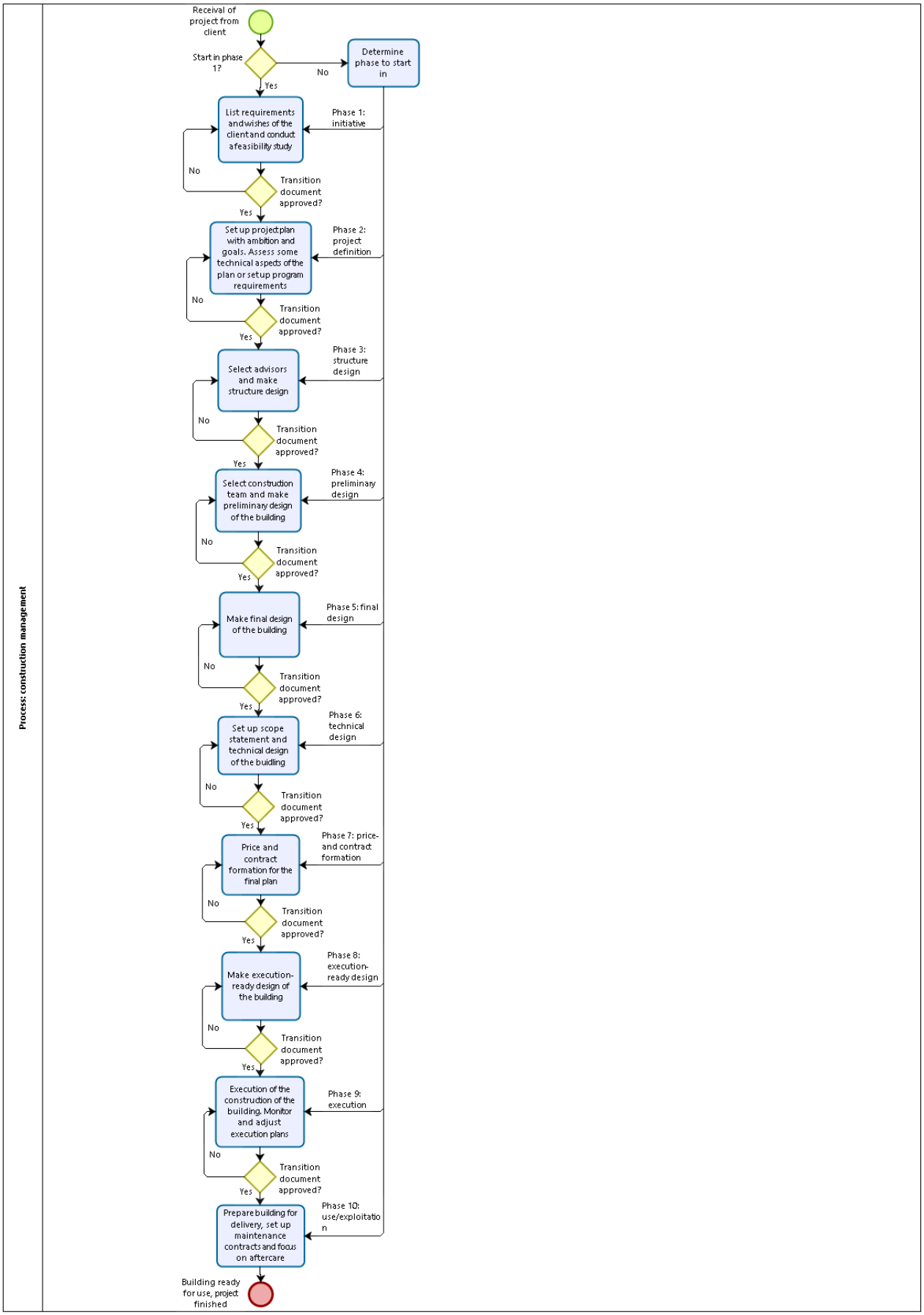
3.4.1.10 Phase ten

Phase ten is the last phase. In this phase, the project manager starts with determining maintenance periods and guarantees, followed by a remedy of all delivery points. The project manager supports the client in moving to a new location and provides aftercare. Clear communication between the project manager and client is important when moving the client to the new building. When the contractor and installer handed in all their documents, the project manager sets up the construction folder containing all documents of the building. To make all parties guarantee that they executed their tasks correctly, the project manager asks all parties to put their signature under all delivery points. Furthermore, the contractor ends its CAR insurance. This insurance is only valid during the construction period. The project manager is responsible for new proper insurance for the building. The project coordinator can support the project manager in executing the actions. When phase ten is finished, the last transition document is set up by the project manager. If the client and the director approve the document, the construction project is finished. However, the project manager will keep in touch with the client to manage aftercare and maintain a good relationship.

3.4.2 Simplified flowchart

To make the process easier to understand and draw conclusions out of it, the simplified model is set up (figure 3). The simplified flowchart is not designed as a swimlane diagram. To check where and how the objectives should be implemented, only the core activities in the correct order are important. Per phase, the most important output of that phase is mentioned. Every phase can be entered from the beginning. As mentioned, when a phase ends, the transition process starts. The current state of the project is described based on quality, time, and money. It can be seen that the earlier circular objectives are introduced to the client, the higher the chance the objectives will fully be adopted in the project. It is important to realize that in phase 10, not much can be changed in the building. However, it would still be possible to think about the future, for example, requesting a material passport (section 2.2). This passport contains all materials that are used to construct the building. The more we move towards the first phases, the more influence Kleissen can have on a project. Besides, sustainability is not part of the current structure of the transition document. This means that there is no official evaluation of sustainability implementations in a construction project.

Figure 3: Simplified flowchart of the construction management process



3.5 Conclusion

As mentioned in the chapter, the current situation regarding the implementation of circularity in Kleissen's projects is assessed based on their label, phase plan, transition document, and current way of tendering. In this section, the first question mentioned at the beginning of the chapter is answered:

- How is circularity currently implemented in projects of Kleissen?

#HoudbareHuisvesting is a label developed by Kleissen to give meaning to sustainability. It is not the case that there are no circularity objectives included in the label. As mentioned, the label covers the circular strategies that belong to the goal of protecting material sources. However, the circular strategies are not easily deduced from the label. Following the opinions of project managers and board members, every project manager performs #HoudbareHuisvesting in its own way. There are no clear guidelines to introduce this method to a client and structurally implement circularity. In the phase plan, that is elaborated by a detailed flowchart, the term 'sustainable construction' is mentioned. This action refers to implementing the method of #HoudbareHuisvesting. In no other phases, 'sustainable construction' or anything related to circularity or sustainability is mentioned. In fact, #HoudbareHuisvesting is not part of the transition document, which makes it a less import topic compared to the topics money, organization, time, information, and quality. In the assessments of tenders, sustainability is one of the criteria mentioned in the BPKV model. However, the sustainability criteria are subtle and require a personal interpretation of sustainable construction. This, taken together with a different distribution of weightings over the criteria per tender, lead to an unstructured way of requesting sustainable construction. Besides, there is a risk that sustainability will not be implemented at all.

Combining all the current situation findings, it can be said that there is a method containing circular strategies. This method is packed by the name 'sustainable construction' in the phase plan and refers to the label #HoudbareHuisvesting. However, the execution of this method is unstructured. Firstly, except for phase 2, sustainable construction is not mentioned in the prescribed working method (the phase plan), while every phase can be entered when a client needs the construction management service. Secondly, the applications of sustainable construction are not assessed in transition documents. Finally, sustainability criteria and the weightings per criteria differ per tender. This means that sustainable construction is unstructured requested, with a risk of no implementation at all. In conclusion, a start has been made on implementing circular construction, but this is not supported by a method with underlying objectives.

4. Stakeholders' interests

In this chapter, the stakeholders' interests are discussed. Information about the stakeholders' interests concerning circular construction is gathered through interviews and a survey. In section 4.1, the different stakeholder types are explained. In section 4.2, the interview structure is explained, followed by a summary of the interview results per stakeholder. Section 4.3 shortly concludes the interview results. Furthermore, in section 4.4, the survey is fully explained. Section 4.5 describes the survey results per stakeholder type. Lastly, in section 4.6, exploratory research is conducted to find relations in the choices made by the respondents. In this chapter, the following question is answered:

- What are the interests of the company's stakeholders, and how do they interpret circularity in construction?

4.1 Stakeholder types

Before explaining the interviews and survey, it is important to clarify the different stakeholder types that are focused on. Three different external stakeholders are focused on during this research. These are architects, contractors, and clients. Based on conversations with Eugenie Knaap, these stakeholders were chosen to focus on. This choice was motivated by the fact that architects, contractors, and especially clients have the most influence during a construction project, hence also on circular construction. The clients are divided into different stakeholder types per work field. To narrow the research scope, the choice was made to only focus on the work fields where Kleissen pulled out most projects. These are clients from the residential, educational, and care work field. With this classification of stakeholders, interviews and surveys were conducted.

4.2 Interviews

For the interviews, general interview questions were drawn up. The same questions were asked to all stakeholder types to be able to compare the stakeholders' answers. All interviews have been conducted between the first of April 2020 till the first of July 2020. The interview's goal was to find out the stakeholders' interpretations, experiences, and priorities regarding circular construction. See Appendix A for the asked questions. Interviews were also used to create an entrance into the stakeholders' busy agendas to inform them about the importance of filling in the survey for my research. All stakeholders were first approached by a project manager to find out whether they would like to cooperate. In total, nineteen stakeholders were interviewed. Due to COVID-19, almost all interviews took place through Microsoft Teams.

4.2.1. Interviews with architects

Four architects were interviewed. Almost all architects had their own interpretation of circular construction and were able to give meaning to it. One mentions that the goal of circular construction should be to protect material sources. Others mention the importance of reusing materials and constructing detachable. All architects had some experience with circular construction and mentioned methods they used. In the case of renovation projects, one focuses more on preserving materials and always looks at whether the shell of the building could remain. Other architects look at a material level to check which materials can be reused. Another one focuses more on applications that are visible for the public; for example, click bricks. These applications are used because this can more easily result in publicity for the client. The different ways of implementing circularity come forward from the interpretations of architects of circular construction. Most of the time, architects experience that clients are willing to cooperate with the architect's ideas to implement circularity. Still, as soon as the client sees the price difference, the client drops out. So architects are aware of the importance of circular construction and are willing to give meaning to it. The only bottleneck is that clients have too

little interest in circular construction, making the architects wait for a client's initiative before submitting circular applications.

4.2.2. Interviews with contractors

Four contractors were interviewed. The interpretations of contractors on circular construction do not differ. Reusing materials is seen as the most important aspect of circular construction. All contractors mention that sometimes recycling is done at the construction site and that materials are separated when demolishing a building. Most contractors do not have a lot of experience with circular construction but would like to gain experience. When a client would like to build circular, one of the contractors would give shape to circular construction by using prefab constructions, bio-based materials, and reusing materials. Another contractor has some experience with circular construction in a project and gives examples of the project's circular applications. He mentions the importance of detachability to make sure materials can be easily reused and the importance of good cooperation between all parties to collectively execute circular construction. Some bio-based materials were used in his project, and all materials were processed as little as possible. This type of project was executed because the client wanted to stimulate the sector to start focusing on circular construction. Based on these interviews, it can be stated that, with some exceptions, most contractors still conventionally construct buildings. There is an interest in implementing circularity, but this depends on the client. Contractors mention that quality and budget are of paramount importance, while circularity is still in its infancy and seen as extra costs. Because of this, clients do not prioritize circular applications in their construction projects.

4.2.3. Interviews with clients

Ten clients are interviewed. Three from the residential work field, five from the educational work field, and two from the care work field.

4.2.3.1 Clients residential

Clients from the residential work field are quite familiar with circular construction. Clients from the residential work field interpret circular construction as closing material loops to prevent the use of natural sources. The clients mention that they notice that circular construction is becoming a more and more important item. Which is why they would like to become familiar with it. One of the interviewees already has some experience with circular construction and still tries to complement these experiences. In a certain construction project, they tried to implement as many circular applications as possible and made an external party execute a circularity calculation. Based on these findings, they determined 'quick wins' on circularity. They currently try to implement these quick wins on every project. Another interviewee mentions that they are currently executing a project where circularity plays a key role. All external parties were involved from the start, and together they came up with circular applications. One of the clients from the residential work field mentions that a building's detachability is less important for housing corporations compared to utility construction. The houses will have the same function over a certain period. However, it is important to keep in mind the change of family compositions. Besides, adaptable houses give more freedom to the layout of the house and make demolishing easier. The most important interest of housing corporations is to keep the tenant's housing costs low. In other words, houses have to be built as cheaply as possible, low in maintenance costs, and energy-efficient. Furthermore, the occupant of the house would appreciate it if everything looks brand new.

4.2.3.2. Clients education

The first striking thing of the interviews with clients from the educational work field was that one client googled circular construction to determine its definition. This indicates that the client did not have an own interpretation of circular construction. Another client mixes different terms up and mentions

aspects of energy-efficiency when an interpretation of circular construction was asked. However, most clients from the educational work field explain that they know that circular construction is something that they have to start focusing on. One client mentions that circular construction is all about selecting the right materials. The client started focusing on setting up material criteria in the tender guideline. However, the budgets of these clients come from the municipality. These are minimal budgets that even make conventional construction hard to execute. One of these clients' biggest interests is minimizing the maintenance of the building because the organization is responsible for this. Other important interests mentioned by the interviewees are making sure the building fits the end-users, adapting the building to 'educational trends,' optimizing the building's energy-efficiency, and making sure the building blends in its environment.

4.2.3.3. Clients care

Clients of the care work field interpret circular construction as reusing materials and selecting the correct materials. Both interviewees have no experience with implementing circularity in construction. The clients are interested in circular construction from an environmental perspective with financial restrictions. Circular construction must have an added value as the care work field has tight budgets. The budgets are provided by the NZA (Dutch care authority). The budgets depend on care weight parcels. The health insurance law determines the number of capital costs. The higher the parcel, the higher the budget. However, deregulation has been initiated that forces the care work field to take minimal risks to the future, hence constructing not too specific for their patients. This means that buildings have to be built universally to adjust the building to changes in care. When constructing, the most important interest of a residential care institution is to keep the tenants' renting costs low. The problem that the care work field encounters is that they want the building to connect perfectly with the end-user while making sure the building is adaptive in its function.

4.3 Conclusion interviews with stakeholders

Table 3 shows the main conclusions of the interviews with the stakeholders. Based on the interviews, it can be said that the architects have the clearest vision of circular construction. Architects have the most knowledge about circular construction and are ready to implement their ideas. In general, compared to architects, contractors have immersed themselves less in circular construction. However, they clearly show interest, and some have already been part of pilot projects. For both architects and contractors, implementing circular construction is limited due to the client. Most clients drop out when they see that circular construction will result in extra costs.

Table 3 shows the interview results per stakeholder. As mentioned, questions were asked to determine the stakeholders' interpretations, experiences, and priorities regarding circular construction. The interviews showed that architects and clients in the residential work field have some experience in circular construction. Contractors and clients in the educational work field have not much experience with circular construction. Clients in the care work field have no experience at all.

Architects and clients in the educational work field have different interpretations of circular construction. Some architects mention that circular construction is about protecting material sources. Others mention the importance of reusing materials. Also, the interview shows that when a client asks for circular implementations, architects have different ideas. One focuses more on preserving materials, where others focus more on visible applications to the public. Clients from the educational work field do not have a clear interpretation of circular construction or mention that material selection is important. The other stakeholders have a similar interpretation of circular construction. Contractors and clients from the care work field interpret circularity as reusing materials. Clients from the residential work field use a broader term: closing material loops.

In the interviews, the stakeholders were asked to come up with priorities or requirements regarding circular construction. Both architects and contractors mention that the initiative to implement circularity should come from the client. Especially architects have already gained a lot of knowledge about circular construction and want to execute their ideas. However, the client should show that they have an interest in circular construction before submitting circular ideas. The same applies to contractors, but this stakeholder is not yet as advanced in knowledge as architects. Also, contractors prioritize quality and not exceeding the budget of the project.

All clients have some priorities regarding circular construction. For clients in the care and educational work field, the adaptability of the building is important. For education, the building should be able to adapt to educational trends. The building's appearance in the environment and the building's energy-efficiency are important in the educational work field. Simultaneously, the care work field mentions the priority of making the building connect to the end-user. Clients in the residential work field mention that the adaptability of a building in residential construction is less important compared to utility construction. Still, a building's adaptability is a priority because changes in family compositions have to be kept in mind. Besides, the clients mention that the buildings have to look brand new because the tenants appreciate that.

For all clients, the biggest priority is financially oriented. All clients want to keep the budgets low. For the residential work field, and sometimes also for the care work field, the budgets are kept low to keep the tenants' rent low. In the educational work field, only small budgets are provided by the municipality. Even conventional construction is hard to execute within these budgets. Also, keeping the maintenance costs low is important for clients in the educational work field because they have to budget for this themselves.

Table 3: Stakeholder interview results

Results	Architect	Contractor	Client residential	Client education	Client care
1. Experience with circular construction	Some experience with a circular construction	Not much experience with circular construction	Some experience with circ. construction	Not much experience with circular construction	No experience with circ. construction
2. Stakeholder's Interpretations of circular construction	Different interpretations of circular. construction: protecting material sources, reusing materials, constructing detachable	Similar interpretation of circular construction: reusing materials	Similar interpretation of circ. construction: closing material loops	Different or unclear interpretation of circular: construction: Selecting the right materials	Similar interpretation of circular construction: reusing materials
3. Priorities regarding circular construction	No specific requirements. The initiative should come from the client	Quality and budget are of paramount importance. The initiative should come from the client	Changes in family compositions have to be kept in mind, and the building has to look new	Adaptive construction, energy-efficiency, and make buildings blend in the environment	Construct buildings as universally as possible and make it connect to the end-user

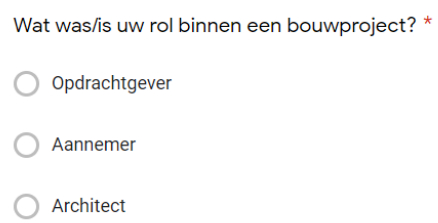
4.4 Survey

The survey's goal is to find out, quantitatively, the interests of all stakeholders related to circular construction in a construction project. The survey was conducted online with Google Forms and after the period of conducting interviews with stakeholders. Using the survey's output, exploratory research on the output is executed. Every respondent received the same survey to ensure that a comparison between the stakeholders is possible. The survey was executed in Dutch and kept as short as possible to ensure that all respondents can answer the questions. A total of twenty-nine stakeholders filled in the survey. As mentioned, at the end of every interview, the interviewee was asked to fill in the survey. Also, project managers have sent the survey to stakeholders from which they expected cooperation from the stakeholder.

4.4.1 Survey questions

The survey consists of four questions for architects and contractors. Clients get five questions because distinction must be made between the work field of the clients. The survey consists of three sections. The first section starts with asking the function of the respondent within their organization. This question is followed by the respondent's organization's role within a construction project (figure 4).

Figure 4: Section 1, question 2, the role of the stakeholder



If the respondent selects 'client' at question 2, the respondent is directed to section 2. Section 2 is called the 'work field.' This section contains one question about the work field of the client (figure 5). Architects and contractors are not directed to this section because we assume that they operate in all types of work fields.

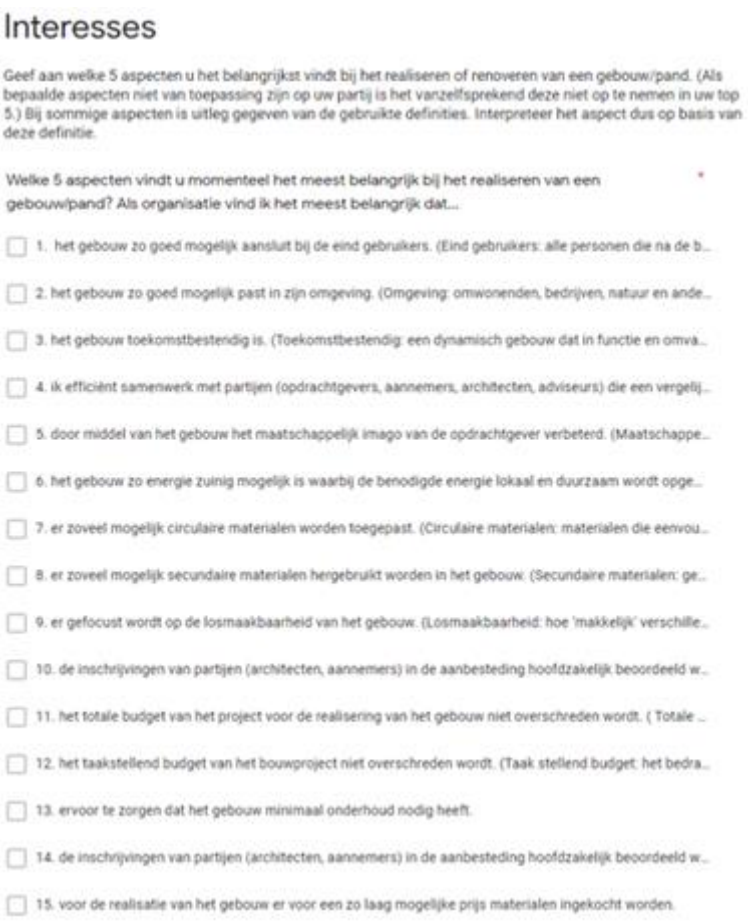
Figure 5: Section 2, question one, the work field of the client

If the respondent selects 'contractor' or 'architect' at question 2 of section 1, the respondent will be directed to section 3. Clients that have filled in their work field in section 2 are also directed to section 3. Section 3 is called 'interests.' In the first question of section 3, the respondent is asked to select five aspects out of fifteen that he or she finds most important when constructing a building (figure 6). See Appendix C.1 for a translated version of figure 6. They are forced to choose exactly five because when using a Likert scale for every aspect, every stakeholder is most likely to find every aspect important, which would lead to a biased output. A Likert scale is a scale that allows the individual to express how much they agree or disagree with an aspect (Mcleod, n.d.). In this case, the scale goes from not important to very important.

The fifteen aspects are chosen based on literature and interviews. The research of Joyce and Paquin (2016, p. 1485) describes the triple bottom line for business models. Businesses are analyzed based on their contribution to people, planet, and profit. The right balance between these so-called layers makes a business sustainable (Joyce & Paquin, 2016, p. 1485). In this research, we want to centralize circular construction instead of sustainability. However, circular construction is considered as a part of sustainability. So the aspects from the article that aligns with the theoretical framework on circular construction (chapter two) can be used in this survey. In the article by Joyce and Paquin (2016), every layer consists of different factors that measure a layer. The three layers of people, planet, and profit can be translated into social, environmental, and financial layers. In this research, these layers are called categories, and the factors are called aspects. Per category, aspects are drawn up based on a combination of the stakeholders' interests found with the interviews and the article's factors that align with the theoretical framework. At least one main interest of every stakeholder type per category is included and supplemented with the article's factors. This resulted in five aspects per category. This amount makes it possible for a respondent to be fully socially, environmentally, or financially focused, following this research's perspective.

So all stakeholders were directed to question one of section 3 (figure 6). The categories are not mentioned in the survey's question to prevent a respondent from being influenced by it. To prevent different interpretations of terms used in the aspects, some terms are explained, as mentioned in figure 6. To make sure personal interpretations are left out, the respondent is asked to answer the organization's perspective (figure 6). A translation of the aspects of figure 6 can be found in Appendix C.1.

Figure 6: Section 3, question 1, fifteen aspects



After the respondents selected five aspects, they were directed to question 2 of section 3. This is the last question of the survey. The stakeholders were asked to rank the five aspects that they selected (figure 7). To make sure every respondent correctly ranked their top five, an example was given.

Since every respondent ranked their five aspects, this makes it possible to translate the data into a Likert scale overall fifteen aspects. The highest-ranked aspect of a respondent gets five points, the lowest rank one point, and the rest zero points. This results in every aspect having a score assigned from zero to five points where 2/3rd of all aspects will have zero points. This way, the priority of every respondent's top five aspects is implemented. This method is used to make it possible to use SPSS to execute a factor analysis while preventing biased output. Factor analysis can only be executed when every question is answered with a Likert scale. Furthermore, the survey results will show the points per aspect for all stakeholders and per stakeholder type while keeping in mind the ranks of every respondent's aspects.

Figure 7: Section 3, question 2, ranking the five aspects

4.5 Survey results

In this section, the results of the survey are given. All results are visualized by tables and charts. In Appendix C.2, all survey outputs can be found. The appendix contains the exact scores per respondent and the points per interest for all stakeholders and per stakeholder type. In total, twenty-nine stakeholders filled in the survey. Almost half of the respondents were clients. The other half consists of six architects and nine contractors (table 3). In the next sub-sections, the survey results per stakeholder are given. The charts show the total points on the y-axis and the different aspects on the x-axis. The aspects with the most points can be considered as the stakeholder's main interests.

Table 4: Number of respondents per stakeholder type

Role	**Number of respondents**
Architects	6
Contractors	9
Clients	14
Total	29

The clients that filled in the survey operate in three different work fields: residential, education, and care. In table 5, the number of clients per work field that filled in the survey is given.

Table 5: Number of respondents (clients) per work field

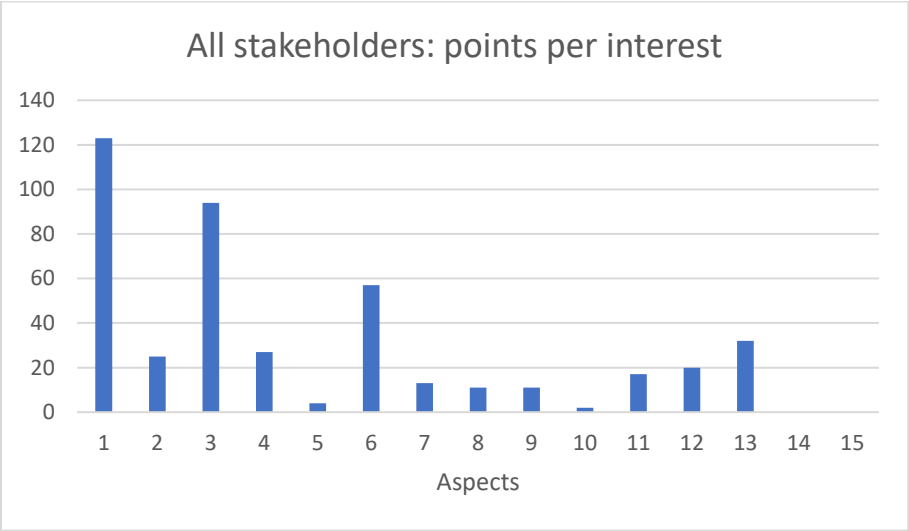
Work field	**Number of clients**
Residential	3
Education	9
Care	2
Total	14

4.5.1 Results all stakeholders

Since we want to know the stakeholders' interests, question 1 of section 3 is important. Every respondent gave their five most important aspects and ranked them in the next question. As mentioned before, based on the ranks of the respondent, the highest-ranked aspect is assigned five points and the lowest rank one point. The aspects are considered as potential interests of a stakeholder. All aspects that are not selected by the respondent get zero points.

Every aspect is assigned a certain amount of points based on every respondent's ranking. Based on all output, the chart in figure 8 is made. Figure 8 shows the points per interest with the ranks of every aspect of all the respondents taken into account. It can be seen that interest one is most important in general. Interest one is about making sure the building fits the end-users. After interest one, interest three and six are the most important. Interest three is about making sure the building is future proof. Interest six is about the importance of making the building as energy efficient as possible and that the required energy is generated locally and sustainably. None of the respondents selected interests 14 and 15 as somehow important. Interest 14 is about selecting parties in the tender, mainly on price and quality. Interest 15 is about when constructing a building; the materials are bought at the lowest price possible. Since none of the stakeholders selected these aspects, these aspects will also have zero points regarding the stakeholder type results.

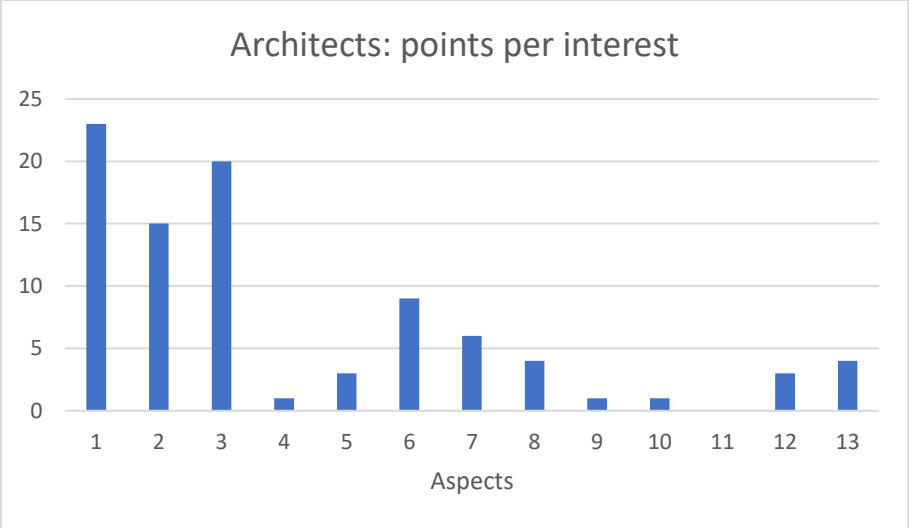
Figure 8: Points per interest for all stakeholders



4.5.2. Results architects

To analyze architects' answers, the scope is narrowed, and only the output of architects is selected. See Appendix C.2 for the exact number of points per interest. Since none of the respondents selected interest 14 and 15, these interests are left out in figure 8. The six architects that filled in the survey find interest 1, 2, and 3 most important. This indicates that architects consider it most important that the building fits the end-users. After this interest, constructing future-proof buildings is important. In the graph of all stakeholders, interest 2 is not very important. However, architects are mainly the ones that gave interest two most points. Which is why it is at place three of the most important interests. Interest 2 is about making sure the building fits in its environment. The architects did not assign any points to interest 11. This indicates that their interest lies not in making sure that the project's total budget does not exceed.

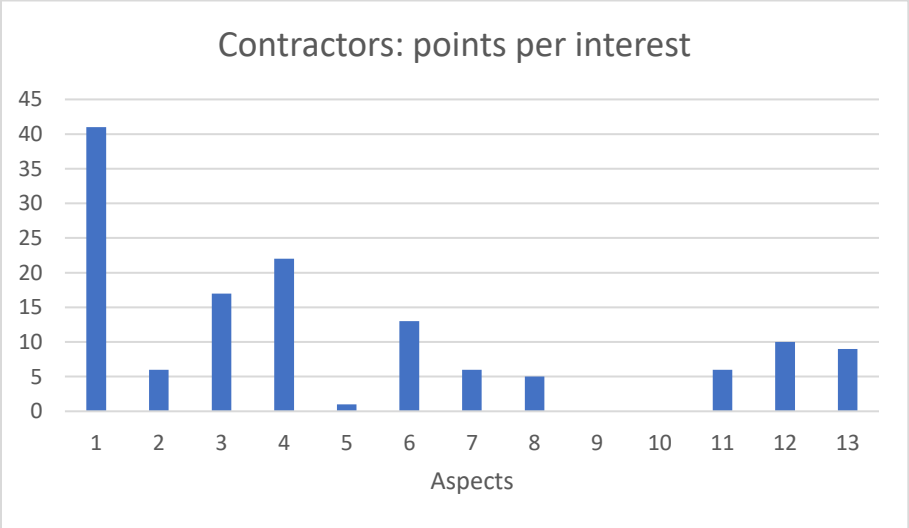
Figure 9: Points per interest for architects



4.5.3. Results contractors

Only the output of contractors is selected to analyze the answers of contractors. See Appendix C.2 for the exact number of points per interest. Figure 9 directly shows that the contractor's interests do not lie in interest 9 and 10. In other words, of all nine contractors, no one finds focusing on the building's detachability and mainly assessing tenders on their sustainability effort important. Again, interest one scores very high. Afterward, interest 4 has the highest score. Compared to architects and all stakeholders in general, this score is quite high. Interest 4 is about efficient cooperation with all parties. Also, for contractors, interest 3 and 6 are important.

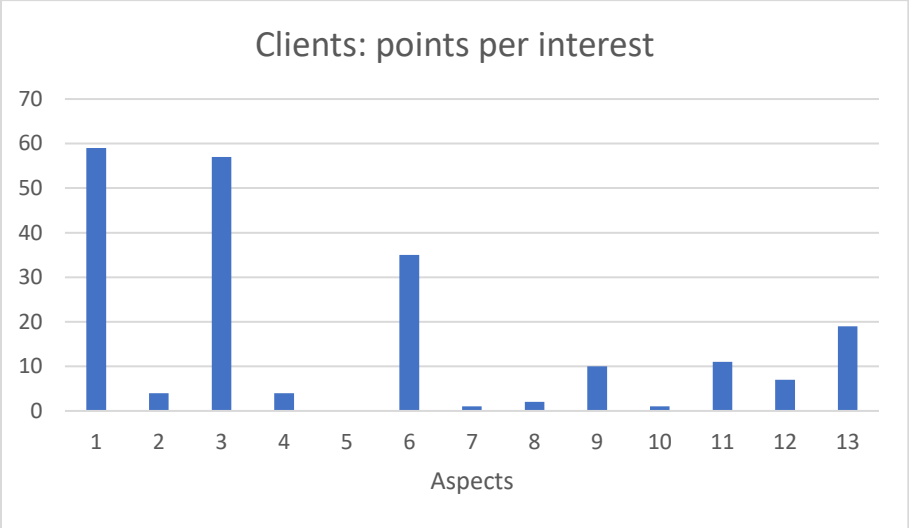
Figure 10: Points per interest for contractors



4.5.4. Results clients

To analyze the answers of all clients, the output of clients is selected. The output contains clients from all work fields. See Appendix C.2 for the exact number of the points per interest. Clients are the only stakeholder type that did not assign any points to interest 5. This indicates that their interest lies not in improving the social image of the client through the building. Interest one and three have by far the highest score. After these interests, interest 6 follows. In conclusion, all clients find it, in general, important that the building fits the end-users, making sure the building is future proof and energy-efficient.

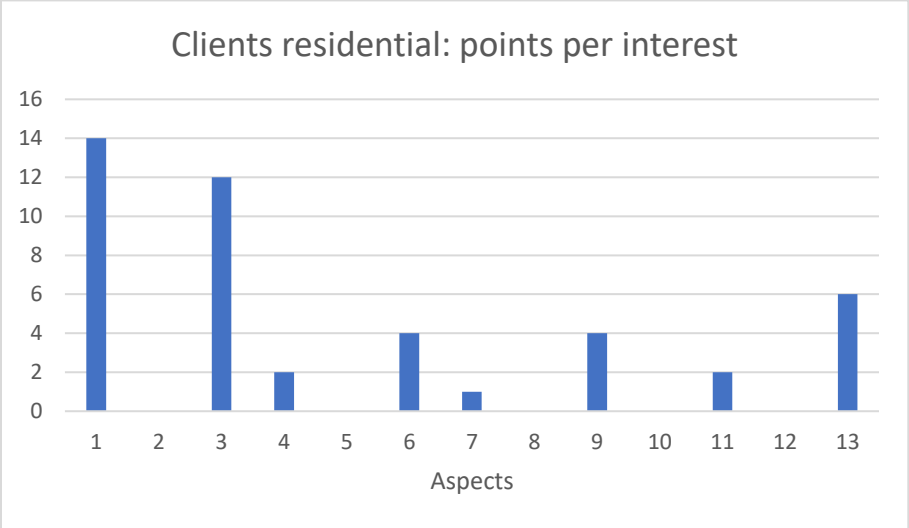
Figure 11: Points per interest for all clients



4.5.4.1 Results clients residential

The scope is a little more narrowed by looking at the clients' answers per work field. The first work field we look at is the residential work field. See Appendix C.2 for the exact number of points per interest. Again interest 1 and 3 scores high. However, after these interests, interest 13 has the highest score. Interest 13 is about making sure the building needs minimal maintenance. This indicates that after interest 1 and 3, minimal maintenance is an important aspect for clients in the residential work field. However, it is important to keep in mind that these conclusions are based on very little output.

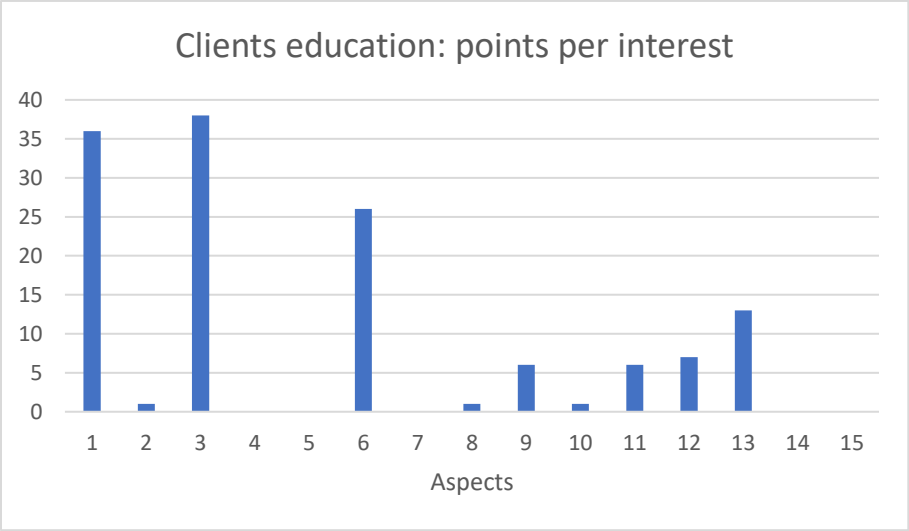
Figure 12: Points per interest for clients residential



4.5.4.2. Results clients education

The second work field that we consider is education. See Appendix C.2 for the exact number of points per interest. As expected, interest 1 and 3 have the highest score. These interests are followed by interest 6. Clients in the educational work field find the energy efficiency of the building quite important. Also, interest 13 is worth mentioning. After interest 1, 3, and 6, these clients find minimal maintenance also important. Compared to the other work fields, education is the one with the biggest number of respondents and can be considered most reliable.

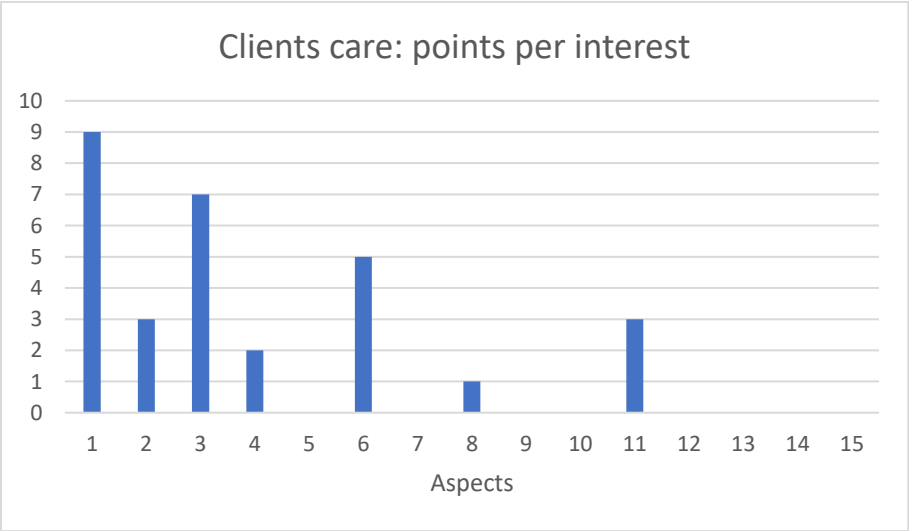
Figure 13: Points per interest in clients education



4.5.4.3. Results clients care

The last work field we look at is the care work field. See Appendix C.2 for the exact number of points per interest. Just like the clients in education, interests 1, 3, and 6 have the highest score. The striking thing is that, compared to the other two work fields, interest 2 has a relatively high score. This indicates that the clients in the care work field find it important that the building fits in its environment. After the first three interests, interest 11 also has a good score. This means the client finds it important that the total budget of the project is not exceeded. However, we have to keep in mind that these conclusions are based on very little output.

Figure 14: Points per interest for clients care



4.6 Exploratory research of the survey output

Through the survey, the goal is to find out more than only stakeholders' interests. The survey should contribute to finding relations in the choices made by the respondents. These relations can support in setting up a method and circularity objectives that fit the stakeholders' interests.

The most obvious is to perform a statical analysis of the survey's output. This was not possible. Every aspect mentioned in section three, question 1 of the survey (section 4.4.1), should be considered as an independent variable to conduct a statistical analysis. In this survey, instead of using a Likert scale for every aspect, stakeholders were asked to choose five out of fifteen aspects and rank them. This was advised by Kleissen to prevent that stakeholders find all aspects important, but it also made the variables (aspect scores) dependent. In other words, when a respondent ranked an aspect as 'most important,' it is not possible to find another aspect also 'most important.' Furthermore, the current sample size cannot be considered adequate to conduct statistical analysis.

This is why the choice is made to conduct exploratory research by manually finding patterns in the data. These patterns support in setting up a conceptual meaning about relations between aspects for certain stakeholders.

4.6.1 Tree diagram

Dr. K. Poortema (Teacher statistics at the University of Twente, personal communication, 2020) advised to first visualize the stakeholders' choices made in the survey using a tree diagram. A tree diagram visualizes the ranks of the aspects of the respondents. The ranked aspects can be seen as paths taken by a stakeholder. In total, four tree diagrams are made. One diagram for all stakeholders in general, and one per stakeholder type.

The first tree diagram is based on the output of all stakeholders. The other three tree diagrams are based on the output per stakeholder type. The tree diagram of all stakeholders is an aggregation of all paths per stakeholder type. The diagram of all stakeholders contains every respondents' ranking of five aspects. The ranks can be seen as paths in the diagram. A number in a small colored rectangle represents an aspect. The vertical light blue rectangles represent the ranks of the aspects. A path starts in the small black rectangle named 'start.' The path contains an aspect in every rank. The survey's output shows that the respondents only ranked aspects 1, 2, 3, and 4 as 'most important.' Every main path starts with an aspect that is ranked as 'most important.' The main paths that start from aspects 1, 2, 3, and 4 are given different colors. The small black numbers next to or underneath an aspect are the number of respondents that took this path. So nineteen respondents choose aspect one as their most important interest. After aspect 1, seven respondents choose aspect three as their most important interest. Paths are denoted as follows: x-x-x-x-x. The first 'x' refers to the aspect that is on rank 1. The last 'x' refers to the aspect that is on rank 5. Based on these paths, an attempt is made to find patterns. These patterns can support finding a relation between aspects.

The meaning of every aspect is given in Appendix C.1 to understand the tree diagrams and patterns. As mentioned, every respondent was asked to select and rank five aspects out of fifteen that their organization finds most important.

4.6.1.1 Tree diagram all stakeholders

The tree diagram based on all respondents' output is elaborately explained in this section (figure 15). Every main path, starting with the aspect at rank 1, will be shortly explained. The main paths are given colors: green, yellow, blue, and grey.

The first main (green) path that most stakeholders take starts with aspect 1 (figure 15). Nineteen respondents choose aspect one as their most important aspect. From aspect 1, respondents go in 8

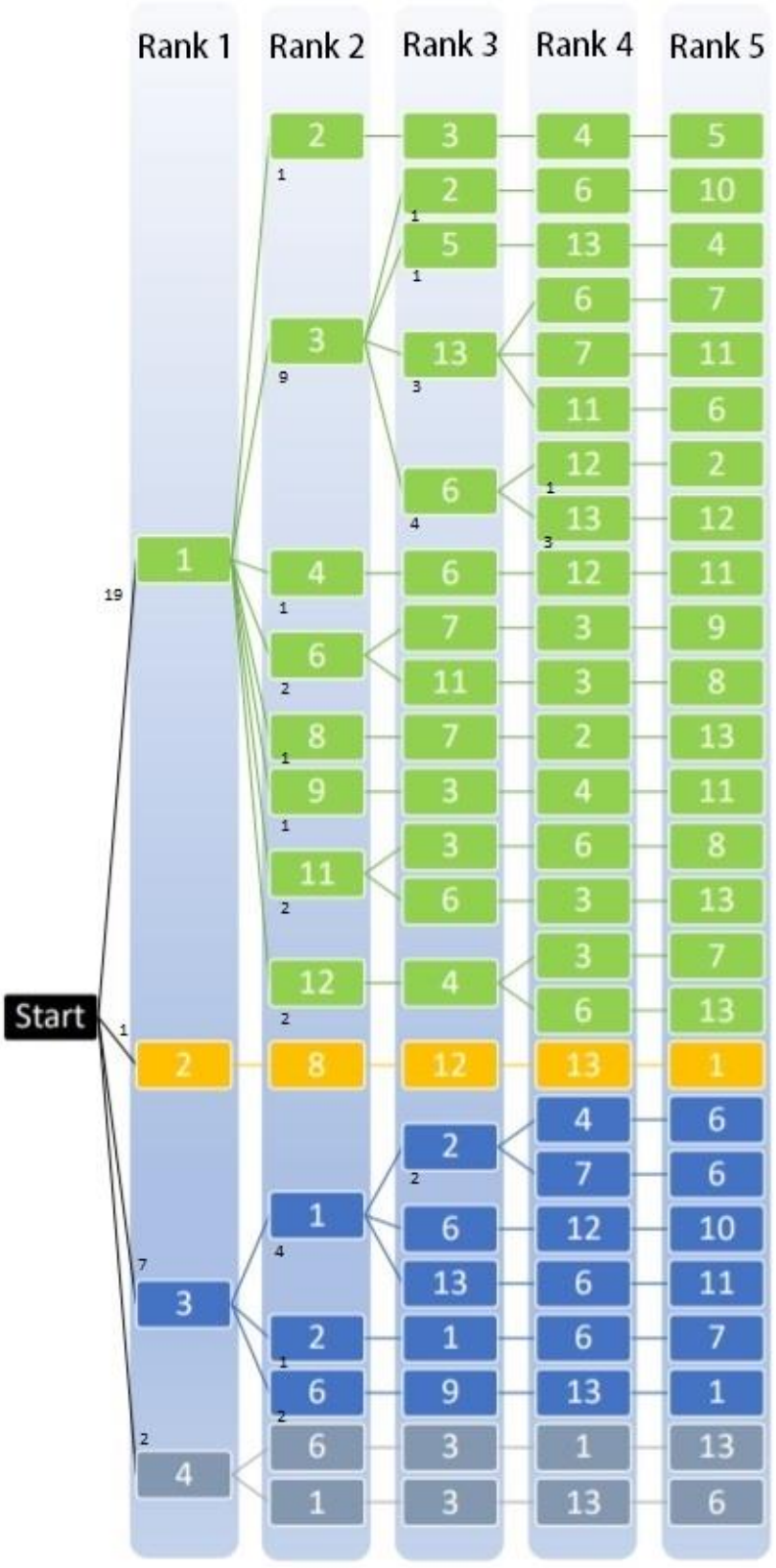
different directions. Aspects 2, 4, 8, and 9 are chosen by only one respondent at rank 2. Aspect 6, 11, and 12 are chosen by two respondents at rank 2. Nine respondents that first chose aspect one as the most important rank aspect three at rank two. The aspects in rank two that were chosen by only one respondent for each aspect follow their own path and will not split up anymore. Except for aspects 12, aspects that were chosen by two respondents will split up into two paths. Aspect 12 was chosen by two respondents. Both respondents rank aspect four at rank 3. After aspect 4, the two respondents split up in their own paths. The nine respondents that chose aspect three at rank 2 split up into one respondent choosing aspect 5, three respondents choosing aspect 13, and six respondents choosing aspect six at rank 3. The three respondents that choose aspect 13 at rank 3 split up into three different paths. The four respondents that choose aspect six at rank three are split up into two paths. One respondent chooses aspect 12 at rank 4; three respondents choose aspect 13 at rank 4. So nineteen respondents took the green path, which is why nineteen paths are starting from aspect 1.

The second main path is colored orange. The path only has one direction since only one respondent chooses this way of ranking these aspects. The respondent finds aspect two most important, followed by aspects 8, 12, 13, and ends with aspect 1.

The third main (blue) path starts with aspect 3. Seven respondents ranked aspect three as 'most important.' From aspect 3, respondents go in three different directions. Aspect 2 is chosen by one respondent for each aspect. Aspect 6 is chosen by two respondents, and four respondents rank aspect six at rank 2. The respondent that chose aspect two at rank 2 follows its path. Aspect 1 was chosen by four respondents and split up in three directions. Two respondents rank aspect two at rank three, and aspects 6 and 13 are chosen by the other two respondents. The two respondents that chose aspect 6 chose the same aspects for the rest of the ranks. The two respondents that chose aspect two at rank 3 split up into two different parts. So seven respondents took the blue path. Two of them took the same path.

The last path is taken by two respondents and starts with aspect 4. From aspect 4, the two respondents choose two different aspects. One chooses aspect 6, the other one aspect 1. The respondent that chose aspect 6 chooses aspects 3, 1, and 13. The respondent that chose aspect 1 chooses aspect 3, 13, and 6. The two respondents take different paths because they have a different ranking. However, both rankings contain the same aspects.

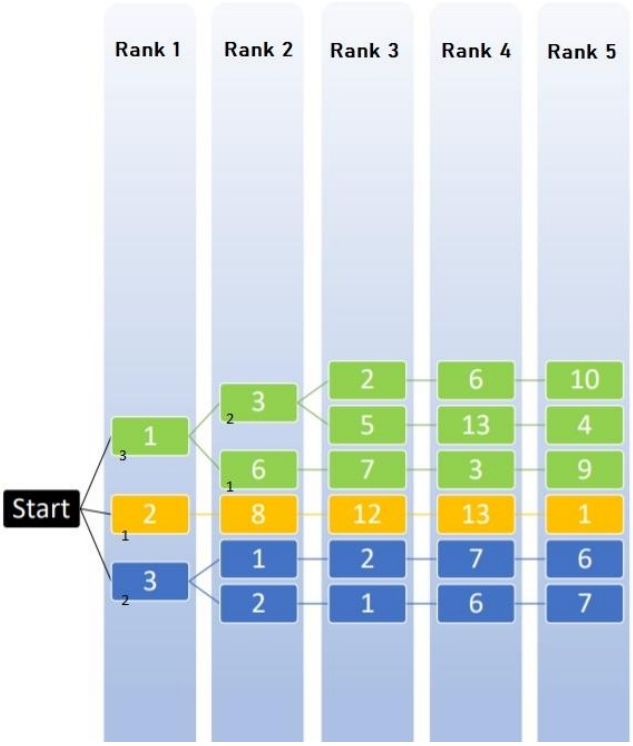
Figure 15: Tree diagram of all stakeholders



4.6.1.2 Tree diagram architects

In figure 16, the tree diagram based on the output of architects can be found. Six architects filled in the survey. Architects choose aspects 1, 2, and 3 as the most important aspects. Most of the architects choose aspect one as 'most important.' Most of the architects that choose aspect one as the most important choose aspect three at rank 2. There is one architect that finds aspect two most important. The other two architects find aspect three most important.

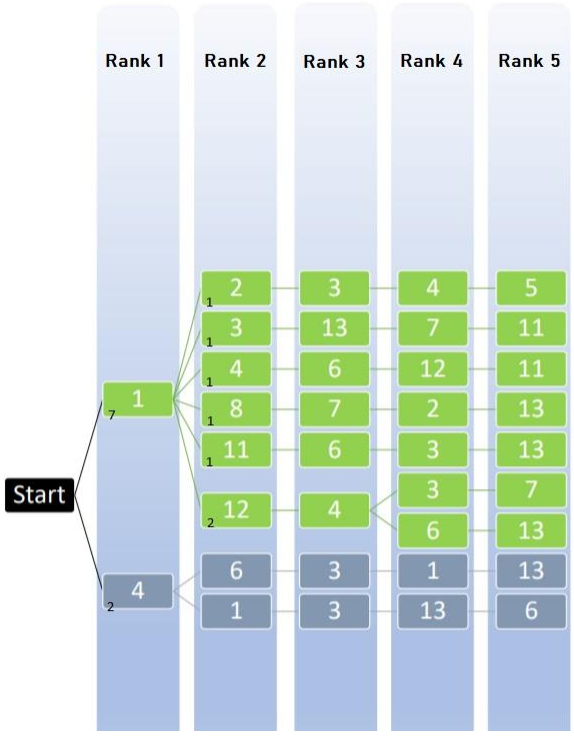
Figure 16: Tree diagram of architects



4.6.1.3 Tree diagram contractors

In figure 17, the tree diagram based on the output of contractors can be found. Nine contractors filled in the survey. Seven contractors find aspect one most important. From aspect 1, paths go in a lot of different ways. Two contractors choose aspect 12 at rank 2. The other five aspects at rank two are chosen by one respondent for each path. Two contractors find aspect four most important. From aspect 4, the contractors split up in different paths.

Figure 17: Tree diagram of contractors

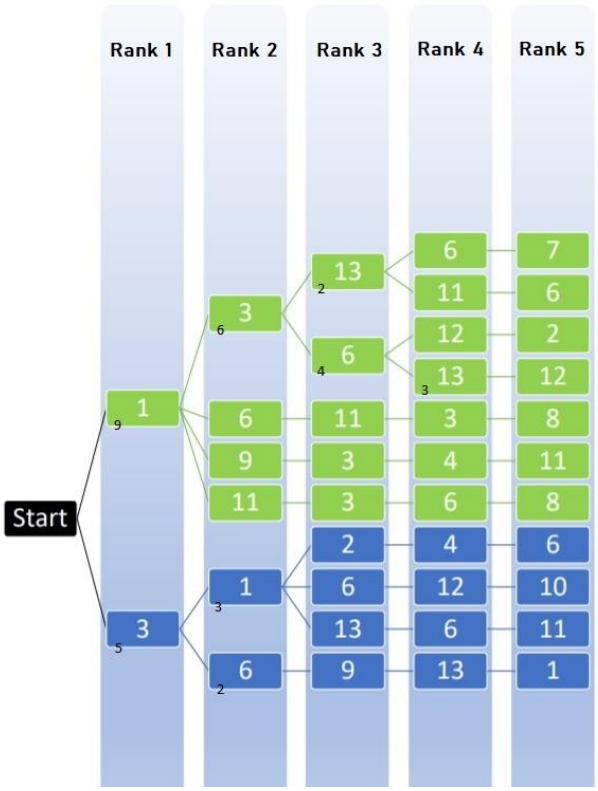


4.6.1.4 Tree diagram clients

Fourteen clients filled in the survey. Creating tree diagrams for clients per work field leaves us with a few paths per work field. Only the work field of education could be considered as somewhat useful to elaborate. However, due to time constraints, the choice is made to take all clients' paths together and not elaborate on all work fields.

From the fourteen clients, nine clients find aspect one most important (figure 18). The others find aspect three most important. The clients that choose aspect one at rank 1 split up in four different paths. Six clients choose aspect three at rank 2. The three other clients take a separate path. From the clients who chose aspect three at rank 2, four chose aspect six at rank 3. The others choose aspect 13 at rank 3. From aspect 13, the path splits up into two paths. From aspect 6, most clients choose aspect 13 at rank four and choose aspect 12 at rank 5. Most of the clients that find aspect three most important choose aspect one at rank 2. After aspect one at rank 2, the path splits up into three different paths. Two clients choose the same path, starting with aspect three as most important, followed by 6-9-13-1.

Figure 18:Ttree diagram of clients



4.6.2 Patterns in the data

As mentioned, this exploratory research aims to find patterns that support setting up a conceptual meaning about relations between aspects. These relations can be considered as conceptual interests. Finding these patterns is important to get an understanding of the choices made by the respondents. If there is a pattern, this can indicate that there is a relation between aspects for a certain stakeholder.

In the tree diagram, some ranking decisions are made by a lot of respondents. These decisions can be conceptually interpreted as a relation between two aspects since many stakeholders find both important. The choice is made to consider a path that is taken by two or more respondents as a potential pattern. Also, paths containing the same aspects but in a different order are considered as

potential patterns. This means that every single path is compared to every other path to find a pattern. In summary, paths are assessed and named patterns, based on the following points of attention:

1. Paths chosen by many respondents, less than two respondents, is considered as not a useful pattern;
2. Different paths containing the same aspects, but in a different order.

4.6.2.1 All stakeholders: patterns based on the number of respondents

First patterns are found in the tree diagram for all stakeholders based on the first point of attention. These are patterns found based on paths taken by more than one respondent.

The first striking choice of the respondents is that most rank aspect 1 as most important. From these respondents, most choose aspect three as their second important interest. After aspect three, first aspect six is most chosen, then aspect 13. From the respondents that choose aspect 6, most of them choose aspect 13 at rank 4. The three respondents choosing aspect 13 at rank four also choose aspect 12 at rank 5. This creates a pattern because there are no other paths taken by exactly three respondents. After aspect 13 at rank 3, the three respondents split up in different paths, which makes them less useful when finding relations between aspects. From aspect 1, there are three paths chosen by two respondents. Two respondents choose after aspect 1, aspect six at rank 2. After aspect six, the path is split up into two paths. Two respondents choose aspect 11. This path also splits up. Two respondents choose aspect 12, and then both choose aspect 4. After aspect four, the path splits up. All patterns found based on the tree diagram paths and start with aspect one are mentioned in table 5 and are highlighted in green.

Another path that is taken by a group of respondents starts from aspect 3. From aspect three, most respondents choose aspect one at rank 2. Two respondents then choose aspect two at rank 3. The other two split up in different paths. After aspect two at rank 3, the two paths split up. This pattern is included, in blue, in table 5. Another pattern starting from aspect three, can be found. After aspect 3, two respondents choose aspect 6. These two respondents follow the same path as the rest of the ranks.

Two respondents find aspect four most important. After aspect four, the two paths split up. Based on finding patterns on more than two respondents, this path cannot be considered as a pattern. However, we also assumed that a pattern could be found based on a different order of the same aspects. This will be covered in the next section.

4.6.2.2 All stakeholders: patterns based on the same aspects in a different order

In this section, patterns are found in the tree diagram of all stakeholders based on paths containing the same aspects but in a different order. Every path is checked and compared to any other path. We start comparing every path from the top of the tree diagram and work downwards.

We directly see that path 1-2-3-4-5 does not have other paths with the same aspects. However, there is one blue path containing four similar aspects. This path, 3-1-2-4-6, only has a different aspect at rank 5. More paths look similar to this path but have one different aspect. Unfortunately, since the paths do not contain the same, the paths are not included in table 5. When working downwards, we find the path 1-3-13-11-6. The green main path also contains path 1-11-6-3-13. This path has the same aspects but in a different order. Looking further downwards, the main blue path contains path 3-1-13-6-11. This is also the same path but in a different order. All three paths are considered as patterns and mentioned in table 5. On the bottom of the tree diagram, there is a grey main path starting with aspect 4. Two respondents choose aspect four at rank 1. From aspect 4, the path split up into two different paths. One path contains aspects 4-6-3-1-13, the other one contains aspect 4-1-3-13-6. The paths have

the same aspects but in a different order. Both paths are considered as patterns and can be found in table 5.

4.6.2.3 Patterns per stakeholder

The patterns per stakeholder are based on the tree diagram of every stakeholder. The goal of finding patterns per stakeholder is to find out who is responsible for the different patterns. This supports setting up the conceptual interests of the different stakeholders. Only the patterns of all stakeholders are split up under the two points of attention mentioned in section 4.6.2. The patterns per stakeholder are not split up and based on both points of attention. This is done to keep the table readable. It can be seen that the grey pattern found in the tree diagram of all stakeholders comes from the contractors' ranking. Also, the two blue patterns (3-1-2-7-6 and 3-2-1-6-7) come from the architects' ranking. Furthermore, clients have the most number of patterns. This can be explained by the fact that clients are the largest group of stakeholders.

Table 5: Patterns derived from the tree diagrams

Rank1	Rank 2	Rank 3	Rank 4	Rank 5
All stakeholders: patterns based on paths chosen by many respondents				
1	3	13		
1	3	6	13	12
1	6			
1	11			
1	12	4		
3	1	2		
3	6	9	13	1
All stakeholders: patterns based on different paths containing the same aspects, but in a different order				
1	3	13	11	6
1	11	6	3	13
3	1	13	6	11
3	1	2	7	6
3	2	1	6	7
4	6	3	1	13
4	1	3	13	6
Architects: patterns				
1	3			
3	1	2	7	6
3	2	1	6	7
Contractors: patterns				
1	12	4		

4	6	3	1	13
4	1	3	13	6
Clients: patterns				
1	3	13		
1	3	6	13	12
3	6	9	13	1
3	1			

4.6.3 Conceptual interpretation of patterns

There are 12 patterns found based in the tree diagram containing all stakeholders' output. These patterns can give a conceptual interpretation of a relation between the aspects. We look for relations between aspects for all stakeholders and per stakeholder type. In the patterns, we search for aspects that are related to each other. This is done by looking at how frequently two aspects are mentioned in different patterns. To find a relation between aspects, we look at the table containing all patterns (table 5) and analyze how often two different aspects occur in a pattern. A relation between an aspect 'x' and 'y' is considered when more than half of the patterns of a certain stakeholder (and for all stakeholders) contains both aspects. In other words, when a stakeholder finds aspect 'x' important, this stakeholder also finds 'y' in most cases important. This relation can be seen as a potential interest of a stakeholder. Only relations between two aspects are analyzed to keep the relations clear. All potential interests can be found in appendix D. The formulation of this potential interest is unclear because it is uncertain whether the relationship exists and what kind of relationship it is.

The table in appendix D shows for which stakeholder the relationship has been found and the number of patterns containing these two aspects (see column 'frequency' in appendix D). As mentioned, in this exploratory research, relations are only considered when more than half of a certain stakeholder's patterns contain both aspects. So the frequencies mentioned in the table of Appendix D are all more than half of the total number of patterns of that stakeholder.

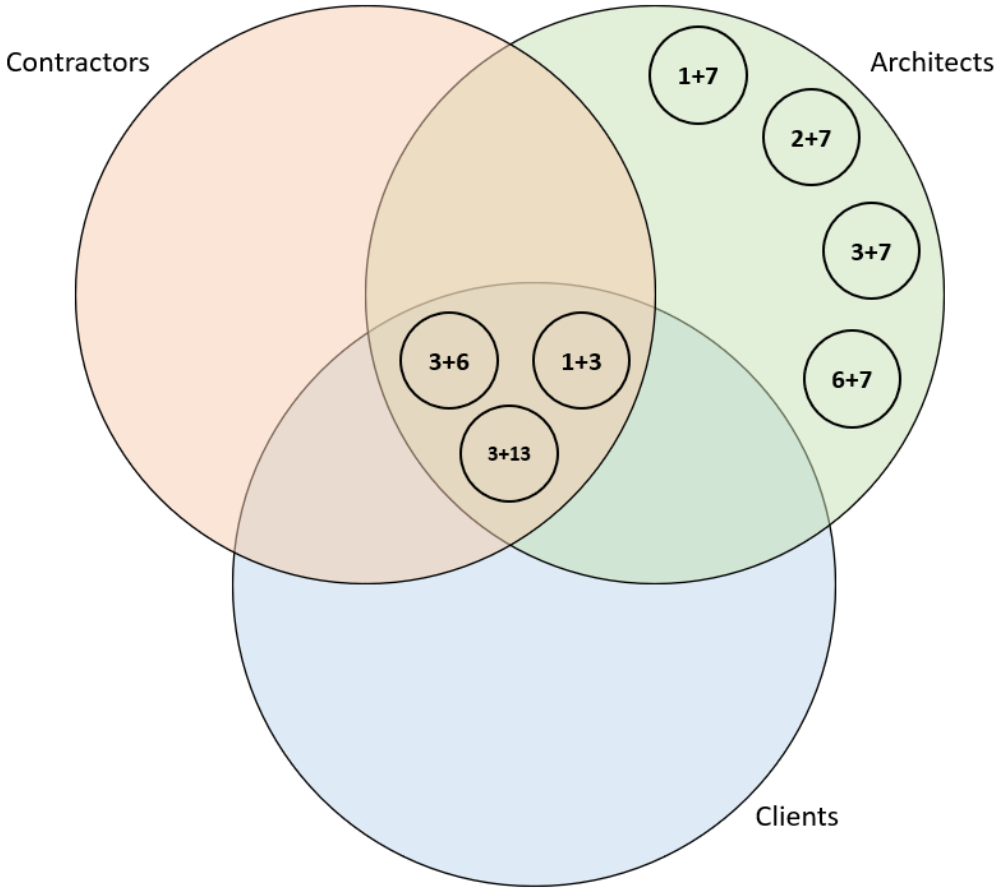
The relations between the aspects can be seen as potential interests. For this research, the relations between aspects containing a circular aspect are most interesting. These relations are highlighted in green in Appendix D. These relations can be considered as a potential interest of a stakeholder regarding circular construction. To get a better understanding of the relations, visualization is made. Figure 19 shows a Venn diagram of the relations containing a circular aspect. As can be seen in Appendix D, for all stakeholders, a relation containing a circular aspect is found between aspects 3 and 6, 1 and 3, and 3 and 13. Aspect 3, 'making the building future proof,' is the aspect responsible for making the relation related to circularity. As mentioned in the table in appendix C.1., making the building future proof means making the building adaptive in function and size. This is related to the strategy of designing for disassembly (section 2.4.2). Figure 19 shows that clients and contractors have the same potential interests. Based on the output of architects, four relations containing a circular aspect are found. Here, aspect 7, 'using circular materials', is the aspect responsible for making the relation related to circularity. The figure shows that architects have the most conceptual interests related to circularity.

If the relations mentioned earlier are real, the aspects can be combined and reduced to one interest. For example, combining aspects 1 and 3 could give us the interest of 'constructing for evolution.' In this case, evolution could be considered as the change of the wishes, properties, and composition of a certain type of end-user over the years. In case clients have this interest and architects and contractors can comply with this interest, already at the start of a construction project, a possible other function of the building must be considered. Making the construction team think about the building's adaptive

capacity fits the ‘design for disassembly’ strategy. Converting this interest into an objective, would stakeholders stimulate implementing circular construction.

In this way, relations between the aspects could be interpreted and formulated as one interest. By subsequently responding to this interest, circular construction can take place. However, it is difficult to determine what kind of relationship exists between the different stakeholders' aspects and whether these relations are real. It can only be said that based on the survey’s output, patterns can be found that point out potential relations between aspects for different stakeholders. Further research into these potential interests is needed to determine whether the relations are real and the kind of relationship between the aspects.

Figure 19: Relations between aspects



5. Circularity approach at other organizations

The goal of this part of the research is to find other organization's approaches of implementing circularity. Instead of setting up circularity objectives from scratch, it might be possible to learn from other organization's circularity approaches. For this, in section 5.1, interviews with other organizations have been conducted. Through web research, residential and utility construction projects on websites of other construction management agencies called 'circular' were found. At the end of the interviews about the stakeholders' interests with clients, contractors, and architects, the question was asked whether they knew other organizations that currently focused on circular construction. Construction management agencies that promoted 'circular projects' on their website were not open to an interview about their circularity approach. Eventually, only two interviews took place. One with a project manager of a construction management agency that promoted a circular project on their website. The second one is a housing corporation. The corporation has experience with circular construction and sets up an 'experimental garden' to gather other parties to learn more about circular construction. In section 5.2, the conclusions regarding the interviews are given. This chapter focuses on answering the following research question:

- What circularity objectives do other organizations operating in residential and utility construction set in their project plan?

5.1 Interviews

In this section, the two interviews are described. There is only one interview with a construction management agency since other construction management agencies were not open to an interview. Based on a recommendation during another interview, a housing corporation was approached for an interview.

5.1.1 Construction management agency

On the website of Company Y, a project is mentioned that is called circular. Company Y is a construction management agency and managed a project for the education building for Safety Professions courses of School X in Leeuwarden. In the interview, the project manager explained that the client wanted to be a forerunner and implement circularity. The construction management agency had experience with building following the BREEAM requirements and achieved a minimum score of 'excellent.' BREEAM is a sustainability certification. The building needs to fulfill certain requirements, also requirements related to circularity to get this certification. However, the project manager mentions that they found BREEAM quite enigmatic. There is little room to give your interpretation. In fact, in some cases, you might consider other options more sustainable. For the project, School X getting certain certifications was not the primary goal. The buildings needed to be as energy-efficient and circular as possible. There were no clear requirements or circularity objectives; only GPR scores needed to meet certain values. The striking thing about this project is that it did not cost much extra money compared to a conventional construction project of this size. An important aspect of this project was that all parties involved had the same drive to make the building as sustainable as possible. Also, the technical plan of approach was not strictly enforced to enable adjustments and let go of criteria where needed. Parties, such as the contractor, must be prepared to go out and search for local secondary materials. The project manager explains that they interpret circularity as using new materials as little as possible, using materials that can easily be supplemented by nature, and constructing demountable. This interpretation is similar to the theoretical framework stated in chapter 2.4 of this report. For more details about all circular applications, the project manager of Company Y refers to the project manager of School X. The project manager says that it currently mainly depends on the client, whether circularity is an important item or not. In this case, it was, and together with other parties, an attempt was made

to construct a building as circular and energy-efficient as possible. Company Y wants to at least make the client aware of circular construction. There is no approach to convince clients to implement circular construction. If there are ambitions, it is up to the design team to come up with circular applications. As the construction of School X, such projects will serve as an example to other clients that circular construction is possible without exceeding the budget.

5.1.2 Housing corporation

At the end of an interview with circularity expert Z, the advice was given to contact the quartermaster of Company X. Company X is a progressive housing corporation with experience in circular construction. Currently, the organization started a circular experimental garden. This is a project to bring together various circular ideas and products with different parties. The goal is to handle raw materials responsibly when applying and monitoring proven and new circular ideas. The findings of this experimental garden can be applied to future projects. In the interview, the quartermaster explains that the first step towards circular construction was made through a project where three apartment complexes had to be modernized. The goal was to implement circular construction in this project. The contractor of that project had involved an external party, Albaconcepts, to advise on implementing circular applications. This advice was based on the building circularity index. On the website of Albaconcepts, they explain that material use and the detachability of materials are the two components that give substance to this circularity concept. The quartermaster explains that they do not let this circularity index be calculated for every project because it is quite expensive. However, they use the ‘big wins’ on circularity of this project for every future project. Following the quartermaster, the big wins on circular construction focused on the detachability of materials and using bio-based materials. For future projects, Company X wants to have a more detailed approach to circular construction, which is why the experimental garden is set up. The quartermaster also points out that a too-strict approach in the request of other parties often comes at the expense of a project's quality and creativity.

5.2 Conclusion

On the web, there are many organizations, including construction management agencies, that promote circular projects on their website. However, many of these organizations do not want to talk about the circularity aspects of this project. The project manager of the first interview explains that they do not have a specific approach to convince clients to implement circularity. The agency at least wants to make the client aware of circular construction. It depends on the clients, whether circularity is implemented or not. If the client finds circular construction important, other parties will be gathered with the same vision on circular construction as the client.

Company X is a housing corporation and could be a client of Kleissen. The corporation has had a calculation performed by an external party to find ‘big wins’ in circular applications. In the request of future projects, they emphasize the importance of implementing these ‘big wins.’

In conclusion, it can be said that based on this research, most parties do not have clear circularity objectives in their project plans. Interviews with clients and the one with Company Y show that circular construction is applied by putting together the right parties with creative ideas. However, like Company X, there can be parties that have executed calculations at one project to structurally implement the best circular applications in their future projects. For Company X, these applications are focused on the detachability of materials and using bio-based materials. There can be more organizations with this approach, but they are not included in this research.

6. Circularity objectives

In this chapter, the circularity objectives are set up. As explained in chapter five, there were no clear circularity objectives found in other organizations' project approach. This is why the circularity objectives stated in this chapter are mainly based on the literature research, interviews, and exploratory research on the output of the survey.

First, in section 6.1, the main objective is given. This objective is based on the theoretical framework of chapter two. As explained in chapter three, Kleissen's label of circular construction aligns mostly with the theoretical framework. The theoretical framework describes three strategies to achieve the main objective. In section 6.2, these three strategies are described as sub-objectives for Kleissen. To achieve the main objective, sub-objectives should be achieved. To achieve the sub-objectives, Kleissen should approach clients with objectives that fit all stakeholders' interests. In chapter four, the survey results were explained, and exploratory research (section 4.6) was conducted. Section 6.3 repeats the stakeholders' interests and explains what can be concluded from the exploratory research.

The possible conceptual interests containing a circular aspect are highlighted in green in Appendix D. Finally, in section 6.4, a conclusion on the conceptual interests and objectives for stakeholders is given. This chapter focuses on answering the following questions:

- What should be the main and sub-circularity objective(s) for Kleissen?
- What are the conceptual circularity objectives that are in the interests of the stakeholders?

6.1 Main circularity objective

The main objective of circular construction is already mentioned in the theoretical framework in chapter two. Kleissen's label #HoudbareHuisvesting covers this objective, as mentioned in section 3.1. Following the desk research and interviews with circularity experts (chapter two), the main circularity objective can be stated as:

''Protect the material sources when managing a construction project.''

6.2 Sub-objectives

The strategies mentioned in the theoretical framework of chapter two can be described as sub-objectives supporting in reaching the main circularity objective. As mentioned in chapter three, these strategies are also included in the label #HoudbareHuisvesting.

The sub-objectives are:

- **Reuse materials when managing a construction project.** In a construction project, a distinction must be made between renovation and new construction. During the renovation, a search must be done for materials that can be reused per material category. In the case of new construction, then there must be a local search for secondary materials per material category.
- **Design for disassembly when managing a construction project.** In a construction project, dry connections between materials should be designed and constructed. Materials can be easily and cleanly detached, which simplifies the reuse of materials when the building enters its ending phase. This also makes it possible to easily change buildings in function and size.
- **Use circular materials when managing a construction project.** This means that in a construction project, the focus should be on using materials that come from sources that can recover fast. Per material category, materials that are exhaustive for the earth should be replaced by these circular materials

So during a construction project, the advice is given to convince the client of reusing materials, designing for disassembly, and using circular materials. By focusing on achieving these objectives, material sources can be protected.

6.3 Stakeholders' interests and objectives

In this section, the focus is mainly on the survey's output. The section describes what can be obtained from exploratory research. Per stakeholder, the five most important interests are given. Based on these interests and exploratory research, conceptual interests are given. Subsequently, examples of possible circularity objectives for a stakeholder based on the conceptual interests are given. The possible circularity objectives are examples of objectives that could motivate stakeholders to implement circularity.

The conceptual circularity objectives are based on the relations found between aspects, as mentioned in the exploratory research. The kind of relation between the aspects is unknown. This is why a conceptual interest is given with examples of possible circularity objectives that can be associated with this conceptual interest. So it has to be kept in mind that these objectives are examples based on a certain interpretation of the relation between the aspects.

6.3.1. All stakeholders' interests and objectives

The survey results give the interests of all stakeholders. Simply formulating these interests as objectives will not directly result in circularity objectives that stimulate stakeholders to implement circular construction. Most of these interests simply do not contain circular aspects. Only aspects 3, 7, 8, and 9 show that a stakeholder is interested in circular construction.

The following five interests are most important to all stakeholders when constructing a building:

- Aspect 1: The building fits the end-user;
- Aspect 3: The building is future-proof;
- Aspect 6: The building is as energy-efficient as possible, where required energy is locally and sustainably generated;
- Aspect 13: The building needs minimal maintenance;
- Aspect 4: Efficient cooperation with all parties.

The best way to enable all parties to implement circular construction is by finding circular objectives that contain these interests. The relations containing a circular aspect found in chapter 4.6 can assist in setting up circularity objectives. As mentioned in that chapter, nothing can be said about the kind of relation between these aspects. This makes it difficult to set up these circularity objectives for Kleissen per stakeholder. The conceptual interests found in section 4.6.3 are based on relations between aspects 1 and 3, 3 and 6, and 3 and 13. No relation was found between a circular aspect and aspect 4. Based on these relations found, a conceptual interest is given along with examples of possible circularity objectives that can be associated with this interest.

The first circularity objectives are based on the relationship between aspects 1 and 3. An example of a conceptual interest based on a relation of aspect 1 and 3 is already mentioned in chapter 4.6.3 and reads as follows: construct the building for evolution. Keep in mind that this interest's formulation fully depends on the kind of relation between these aspects. Hence this interest is just an example.

Examples of possible circularity objectives based on the mentioned conceptual interest of the relation between aspect 1 and 3 can be:

1. Make the building be adaptive in layout and format to make it at least fit one other type of end-user by using dry connections;
2. At least 80% of the used materials can be reused when the building should be adjusted to fit another end-user;
3. Only circular materials will be replaced when the building needs to fit another type of end-user.

The first example of a possible circularity objective can be categorized as a circularity objective that supports the sub-objective of designing for disassembly. The building should be designed detachable to make it fit at least one other type of end-user. Also, the objective somehow supports the sub-objective of reusing materials. By focusing on using dry connections, materials can be more easily reused because the material can be separated 'cleanly.' The second possible circularity objective can be categorized as a circularity objective that supports the sub-objective of reusing materials. The construction team has to think about constructing the building so that 80% of the materials can be reused when the building needs to fit another type of end-user. The third circularity objective supports the sub-objective of using circular materials. The construction team is stimulated to use circular materials effectively because when adjusting the building for another type of end-user, only circular materials can be replaced.

Another conceptual interest is based on the relationship between aspects 3 and 6. Depending on the kind of relation between these aspects, a possible relation can be formulated as using energy-efficient applications that are future proof. Future proof can be interpreted as using energy-efficient applications that can be reused, committed to various functions, and adaptable.

Examples of possible circularity objectives based on the mentioned conceptual interest of the relation between aspect 3 and 6 can be:

1. At least use two energy-efficient applications that can be adjusted when the building changes from size and function;
2. At least use one energy-efficient application that generates energy sustainably and can be fully reused at the end of life of the building;
3. Make use of at least two circular materials that can be replaced easily and increase the building's energy efficiency.

The first example of a possible circularity objective based on a possible relation between aspects 3 and 6 supports the sub-objective of designing for disassembly. The energy-efficient applications should be designed to be disassembled and put together when the size and function of the building changes. The second possible circularity objective can be categorized as an objective that supports the sub-objective of reusing materials. The construction team should implement two energy-efficient applications and keep in mind that these applications should be fully reusable in their end of life. The third possible circularity objective supports all sub-objectives. The construction team is stimulated to use at least two circular materials that increase the building's energy efficiency and are easy to be replaced. To make the circular materials easily replaceable, the materials should be designed for disassembly. This also makes the materials easier to be reused. As an example, durable isolation materials can be used. However, they should be designed for disassembly.

The third conceptual interest is based on the relationship between aspects 3 and 13. A possible relation between these aspects can be formulated as: reduce the building's maintenance by making the building future proof. As mentioned, this relation can be interpreted in different ways.

Examples of possible circularity objectives based on the mentioned conceptual interest of the relation between aspect 3 and 13 can be:

1. Make sure that all materials at weak spots of the building can easily be removed;
2. Use as many reused materials that need less maintenance than conventional materials;
3. Only use circular materials at weak spots of the building.

The first example of a possible circularity objective can be categorized as a circularity objective that supports the sub-objective of designing for disassembly. The construction team should design the building in a way that weak spots can be easily be removed. For example, by using dry connections at weak spots, the materials can easily be removed when maintenance is carried out. This circularity objective also supports the sub-objective of reusing materials. As mentioned, dry connections support cleanly separating materials, stimulating the reuse of materials. The second possible circularity objective supports the sub-objective of using reused materials. The construction team is stimulated to look for as many reused materials that need less maintenance than conventional materials. The third possible circularity objective supports the sub-objective of using circular materials. This objective makes using circular materials at the weak spots of the building a requirement. In this case, when maintenance is carried out, and materials have to be replaced, mainly circular materials will be replaced. This stimulates the protection of material sources.

6.3.2 Architects' interests and objectives

The survey results point out five interests that are most important to architects. The following interests are most important for architects when constructing a building:

- Aspect 1: The building fits the end-user;
- Aspect 3: The building is future-proof;
- Aspect 2: The building fits in its environment as well as possible;
- Aspect 6: The building is as energy-efficient as possible, where required energy is locally and sustainably generated;
- Aspect 7: As many circular materials as possible are implemented.

It is possible to convert the circularity objectives into requirements in the tender request to implement circular construction. Architects will have to comply with the requirements in the tender and explain their plan of approach. As mentioned in section 6.3.1, the possible circularity objectives are based on the conceptual interests of chapter 4.6. This conceptual interest is based on a relation between two aspects, where one aspect is a circularity aspect. The kind of relationship is not known, so a possible interest is given with examples of possible circularity objectives that can be associated with this interest.

The first examples of possible circularity objectives for architects are the same as all stakeholders in section 6.3.1 (see figure 19). However, architects do have four relations between aspects that are not mentioned yet. For every relation, a conceptual interest is given, along with one example of a possible circularity objective associated with that interest.

The first three examples of possible interests with the associated examples of possible circularity objectives are already given in section 6.3.1. The fourth possible interest for architects is based on the

relationship between aspects 1 and 7. It can be formulated as: use circular materials that fit the end-users as well as possible. This interest is just an example.

An example of a possible circularity objective based on the mentioned conceptual interest of the relation between aspect 1 and 7 can be:

- Every building envelope should contain at least one circular material that fits the end-user.

This example of a possible circularity objective supports the sub-objective of using circular materials. The construction team is forced to look at every building envelope and apply at least one circular material per envelope that fits the end-user.

The fifth interest is based on the relationship between aspects 2 and 7. This conceptual interest can be formulated as: use circular materials that fit the environment as well as possible.

An example of a possible circularity objective based on the mentioned conceptual interest of the relation between aspect 2 and 7 can be:

- Only use circular materials at all viewpoints of the building that fit the environment and can easily be replaced;

This example of a possible circularity objective supports all sub-objectives. Using this objective, the architect must think about applying circular materials at all viewpoints and making them detachable. By focusing on the circular materials' detachability, they can be more easily cleanly separated and hence reused.

The sixth interest is based on the relationship between aspects 3 and 7. This conceptual interest can be formulated as: use circular materials that can be adapted in function and size.

An example of a possible circularity objective based on the mentioned conceptual interest of the relation between aspect 3 and 7 can be:

- Make 80% of the applied circular materials reusable by using dry connections.

This example of a possible circularity objective also supports all sub-objectives. The objective stimulates an architect to use circular materials and design them so that at least 80% can be easily reused.

The seventh interest is based on the relationship between aspects 6 and 7. This conceptual interest can be formulated as: make the building as energy efficient as possible by using circular materials.

This example of a possible circularity objective is based on the mentioned conceptual interest of the relation between aspects 6 and 7. The objective is already mentioned in section 6.3.1 and was formulated as:

- Make use of at least two circular materials that increase the energy efficiency of the building.

As mentioned in section 6.3.1, this objective supports all sub-objectives because the architect is stimulated to use circular materials and design them to easily be replaced.

6.3.4 Contractors' interests and objectives

Based on the survey results of section 4.4, the most important interests of contractors are pointed out. The following interests are most important for architects when constructing a building:

- Aspect 1: The building fits the end-user;
- Aspect 4: Efficient cooperation with all parties.
- Aspect 3: The building is future-proof;
- Aspect 6: The building is as energy-efficient as possible, where required energy is locally and sustainably generated;
- Aspect 12: The task budget of the construction project should not be exceeded.

Also, for contractors to implement circular construction, it is possible to convert the circularity objectives into the tender request requirements. Contractors will have to comply with the requirements in the tender and explain their plan of approach. The conceptual interests are based on a relation between two aspects, where one aspect is a circularity aspect. As mentioned, the kind of relationship is unknown, which is why only a possible interest is given associated with possible circularity objectives as examples.

As shown in figure 19 of section 4.6, the relations between aspects of contractors are the same as those mentioned for all stakeholders. Contractors do not have any relations between aspects that other stakeholders do not have. See section 6.3.1. for the possible circularity objectives of contractors.

6.3.5 Clients' interests and objectives

The survey results show the most important interests of clients per work field. The interests per work field are based on very little data, which makes the interests a less good reflection of reality. For the same reason, the choice was made to only analyze all clients' paths in the exploratory research and not per work field. Therefore, the possible conceptual interests per work field will be unreliable. By focusing on all clients in the exploratory research, paths and patterns are found in all clients' data making the relations between aspects in the patterns more reliable. If the relations are more reliable, the conceptual interests are also more reliable.

The following interests are most important for clients of the residential work field:

- Aspect 1: The building fits the end-user;
- Aspect 3: The building is future-proof;
- Aspect 13: The building needs minimal maintenance;
- Aspect 6: The building is as energy-efficient as possible, where required energy is locally and sustainably generated;
- Aspect 9: Focus on the detachability of the building.

The following interests are most important for clients of the educational work field:

- Aspect 3: The building is future-proof;
- Aspect 1: The building fits the end-user;
- Aspect 6: The building is as energy-efficient as possible, where required energy is locally and sustainably generated;
- Aspect 13: The building needs minimal maintenance;
- Aspect 12: The task budget of the construction project should not be exceeded.

The following interests are most important for clients of the care work field:

- Aspect 1: The building fits the end-user;

- Aspect 3: The building is future-proof;
- Aspect 6: The building is as energy-efficient as possible, where required energy is locally and sustainably generated;
- Aspect 11: Not exceeding the total budget of the project when realizing the building;
- Aspect 2: The building fits in its environment as well as possible.

The following interests are based on the output of all clients and hence most important to all clients:

- Aspect 1: The building fits the end-user;
- Aspect 3: The building is future-proof;
- Aspect 6: The building is as energy-efficient as possible, where required energy is locally and sustainably generated;
- Aspect 13: The building needs minimal maintenance;
- Aspect 11: Not exceeding the total budget of the project when realizing the building.

As mentioned, the circularity objectives are based on a conceptual interest. This interest is formulated depending on the relation between the aspects where the interest is based on. The kind of relation is unknown, so a possible interest is given with associated examples of possible circularity objectives. However, the relations found for clients are the same as for all stakeholders (see figure 19 in chapter four). These possible interests with examples of circularity objectives are already elaborated in section 6.3.1. See section 6.3.1 for the conceptual interests and associated examples of circularity objectives.

6.4 Conclusion stakeholders' interests and circularity objectives

In conclusion, protecting material sources should be the main objective when focusing on circular construction. This objective is supported by three sub-objectives. Achieving sub-objectives brings us closer to protecting the material sources. The sub-objectives consist of reusing materials, designing for disassembly, and using circular materials.

Focusing on reusing materials means that the reuse of materials should be considered in the initial phase of the construction project. Secondary materials can be reused when a building has to be renovated or has to be demolished first. In case of completely new construction, secondary materials can be searched locally. For example, using secondary materials of a demolition project nearby. Focusing on disassembly means that already in the design phase, consideration should be given to the easily disassembling the building. This makes the building more adaptive in its size and function.

Furthermore, as the examples of possible circularity objectives show, designing for disassembly and reusing materials can often go together. Designing for disassembly simplifies the disassembly of materials. This serves as an incentive for reusing materials when the building enters its final phase or when it has to be adapted. Focusing on using circular materials means that in a construction project, preferably already at the start, materials are searched for that come from sources that can easily recover. For example, the source of steel, iron ore, takes much longer to restore a kilo of steel than the source of wood. If a circular material can perform the same function as a conventional material, then the conventional material should be replaced.

The examples of possible circularity objectives also show that there are many possibilities of supporting more than one sub-objective with only one circularity objective. Circularity objectives can be formulated in a way that they have tangents with all sub-objectives. However, the way a circularity objective is formulated depends on the interest it is based on. As mentioned earlier, the way this interest is formulated depends on the kind of relation between the two aspects. This is why the circularity objectives mentioned in section 6.3 were all examples based on a possible interest. These

circularity objectives cannot be considered reliable but only seen as examples of objectives that support the sub-objectives.

The interests found based on the survey's results in chapter 4.4 can be considered as somehow reliable. Remarkable is that all stakeholders find it important to make the building fit the end-user and build future proof. Especially the last one shows that stakeholders are open to circular construction. This does not necessarily have to be conscious, but some stakeholders are interested in making the building adaptive in size and function. This interest fits the sub-objective of designing for disassembly. Other important interests for all stakeholders are making the building as energy efficient as possible, making sure the building requires minimal maintenance and efficient cooperation with all parties.

Architects have instead of focusing on the maintenance and efficient cooperation, an interest in making the building fit in its environment, and using circular materials. This shows that architects have two interests that can be related to sub-objectives. As mentioned, making the building future proof supports the sub-objective of design for disassembly. Using circular materials shows that architects are open to think about ways of using circular materials instead of conventional materials.

Contractors have, instead of focusing on minimal maintenance, an interest in not exceeding the task budget of the construction project. This shows that contractors do have an interest in almost the same interests as all stakeholders but want to keep in mind the project's budget. When trying to achieve the sub-objectives, it has to be kept in mind that costs are not too high.

For the clients, interests per work field are found. Every type of client contains aspects of 1,3, and 6. This indicates that all clients are interested in making the building future proof and thus support the sub-objective of designing for disassembly. Clients of the residential and educational work field find minimal maintenance quite important. Clients from the residential work field also find the detachability of the building important. This shows that this client can be very cooperative in supporting the sub-objective of designing for disassembly. At the same time, clients from the educational and care work field have a bigger interest in not exceeding the budgets when constructing a building. Clients from the care work field even show that they find it important that the building fits in its environment.

By finding circular applications that fit the stakeholders' interests, stakeholders can be easily convinced to implement circular construction. Furthermore, by including circular requirements in the tender request related to the architect's or contractor's interests, architects and contractors will be stimulated to implement circular construction. For example, it is known that architects want are open to implementing circular materials. A requirement in the tender request could be to ask them to use at least five circular materials. For contractors, we know that they are open to design for disassembly but are reluctant to exceed the construction project budget. A requirement in the tender request for contractors could be to use dry connections at every spot when no extra costs will be involved.

The exploratory research of chapter 4.6 showed that there are patterns in the output data of the survey. These patterns showed that relations between aspects could be assumed. However, nothing can be said about the kind of relation. This makes it impossible to formulate a relation as one interest. Because of this, the circularity objectives supporting a sub-objective cannot be considered more than just examples. The advice is given to focus on the found interests and try to find circularity objectives that are in line with the stakeholders' interests. The circularity objectives can be formulated similarly, as in chapter 6.3.

7. Conclusions, discussion, and recommendations

In this chapter, we review the steps that are taken to be able to conclude. In section 7.1, the conclusion of the research is given. In the conclusion, all sub-questions are shortly discussed, and the main research question is answered. After the conclusion, in section 7.2, the current feasibility of circular construction is discussed. Section 7.3 provides a recommendation to Kleissen regarding the implementation of the circularity objectives. This recommendation aims to formulate the changes that should be made to structurally implement the provided solution. This section also contains a sub-section where further research is discussed.

7.1 Conclusions

We started the project by setting up the best formulation of circular construction. This was done through literature research, desk research, and interviews with circularity experts. We focused on answering: '' How can circular construction be formulated?''. After discussing the researches and interviews, a theoretical framework was set up. The framework took all information coming from the literature, CB23 platform, and circularity experts in one. The formulation of circular construction with its associated strategies would later be converted into the fundamental objectives of circular construction.

In the next step of the project, we mapped the current situation of Kleissen. The main goal was to get a thorough understanding of the current situation. The focus was on answering the following questions: ''How is circularity currently implemented in projects of Kleissen?'' and ''How does the current supply chain of Kleissen's construction management process, in general, look like?''. Analyzing the label and linking it to the theoretical framework of chapter two showed that #HoudbareHuisvesting already included circular construction. We discussed the way of tendering, the phase plan, and transition documents. Tender requirements regarding sustainability were not specific, and the transition documents did not contain the topic sustainability of circularity. A detailed and simplified flowchart was made to better understand the construction management process and where #HoudbareHuisvesting is currently integrated. The flow charts visualized how the current supply chain of Kleissen looks like.

Chapter four provided the interview results, the survey's outcome, and the exploratory research on the survey's output. We focused on the question: ''What are the interests of the company's stakeholders, and how do they interpret circularity in construction?''. Architects, contractors, and clients were interviewed and filled in the survey. We first discussed the interview (Section 4.2) and concluded that stakeholders have different interests and experiences regarding circular construction. Secondly, we discussed the survey results. Based on the results, conclusions are drawn up per stakeholder type. Finally, exploratory research was conducted. The research showed that based on paths found in the survey's output data, patterns could be found. We concluded that these patterns indicate that there can be relations between the aspects mentioned in the survey. These relations could lead to a potential interest.

In chapter five, the circularity approaches of other organizations are discussed. The following questions were answered: ''What circularity objectives do other organizations operating in residential and utility construction set in their project plan?''. The interviews with the organizations that wanted to speak to use were discussed. We concluded that other organizations did not have a specific request, approach, or objectives regarding circular construction within the scope of our research.

The next step of the project was to set up the circularity objectives. The following questions were answered: ''What should be the main and sub-circularity objective(s) for Kleissen?'' and ''What are the circularity objectives that are in the interests of the stakeholders?''. The first question was answered

using the theoretical framework of chapter two. The main objective of circular construction can be formulated as: ''protecting the material sources''. The sub-objectives are based on the corresponding circular strategies: using circular materials, reusing materials, and design for disassembly. The second question was answered by setting up potential interests and examples of circularity objectives based on the exploratory research of section 4.6. It should be kept in mind that these circularity objectives are examples based on potential interest. The interests are set up based on a relation between two aspects. Whether this relationship truly exists and what the kind of relation is, is unknown. However, the stakeholders' interests are known and can support effectively approaching stakeholders regarding the implementation of circular construction.

7.1.1 What are the circularity objectives that form a method to implement circularity in construction projects structurally?

All the previously discussed chapters serve to answer the main research question. In this project, we noticed that Kleissen does currently not structurally implement circular construction. Mainly in chapter six, we stated the circularity objectives that answer the research question. We distinguish one main circularity objective and three sub-objectives.

The main objective of circular construction is: **protect the material sources**. Circular construction should have the objective of protecting the sources of materials. This objective can be achieved by achieving the sub-objectives:

- **Reuse materials when managing a construction project.** In a construction project, a distinction must be made between renovation and new construction. During a renovation, a search must be done for materials that can be reused per material category. In the case of new construction, there must be a local search for secondary materials per material category.
- **Design for disassembly when managing a construction project.** In a construction project, dry connections between materials should be designed and constructed. Materials can be easily and cleanly detached, simplifying the reuse of materials when the building enters its ending phase. Also, this makes it possible to easily change buildings in function and size.
- **Use circular materials when managing a construction project.** This means that in a construction project, the focus should be on using materials from sources that can recover fast. Per material category, materials that are exhaustive for the earth should be replaced by these circular materials.

To achieve these sub-objectives, it is important to motivate the stakeholders to construct circular. For this reason, the interests of the stakeholders were analyzed. As mentioned in section 6.3, there can be circularity objectives found that fit the interests of stakeholders. By approaching stakeholders in this way, there will be a greater chance that circular construction will occur and that sub-objectives will be achieved. These circularity objectives are not mentioned in the conclusion because they are based on conceptual relations between aspects.

The research shows that the circularity objectives also involve a change in the current working method. The current working method does not support the implementation of circular construction. A change in the working method is needed to implement these circularity objectives and solve the action problem. This will be further described in the recommendation (section 7.3). A change of the working method and the circular objectives together serve as the foundation of a more structural circular construction implementation.

7.2 Discussion

Although the government strives for circular construction in 2050, full circular construction will be hard to execute. Besides that, circular construction is a different and perhaps an unknown way of constructing. The current tax system limits the implementation of circularity in construction.

To build fully circular, a change in the tax system will have to take place. A lot of circular materials are currently more expensive than conventional materials. Also, reusing materials requires labor because the secondary materials have to be processed in most cases. Furthermore, making architects focus on elaborating various functions of the building will also require extra labor.

In this tax system, labor is expensive and conventional materials are cheap. In other words, implementing circular construction will currently often be more expensive than conventional construction. By taxing less on labor and more on environmentally harmful materials, including materials from sources that will not recover fast, full circular construction could be achieved.

For now, focusing on protecting the material sources by addressing stakeholders' interests in every construction project will be a first great attempt to implement circular construction.

7.3 Recommendations

The research question mentions that circularity objectives should form a method. An advised method should support Kleissen in using the circularity objectives. Chapter three shows that the current prescribed working method is most likely ineffective when implementing circular construction. To improve the working method, circular construction should be an action in the phase plan, a part of the transition document, and a tender requirement. This will support every project manager to focus on achieving the circularity objectives.

A conceptual method of implementing circular construction when managing a construction project should consist of the following steps:

1. **Use the circularity objectives.** The first step towards circular construction should be to focus on using the circularity objectives to implement circular construction. Therefore, circular construction should be an action mentioned in every phase of the phase plan. What these actions entail are explained in the next steps of the advised method.
2. **Refine the circularity objectives based on the interests of the stakeholders.** Before a project starts, the circularity objectives should be refined based on the interests of the stakeholders. The objectives mentioned in section 6.3 can be used as examples. Refining the circularity objectives can be done based on the interests found in this research or through conversations with the client.
3. **The next step is to approach the client with refined circularity objectives.** In this way, there is a greater chance that the client can be stimulated or convinced to implement circular construction. Only using the sub-objectives can be considered by a client as objectives that will not immediately benefit them.
4. **Apply the circularity objectives in the tender requests for architects and contractors.** The refined objectives are converted into requirements. Also, these objectives can be supplemented with circularity requirements that match the architect or contractor’s interest. In this way, architects and contractors are assessed on these requirements with the BPKV model. By requesting, based on architects' or contractors' interests, the stakeholder will be encouraged to think about circular construction and come up with solutions.
5. **During the construction project, check and manage the achievement of the circularity objectives.** After every phase, the current status of achieving the objectives should be

checked, discussed, and perhaps adjusted. Therefore, the transition document should contain a chapter that discusses circular construction.

6. **The report used circularity objectives and applications**. A database containing this information will contribute to improving the circularity objectives. It provides an overview of the used circularity objectives and applications. Also, these objectives and applications can be used in later projects. Based on the applications found, the objectives can be improved by making them more specific. Please note that making the circularity objectives specific can be at the expense of creative and innovative ideas from architects and contractors. These parties must also be given the time to get used to circular construction and deepen their knowledge.

Secondly, It is advised to consult with the client to request a material passport for the building. With the aid of a material passport, materials retain their identity to not be lost anonymously as waste (Madaster, 2017). All materials in the building are documented. This will simplify the reuse of materials in the final phase of the building.

Finally, a small adjustment in the label #HoudbareHuisvesting is recommended. As mentioned in chapter three, the main objective of circular construction and the circular strategies are included in this label. However, they do not come forward clearly. Circular construction could be placed in the label with a separate heading, to emphasize that Kleissen is a forerunner in circular construction and strives to protect the material sources. Per heading, circular strategies can be mentioned. This clarifies how Kleissen interprets circularity and wants to implement circular construction.

7.3.1 Further research

This research shows that stakeholders are open to circular construction. In chapter six, the circularity objectives are mentioned that will contribute to circular construction. Section 6.3 explains the exploratory research that was conducted to set up conceptual objectives. Further research is needed to find out whether the relations between the aspects can be considered as real. If this is the case, aspects can be linked to each other. This research can consist of conducting another survey with more specific questions. The questions should be asked in such a way that it is possible to perform statistical analysis.

Further research could also go deeper by looking at the stakeholders' interests in specific circular applications and how far a stakeholder would go to implement this circular application. This will allow circularity objectives to be formulated even more specifically.

The conceptual method in section 7.3 explains that all circular applications found during a project should be reported. In addition to this, research could be performed to find out all circular applications that support achieving the sub-objectives. Instead of finding out the applications through projects, Kleissen will already be aware of several applications and can then nominate them to the client.

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9. Appendix

In this chapter, the appendices are given. Appendix A provides the questions used to interview the stakeholders. Appendix B gives a detailed flowchart of the construction management process. Appendix C.1 and C.2 belong to the survey. C.1 provides a translation of the interests in the survey. C.2 gives the survey's output. Appendix D provides a table containing all relations found between aspects in the exploratory research.

Appendix A

This appendix contains the interview questions that were asked to circularity experts and the stakeholders. This is a translation because the interviews took place in Dutch.

Interview questions

1. What was your role in the construction process? Which project did you collaborate on?

2. How do you interpret circularity?

3. To what extent does the application of circularity have a priority for you in the realization of a new building? Is this something you are already busy with?

4. What are the most important (most important) factors for you that determine how circular a building is?

5. Do you have experience in applying circularity?

    a. Organization answers 'yes': what were these circular implementations?

    b. Organization answers 'no': are you familiar with other circular applications?

6. What can / has convinced you to apply circularity and when is this feasible for your company?

    a. Organization answers 'yes': what does convince you to apply circularity?

7. What limits you to applying circularity?

8.How do you approach clients / architects / contractors to apply circularity?

    a. Organization answers 'I do not' or something similar: how should clients / architects / contractors be approached to apply circularity?

9. Do you have experience with the specifically requesting circularity?

    a. Organization answers 'yes': what did you request regarding circularity?

10. Do you have sources / organizations / platforms or persons within (or outside) your company who can tell me more about circular applications?

11. Do you know / have you worked with other construction management agencies that have a similar active attitude on sustainability?

    a. Organization answers yes: which organization?

Appendix B

This appendix contains a detailed flowchart. The flowchart is based on the phase plan and cut into two documents because of its size. In order to properly display the detailed flowchart, it has been added as a supporting document. See **'supporting document A'** for phases 1 to 5. See **'supporting document B'** for phases 6 to 10. The detailed flowchart is explained in section 3.4.1.

Appendix C.1

This appendix contains the aspects proposed to the stakeholders in section 3, question 1 of the survey. This table shows the meaning of every aspect. As mentioned in the survey (section 4.4), the aspects are called interests. The stakeholders were asked to select and rank five out of the fifteen aspects.

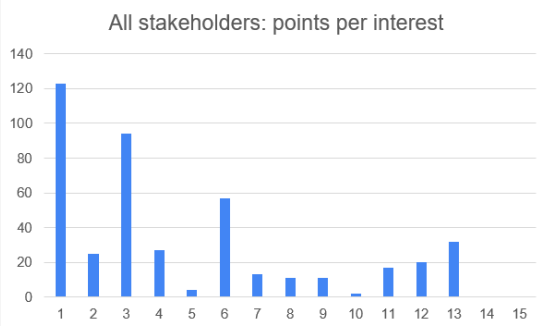
Aspect	
1	The building fits the end-users as close as possible. (End users: all persons who will use the building after construction.)
2	The building fits into its environment as well as possible. (Environment: local residents, companies, nature, and other objects around the building land.)
3	The building is future-proof. (Future-proof: a dynamic building that can be adapted in function and size.)
4	I work efficiently with parties (clients, contractors, architects, consultants) who have a similar vision.
5	Improve the social image of the client by means of the building. (Social image: the image of persons. To what extent people see and experience that the client takes his social role as an organization in society seriously.)
6	The building is as energy-efficient as possible, whereby the required energy is generated locally and sustainably.
7	As many circular materials as possible are used. (Circular materials: materials that can easily be reused and can be degraded in an environmentally friendly manner in their final phase.)
8	As many secondary materials as possible are reused in the building. (Secondary materials: disassembled materials. Materials that have already had a "life" and can be reused because otherwise they would be processed as waste or raw material.)
9	The focus is on the detachability of the building. (Detachability: how 'easy' to disassemble different materials in a building. Ensuring that materials in a building are connected in such a way that they can be easily separated makes a building remountable and therefore reusable.)
10	The registrations from parties (architects, contractors) in the tender are mainly assessed on sustainability.
11	The total budget of the project for the realization of the building is not exceeded. (Total budget: the total amount that the client makes available for the entire project: from nothing to the final delivery of the building.)
12	The task budget of the construction project is not exceeded. (Task Budget: The amount needed and available to perform a task.)
13	Ensure that the building requires minimal maintenance.
14	The registrations from parties (architects, contractors) in the tender are mainly assessed on price and quality.
15	For the realization of the building, materials are purchased for the lowest possible price.

Appendix C.2

This appendix shows the results of the survey. The results are analyzed in Excel. The charts show the total points on the y-axis and the different aspects on the x-axis. The tables provide the exact number of points per interest.

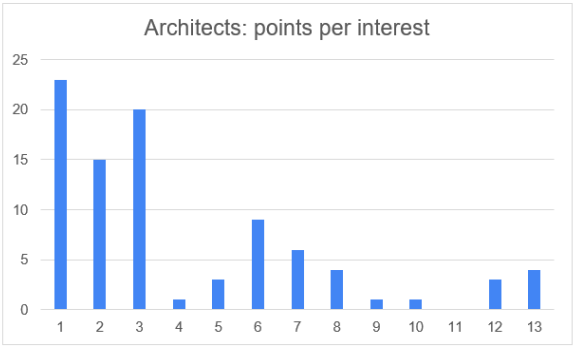
All stakeholders:

Interest	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Points	123	25	94	27	4	57	13	11	11	2	17	20	32	0	0



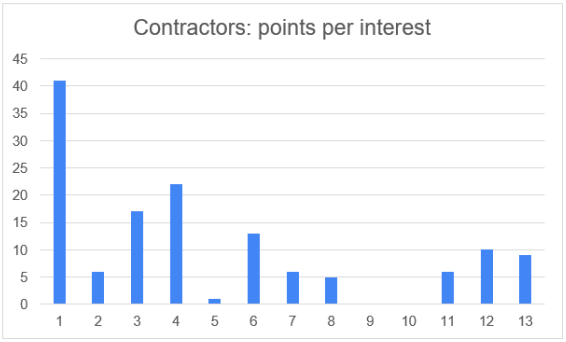
Architects:

Interest	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Points	23	15	20	1	3	9	6	4	1	1	0	3	4	0	0



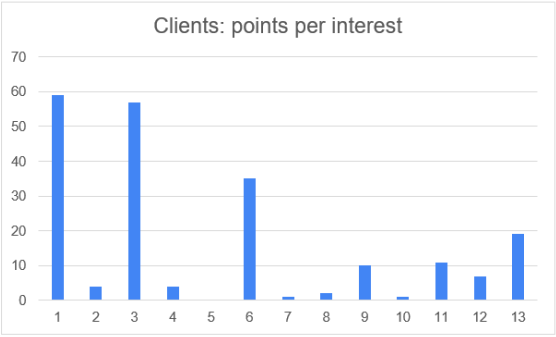
Contractors:

Interest	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Points	41	6	17	22	1	13	6	5	0	0	6	10	9	0	0



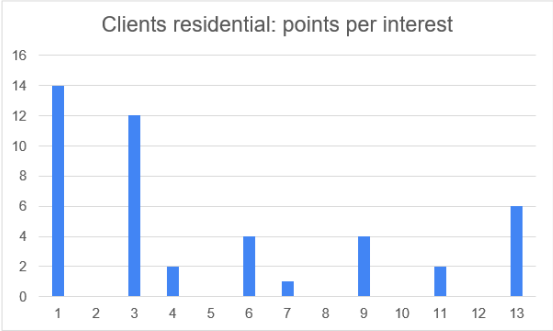
All clients:

Interest	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Points	59	4	57	4	0	35	1	2	10	1	11	7	19	0	0



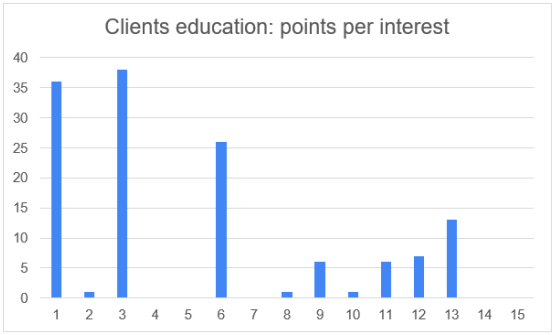
Clients residential:

Interest	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Points	14	0	12	2	0	4	1	0	4	0	2	0	6	0	0



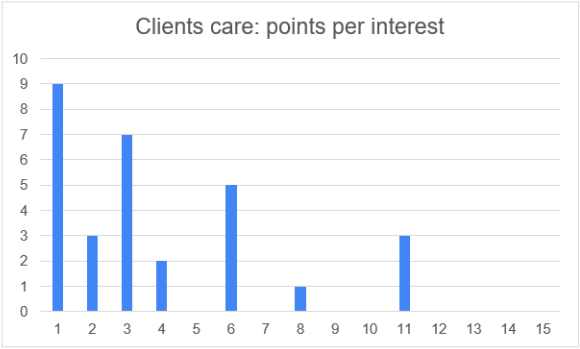
Clients education:

Interest	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Points	36	1	38	0	0	26	0	1	6	1	6	7	13	0	0



Clients care:

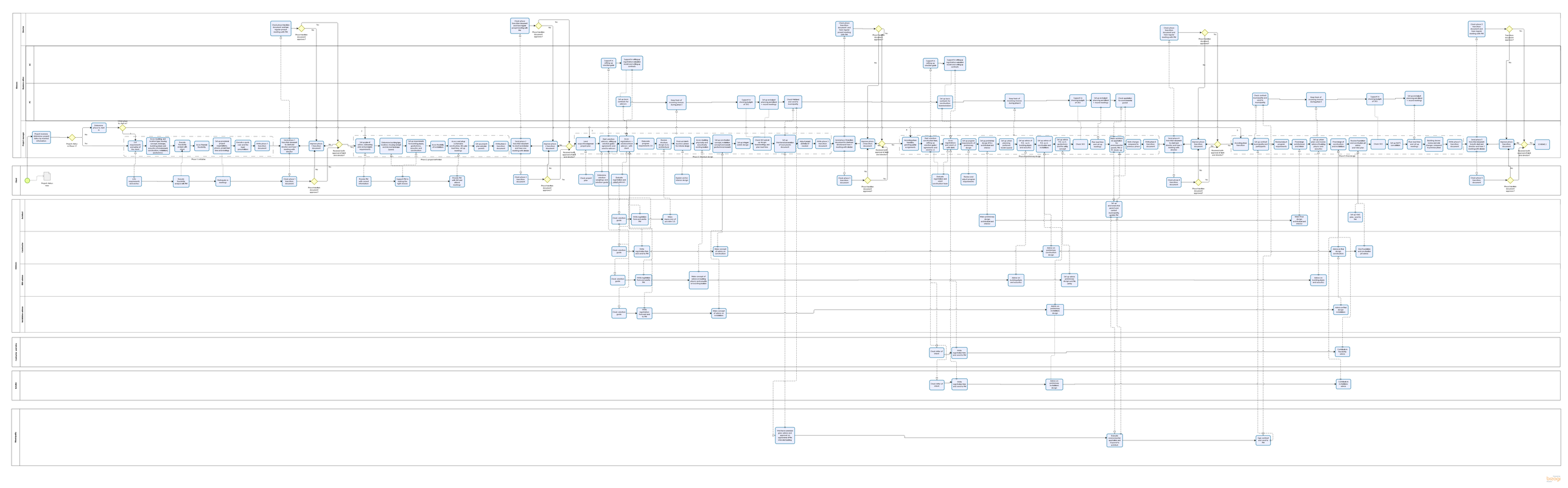
Interest	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Points	9	3	7	2	0	5	0	1	0	0	3	0	0	0	0

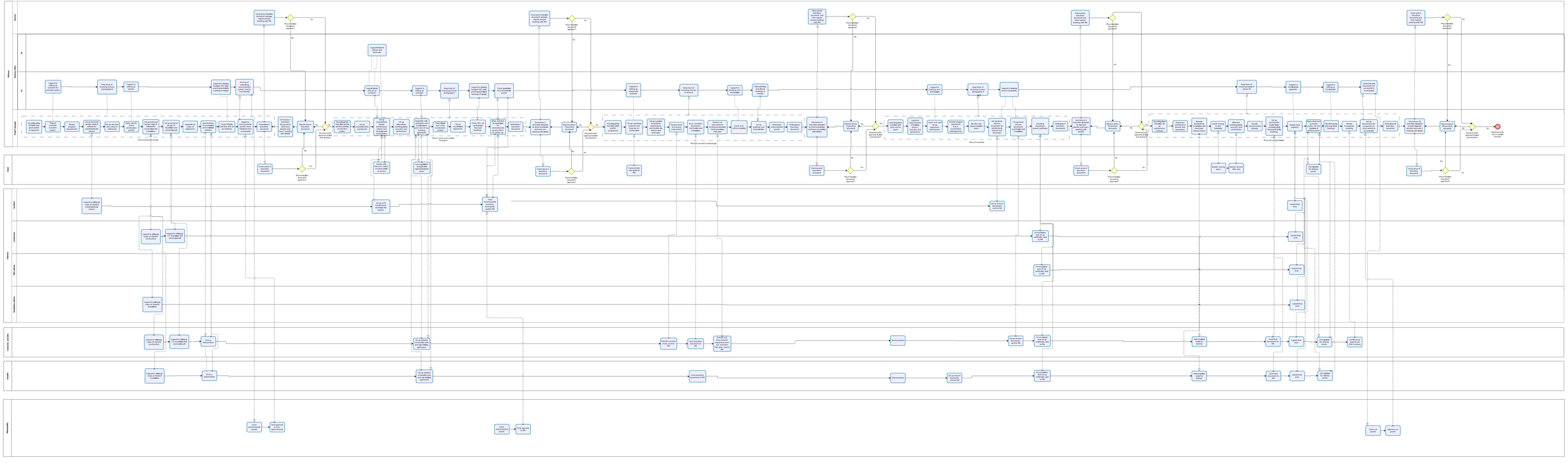


Appendix D

This appendix contains the table mentioned in chapter four and six. Per stakeholder type (first column), the relation between two aspects is given. The frequency column shows the number of patterns containing this relation. The green rows show the relations that contain a circular aspect, making them a circular relation. Based on these circular relations, conceptual interests were set up in chapter six.

Stakeholder	Combination of aspects	Frequency
All stakeholders	1 and 3	11
All stakeholders	1 and 6	10
All stakeholders	3 and 6	9
All stakeholders	1 and 13	8
All stakeholders	3 and 13	8
Architects	1 and 3	3
Architects	1 and 2	2
Architects	1 and 6	2
Architects	1 and 7	2
Architects	2 and 6	2
Architects	2 and 7	2
Architects	3 and 6	2
Architects	3 and 7	2
Architects	6 and 7	2
Contractors	1 and 4	3
Contractors	1 and 3	2
Contractors	1 and 6	2
Contractors	1 and 13	2
Contractors	3 and 6	2
Contractors	3 and 13	2
Contractors	6 and 13	2
Clients	1 and 3	4
Clients	3 and 13	3


Client
Project Manager
Architect
Structural Engineer
MEP
Civil
Client
Project Manager
Architect
Mechanical, electrical, plumbing
Landscape architect
Structural Engineer
Project Initiation
Phase 1 Initiation
Phase 2 Project Activities
Phase 3 Concept design
Phase 4 Developed design
Phase 5 Technical design
Phase 6 Construction
Phase 7 Handover
Project request, letter by received information
Project letter in Phase 1.7
Determine if EIA is required
Yes
No
EIA requirements and scope
Undertake EIA and obtain approval
Provide feasibility advice with RI
Participate in meetings
Check phase 1 transition document and how it relates to project
Approve phase 1 transition document
Review if suits current circumstances
Prepare RI with current circumstances
Prepare RI taking the legal matters
Review the with SO and Project meeting
Check phase 2 transition document and how it relates to project
Approve phase 2 transition document
Review if suits current circumstances and decision
Project Initiation Document
Phase 1 Initiation Document
Phase 2 Project Activities Document
Phase 3 Concept Design Document
Phase 4 Developed Design Document
Phase 5 Technical Design Document
Phase 6 Construction Document
Phase 7 Handover Document
Check phase transition document and how it relates to project
Approve phase transition document
Review if suits current circumstances and decision


Planner
Planner plan
PE
Project manager
Client
Architect
Architect plan
Interior
Interior plan
Installation planner
Customer, vendors
Installer
Municipality
Check phase handles document, outlines approach and meeting with PM
Phase handles document approved?
Support PM in setting up executive parties
Prepare executive parties
Review executive supervision
Set up technical design, scope of work and architectural and interior
Support in drafting RFP, Foundation and construction all
Support in drafting RFP, Foundation and construction all
Support in drafting RFP, Foundation and construction all