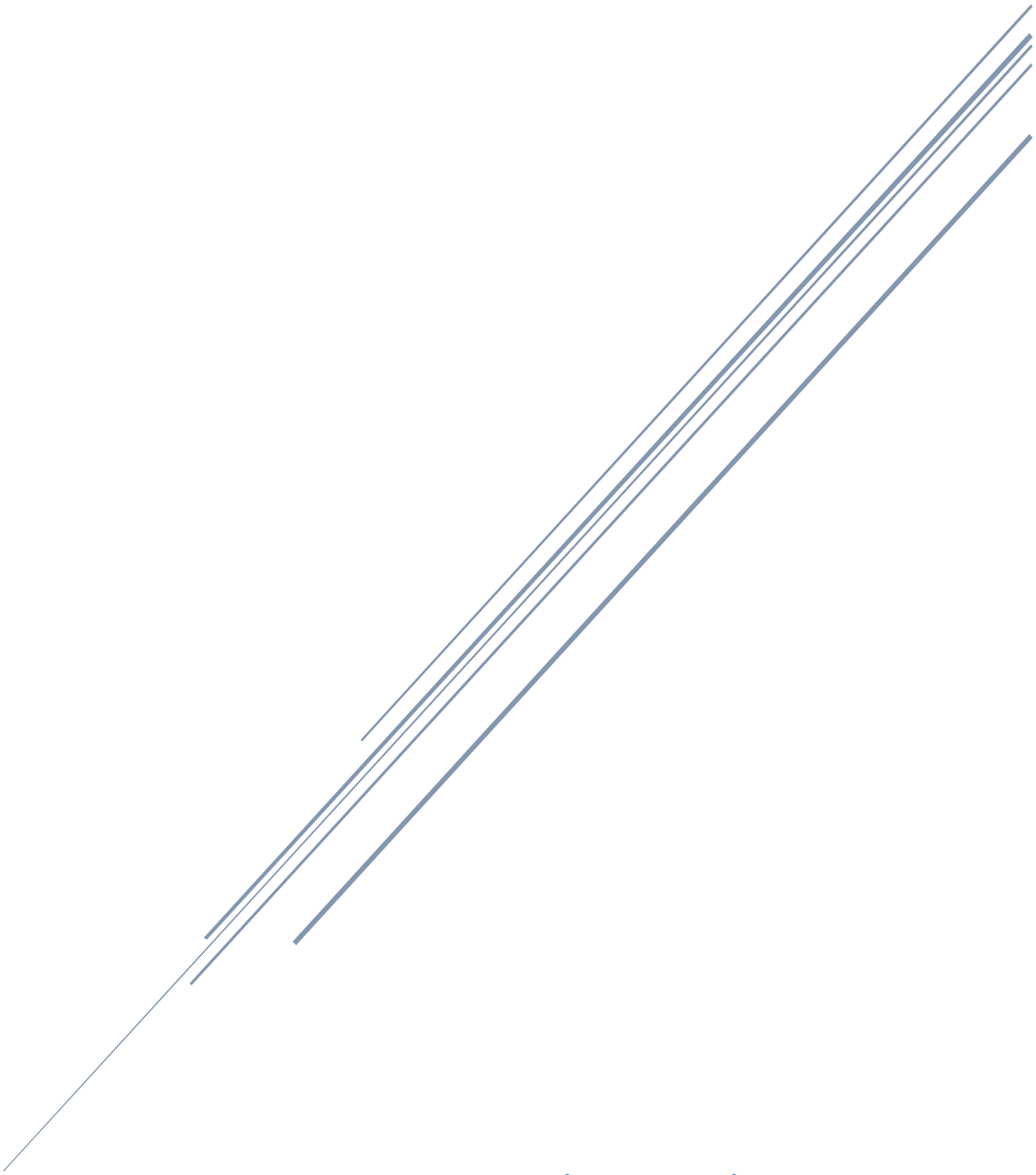
Delft University of Technology

Long-Term Collaboration Process during the lifecycle of circular building components for housing retrofit

Stefanos Voglis



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Long-Term Collaboration Process during the lifecycle of circular building components for housing retrofit

Mapping the collaboration process for the case of circular extension

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Graduation Thesis for Master of Science Construction Management & Engineering at Delft University of Technology

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Abstract

Nowadays, the built environment of the Netherlands is making the transition from the linear to circular economy to meet the goals set by the European Union and the Dutch government of 50% circular economy by 2030. However, there is limited knowledge in the built environment for circular economy projects. In order to generate knowledge on the topic, organisations partner up to complete a project. One of the most important aspects of such partnerships between a variety of partners is collaboration. Successful collaboration between partners is crucial for the partnerships to succeed. However, the built environment is a highly fragmented sector which inhibits collaboration. Furthermore, it is unclear how the long term collaboration process would look like in the context of the circular retrofits. The REHAB project is such a case of partnership between organisations, which develops two circular components for housing retrofits, the circular skin and circular extension. This research develops three process maps to understand if it is possible to create a feasible and useful long-term collaboration process for the development and implementation of the circular extension product.

In order to identify the existing knowledge gap in the academia, a literature review was conducted by analysing circular economy projects, circular economy products and by identifying differences between the practices. Comparing the findings, the gap was identified on the end part of the project lifecycle.

To fit the innovative characteristic of the research, the “Research through Design” (Rtd) methodology is chosen, where possible future scenarios in the form of design variants are simulated. During the first step of RtD (analysis), the design parameters and requirements were identified, as well as the main key factors of collaboration in the context of circularity. This identification happened through a literature review and informal interviews with partners of the circular extension. This determined the parameters of the design variants and the requirements that the design variants have to fulfil. During the next step (synthesis), the three variants were identified and the long term collaboration process variants were designed. Based on this information, three design variants were developed (traditional, balanced, innovative). The third step (simulation) involved presenting the design variants to partners of the circular extension in a semi-structured interview format. The answers of the interviews were analyzed in order to derive learnings, where the goal was to evaluate the feasibility and usability of the long-term collaboration process design variants. During the last step (validation) the researcher employed the help of former fellow students that have conducted similar researches using RtD to guarantee the scientific validity of the research.

The analysis of the answers collected during the interviews showed clearly that the balanced design variant is the most feasible collaboration process currently and the innovative as the most promising variant for the future. The traditional design variant was deemed not feasible. Furthermore, trust and communication are the core characteristics of a long term collaboration. Another conclusion is that the most important design parameter for the long term collaboration process is the business model, since both client and contractor are highly interested in the financial incentives. The most important lesson derived by the answers of the partners suggest that currently it is still too early to establish a clear collaboration process path for the stakeholders that will take place in ten to twenty years. The research provides valuable information to stakeholders of the circular extension on how to improve circularity through establishing successful collaboration and the steps to guide the collaboration. Moreover, the research provides a good base for future researches to be conducted on the topic of long term collaboration strategy. The difference being that a strategy can be more adaptive for future partners than the rigid guides of a process. Furthermore, it is concluded that countries with high regulated housing sector can adapt to circular economy practices and create successful collaboration easier than countries with a free market.

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1. Introduction and Research Proposal

The first part of the chapter dives in the topic of circular economy. The second part involves the identification of the research gap. The last part delves into the research methodology and strategy.

1.1 Introduction of research

The industrial economy has seen an exponentially growth the last century, mainly due to the technological growth. However, it has barely moved beyond one fundamental characteristic established in the early days of industrialization. That of a linear model of resource consumption that follows a 'take-make-dispose' pattern (EMF, 2013). The life cycle of buildings, beginning from design to decommissioning, is accountable for roughly 15% of the world's fresh water resources, as well as 40% of the world's energy usage, and produce roughly 30% of the greenhouse emissions released in the atmosphere (Reddy, 2016). Moreover, it is forecasted that more than three billion new individuals will be entering the consuming middle class by 2030 (EMF, 2013). In order to meet the needs of the present without compromising the ability of future generations to meet their own needs (Brundtland, 1987), the linear consumption model is required to be converted to a more sustainable model. Circular Economy is a promising prospect.

In the research done by Kirchherr, Reike, & Hekkert (2017), a systematic analysis was conducted specifically on current circular economy (CE) understandings. In total 114 definitions where analyzed and concluded that CE is an economic system that replaces the 'end-of-life' concept by reducing, alternatively reusing, recycling and recovering materials in production, distribution and consumption processes. In the construction sector, circular economy practices mainly focus on using construction and demolition waste in road fillings, which results in downscaling of the materials (Yuan & Shen, 2011). Efforts are being taken from various organisations such as the Ellen MacArthur Foundation and the European Commission in order to promote circular economy practices. These practices have as main focal point to narrow, slow and finally close the material loops (Bocken N. M., De Pauw, Bakker , & Van der Grinten, 2016)The butterfly figure created by the Ellen MacArthur Foundation perfectly illustrates the CE practices:

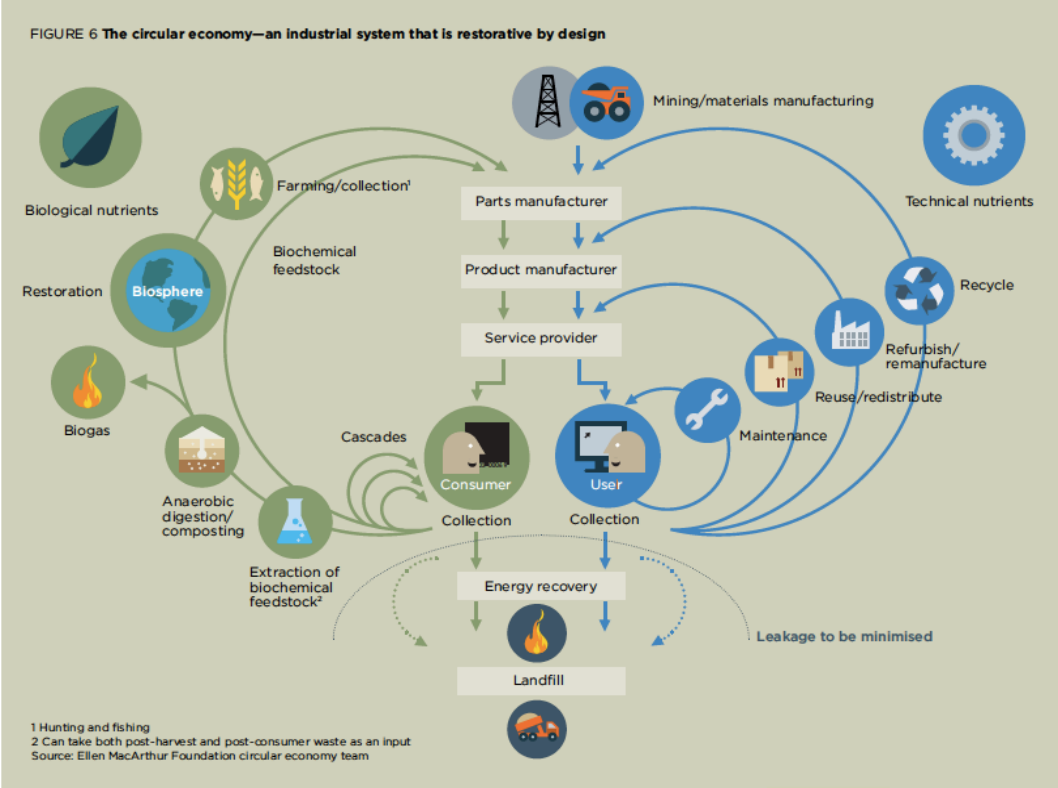

Figure 1.1 Butterfly Model (EMF, 2013)

Looking towards a more sustainable future, the Dutch government aims on developing a fully circular economy by 2050 and a 50% reduction in the use of primary raw materials such as minerals, metals and fossil fuel by 2030 (A Circular Economy in the Netherlands by 2050, 2016). Another goal of the Dutch government is the zero carbon dioxides emissions from housing until 2030 (Affairs, 2016). However, the existing housing building stock of the Netherlands originates from the first half of the previous century. Furthermore, forecasting research present that one million new houses need to be constructed in order to meet the increased demand of the booming housing market (Transformatiepotentie van de stad, 2017). Moreover, according to IEA (2013), 75-90% of the existing buildings will be on use in 2050, which results in the need to improve the energy performance of this building stock. In response, the European Union released a directive in order to stimulate renovation works by improving energy efficiency (EU, 2002).

The main principal of the CE is to make optimal use of the inner technological cycles of maintain, reuse and remanufacture, hence minimize waste (Van Stijn & Gruis, 2019). By replacing one or more of the main components that a building is consisted of during renovations and retrofit. The building stock is progressively converted into a circular one (Van Stijn & Gruis, 2019). Therefore, introducing circular components with circular design during retrofit or renovation works presents a viable path towards circularity in the Built Environment (BE).

The transition from linear to circular BE is a challenging endeavor that requires an array of organisations and individuals to come together. From material supply chain to construction experts, architects all the way to workers. All these individuals play a key role in conducting their respective activities with circularity at its core. In the context of creating a circular economy product in the BE, all these individuals would require to coordinate decision making, share information (Leising E. J., 2016) all in all to collaborate. In their research, Leising, Quist, & Bocken (2018), state that it is essential to include supply chain collaboration across the lifecycle of buildings from start to End of Life in the context of circular environment. In order to slow and eventualy close material loops, it is vital to incorporate the supply chain as a whole and to involve all parties from raw material to end users (EMF, 2016; Seuring & Müller, 2008). This research dives in depth on this collaboration process across the lifecycle of a circular economy product in the built environment. The goal of the research is to develop a feasible and usable long-term collaboration process map and identify lessons learned for a circular building component.

The rest of the first chapter is introducing the research gap, research questions and strategies. The second chapter (Analysis) is focused on the literature review conducted for this research. The third chapter (Synthesis) involves the design of collaboration variants. The fourth chapter (Simulation & Evaluation) involves the data gathering process from semi-structured interviews with partners from the “REHAB” project. The fifth chapter (Validation) involves the validating process of the research. The sixth chapter (Discussion) involves the discussion points of the research. The seventh chapter (Conclusion) draws the conclusions of the research. The final eighth chapter (Reflection) involves the final personal reflections of the researcher.

1.2 Introducing the niche

According to Van Stijn & Gruis (2019), the integration of circular components requires changes in the design, supply chain and business model. These changes can be used to innovate and improve renovation practice and outcome. Moreover, circular renovation would present the opportunity for a different cycle of interventions in the housing stock (Brinksman, 2017). By implementing circular design during retrofits, it allows a smaller more frequent adjustments like “small sprints” which can keep the building up to standards for a longer period of time (Van Stijn, 2020).Circular design can also broaden the choices and flexibility of the design for the tenant or owner (Van Stijn, Gruis, & van Bortel, 2018). One of the main circular design principles is modularity according to Bakker, Den Hollander, Van Hinte, & Zijlstra (2014), By using modularity, the loop cycle is slowed down and provides the choice to the owner to conduct the maintenance or renovation when is financially viable. Moreover, modularity can be customized in the needs and preferences of the tenant or owner, which results in a better life environment as well as to be able to adapt the design for future (Brinksman, 2017).

In this context, TU Delft and partners collaborate in the 'REHAB' project. The 'REHAB' project aims at developing two circular building components for housing renovation, a circular skin and a circular extension (TU Delft, 2019). The circular extension is a system made up of standardized modules using circular materials. By using modular construction and mass-customization, it is possible to adjust the extension to meet changing housing needs. It is also easy to replace individual components while the building is in use and in the end of the lifecycle the modules can be reused.

To design the circular extension, a variety of partners collaborated and still collaborate as the project is ongoing. These partners included consultants, suppliers, housing associations, tenants, construction partners and maintenance partners. This type of collaboration between so many partners, with so many different needs and goals in an innovative environment is highly challenging.

The collaboration process spans throughout the lifecycle of the component, from design all the way to decommissioning and for circular components towards reintroduction in the construction loop. In order for the circular extension to be a success, it is important that the collaboration process is successful. However, the collaboration of the circular extension cannot be based on the typical collaboration between partners in the BE as the scope of the project has fundamentally different goals. Firstly, it is needed to understand the difference between the typical collaboration process for a circular construction project renovation and the collaboration process of a circular component.

1.3 Known knowns and unknowns

With the introduction of sustainable and circular practices, the complexity of the projects rose significantly. In order to co-op with increased complexity, organisations collaborated to achieve the desired goal. These collaborations take place in the form of partnerships (Stiles, 1995; Douma, Bilderbeek, Idenburg, & Looise, 2000) These partnerships are based on collaboration and knowledge sharing between partners.

However, the BE is a highly rigid and fragmented sector, which reduces mutual knowledge capturing and sharing, inhibits knowledge production and limits learning and innovative solutions (Hertog & Brouwer, 2001). Nonetheless, in order to grasp the maximum potential value created by CE practices individuals are required to collaborate in a successful way. In their research, Leising, Quist, & Bocken (2018), examined three CE renovation projects and concluded that stakeholder collaboration was one of the key factors in the success of the investigated projects. Therefore, it is important to understand how partners collaborate in the BE and the possible short comings.

In the BE, projects follow the classic life cycle phases of Initiation, Design, Construction, Operation and finally Decommissioning (Gransberg & Ellicott, 1997) as illustrated in the following figure.

Figure 1.2 Lifecycle of Construction Project

However, research studies have identified this lifecycle model as one of the main causes for failure of construction projects (Fulford & Standing, 2014; Nawi, Lee, Azman, & Kamar, 2014). Communication is fragmented between the different phases of the project, which results in a fragmentated collaboration between experts. The absence of communication and commons goal results in an incomplete scope and therefore failure to deliver. The following figure illustrates the fragmentation problem.

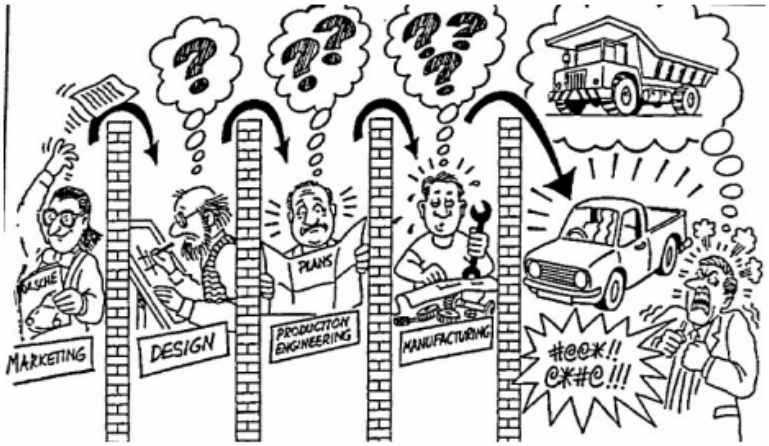

Figure 1.3 Over the wall syndrome (Nawi, Lee, Azman, & Kamar, 2014)

The lifecycle of a circular construction project does not defer much from the one proposed by (Gransberg & Ellicott, 1997). The only difference is the introduction of process loops during the maintenance and decommissioning phases in order to achieve the circularity goals. Figure 1 illustrates these loops. The introduction of the loops increases the complexity of the project and creates a hazardous environment for collaboration.

It is clear that the BE has a fragmented collaboration profile. This fragmentation exists in all projects, from the design of a new building to renovation works. Therefore, it is important to identify and compare the lifecycle of a normal renovation component and the lifecycle of a circular renovation component. By doing this comparison, the difference between the collaboration process of the partners is determined. Hence, the research can identify the knowledge gap that exists in the collaboration process.

1.4 Collaboration during circular renovations

In the built environment collaboration became necessary to co-op with the ever-increasing pace of technological developments and specific innovative requirements every project requires. The literature on the topic of collaboration in the built environment presents it mainly as a tool for a successful partnership between companies in order to achieve a demanding and innovative project. In order to create a better environment for collaboration to take place within, new strategies such as integrated practices (Elvin, 2007), building information modeling (Eastman et al., 2011) and lean design and construction (Koskela, 1992) where established. The literature for CE collaboration in the built environment follows the steps of older publications such as (Shelbourn, Bouchlaghem, Anumba, & Carrillo, 2007) and identifies that the most important factors for collaboration are stakeholder engagement, supply chain collaboration and sustainable business model (Bocken N. M., De Pauw, Bakker , & Van der Grinten, 2016; Leising E. J., 2016; Leising, Quist, & Bocken, 2018)

Nowadays, studies of collaboration in renovations are closely correlated with circular economy practices (Leising, Quist, & Bocken, 2018; Sposato, Preka, Cappellaro, & Cutaia , 2017; Karhu & Linkola, 2019; Hossain, Thomas, Antwi-Afari, & Amor, 2020; Iyer-Raniga, 2019; Mlencik, et al., 2012) In this context, the EMF with partners in the BE created the CE100 program, which aimed to enable organisations to develop new opportunities and realize their circular economy ambitions faster. In the CE100 is the ‘CO. Project’, which aims to overcome challenges and explore opportunities faced by organisations making the transition to a circular economy that may otherwise not be able to address in isolation. The CO. Project refers to a number of case studies conducted between construction companies in order to provide the CE100 community useful information about circularity in the BE (EMF, 2016).

The case study used the ReSOLVE framework for the built environment. The framework was introduced by the EMF (2015), and it identifies six different ways that organisations and governments can think about applying circularity: Regenerate, Share, Optimize, Loop, Virtualize and Exchange. The cases vary from infrastructure projects to building projects. In order to identify the communication process, the project focused on circularity without using circular components or product-service business models (EMF, 2016).

The first project that is researched is the “Rehafutur Engineer’s House”. The main goal of the project was to improve energy efficiency of the historic building by reusing material removed from the building itself or from recycled material. In order to achieve the scope, 11 partners organisations collaborated together. This partnership had at its core mutual knowledge sharing and to build expertise for future circular renovation projects. Collaboration was a key concept to achieve the goal, thus training sesions were held on site with all trade partners to make this intricate system of air-tightness work. Thus collaboration between the partners took place during the design, extraction of material as well as during reconstruction. A number of partners formed a partnership with aim to monitor the performance of the renovation.

The second project that is investigated is the “Brummen Town Hall”. The project focused on creating a building with a lifecycle of 20 years. In order to achieve the envisioned scope and convince suppliers, intense involvement of a circular economy expert team and close co-operation between architects, circular economy experts and building experts were required to guide the design and construction process. The project utilized modular construction, and in collaboration with the highly innovative technique of material passports, the building is used as a material bank. Involvement of suppliers in the early stages of the design phase resulted in a higher degree of circularity. The project depended heavily in Building Information Modelling (BIM) in order to share knowledge and information between the different involved experts. Therefore, collaboration during this project was conducted heavily in the design of the project as well as during the construction.

The last project that is explored is the Alliander head office project in Duiven, the Netherlands. An excellent example of a project achieving its sustainability goals. Moreover, the building was the first to acquire the BREEAM-NL outstanding sustainability certificate. Three principals were established as design strategies: conservation and reuse of the existing materials, minimization of material use, and employment of materials that can later on continue their biological or technical life. To achieve such a project, ten partners collaborated closely for almost four years. It is clear that the collaboration process was heavily conducted during the first phases of the projects. Furthermore, the project already established some guidelines for future collaborations by establishing the three principals.

Therefore, the first step towards identifying the knowledge gap is to identify the lifecycle of circular renovations with the information derived from the above projects. The lifecycle for circular renovations is divided into two phases, design and implementation. It is important to mention that the two phases are intertwined and the flow of information must flow both ways. During these phases there are different factors that shape and affect the collaboration procedure. The following figure illustrates how the collaboration process is divided in the lifecycle of a renovation project in combination with the three factors for collaboration by (Leising, Quist, & Bocken, 2018; Leising E. J., 2016; Bocken N. M., De Pauw, Bakker , & Van der Grinten, 2016)The following figure is created by the research author in the bases of the personal interpretation of the above information. The figure clearly illustrates that stakeholder engagement is conducted in the first two phases of the product, the supply chain is engaged during the middle of the product lifecycle, and finally the business model plays a role in the first and last stages of the product lifecycle.

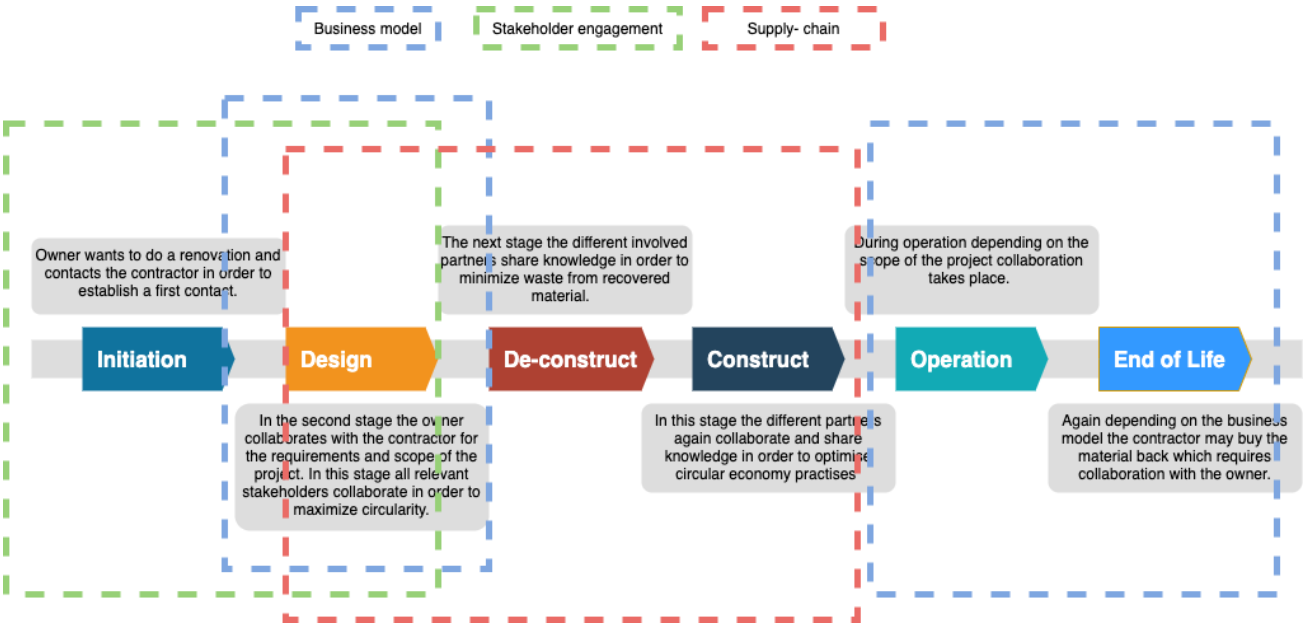

Figure 1.4 Collaboration process for a circular renovation

1.5 Circular Component collaboration process

In order to identify how the collaboration process for a circular component is conducted, the same methodology as above is followed. The study of the CO. Project includes various cases of circular components. By using these cases as a reference point, a possible collaboration process can be drawn for the circular extension.

The first case that is reviewed is the “Bus Boarder Platform”. The project developed a raised bus platform from recycled material and adopted a modular design. The aim of the project is to improve accessibility at bus stops in a sustainable way. The component is created from 100% recycled material and recyclable PVC and uses an interchangeable modular design. The lead company ZICLA looked for the participation of all the main stakeholders of the product value chain. Initially, the collaboration was between the client, the city council, and transportation authority, in order to gain permit for the pilot program. Furthermore, industrial designers were contacted during design to collaborate to create a modular system. During implementation, waste generator partners that provided the plastic collaborated alongside injection industry partners, in order to maintain the components of the project. It is interesting to observe the stakeholders and supply-chain be involved from the start. Moreover, the project can have a very interesting business model, such as a lease contract in which the contractor provides the service of a bus platform in the form of the platform.

Moving on, one of the most promising circular components project the BioBuild structural façade panel is studied. Arup, together with twelve other European companies and institutions involving architects, material scientists, manufacturers and testing laborites created the façade that received the JEC Innovation Award for the “best innovation in composite for construction” in 2015. It is evident from the study that the focus of the project was to use bio composite materials and a modular façade system. When one unit reaches End of Life (EoL), the bio composite material can be resold as fertilizer, which results in a very interesting business model for the supplier. The main collaboration process for this product is set in during the design phase. All of the partners collaborated in order to create a challenging fully circular design. For this project it is interesting to observe how collaboration achieved such a high circularity in such a high complex environment. Furthermore, the importance of supply-chain collaboration is mentioned many times as an important factor in the success of the project. The project is still ongoing and it is intriguing to observe the possible business models that will be available.

The final case is the “ROC A12 School: Carpet Lease”. In this case, “DESSO” has developed a Cradle to Cradle® circular carpet to be used in schools. The company conducted different studies to show the health benefits of having an AirMaster® in schools. By using this carpet, the amount of dust particles greatly decreased and in cases more than halved. In order to stand by the C2C principles the company created a take back program. However, legislation at the time stated that the user is the owner of the carpet. In light of this, DESSO collaborated closely with legislators and school officials to create a business model that will enable ownership of the carpet to be shared between user and producer. Finally, a lease with take-back at EoL business model was created. For this case it is interesting to observe how contractor, owner and legislators collaborated in the design phase of the product to enable the C2C principles of the company.

All in all, all projects depend highly in the design of the products, and hence collaborate heavily with all the involved stakeholders to incorporate all the available expertise into the design. Moreover, it is observed how different products by choosing different business models adjust the supply-chain and most importantly, how business models shape the end-part of the project. It is clear the components have a long-term horizon from typical renovation, and strive for the highest circularity performance.

The circular extension also aims to narrow the loops. The use of components, parts and materials for longer period to slow the loop and to close the cycles between end-of-use (EoU) or EoL and production, closing the loop (Bocken N. M., De Pauw, Bakker , & Van der Grinten, 2016) Value Retention Processes (VRPs) also known as R-imperatives where created to support reaching circular economy. In their research, Reike, Vermeulen, & Witjes (2018), identified nine possible VRPs. These VRPs are defined as: Refuse, Reduce, Resell/Reuse, Repair, Refurbishment, Remanufacture, Re-purpose, Recycle, Recover Energy and Re-mine. These VRPs play an essential part in creating a CE building component. By reusing material and modules in its original or refurbished form the sustainable value is captured. Moreover, this sustainable value is not only captured during maintenance, but also during decommission as the same materials follow the same route and are reused. These VRPs will depend highly in successful supply-chain collaboration in order to fulfil its goals. Moreover, due to the involvement of many parties in the supply-chain, collaboration is a key factor to achieve the desired circular goals.

These different factors shape the collaboration process of the circular extension. In the context of this research, the circular extension represents a case in which the research is trying to identify collaboration processes. Therefore, it is important to have a grasp on how the collaboration process will appear for the circular component. By corelating the information from the previous cases and the existing knowledge on the circular extension, the following process is devised. The following figure is created by the research author in the bases of the acquired information.

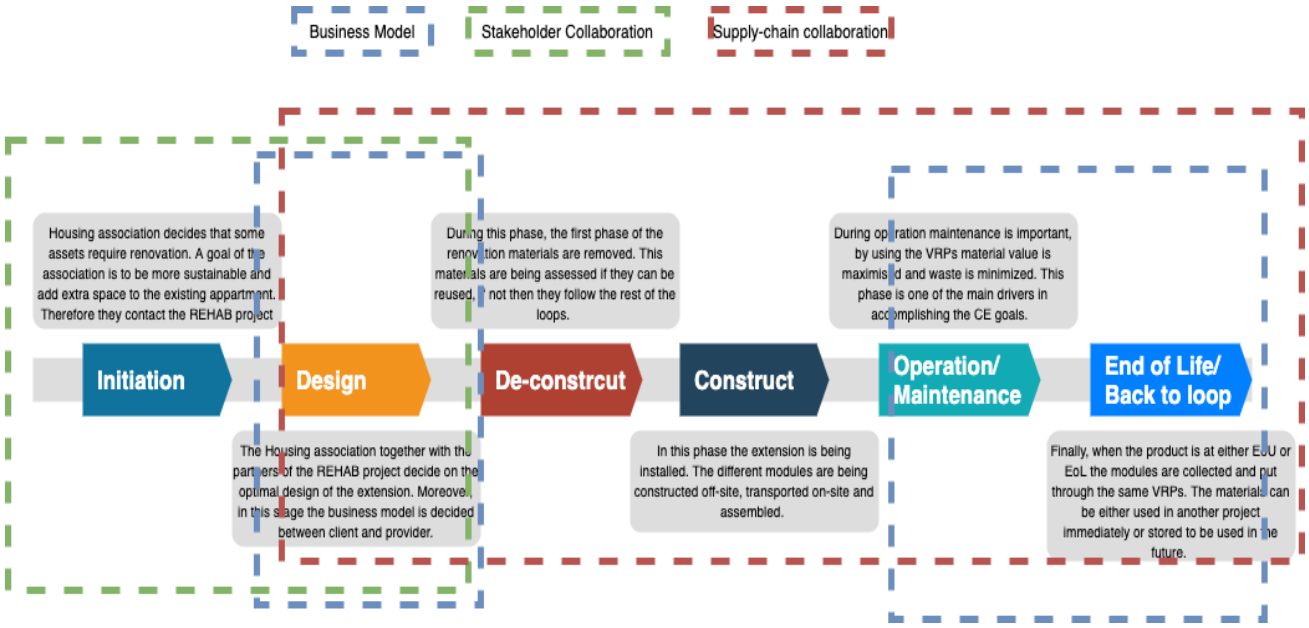

Figure 1.5 Possible Collaboration process of a circular component

1.6 Problem Statement

The next step is to directly compare the two processes in order to identify possible differences and potential knowledge gaps.

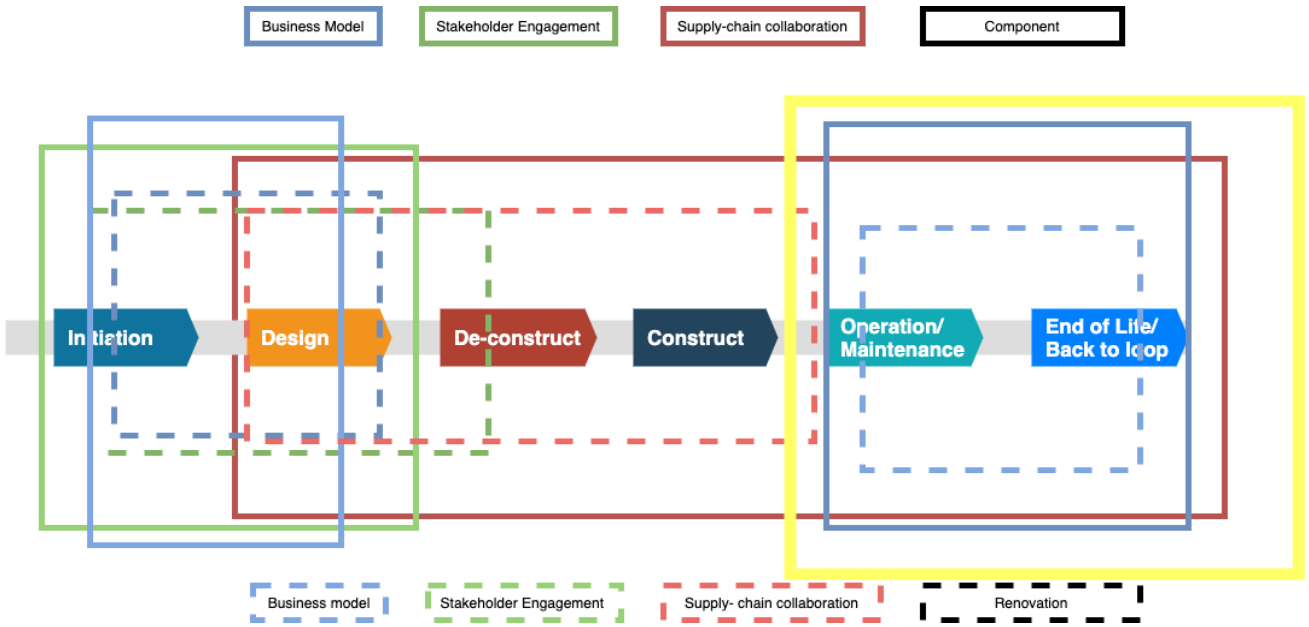

Figure 1.6 Comparison between circular renovation project and circular component lifecycle

Typical renovation projects do not look beyond the scope of the renovation, hence the smaller supply-chain collaboration box. On the other hand, circular components look towards supply-chain collaboration as a means to enhance circular performance. The gap lies with in the yellow outlined box. Supply chain collaboration for a circular product has a longer-term view in comparison with the circular renovation's projects.

However, the underlying gap does not lie only during the operation/maintenance and EoL phases of the lifecycle of the product. The collaboration process is established and set during the early stages of the project. Therefore, to create a collaboration process that is suitable for the needs of a CE product, it is required to dive into the whole lifecycle of the product, setting the collaboration from beginning to the end of the lifecycle.

It is required to look towards into the long-term future of a project (Leising, Quist, & Bocken, 2018) and how materials are managed during the operation of the asset and decommission. Through research it is known that Value Retention Processes (VRPs) present an excellent method of acquiring these long-term gains (Reike, Vermeulen, & Witjes, 2018). Moreover, it is known that in order for the VRPs to succeed, collaboration between different actors with different expertise are required. This collaboration spans many years, from the beginning of the project until the end of it. On the other hand, collaboration in the BE is hindered due to fragmentation (Nawi, Lee, Azman, & Kamar, 2014) and a loosely coupled supply-chain (Dubois & Gadde, 2002). Moreover, when implementing new business models such as product delivery methods of components and long-term VRPs, the supply-chain collaboration knowledge in the BE is very limited.

Problem Statement

There is a lack of knowledge in academia and practice on the topic of long term collaboration in context of the circular economy. More particularly, in the context of circular building retrofits and circular building extension. Moreover, according to the literature review, successful collaboration process among the supply chain is key to realizing the shift from linear to a circular building environment. The current literature focuses on creating models. However, there is a lack of clear steps that guide the collaboration process throughout the lifecycle of a product.

Research Goal

The goal of the research is to develop a feasible and usable long-term collaboration process map for a circular component and identify lessons learned that will aid the product on its circular goals. By analysing the main factors that affect the collaboration process, and using them to design different collaboration processes. These collaboration processes will be shown in the form of maps and will illustrate the collaboration processes throughout the lifecycle of the circular extension project. The research is using the circular extension component, by the “REHAB” project as a study case.

1.7 Research question

At first, in this section a detailed overview of the research question, aim and objectives will be presented. Secondly, the methodology and strategy followed during the research are presented.

1.7.1 Research question

Main research question:

Is it possible to develop a feasible and useful long-term collaboration process for development and implementation of the circular extension product?

The main research question is derived by the gap that the research is exploring. By designing a number of different collaboration process maps and evaluate the feasibility and usability with the help of experts, the knowledge gap that exists in academia begins to close.

To answer the main question, three design collaboration process variants are developed. These design variants will illustrate the steps that the collaboration will have to follow in relation to the product lifecycle. By presenting these design variants to experts, information can be derived that will answer the main research question.

1.7.2 Research sub-questions

In order to answer the main research question, seven research sub-questions are formulated. Each sub-question is directed towards a different part of the research and is acting as a guiding arrow. The first three questions relate towards the analysis phase of the research. The following two questions are related to the synthesis phase. The sixth and seventh questions are related to the simulation phase.

Sub-question 1:	*What are the design parameters for a long-term collaboration process for the circular component?*
Sub-question 2:	*What are the main factors that influence the success of collaboration?*
Sub-question 3:	*What are the requirements that the long-term supply-chain collaboration process needs to fulfil?*
Sub-question 4:	*How do the design parameters set the characteristics of the different collaboration designs?*
Sub-question 5:	*What are the different long-term collaboration variants for the circular extension?*
Sub-question 6:	*How do experts perceive the usability and feasibility of the different collaboration process design variants?*
Sub-question 7:	*What are the lessons that can be learned on the collaboration process for the circular extension?*

1.8 Research method

Due to the innovative aspect of the long-term collaboration on a circular component, there is a limited amount of publications. These publications represent the existing knowledge pool, which does not represent the base information to conduct this research. Therefore, a different research method is required. Typically, graduation research projects use either qualitative, quantitative or a mixed method (Williams, 2007). Qualitative research seeks to interpret social phenomena such as interactions, behaviors and communication in terms of the meanings people bring to them (Pope & Mays, 2020; Hennink, Hutter, & Bailey, 2020). On the other hand, according to Creswell (2003), qualitative approach involves the accumulation of data so that information can be quantified and subjected to statistical treatment in order to support or refuse “alternative knowledge claims”. In mixed methods, researchers combine methods of collecting and analysing data from qualitative and quantitative research methods in a single research study (Creswell, 2003). However, these methods are constrained in researching the existing pool of information.

Research-through-design (RtD) aims to generate ‘generalizable’ knowledge for a class of problems or products through designing (Buchanan, 2001). RtD utilizes designs to change the existing reality in order to observe a knowledge gap. RtD has a younger history in comparison to qualitative and quantitative methods with its roots starting in the 60’s. Afterwards, there was a drop of interest which was rekindled in the 90’s and the last decade has steadily grown. Nowadays, RtD uses systematic design processes models. These models are a simplified abstraction of the design process and are consisted of three consecutive steps: analysis, synthesis and evaluation (Groat & Wang, 2013). Though the model seems linear, iterations are a necessary part of the process. The first step, analysis, includes a systematic literature review on the existing situation, which results in the identification of the design parameters. The knowledge derived from the analysis is then used in the synthesis phase to generate different design variants. Finally, the design variants are simulated during the simulation phase, where the experts evaluate the designs on the bases of their own expertise.

This research will follow the basic design cycle proposed by Roozenburd & Eekels (1995). It uses the same step as the systematic approach by Groat & Wang (2013), with one addition: 1. Analysis, 2. Synthesis, 3. Simulation, 4. Validation. By analysing the existing status, the analysis phase creates the design parameters for the synthesis design as well as the requirements that the designs have to fulfil. The next step, synthesis, is the process of organizing, combine and manipulation of gathered information into a cohesive structure (Kolko , 2010). The information used to design the variants are the output of the analysis phase and the input of the synthesis phase. Thereafter, the output of the synthesis phase are the design variants that will be used as the input for the simulation phase. During the simulation phase, experts observe the design variants and can provide their professional knowledge and evaluate the designed variants. The last step is validation, which is conducted by interviewing colleagues that have conducted research on the same topic and can validate the research methods, strategy and findings.

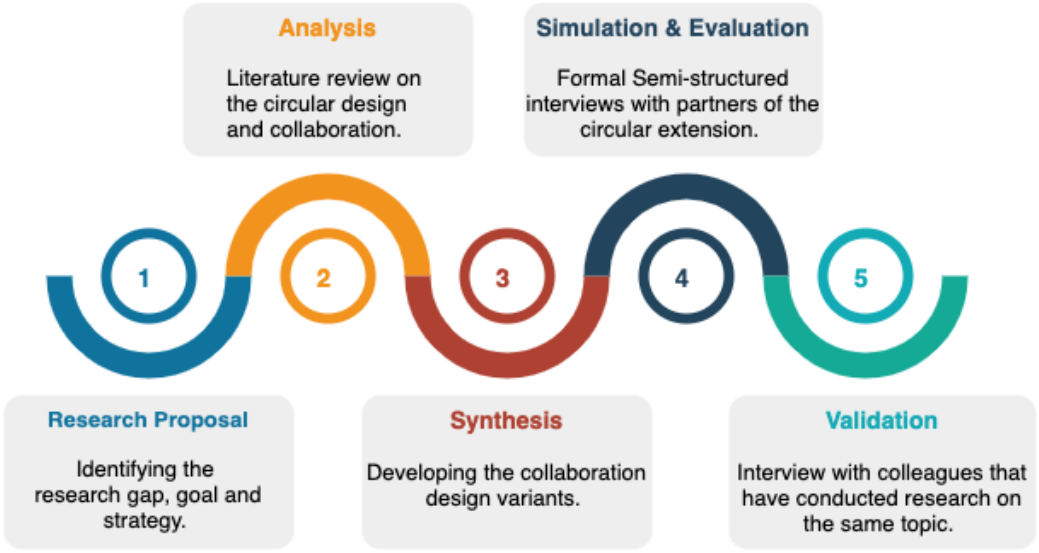

Figure 1.7 Research Strategy Steps

1.9 Research Strategy

In order to answer the research question, firstly a research strategy must be formed. This section establishes the research strategy that the research is following. The strategy will follow the basic design cycle as proposed by Roozenburd & Eekels (1995).

1.9.1 Analysis

Analysis is the first phase of the research. The aim of the analysis is to create the information base that the research rests upon. This information will be used in different phases of the research and play a key role on the outcome. The analysis phase creates two outputs: design parameters for variants, and requirements that these variants have to fulfil.

In order to generate these outputs, the analysis phase is looking into the existing status-quo. To explore the status-quo, an extensive literature review is conducted of past circular economy components. The components need not only be from the BE sector, but will be required to fulfil some conditions, such as circular goals, innovative business models and stakeholder engagement.

The first part of the analysis uses the projects of the CE100 that were explored during the research gap identification. By analysing the characteristics that each project focused on, a pattern of different design parameters is formed. The aim is to identify the design parameters that will be used as the design parameters for the design process of the long term collaboration variants. Therefore, the first sub-question is formulated:

Sub-question 1: *What are the design parameters for a long-term collaboration process for the circular component?*

The next step is to determine the factors that contribute to the success of collaboration. Firstly, the status-quo of collaboration process in the CE is analyzed. This literature review will result on identifying the most common traits that successful collaboration process shares with each other. Secondly, since there is no clear collaboration process design for CE components identified, a design for supply chain collaboration for a linear economy product is chosen. In order to fit the CE profile of the circular extension the design process is analyzed and remodeled with CE traits identified during the last literature review. The aim is to answer the second sub-question:

Sub-question 2: *What are the main factors that influence the success of collaboration?*

The final stage of the analysis phase involves the identification of the design requirements that the design variants have to fulfil. The requirements will be established from analysing the existing status-quo of CE components, and the requirements of the involved parties. The information is derived by the literature review conducted to answer the first sub-question, as well as the interviews conducted with the client and contractor. Therefore, the final sub-question of the analysis phase is formulated:

Sub-question 3: *What are the requirements that the long-term supply-chain collaboration process needs to fulfil?*

The analysis phase is using literature review of the status-quo of CE components and informal meetings with involved parties of the circular extension to produce three sets of outputs. The first set are the design parameters that will have the form of variables that will change the design process. The second set are the design parameters. The parameters will be influenced by the design parameters in order to produce a different long-term supply chain collaboration process. Finally, the last set are the design requirements that these collaboration process will be evaluated upon.

1.9.2 Synthesis of design variants

The synthesis presents a challenge to the research. Even though the base information is presented during the analysis chapter, the synthesis chapter seeks to create a design with all the relevant information. In order to finally achieve the collaboration design, a series of research sub-questions need to be answered. The first step is to understand how to create three different collaborations designs. These will lead to the creation of the main relationship grid that the design will be based on. This will be achieved by observing how the design parameters set the collaboration. Therefore, the following research sub-question is devised:

Sub-question 4: *How do the* design *parameters set the characteristics of the different collaboration designs?*

The second step of the synthesis is to develop the collaboration designs. This will be done by grouping all the information provided by the analysis chapter and the information established by answering the fourth sub-question. This will result in the formulation of the collaboration process map and the different design long-term collaboration process variants.

Sub-question 5: *What are the different long-term collaboration variants for the circular extension?*

The aim is to create different layers of information that will be set together to create the collaboration designs. The first layer will be the collaboration: time in the form of a product lifecycle and relationship between involved parties in its step. The second layer of information will be in the form of a collaboration process map. The process map follows the steps of collaboration across the lifecycle of the product. Lastly, the collaboration process variants are designed.

1.9.3 Simulation and Evaluation

The next phase is the simulation phase. The aim of the simulation phase is to monitor how experts observe the collaboration process variants. The designed collaboration process variants of the synthesis phase are used as input, and the output will be the potential performance of the design variants. The reason of presenting the collaboration variants to experts is to benefit from their professional expertise. In order to support the potential performance of the design variants not only from criteria identified during the literature review, but from real world experience. Therefore, the following research sub-question is formulated:

Sub-question 6: *How do experts perceive the usability and feasibility of the different collaboration process design variants?*

In the direction of answering the above question, a series of steps are required to be conducted. The first step involves the format that the collaboration variants will be presented to the experts. The chosen format is in the form of semi-structured interviews. The interviews include the same partners that where interviewed during the analysis phase. During the interviews, firstly, a small presentation is conducted in order for the interviewee to grasp the research goal and design variants. Thereafter, a set of open preset-questions are asked. The questions are aimed towards evaluating the usability and feasibility of the designed variants in the context of the circular extension. The answers will provide the necessary information to answer the seventh research sub-question:

Sub-question 7: *What are the lessons that can be learned for the collaboration process of the circular extension?*

Table 1.1 Semi-structured interview questions

Interview questions	
Usability	Does the process map include all the information needed to support the collaboration process of the development of circular extension? Which information would you exclude or is missing?
	Which process design variant would you use and why?
	Do you think that the engaging actors would be able to implement the designed processes? Why or why not?
Feasibility	Do you think that the traditional, innovative and balanced collaboration process and implementation of VRPs would be economically feasible?
	Could you highlight any strengths and weakness of the developed designs, in your opinion?

1.9.4 Validation

The following research phase is the validation. As stated before RtD utilizes designs to change the existing reality in order to observe a knowledge gap. It is a process in which by using a different mix of methodologies, researchers try to discover a practical solution. The method is based on creating a multitude of design with the hope that one of them is the right solution to the gap. By contemplating the developed results, knowledge is created. However, the application of the validity criterion of classic science would result in a conclusion that RtD is unscientific (Gaver, 2012). Therefore, in order to validate the research, an independent validation method was developed. Parallel to this research, two Construction Management and Engineering (CME) graduate students conducted their graduation research on other aspect of the REHAB project. These students were interviewed and asked to validate the research logic and the research results.

The interview had the same profile as the simulation phase. Firstly, a small presentation was given to present the research gap, questions, method, and the analysis, synthesis, and simulations phases. The second part consisted the questions:

Question 1: Do you consider the chosen knowledge gap and problem relevant?

Question 2: Do you consider the chosen methods appropriate to fulfil my design goal and research goal?

Question 3: Do you consider the results I got during my research fulfil my design and research goal and fills the identified knowledge gap?

Question 4: Do you consider the developed design variants describe the collaboration process clearly?

Question 5: How would you improve the developed designs?

1.10 Scientific and Societal Relevance

1.10.1 Scientific relevance

Present literature lacks the examples of collaboration process design developed for the whole product lifecycle. Most collaboration processes are focused on linear economy products or non-BE products. Recently, research has been conducted in the topic of long term collaboration in the circular environment (Leising E. J., 2016; Leising, Quist, & Bocken, 2018; Geissdoerfer, Morioka, De Carvalho, & Evans, 2018; Mishra, Chiwenga, & Ali, 2019). This research incorporates information from these publications in order to create a map for the circular extension. Moreover, this research aims to create a better understanding by creating a process map instead of a model. Mapping the activities and options that could or should take place throughout the collaboration process. Furthermore, by evaluating a collaboration process for the circular extension, the collaboration knowledge domain is enriched.

1.10.2 Societal relevance

According to a report by Abergel, Dean, & Dulac (2017), the building and construction are responsible for 39% of all carbon emissions in the world. The introduction of circular economy practices in the BE is of paramount importance to lower and eventually eliminate the carbon emissions emitted by the BE sector. By establishing good collaboration processes for the circular extension, the research helps in the transition towards a circular BE. Therefore, it assists achieving the circular goals set by the government of the Netherlands for 2030 and 2050.

2. Analysis

2.1 Introduction

As the research gap which the research aims to address is identified, the research moves to the next phase of the strategy, the analysis. The analysis phase represents the "information pillars" that the research rests upon. As stated in the previous chapter, the analysis aims to answer three questions, therefore it has a threefold aim. First, to analyse the status-quo of the long-term collaboration process of a circular component. Second, to identify the design parameters of the long-term collaboration process. Lastly, determine the design requirements that the collaboration variants will be evaluated upon.

This will be based on two sets of information.

1. Informal meetings with partners of the circular extension project.
2. Analysis of the status-quo for long-term collaboration process of circular components.

The purpose of the informal meetings with the partners is to broaden the understanding of the project requirements. Furthermore, the analysis of the status-quo for long-term collaboration processes for circular products will highlight certain patterns that will help identify the design parameters. As stipulated above, the analysis phases aim to create the foundation of the research. In order to create this, the following three sub-questions are formulated.

Sub-question 1: *What are the design parameters for a long-term collaboration process for the circular component?*

Sub-question 2: *What are the main factors that influence the success of collaboration?*

Sub-question 3: *What are the requirements that the long-term supply-chain collaboration process needs to fulfil?*

In order to answer the research questions, the analysis phase is structured as follows. Firstly, four circular economy projects are presented. The aims are to identify different collaboration processes that the past projects used. On the second section, the same parameters that where identified for the circular components are identified for the circular extension. The aim is to identify the factors that compose these design parameters. Moving on, the collaboration process is further explored. The aim of this section is to identify the different parts that compose a collaboration and create a toolbox with these factors. The next section follows the informal meetings with the partners, where the aim is to understand their views and requirements of the project. The last section aims to identify the different requirements that the designs of collaboration has to fulfil.

2.2 Circular Economy Projects

In this section, the aim is to identify different collaboration processes in order to identify the design parameters important for circular economy products.

2.2.1 Circular Economy Design Parameters

First, the circular economy design parameters have to be set. These design parameters represent the core actions that every CE project or product is required to follow in order to be named circular. Circular economy aims on narrowing, slowing and finally closing the material loops. Following the publication by (Van Stijn & Gruis, 2020) the publication is developing an integral design tool for circular building components. Part of the research identified as circular economy design parameters Technical Model, Supply-Chain Model and Business Model.

Each design parameter looks in a different aspect of the circular product. However, they play a key part in creating a circular product. These parameters closely resemble the most important factors for collaboration used during the section 1.4 and 1.5 (stakeholder engagement, supply chain collaboration and sustainable business model). Moreover, in order to incorporate the processes of slowing, narrowing and closing the material loops, an extra parameter is incorporated, the Value Retention Processes according to the definition by Reike, Vermeulen, & Witjes (2018). More extensive definitions for the circular economy design parameters are provided during section 2.3.

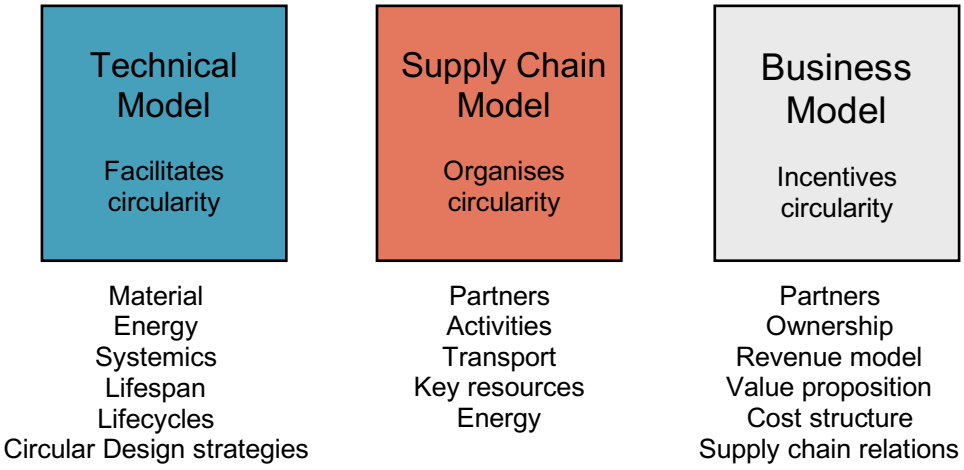

Figure 2.1 Circular Economy Design Variants by (Van Stijn & Gruis, 2020)

2.2.2 Project Selection

Since the design process uses the circular extension component as a case study, the cases derived from the literature must resemble the profile of the circular component. Therefore, the cases that are selected to be analyzed in this section must closely fit the circular extension component. Hence, the first step is to present the circular extension and identify the characteristics that form the profile of the project. The circular extension is a part of the 'REHAB' project, a collaboration between TU Delft, AMS Institute, ERA Contour and Eigen Haard. The project combines the idea of retrofitting in housing with the circular economy model. The 'REHAB' project is divided in two subprojects, the circular skin and the circular extension. The aim of the project is to merge the two subprojects and create an interchangeable stock of materials and components (material bank) in the form of services. The circular extension system is made up of standardized modules using circular materials. The modular system makes it also possible to adjust the extension to meet changing housing needs. It is also easy to replace individual components while the building is in use. If the extension is no longer needed, the modules can be disassembled and used elsewhere, and at the end of lifecycle the materials can be recycled (TU Delft, 2019).

According to provided documents, the main characteristics of the circular extension are:

- Circular economy: The circular extension aims to create a component that is using mainly recycled material and will be using recycled material throughout the product lifecycle. Figure 1 represents the material flow that the circular component aims to achieve. Therefore, the first requirements are circular economy practices as a core characteristic of the project.

- Product: The circular extension is moving away from a typical construction project profile, which has a beginning and an end, towards a product oriented profile which has no clear end date. Therefore, it is favorable for the case to implement product rather than project profile.

- Modular construction: The circular extension is employing modular design. The reason being that by using modular design the can be 'scalable', it can be taken apart and used in different configuration or entirely different site. Hence, modular construction is a critical characteristic of the researched cases.

- Partnership within organisations (collaboration): The circular extension is a highly innovative project with high complexity. Therefore, collaboration between different partners with a range of expertise is essential for the project to achieve its goals. Therefore, a supply chain that incorporates a variety of partners is an essential characteristic.

Moreover, it is not a pre-requisite for the cases to be from the built environment. On the contrary, by researching cases out of the BE, new possible information can be identified that can help with the design process. The majority of the following cases are part of the "CO. Project" used during the chapters 1.4 and 1.5, as well as a case from the smartphone industry.

Followingly, the next step after the case identification is the case analyses. The aim is to identify which of the three elements (business model, supply-chain collaboration, stakeholder engagement) these cases used in order to facilitate the long-term supply chain collaboration in the context of CE. These parameters then will be used as the bases for the design parameters used during the collaboration process design for the circular extension.

Bus Boarder Platform (Vectorial® System)

The first case that is analyzed is the "Bus Boarder Platform". The project developed a raised bus platform from recycled material with a modular design. The aim of the project was to improve accessibility at bus stops in a sustainable way. The component is created from 100% recycled material and recyclable PVC, moreover it has an interchangeable modular design. The lead company ZICLA aimed for the participation of all the main stakeholders of the product value chain during the concept design and the creation prototype phase. Initially, the collaboration was conducted with city council and transportation authority to gain permit for the pilot program. Furthermore, industrial designers were involved during the design phase to collaborate in order to create a modular system. During the implementation phase, waste generators partners provided the plastic for the construction of the modules which then were given to the client (public authority). Public space workers can conduct the installation, while injection industry partners collaborate in order to maintain the components of the project. The design enables for one worker without the need for heavy machinery to perform the maintenance. Moreover, ZICLA provides recycling services for the modules that have reached the EoL. In this case, ZICLA receives the necessary material from the recycling company and manufactures the parts. Afterwards, the provider transports the modules and the assembly takes place. During the maintenance phase, material is reintroduced in the recycling company for reuse.

For this product the long-term supply-chain collaboration is based on the business model that the component is provided. The extend of collaboration is based on the type of contract between ZICLA and the customer. The product has seen use in Spain, France, USA and Australia, and therefore has an international profile. Therefore, the supply-chain cannot be the same as the project aims to be circular. New local supply chains have to be established to accommodate the needs of the product. Hence, by providing the Vectorial System as a product with a maintenance system, ZICLA becomes the initiator of the supply-chain and manages the collaboration between the partners. On the other hand, if the client is responsible for maintenance and decommission of the product, the client is responsible for the supply-chain collaboration.

BioBuild

BioBuild structural façade panels are one of the most promising circular components in the BE conceived the last decade. Arup, together with twelve other European organisations and institutions involving architects, material scientists, manufacturers and testing laborites created the façade that received the JEC Innovation Award for "best innovation in composite for construction" in 2015. BioBuild is the world's first self-supporting façade panel for the BE made of bio-composite material.

The project's aim is to shape a better BE by developing and implementing materials based on rapidly renewable natural resources. The renewable natural resources come in the form of biocomposite materials. Biocomposites are created by natural fibers such as flax, hemp, jute, as well as natural resins made from the byproduct of agricultural processing of corn, sugar cane and other (Arup, 2015). Developed mainly for commercial office buildings, the panel is 4 metres high and 2,3 metres wide, and includes a window. The panel is designed as a fully prefabricated unit.

In the first stage, the consortium partners agreed on the allocation of partner's roles. This decided who would be responsible for the different steps needed to manufacture each of the four parts that composes the panel. The partners agreed on the final configuration of each part in regard to materials composition, such as fiber, core material, resin type etc. Thirdly, the partners that were involved on design and manufacturing tasks selected the most appropriate manufacturing method for each demonstrator while considering all the design/production constraints. All partners in the consortium were consulted to identify and understand the materials properties and materials processing factors that were linked with the different performance requirements to be specified. The manufacturing processes were permanently monitored by all processing partners in order to minimize the use of energy and to maintain the correct balance between fiber degradation, cure quality and process speed. The results were sent to TNO for inclusion in the Life Cycle Analysis.

Furthermore, the importance of supply-chain collaboration is mentioned many times as a crucial factor in the success of the project. During the design phase of the product, all organisations collaborated closely to create the design. Moreover, this collaboration is required to continue during the maintenance phase of the product. Collaboration was achieved by creating an environment of trust and communication between all partners. This was achieved by exploiting each partners expertise and combining all the newly developed knowledge in the product.

Carpet Lease

The next case is the ROC A12 School: Carpet Lease". The aim of the organisation is to create a product that will have a positive impact on human health and environmental biosphere. In this case, "DESSO" has developed a circular economy carpet using the Cradle to Cradle® techniques. The main principle of Cradle to Cradle® is that goods are designed to be returned at the end of their first lifecycle, to be reused in technical production, or to be returned to the biosphere (Braungart & McDonough, 2002). The company conducted different studies to show the health benefits of having an AirMaster® in school environment. By using this carpet, the amount of dust particles greatly decreased and in cases more than halved. Furthermore, DESSO created a business model which enables the clients to lease the asset for the next seven to nine years. All costs are determined upfront. Hence, the client can adjust the paying period and amount. DESSO has created a take back program for the carpet. When the contract ends, the organisation carefully removes, takes back, disassembles and recycles the carpet into new flooring. However, legislation at the time stated that the user is the owner of the carpet. In light of this, DESSO collaborated closely with legislators and experts to create a smart Velcro tape to anchor the carpet on the floor. Hence, the carpet can be easily removed in the future. DESSO is using an extensive supply chain network to acquire the necessary material to create the carpet. All materials are then certified to fulfil the Cradle to Cradle® specifications. The main source of recycled material is old carpets. These carpets provide the necessary material for the core structure of the carpet. Other material sources include recycled fishing nets from the fishing industry, and the use of carbonate (lime), which is a waste of products of the Dutch drinking water industry.

Fairphone

Smartphones dominate the current technological world. From children to elderly, approximately 3,6 billion users are recorded with forecasts predicting a rise to 4,3 billion by 2023 (Statista, 2020). The smartphone industry is one of the most damaging to the environment. This is due to the use of limited virgin material for batteries, circuits and other parts. Fairphone is a Dutch based company which aims to create a fairer electronics industry from inside. To achieve that they created a smartphone with a modular construction, reused material and responsible material sourcing. The organisation split the goals into four objectives: creating products that last, reducing e-waste, choosing fairer materials and putting people first.

The first objective is to create a long-lasting phone which is easy to repair. Hence, the creation of the first modular phone built with repairability at its core. The phone is consisted of different parts (modules). If e.g. the camera or the processor is broken, it can be easily repaired. Secondly, creating a lasting and modular design and incentivizing costumers to return old phones that are not using, results in minimizing wasted material. Thirdly, the selection of fairer material, since the average smartphone material originally enters the supply chain from the mining sector, which is a sector known for high pollution index, extremely dangerous working conditions and child labor. By sourcing more responsibly materials, the organisation creates a fairer supply chain. The last objective aims to create a better working environment by including health and safety checks and worker representation. Moreover, Fairphone has entered the Clean Electronics Production Network (CEPN), which aims to create an electronic industry with zero exposure of workers to toxic chemicals.

Fairphone considers supply chain to be the heart of the project. To create a fair supply chain, Fairphone conducted an extensive research on their partners, since not all providers where in direct collaboration with the organisation. According to Fairphone, “Supply chains are long and complex, and we believe that getting suppliers involved in our mission is the only way to increase understanding of the issues and to influence real change” (Fairphone, 2020). To identify all these partners, Fairphone uses a collaborative approach in its due diligence process. This process can lead to a journey from top to bottom of the supply chain, creating a paper trail and revealing each partner involved, step by step (Fairphone, 2020). Moreover, in instances that the conditions for sustainability and fair employment are not met, Fairphone collaborates with the partners to identify the root cause of the issues and develops a plan for sustainable improvement.

It is observed therefore, that Fairphone is using technical design as a modular design for smartphones that can be easily repaired and recycled. A smart business model, which aims incentivizes costumers to return their old phones when it’s time to buy a new one. Furthermore, this endeavor rests on top of a fair supply chain which is based on trust and collaboration to achieve the sustainability goals set in the Code of Conduct. Fairphone releases each year a new study of their supply chain partners. It is very interesting to observe the close ties the organisation keeps with all partners to ensure that their sustainability goals are met.

2.2.3 Conclusions

The aim of this section is to derive the most important parameters that these cases followed in order to achieve their CE goals. This is accomplished by analysing how past cases used supply chain collaboration, business models and technical design to stir the collaboration process. These cases share common characteristics. The aim is to identify preliminary options of the design parameters and create a basis of design parameters on which the design variants will be designed during the synthesis phase. The following Table 2.1 sums up the core characteristics of each reviewed circular project. Table 2.2 illustrates how each project approached the CE design parameters.

Table 2.1 Summary of Projects

Bus Boarder Platform	The collaboration process used by ZICLA for the Bus Boarder Platform follows: The first step is to buy the cables from external partner then separate the PVC and copper. The copper then is resold and the revenue stream is used for the product. The next step is creating the modules from the recycled PVC, transportation, installation and finally maintenance. Therefore, ZICLA uses external partners to expand the supply-chain, which also provides the possibility of re-selling product which creates economic and environmental value. Furthermore, the use of modular design promotes the circular economy goals by creating a scalable project profile. Finally, ZICLA can adjust the business model that is offering its product to fit the customer needs. For example, a municipality that has a large supply-chain network can produce and maintain its own platform in comparison to a small village with a limited supply-chain network.
BioBuild	BioBuild has a very similar profile to the BusBoarder Platform. A large number of construction organisations collaborate to create the technical design. This design uses modular construction and standardized modules. Furthermore, the component is based on a diversified supply-chain network with partners from different sectors. Finally, the panel can be provided in different forms, a costumer can choose to buy the product and maintain it, given that the correct supply-chain network can facilitate the maintenance. On the other hand, a costumer can choose to lease the façade and pay in installments.
Carpet Lease	Carpet Lease follows a similar path. The company employees different supply chain partners for the necessary material to create the product. The most noticeable aspect of the collaboration process is in the form of the business model that DESSO provides the component. A lease program of seven to nine years, with costs calculated in the beginning of the contract, and a take back service provides a component to the client with dynamic features.
Fairphone	One of the selling points of Fairphone is the modular construction the smartphone is based on. These designs enable easy repairs to be made, even by the costumer. This is in contrast with the majority of current smartphones, where repair require expertise and high costs which renders them not economic and ecological viable. Furthermore, Fairphone has developed a strong collaboration procedure with all partners that form the supply-chain network. The reason being that Fairphone aims to share profits equally with all its partners and create a healthy and good environment for all the employees. Fairphone is also incentivizing people to return their existing phone with lower prices which results in material being recycled.

Table 2.2 Forms of Collaboration Processes

	"Bus Boarder Platform"	"BioBuild"	"Carpet Lease"	"Fairphone"
Technical Design	• Modular design • Recycled material	• Recycled material • Modular design	• Recycled material • Easily detachable	• Modular design • Recycled material
Supply Chain Model	• Electricity grid operators • Construction partners	• Agriculture partners • Construction partners	• Carpet industry • Drinking water industry • Fishing industry	• Mining partners • Smartphone industry
Business Model	• Buy • Lease	• Buy • Lease	• Lease	• Buy
VRPs	• Re-sell • Re-use • Repair	• Re-sell • Re-use • Repair	• Repair • Reuse	• Reuse • Refuse • Refurbish

The above table illustrates how each case product tackles the set of circular economy design parameters. A shared trait among all products is modular design. This follows the findings of the report by Bertram et al. (2019) that modular design is a core characteristic that consist a circular building component. Moreover, the use of recycled material during the construction of the products is a common trait among all research products. This is in line with the report by the EMF (2013) that recycled material is a prerequisite for a product to be called a circular product. All products follow a similar path towards the technical design parameter, which illustrates the importance of modularity and the use of recycled material in a CE product.

Moving on to the Supply Chain Model, the research products show a variety of supply chain models. For example, the BioBuild utilizes a broad supply chain with partners from the BE and from the agriculture sector. In the same logic, the carpet product by DESSO is utilizing a variety of partners from different sectors. These represent open supply chain models enables the move towards CE (Guide & Van Wassenhove, 2009). However, according to Weetman (2017) there is a variety of supply chain models that support this move.

The next design parameter is the business model. Here the products also have different approaches. For example, the carpet product by DESSO is a leased product to the school where DESSO maintains the product and collects it in the End-of-Use. On the other hand, the Bus Boarder Platform provides the client with the opportunity to buy the product and provide maintenance services or lease the product. These closely represents the Product-Service-System (PSS) (Tukker, 2004; Tukker, 2015).

The last part focuses on the VRPs. All researched products used some forms of Value Retention Processes. The most common forms are the re-use of materials, the repair and recycle. However, there is a difference between the state of the product during maintenance. For example, the Bus Boarder Platform aims to bring the product to its original state during maintenance. On the other hand, the BioBuild component is looking forward to incorporate new innovative techniques and design to improve the product during maintenance.

2.3 The Circular Extension Design Parameters

To begin with, this section starts with an extensive analysis of the circular extension. The aim is to research the design parameters of the circular extension that affect the long term collaboration process.

As mentioned, the 'REHAB' project is divided in two subprojects, namely the circular skin and the circular extension. The aim of the project is to merge the two subprojects and create an interchangeable stock of materials and components (material bank) in the form of services (TU Delft, 2019). As defined above, the circular extension project is based on four main circular design parameters.

Firstly, the technical model aims to introduce CE ideas into the built environment. Currently, approaches in circular economy model focus on these three topics:

- Narrowing loops: material and energy reduction
- Slowing loops: designed for long life, standardization + compatibility, easy maintenance and upgrades + adjustments
- Closing loops: designed for disassembly, re-assembly and recycling

Aiming to integrate these values in the built environment, technical design ideas such as modular design, lean construction, shearing of components, legolization, mass-customization and building system construction have emerged.

The second parameter is the supply chain model. This parameter focuses on the involved partners and the activities that take place from beginning to the end of the project. The goal is to have a fully circular supply-chain from inception to completion, with trust at its base value. Moreover, the supply-chain plays a crucial part to support the technical model and is integral to its success.

The third parameter is the business model. This parameter aims to maximize economic and environmental value through different market approaches. The business model is rather important as it sets the relationship between the client and the contractor.

Lastly, in order for the project to achieve its CE goals, it will need to fulfil the technical specifications of narrowing, slowing and finally closing the material loops. This will be achieved by the so-called Value Retention Processes (VRP) such as remanufacturing, refurbishment, repair and arranging direct reuse, enable, to varying degrees, the retention of the value and possibly the creation of new value at a lower environmental impact (UNESCO, 2018).

The technical model, the supply chain model and the business model compose the design parameters together with the VRPs. By changing the conditions of each model, a different collaboration process emerges. Therefore, it is required to further explore the components of these models.

2.3.1 Technical Model

First, the technical model is analyzed, following the available information provided by the 'REHAB' project. The aim is to identify the different factors of the technical model that can affect the long term collaboration process.

The first successful extension was placed in October 2020 in a housing renovation. The design used standardized modules, in order to enable changes in the design to fit future needs. Moreover, the façade of the extension consisted of wood that was reclaimed during the renovation and the doors originate from another renovation project. Following, schemes of the design are provided to better understand the technical aspects of the circular extension. The first figure illustrates the front of the building with the extension placed.

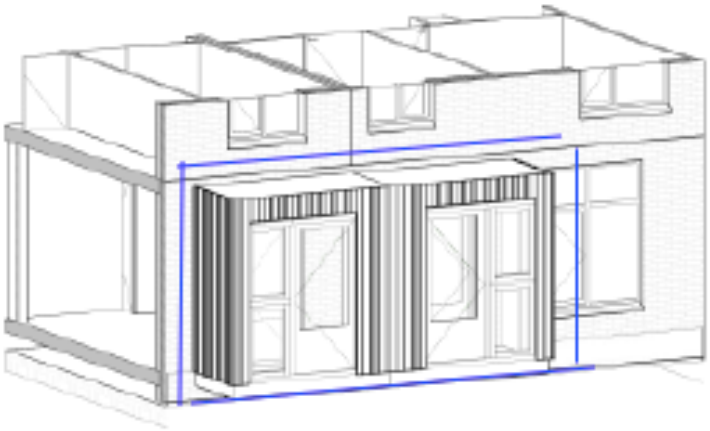

Figure 2.2 Front view of the building with the circular extension, circulated by the blue line (source: (Van Stijn, 2019)

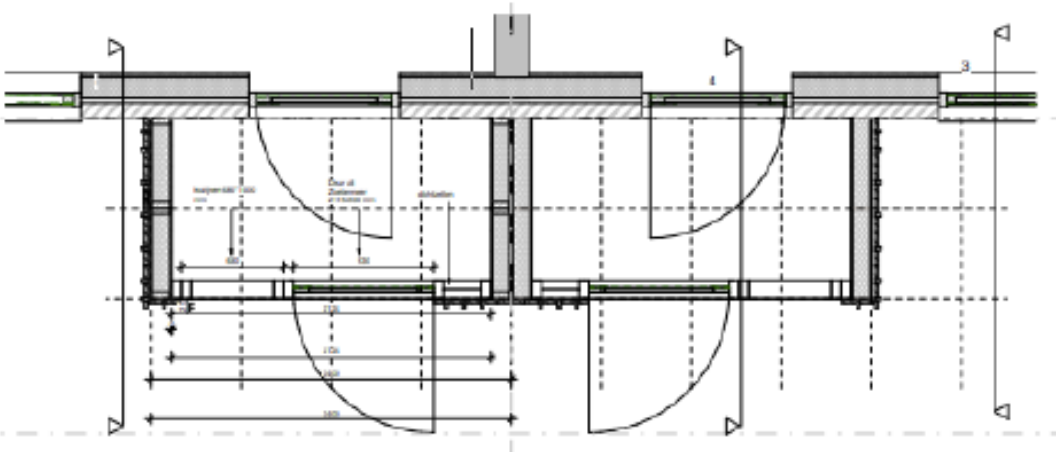

Figure 2.3 Top view of the circular extension (source: Van Stijn, 2019)

Figure 2.4 Exterior view of the first circular extension (source: Van Stijn, 2019)

During this project, the circular extension was placed as an extension that is located in the garden exit of the apartment. Figure 2.4 illustrates the first successful installation of the circular extension. As illustrated by Figure 2.2, the circular extension is a box that is consisted of a roof, floor, two windows, one door and surrounding walls with isolation. The installation for this design is made for two apartments. The aim is to streamline the construction process, minimize the installation time and to use fewer materials.

Keeping up with the project goals, the design of the circular extension for this project is using recycled material. The windows, frames and screws that are removed from the façade during renovation are reused for the extension. Moreover, the drainage system, doors, frames and screws come from another renovation project, that would otherwise have been decommissioned. As stated above, the façade made by wood that was extracted from the residence during renovation, as well as the isolation material and water proofing coat.

Furthermore, the extension uses a grid system of modules with dimensions of 60x60 cm. These dimensions are derived as common dimensions found in construction projects, for example a washing machine is typically 60x60 cm. These modules are constructed off-site and assembled on-site. By using a modular system and a legolization system, the design can be adopted to fit the needs of each individual project.

The technical model aims therefore to facilitate circular economy design practices in the form of narrowing, slowing and finally closing the material loop. This is achieved by using standardization modular construction which is easy to assemble and disassemble and use recycled material. Therefore, the parameters that compose the technical model and can affect the long-term collaboration process during maintenance are the following: modularity, recycled material, off-site construction and legolization.

2.3.2 Supply-Chain Model

According to Stevens (1989), the supply chain is a series of connecting activities which focus on planning, coordination and controlling, material, parts and finished goods from suppliers to costumers. Since then, the supply-chain literature has expanded to fit the needs of each sector. The first research connecting sustainability and supply chain was by Elkington (2004). The author introduced the idea that organisational sustainability consists of three components: the natural environment, society and economic performance. Elkington (2004) names these the Triple Bottom Line (TBL) (Farooque, Zhang, Thürer, Qu, & Huisingh, 2019)

Based on Elkingtons idea different terminologies have emerged in the literature, such as “sustainable supply chain management” (Leszczynska & Maryniak, 2017), “green supply chains” (Malviya & Kant, 2015), “environmental supply chains” (Darom & Malaysia, 2019) and “closed loop supply chains” (Souza, 2012; Govindan, Soleimani, & Kannan, 2015) .These concepts respectively address all three components of the TBL.

The CE moves away from a traditional linear supply chain, to a circular “closed loop” supply chain (Farooque, Zhang, Thürer, Qu, & Huisingh, 2019). The closed-supply chain enhances environmental performance by reintroducing materials back in the production line (Guide & Van Wassenhove, 2009). However, there are limitations on how much value recovery can be achieved in a closed loop supply chain. The main reason being, that efforts are restricted within the original supply chain and does not include secondary supply chains or even new auxiliary channel members (Moula, Sorvari, & Oinas, 2017). Moreover, there still is a substantial amount of waste that is generated in a closed loop supply chain that is not feasible to reuse or recycle (Farooque, Zhang, Thürer, Qu, & Huisingh, 2019). However, by collaborating with other organisations in the same sector or in other sectors more value from materials can be reintroduced and waste be minimized (Weetman, 2017).

Therefore, a closed loop supply chain can have one the following profiles:

- Closed-Closed Loop: Purchasing or reselling material within the original existing supply chain.
- Open-Closed Loop Same Sector: Purchasing or reselling material in other organisations in the same sector.
- Open-Open Loop Different Sector: Purchasing or reselling materials with organisations across a large number of sectors.

Starting from a Closed-Closed Loop supply chain model, the collaboration is conducted between existing partners. Hence, collaboration can be easily conducted as information and communication channels already consist. Trust and openness are already established between the partners with environmental and economic incentives established between partners. However, Closed-Closed Loop supply chains present smaller possibilities to share material, hence the biggest the possibilities to generate waste.

Moving towards a more diverse Open-Closed Loop supply chain, collaboration in Open-Closed Loop supply chain within the same sector is more challenging than the Closed-Closed Loop. Information and communication channels may not exist at all. Trust is difficult to be established since organisations may be direct competitors. A common goal is to create ecological value through the reuse of materials.

Finally, the Open-Open Loop cross-sector supply chain poses the highest difficulty for collaboration. As organisations do not share communication and information channels, collaboration between can be extremely challenging. Even communication is hard, as different sectors communicate in a completely different way from others. In this case also ecological value, as well as economical value create a strong incentive for organisations to collaborate.

2.3.3 Business Model

According to Rasmussen (2007), business models are concerned with defining the competitive strategy through the design of the product or services it offers to the market. However, circular approach moves away from a linear business model of production of take-make-use-dispose system reliant on fossils fuels. The aim of the business model shifts from creating profit from selling artifacts to generating profits from the flow of material and products over time (Bocken N. M., De Pauw, Bakker, & Van der Grinten, 2016; Bakker, Den Hollander, Van Hinte, & Zijlstra, 2014).

In their research, Bertram et al. (2019) explore the transition from a project based to product based modular construction. As Bertram et al. (2019) emphasise in their report, modularity is the key to move to a service based system. Even though the report is focused on the financial benefits of the modular construction, the environmental benefits are also pointed out, with main point the interchangeability of materials between each module. Therefore, modularity can be used to achieve the circular goals of the project by enabling the result-oriented business model. Moreover, as stated by Bertram et al. (2019) in their report, another way of moving towards services are the so called Product-Service-Systems.

According to Tukker (2004), a product-service system (PSS) is defined as a system of services and tangible products designed so that jointly are capable to fulfil specific customer needs. Moreover Tukker (2004) emphasises that PSSs can enhance competitiveness and foster sustainability simultaneously. Tukker (2004) identified three main categories of product service systems. The first is product-oriented services, a typical way of operating by selling a product with some extra services. The second category is the use-oriented services, where the product still plays the main role. The ownership remains with the provider and the product can be used by other users as well, where leasing and product pooling are subcategories. The final category is the result-oriented services, where the client and provider agree in principle on a result and there is no predetermined product involved.

As stated by Tukker (2004), the result oriented services are the most promising in terms of facilitating a shift to a circular and resource-efficient economy. A typical example is Laundry Services. The costumer has a need (to wash clothes) and instead of buying and owning a washing machine, the costumer goes to a laundry service store and acquires the services of the store. Therefore, there is no exchange of product but only services, which results in all materials products, and consumables used to deliver the result become cost factors, which creates an incentive to minimize their use.

To date the most widely used PSS can be identified by combining a product and a service (use-oriented services) in which interaction takes place before or during purchase, but may also take place after purchase. It is evident that a main motive of PSS providers to offer both products and services, is that PSSs allow for more long-term and dynamic relationships between supplier and costumer (Michelini, Moraes, Cunha, Costa, & Ometto, 2017). The most successful business strategies based on use-oriented follow the Apples iPod (mp3 player device) with their music retail services iTunes, as well as Nespresso with their coffee cup machine (product) and the services in the form of capsules.

Therefore, the circular extension project can follow three different business strategies. These strategies are inspired by the business model proposed by Tukker (2004), however small changes have been made to fit the BE profile of the product.

1. Product-oriented services: Contractor designs and builds the product with option for maintenance and decommission services. The product is owned by the costumer, traditional construction project.
2. Use-oriented services: Contractor designs, builds, maintains and decommissions the product. Ownership is originally of the costumer and during decommission the contractor assumes ownership. State-of-the-art model are used in a few projects already.
3. Result-oriented services: Most innovative model, as costumer has minimal involvement with the product, and the contractor designs, builds, maintains, operates and lastly decommissions. A typical lease product model.

All strategies have their merits and can have a catalytic factor in enabling the product to fulfil its circular goals. The communication process will be identical for the first two strategies with slight differences. The reason being that, is the supply-chain remains the same as the product is still owned by the costumer during maintenance. The third strategy is quite innovative and in its infancy state in the BE.

2.3.4 Value Retention Processes

The long-term collaboration process will be conducted during the maintenance phase of the project. As mentioned before, during these phase the VRPs will spring into action in order to retain material value into the process loop. The idea sprang initially from the R-hierarchies or imperatives. The most known are the 3R of “reduce”, “reuse” and “recycle” (Yoshida , Shimamura, & Aizawa, 2007). Moreover, as circular economy has risen the last decade as a promising solution to the environmental problems, more research has been conducting into further developing the R imperatives. Since then, new ideas such as the “4R’s” (King, Burgess, Ijomah, & McMahon, 2005) and “5R’s” (Gerrard & Kandlikar, 2007).

In the literature exists an immense number of publications on the topic. Reike, Vermeulen, & Witjes (2018), conducted an impresive literature review, by indentifying publications about the R imperatives. They created a more complete set of ten “R’s” in total. They named the Value Retention Processes, which as the name suggest, are procceses designed to retain the value of materials in the creation process. The following scheme illustrates what these VRPs are and how they can be used in the lifecycle of a product.

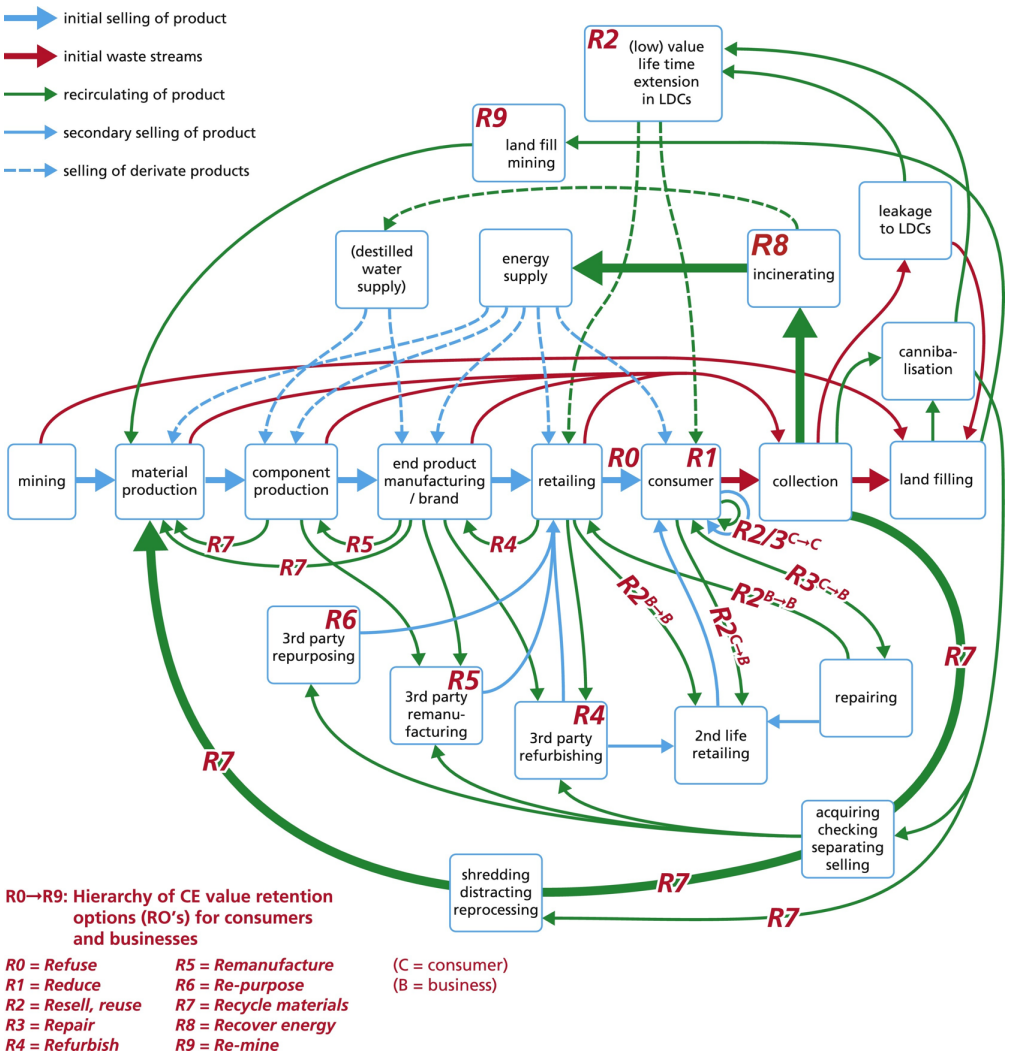

Figure 2.5 VRPs in the product produce life cycle (Reike, Vermeulen, & Witjes, 2018)

Refuse (R0): Designers can refuse to design a product which will incorporate the use of hazardous materials or the use of virgin materials in their design. In the case of the circular extension, designers can refuse the use of virgin materials in the original design. These will lead to a design with recycled material.

Reduce (R1): As the name suggests, the aim is to reduce the use of material and most importantly the waste of material. For the circular extension this can be accomplished by incorporating standardization in manufacturing such as Off-site manufacturing and lean construction. Moreover, modularity and legolization can greatly affect the material reduction during the construction as well as during maintenance as modules as standardized.

Resell, reuse (R2): The aim of this imperative is to resell material to other organisations when they reach the end-of-use, therefore gain further value in another purpose. Reuse refers to reusing the materials or modules without the need of refurbishment or repair in this case. These imperatives play an important role during the maintenance phase of the circular extensions, as material collected during maintenance which have entered the end-of-use can be resold, which has a twofold gain. Economical, by generating revenue where otherwise would require found to dispose. Ecological, by repurposing material that otherwise would be disposed.

Repair (R3): The meaning of repair is to extend the lifetime of a product by replacing broken parts. For the circular extension repair is very valuable during the maintenance phase, as it is going to be used constantly to repair modules.

Refurbishment (R4): Refurbishment refers to the replacement or repairment of components, which results in an overall upgrade of the product. This imperative will also play an important role during the maintenance phase of the circular extension. As technology advances, new sustainability innovation will be introduced in the sector. By implementing the refurbishment, the circular extension can be brought up-to-date, which can result in higher circular performance.

Remanufacture (R5): Remanufacture can be easily be mistaken with refurbishment. The main difference is that in remanufacturing, repair or replacement is used to bring the product to its original state. During refurbishment the product is brought to up-to-date with current innovations. For the circular extension remanufacture plays an important role as well, as it will be used extensively during the maintenance phase.

Repurpose (R6): The concept of repurpose is to identify a different use for the waste material. For the circular extension this can be used to repurpose material that is collected during the maintenance phase into something else in this project, or can be reused in another project.

Recycle Materials (R7): In this context, recycle materials are a mix of mixed streams of post-consumer products or post-producer waste streams that are adopting innovative technological equipment in order to capture as pure metal as possible. The clear difference with the previous “Rs” is that recycled material completely loses the original product structure and therefore can be reapplied anywhere. This imperative will also play an important role during the maintenance phase as material can be recycled and then be reused in the project or other projects. Recycle materials work closely with other “R” imperatives.

Recovery of energy (R8): Recovery means the process of capturing energy embodied in waste. This can be achieved by either incineration in combination with producing energy, or to be used as a biomass. For the circular extension this is out of scope, and materials can be resold to organisations that can use them to recover the energy.

Re-mine (R9): The last “R” imperative is the re-mine, which refers to placing the material after it has reach the end-of-life back in the eco-system with the minimum ecological disturbance. This imperative also falls out of scope for the circular extension, as recovery material can be resold and therefore be re-mined by other organisations with higher expertise.

Due to the innovative and fairly new concept of circular components, the most applicable VRPS are the ones that Reike, Vermeulen & Witjes (2018) indicate as “Short Loop” and “Medium Long Loops” VRPs. With exception of the “R7” (Recycle Materials) the “Long Loops” fall out of scope for this project. They can be achieved by larger organisations with a larger infrastructure and scope.

The Shortest Loops refer to the first R imperatives: Refuse, Reduce, Resell or Reuse, and Repair. These loops exist closer to the consumer and can be linked to commercial or non-commercial actors engaged in extending the life span of the product (Reike, Vermeulen & Witjes, 2018). Also characterized by many scholars as the most preferable “Rs” in the CE, they can have a great impact on the maintenance phase of the circular extension for circularity, as well as for collaboration between the partners.

Medium Long Loops refer to the next three “R” imperatives: Refurbish, Remanufacture and Repurpose. A high number of researches uses the Refurbish and Remanufacture as synonyms, however there is a clear difference as mentioned above. They will have a direct impact on collaboration as one is recreating the existing component with the design specifications, and the other is trying to implement new innovative concepts into the existing design.

2.3.5 Conclusion

In this section the four different models that compose the circular extension design parameters are analyzed. Starting from the technical model modularity, off-site construction, legolization and recycled material are the most important factors. Moving on, three supply chain models are proposed: closed loop, open loop same sector, and open loop different sectors. Next, the business model, three models are proposed: product-oriented, use-oriented and result-oriented.

Finally, the VRPs that can be used are identified as short-term loops and medium long loops. All of these different ways to approach the project will define the collaboration process. By changing the technical model, the supply chain changes, which results in a different collaboration process. Therefore, this will be the input that will be used on the next step of synthesis.

2.4 Supply Chain Collaboration in the CE

In this section, the research focuses on the long-term collaboration process of the circular extension. The aim is to identify the key factors that compose the collaboration.

2.4.1 Status-Quo

Collaboration is a process that involves two or more entities working together in order to achieve a goal or complete a task (Martinez-Moyano, 2006). Supply chain collaboration is two or more autonomous firms that form long-term relationships and work closely to plan and execute supply chain operations toward common goals, thereby attaining more benefits than acting individually (Simatupang & Sridharan, 2005). According to Wilkinson (2005), collaboration takes place at different levels, from small groups with immediate colleagues to multi-disciplinary project teams. In short, collaboration takes many forms and is required in just about every business process. Moreover, Wilkinson (2005) states that successful collaboration is a process of value creation that cannot be achieved through traditional, often hierarchical structures. It is noteworthy that Wilkinson (2005) emphasises that true collaboration requires the stakeholders to set aside self-interest, be that of belief, professional background or role in the project, that they are somehow superior to other members. Additionally, Malhotra & Murnighan (2002) state the importance of collaboration exceeding the self-interest.

However, the construction sector is plagued by project failures and a great deal of studies have been conducted in order to pin-point the causes (Flyvbjerg, 2009; Xianhai, 2012; Gamil & Rahman, 2017). In all studies fragmentation and limited collaboration between stakeholders, especially during the front-end of the project, were two of the main causes that lead to project failure. Hence, the need to understand collaboration in the circular economy context. In the BE, collaboration became necessary to co-op with the ever-increasing pace of technological developments and specific innovative requirements. Hence, the shift from traditional contracting to a knowledge sharing alliances between construction players (Stiles, 1995; Douma, Bilderbeek, Idenburg, & Looise, 2000). In their research for the PIECC Project, Shelbourn, Bouchlaghem, Anumba, & Carrillo (2007) identified three strategies to join in order for collaboration in the built environment to succeed: technical, business and people.

Nowadays, studies of collaboration in the built environment are closely correlated with circular economy practices (Leising, Quist & Bocken, 2018; Sposato, Preka, Cappellaro & Cutaia, 2017; Karhu & Linkola, 2019; Hossain, Thomas, Antwi-Afari & Amor, 2020). This is due to the innovative requirements that circular projects aim to achieve. One of the first publications to connect sustainability and collaboration is by Kusiak & Wang (1993), which stated that ‘collaborative working is essential if design and construction teams are to address the entire lifecycle of the construction product and take account of not only primary functionality, but also productivity, build ability, serviceability and even recyclability (Hudnurkar, Jakhar & Rathod, 2014).

The study that illustrates best the current way of collaboration in the built environment in combination with CE practices, can be given by Leising, Quist & Bocken (2018). The authors studied three cases and defined circular economy in supply chain collaboration as “connecting a network of actors in their supply chain managing data transparency, material flows and exchanges, responsibilities, predictability and sharing benefits”. Moreover, the authors created for the purpose of conducting their research a conceptual framework for studying circular economy supply chain collaboration in the built environment. The framework followed the following principals: Visions of the future, Actor learning, Network Dynamics, Business Model Innovation.

In another study by Dietrich, Eskerod & Dalcher (2010) about collaboration dynamics in multiparter projects, the authors concluded the following eight antecedents for a successful collaboration in the CE: roles and process for collaboration, trust between the actors, physical and cultural proximity, alignment of incentives, commitment to the project, goal congruence and collaborative goals, conflict resolution, expectations fulfilment, socio-cultural skills to enable transformation towards recourse efficiency. In general, the literature for collaboration in the CE follows the same pattern and identifies trust, incentive alignment and commitment to the project as the most important parameters of the project. Therefore, a tool needs to be identified that contains the above factors for the different design variations for the collaboration be designed.

Table 2.3 Most Important Factor of Collaboration

Parameters	**Source**
Commitment	Walter, 2003; Fynes, Voss & Búrca, 2005; Chen, Yen, Rajkumar & Tomochko, 2011; Lynch, Nyaga & Whipple, 2009
Trust	Simatupang & Sridharan, 2005; Simatupang & Sridharan, Design for Supply Chain Collaboration, 2008; Wang, Ye & Tan , 2014; Pamahifar, Byrne, Salam & Heavey, 2018; Jeng, 2015
Communication	Simatupang & Sridharan, 2008; Fynes, Voss & Búrca, 2005; Cao & Zhang, Supply Chain Collaboration: Impact on Collaborative Advantage and Firm Performance, 2011
Information Sharing	Simatupang & Sridharan, 2008; Fisher, 1997; Maskey, Fei & Nguyen, 2020; Jeng, 2015; Pamahifar, Byrne, Salam & Heavey, 2018; Wang, Ye & Tan , 2014
Alignment of Incentives	Simatupang & Sridharan, 2008; Narayanan & Raman, 2004; Norrman & Naslund, 2019
Joint knowledge Creation	Cao & Zhang, 2011; Cao, Vonderembse, Zhang, & Ragu-Nathan, 2010; Zacharia, Nix, & Lusch, 2009
Decision Synchronization	Simatupang & Sridharan, 2008; Simatupang & Sridharan, 2005; Fisher, 1997; Cao, Vonderembse, Zhang & Ragu-Nathan, 2010; Scholyen & Schilder, 2015; Hatani, 2017; Hahn, Duplaga, & Hartley, 2000; Farooque, Zhang, Thürer, Qu & Huisingh, 2019; Eyaa, Ntayi & Namagembe, 2010
Supplier collaborative performance system	Simatupang & Sridharan, 2008; Simatupang & Sridharan, 2005; Forslund & Jonsson, 2013

2.4.2 Design for supply chain collaboration

As mentioned during the first chapter, the research will design a number of different collaboration process variants. This process takes part in the next chapter, the synthesis. However, the bases for the synthesis chapter begins here and as it is important to understand the requirements and parameters of the different design variants. The literature follows the same pattern of identified factors for a successful collaboration in the CE. Therefore, a tool is required to combine all of these factors and create the blueprint on which the design variants will be based upon. This tool is based on the research of Simatupang & Sridharan (2008).

The authors identified five key elements to promote productive behavior in collaboration between partners. The five elements are: Collaborative Performance System (CPS), Information Sharing, Decision Synchronization, Incentive Alignment, Innovative Supply Chain Processes. This is based on previous research conducted by the same authors, and in this research the authors test the theory on a case. The goal of the research was to clarify the architecture of supply chain collaboration that describes its key elements and introduces the concept of design for supply chain collaboration (DfC). The design for supply chain process can help to enable partners to define the ground rules of collaboration and improve overall performance.

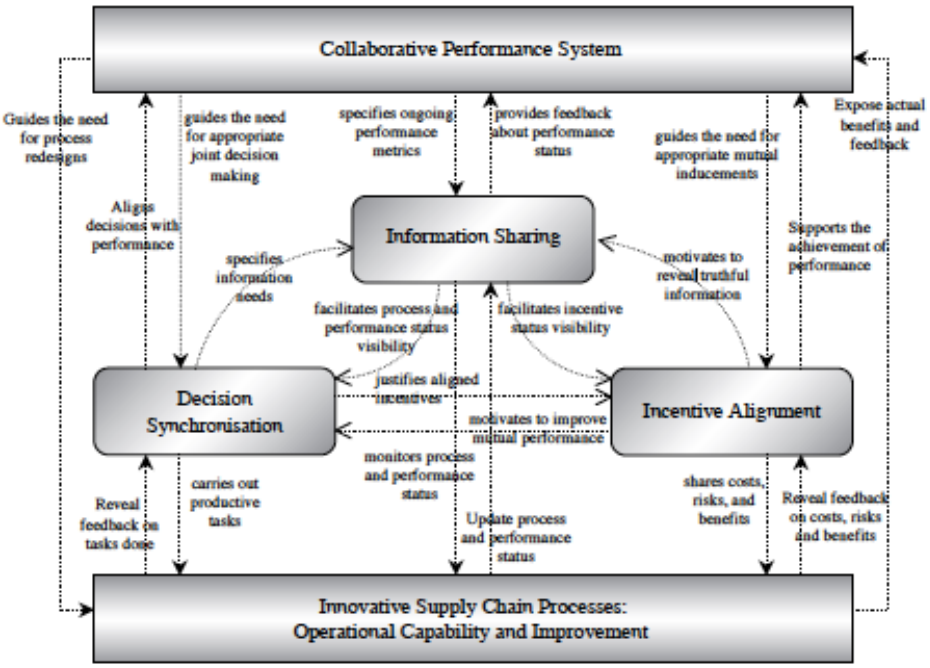

Figure 2.6 The five elements by Simatupang & Sridharan (2008)

In the conclusion the authors state that to establish effective collaboration, all five elements must be in balance and well-coordinated. Moreover, the authors state the close correlation between the five elements: by alternating one, all elements are affected. Furthermore, the authors stipulate the contribution to future research by creating a base framework for future research to be based on. The main reason that this framework is chosen, is because its versatile. It can be adapted to fit different collaboration processes and the relatability with the collaboration processes this research aims to design. Firstly, even though the research is based on the technology sector is clearly oriented towards a product. This creates a relatability with the circular extension. Secondly, the five elements of the DfC are closely corelated with the parameters of the collaboration process found in the literature review. Therefore, it is possible to intergrade missing requirements from the original definition of the five elements to include definitions of the CE. Lastly, due to the versatility of the DfC it presents an excellent environment to design different collaboration variants.

Collaborative Performance System (CPS)

CPS can be defined as the process of creating and realizing performance metrics and objectives. in order to guide the supply chain partners to assess and improve the performance of the supply chain, individually and collectively. These metrics and targets will lead the partners to attaining the objectives of the project and finally achieve good results. The process is designed collectively by all partners, with intermediate performance milestones set to monitor the performance. By creating a CPS, all the partners can become truly committed by understanding what supply chain collaboration aims to achieve and how to contribute to the final result.

According to Simatupang & Sridharan (2008), the CPS is consisted of objectives, metrics, target specificity, an explicit time period and performance feedback. Moreover, the "collaborative objectives" mirror the competitive factors that are gained by the collaboration of the partners. These factors exist in the form of product and services advantage, supply chain costs, responsiveness and to be recognizable by the market as having higher specialization (Simatupang & Sridharan, 2008).

Considering a closer approach to circular economy, a study by Kazancoglu, Kazancoglu & Sagnak (2018) created a framework consisted of six main criteria and 21 sub-criteria about green supply chain management (GSCM). The main criteria for this performance assessment framework are Environmental, Economic, Logistics, Operational, Organisational and Marketing performance. Each of this criteria contains sub-criteria:

Table 2.4 CPS criteria and sub-criteria according to (Kazancoglu, Kazancoglu, & Sagnak, 2018)

Main Criteria	Sub Criteria
Environmental Performance	Decreasing Emissions, Decreasing Energy Consumption, Decreasing Business Waste, Decreasing Environmental Cost, Increasing Environmental Revenue
Economic Performance	Decrease Costs, Increase Revenue
Operational Performance	Increase in quality, Increase Efficiency, Improving Green Manufacturing, Improving Green Packaging, Improving Green Design
Logistics Performance	Improving Green Logistics, Improving Reverse Logistics, Improving green Purchasing
Organisational Performance	Improving Green Image, Incorporating Environmental Management, Green Information Systems
Marketing Performance	Increase Customer Satisfaction, Improving Collaboration with Costumers, Marketing Measures

- Environmental Performance is critical to the circular extension product. Hence, all parties should strive to collaborate in order to decrease emissions by refusing virgin materials into their design, decreasing the energy consumption by creating a modular system and implementing lean construction methods to decrease CO_2 emissions, by reducing business waste by implementing VRPs and Reuse materials, by decreasing environmental costs by standardization and smart construction, and by finally increasing Environmental Revenue by re-selling materials that have reached the EoL.

- Economic Performance for a circular component focuses on cost oriented performance that is purely on minimizing manufacturing and maintenance costs with the technical design of the component, while the revenue-oriented performance is maximizing profit by the use of business-models.

- Operational Performance for a circular component is achieved by increasing the efficiency with the use of supply-chains and technical design, by improving green manufacturing through the technical model and the use of the VRPs. Finally, by improving the eco design by the use of technical design. Improving green packaging and increasing quality are not included, as they are deemed out of the scope for the circular extension.

- Logistics Performance relies highly in the use of supply chain loops. Improving green logistics relies on timely transportations of the material and modules on the site, by improving reverse logistics with the use of VRPs to capture additional material value, and by improving green supply purchasing with the use of open/closed loop supply chains. These practices result in purchasing more Eco labeled materials.

- Organisational Performance focuses on improving the green image of the project, by implementing the circular economy ideas into the project and through-out the project lifecycle without compromising sustainability for financial motives. This will create a green image that other organisations will strive to achieve.

- Marketing Performance leans towards collaboration with the customer, by increasing customer satisfaction by achieving the scope of the project and by improving the cooperation with the costumer by involving him/her from the beginning until the end of the project. Finally, it will create a competitive advantage in the market by increasing the specialization of the partners involved within the project.

Information Sharing

Through information sharing the partners are able to monitor and control the progress of products throughout the lifecycle of supply chain. According to Simatupang & Sridharan (2008), the activity of information sharing covers data acquisition, processing, representation, storage and dissemination of demand conditions, end-to-end inventory status, location, order status, cost-related data and performing data. Moreover, information sharing serves the role of glue between the involved partners in the collaboration process. By having a better understanding of each other, or to be able to “visibly” understand the motives and ways of working leads to a better decision making process. Information sharing generally includes decision synchronization though providing relevant, timely and accurate information required to take effective decisions about the supply chain planning and execution (Fisher, 1997).

Maskey, Fei & Nguyen (2020), conducted a very promising research on the topic of information sharing. The research aimed to empirically examine a comprehensive list of factors that are likely to have an effect on information sharing in supply chains. The research focused on the region of Nepal and collected both data from literature and through questionnaires. The authors divided information sharing in two subdivisions: Operational Information Sharing and Strategic Information Sharing. Moberg, Cutler Gross & Speh (2002) define operational information sharing for short-term activities that can be performed daily or weekly. Whereas strategic information sharing focuses mainly on long-term issues and activities, it has a more strategic nature. Maskey, Fei & Nguyen (2020) divided the factors in 4 dimensions: Relationship Dimension, Intra-organisational Dimension, Inter-organisational Dimension and Environmental Dimension. The following figure illustrates the research model.

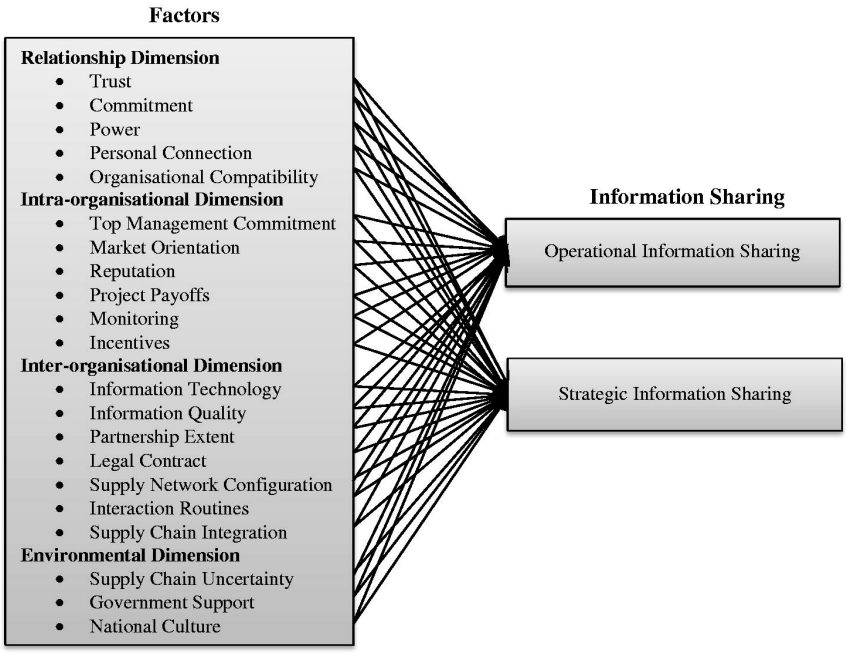

Figure 2.7 Factors of Information Sharing by (Maskey, Fei, & Nguyen, 2020)

Moreover, the authors concluded that the key drivers of Operational information sharing were interaction routines, organisational compatibility, incentives, project payoffs, inter-organisational commitment, personal connection, top management commitment and supply network. The key drivers for strategic information sharing are interaction routines, government support, personal connection and monitoring. Moreover, trust was the key for both operational and strategic information sharing (Jeng, 2015; Pamahifar, Byrne, Salam & Heavey, 2018; Wang, Ye & Tan, 2014). According to the authors, all factors play a role in both strategic and operational information sharing.

Table 2.5 Information Sharing Dimensions

Relationship Dimension	Strong relationship between supply-chain partners is a requisite for the long-term success of the project. Trust and commitment should be shared equally by all partners, from the beginning to the end. In addition, with the introduction of new information technology innovations and BIM technology, there is limited inter-personal communication. However, personal connection and organisational compatibility is important for the successful relations between partners.
Intra-organisational Dimension	Intra-organisation factors arise within the organisation's structure. The most common factors that affect intra-organisational information sharing are information technology, information quality and top management support (Maskey, Fei & Nguyen, 2020)
Inter-organisational Dimension	In contrast with intra-organisational, inter-organisational factors arise between two or more partners. Information technology, information quality, partnership extent, legal contract, supply network configuration, interaction routines and supply chain integration make the inter-organisational dimension. All of these factors are equally important for the circular component and can be adjusted from the technical model to supply chain model, to business model. This dimension is most important for the circular extension.
Environmental Dimension	These dimension refers to factors that are external factors of the project and cannot be influenced by the partners. These are supply chain uncertainty, government support and national culture.

The figure 2.8 illustrates the information sharing dimensions by (Maskey, Fei & Nguyen, 2020). Starting from the center information sharing within the organisation and moving out-wards towards other organisations. Information Sharing is consisted of these four dimensions. Each dimension has its own characteristics, and can be influenced by the main components. The most important being the Relationship and Inter-organisational dimensions due to the long-term profile of the supply chain and the involvement of different partners from different organisations.

Figure 2. 8 Information Sharing Diagram

Decision Synchronization

Decision synchronization seeks to facilitate the coordination of planning and execution decisions between the partners. By synchronizing the decisions process between partners there is a high pay-off in overall terms of reused materials. Joint decisions by partners provide synergetic benefits to the supply-chain (Fisher, 1997). Simatupang & Sridharan (2008) link decision synchronization closely with information sharing between partners. Furthermore, decision synchronization is defined as the process where supply chain partners coordinate decisions for supply chain planning, operations and solution seeking. Moreover, decisions synchronizations involve inventory management, demand forecasting to optimize the supply chain (Scholyen & Schilder, 2015; Cao, Vonderembse, Zhang & Ragu-Nathan, 2010)

Simatupang & Sridharan (2008) state that several questions should be answered in order to achieve decision synchronization. How decisions are made, what information are required, which partner is better fit to give an answer for the decision? Moreover, Diepenmaat, Van Ettekoven & Van Hal (2012) state that there should be an Initiator for the decisions process who will monitor the situation. An open attitude from all partners is crucial, as a not so specialized partner may have a good solution to a potential problem. There exists a small number of studies conducted which include decision synchronization (Simatupang & Sridharan, 2008; Simatupang & Sridharan, 2005; Fisher, 1997; Cao, Vonderembse, Zhang & Ragu-Nathan, 2010; Scholyen & Schilder, 2015; Hatani, 2017; Hahn, Duplaga & Hartley, 2000; Farooque, Zhang, Thürer, Qu & Huisingh, 2019; Eyaa, Ntayi & Namagembe, 2010). These studies present no clear factors or guides that affect the process. However, the majority seems to converge to the same point: there is a need for a good level of trust and information sharing between partners, someone that will monitor the process and a clear planning of milestones of the project. In the case of the circular extension, decision synchronization is conducted mutually by all members. During the design phase, all decisions were made in joined meetings with all involved parties and the client. The technical model and supply chain model will play a role in decision synchronization as this model affect the when, how and which partners will need to synchronize their decisions.

Incentive Alignment

Incentive alignment refers to the process of sharing costs, risks and benefits amongst the partners of the supply-chain (Simatupang & Sridharan, 2008). This process motivates the partners to operate in a consistent mutual manner. According to Simatupang & Sridharan (2008), self-enforcement and compensation fairness measure the performance of the incentive alignment, while compensation fairness ensures that aligned incentives motivate the partners to share equally the loads and benefits of the collaboration. Partner self-enforcement results in an effective incentive scheme by aligning their individual decisions with the shared objective of improving the outcome.

In the literature supply chain incentive alignment is stated as a key antidote for successful supply chain management (Narayanan & Raman, 2004). Moreover, by improving alignment, there is an increase of integration and cross-functional collaboration (Norrman & Naslund, 2019). In their research, Norrman & Naslund (2019) conducted an extensive empirical research to explore and describe the current practice, and to identify gaps of supply chain incentive alignment. The research involved forty-eight responses, as well as an extensive literature review. It concluded that the current practice favors simple mechanics such as price per unit and column discount. Moreover, applying more sophisticated coordinating mechanisms could enhance risk and rewards sharing. According to Norrman & Naslund (2019), these sophisticated mechanisms are proposed by Narayanan & Raman (2004). In their research, Narayanan & Raman (2004) proposed three types of solutions for incentive alignment: Contract Based, Information Based and Trust Based.

1. Contract: In their research, Narayanan & Raman (2004) argue that companies should explore contract-based solutions before utilizing other approaches. Using contracts to make sure that all partners share equally risks and profits is vital for the success of the collaboration.

This plays a vital role in the long term collaboration as it ensures that all partners will be incentivized to follow the contract. However, in the case of the circular extension, which is an innovative project, the partners must collaborate not because they "have to" but because they want to.

2. Information: Information sharing between partners play also an important role for incentive alignment. By sharing information such as goals, ambitions and objectives, the partners have a better understanding on how to proceed with the collaboration. By sharing information, the foundations are built to create an environment of trust and commitment among the partners.

3. Trust: The authors (Narayanan & Raman, 2004), propose to create an environment of trust through intermediates. Even though this is a possible solution for enormous organisations which have a very specific agenda, this is not so applicable in this case. For the circular extension the partners have a "smaller" market value. Therefore, trust must be built upon personal relationships by sharing information openness.

Concluding, incentive alignment for the circular extension is of paramount importance. The long-term collaboration process requires all partners to be aligned in their views and goals. This can be achieved by creating a contract that incentivizes collaboration, promotes information sharing and creates an environment of trust between the partners.

Joint Knowledge Creation (JKC)

In their research, Simatupang & Sridharan (2008) have as final element of the DfC the innovative supply chain processes. Innovative supply chain processes refer to as the design and implementation of adaptive supply chain processes that deliver products and services fast and low price. Innovative supply chain processes are directly linked to the Supply Chain model and therefore will be heavily influenced by it. However, since innovative supply chain processes are already included as a design parameter it is decided that this element altered.

Since, this innovative supply chains partners create innovative knowledge on circular economy practices. Joint knowledge creation on supply chain collaboration is proposed by (Cao, Vonderembse, Zhang & Ragu-Nathan, 2010) and defined it as the extent to which supply chain partners develop a better understanding and response to the market and competitive environment by working together. According to Cao, Vonderembse, Zhang & Ragu-Nathan (2010), there are two activities that form knowledge creation: knowledge exploration and knowledge exploitation.

Knowledge exploration, refers to activities in which partners explore in collaboration new innovative solutions. This activity takes place mainly during the design phase. Partners collaborate to create an innovative product which results in knowledge creation. Knowledge creation can be accomplished also during maintenance. Due to, the innovative profile of the project new knowledge gaps may arise on how to conduct maintenance. Knowledge exploitation, refers to activities in which partners implement the said joint knowledge. This activity takes place during the construction of the project, where knowledge that is created during design is implemented. As well as, during the maintenance phase. In order to, fit this element better with the circular extension process the last element of the design for collaboration is modified. The reason is, to incorporate elements of the collaboration that are missing from the definition of the DfC.

2.4.3 Conclusion

This section focused on identifying the status-quo of collaboration. Firstly, the literature review focused on identifying the factors that establish a successful collaboration process in the CE. A convergence of factors was identified, which led to establishing a toolbox that can be used as the bases for the design of collaboration processes during the synthesis phase. This collaboration process design contains five elements which are further developed and adapted to fit the circular extension project.

2.5 Information from Partners

In this section, the information gathered during the informal meetings with the circular extension partners are presented. Two meetings where conducted: one with the main contractor and one with the client. The meetings have a twofold aim. First to gather information about the circular extension that is not included in the relevant literature, such as technical specifications, maintenance expected schedules, supply chain partners and possible business models that may be used in the future. Secondly, to understand how the partners collaborated during the initial phase of the project, and how they perceived the collaboration in the context of circular economy. The meetings were informal and therefore no clear questioning strategy was followed. In this section, the most valuable information is presented in a brief manner since the transcript are presented in the Appendix.

2.5.1 Contractor Meeting

Most fortunately two member of the circular team project participated during the meeting. Both were members from different phases of the project: one from the design team and one from the implementation team. Therefore, the answers benefited the knowledge from two different viewpoints within one organisation. The first observation is that the contractor, through the collaboration with different partners and TU Delft, strives to fill a requirement of the market for circular products. This collaboration towards circularity will create a knowledge based competitive advantage within the market, which can lead to higher profits. Continuing, the contractor stated that the contract format is currently design & build with an option for maintenance. Moving on, the contractor provided the technical specifications for the circular extension and the three main topics, design, material, maintenance procedures.

On the topic of collaboration, both participants agreed that collaboration between partners is of paramount importance. During the design process, all the relevant partners took part in the form of workshops. These workshops involved the following partners: carpenter, architect, construction designer, roofing specialist, constructions specialist and the client. The development decisions were made within these workshops so the design could benefit from the expertise of the partners.

A high level of trust between the partners existed due to past collaboration, which included completely open knowledge and information sharing. Moreover, it is stipulated that incentive alignment is of outstanding importance. “It is going to take you allot of time, but you gain a knowledge base and advantage, thus you must be motivated”. The supply chain is based on established partners where has been a collaboration before. This incentivizes more the contractor since the trust and information sharing are established and no new efforts need to be made. The most important takes are that the contractor, through the use of circular components and collaboration, creates a knowledge base for innovative projects, which leads to a competitive advantage, as well as the need for trust, information and knowledge sharing between the involved parties.

2.5.2 Client meeting

To begin with, the interviewee stated that the housing market is expanding, with demand projected to rise in the future. The first important take away from the meeting is that it is for the client “very important to create a modular product that can be used in different locations, a scalable product”. This new product can be designed to incorporate recycled material. Furthermore, it is important to the client to create economic value through the reuse of recycled material. Moving on, the client estimates that the frame of the circular extension can be operational for the following forty years, with the wall elements estimated to require replacement within the next twenty years. Moreover, the client is busy creating a list of all the materials that are in use currently. The client as a housing corporation owns more than sixty thousand units in the Amsterdam area. All these assets can be translated in an immense stock of materials that can be used for future projects. However, since the client is a housing corporation, the assets are rented to tenants with low income. These tenants are usually neutral towards sustainable construction and prefer low prices solutions.

The client holds the ownership of the circular extension and is responsible for the maintenance of the project as of now. There is a possibility that the contractor assumes the maintenance responsibility. However, since the client is involved in the Zero on the Meter (NOM) initiative, it requires the project to be maintained in an adequate state, which will not compromise their sustainability goals. Furthermore, the interviewee stated that the client is looking towards other forms of business model such as lease or rent, where the contractor owns the product and the client uses it as a service. However, this requires a shift of ownership mentality which has been established for so many years in the BE.

Finally, the interviewee stated high satisfaction for the fast development of the product. Within two years of its conceptual idea a working prototype was constructed. However, according to the interviewee, the rate moving towards sustainable solutions are still slow. Big organisations need to invest more on circular economy practices in order to achieve the circular economy goals set by the government of 50% circularity by 2030, and 100% by 2050. Additionally, a change in financial mentality is needed. Since new materials according to the interviewee is cheaper to buy and require no extra labor in comparison with used material. However, by the end-of-life the recycled material will have retained economic and environmental value.

2.5.3 Conclusion

It is interesting to observe the differences and similarities between the two partners. On one hand, the contractor focuses on creating knowledge based of circular components which will lead to a market advantage over competitors. This advantage can lead to higher profits in the future as the sector moves towards circular economy. On the other hand, the costumer focuses on creating a product that can be scalable and can be used repeatedly in different locations. By focusing on different strategies, the client and costumer use circular economy practices to create a product that will deliver economical profits.

2.6 Stakeholders

During the interview with the contractor, the involved stakeholders where mentioned. The long-term collaboration process to create the circular extension involves these stakeholders and possible ones in the future. Understanding the roles, interests and goals of the involved stakeholders is a key step towards successful collaboration. The following table provides a list of stakeholders based on the analysis of the provided documentation for the circular extension and the informal interviews with the contractor and client.

Table 2.6 Involved stakeholders of the circular extension

Stakeholder	Type of Organisation	Project Role
Eigen Haard	Housing Association	Project Initiator Client
ERA Contour	Architecture & Spatial Planning	Project Contractor
DOOR Architecten	Architecture & Spatial Planning	Project Architects
TU Delft	University	Circular Economy Advisor
Residents	-	End Users
Van den Oudenrijn	Timber Manufacturer	Timberframe Manufacturer

2.7 Requirements of the Collaboration Process Map

The last step of the analysis chapter is the identification of the requirements that the designed collaboration process variants have to fulfil. This is because the requirements are identified by the extended literature review conducted on collaboration, as well as the first interviews with the circular extension.

Requirement 1

The first requirement of the collaboration process map was identified during the research knowledge gap identification. Fragmentation is a sizable failure factor for projects in the BE (Nawi, Lee, Azman & Kamar, 2014; Fulford & Standing, 2014). Figure 1.3 “Over the wall syndrome” by Nawi, Lee, Azman & Kamar (2014) perfectly illustrates the fragmentation problem. These fragmentation problem spans throughout the lifecycle of the project. Moreover, by incorporating the “Butterfly Model” by EMF (2013) it is clear that the whole lifecycle of a product in the BE requires individual focus. Therefore, the first requirement is that the collaboration process map design variants are required to span throught the product lifecycle.

Requirement 2

The second requirement is derived during the first steps of the analysis phase. By analysing the products of the “CO. Project” and the publication by Van Stijn & Gruis (2020), it is stated there are some key parameters that a product is required to fulfil in order to be circular. These are called the circular economy design parameters. These parameters will be at the very core during the design of the process variant. Therefore, the second requirement is that the collaboration process maps should be based according to the profile of the CE design parameters.

Requirement 3

One of the main goals of this research is to create a collaboration that will enable the VRP to be conducted in order to have a CE product. These processes take place in the far future and with the involvement of many stakeholders. These stakeholder may be part of the supply chain from the design phase or be added later on. Therefore, there is a high number of variables that can affect the implementation of VRPs during the maintenance phase. Therefore, it is required that the process variants include a step that will require the stakeholders to engage in a upkeep process of the collaboration during the maintenance phase.

Requirement 4

The last requirement is derived from the interviews with the partners. It is clear that both contractor and client emphasise the need to create an environment of trust and mutual sharing between all stakeholders. This is in line with the findings of the conducted literature review for collaboration (Simatupang & Sridharan, 2008; Simatupang & Sridharan, 2005; Walter, 2003; Fynes, Voss & Búrca, 2005; Chen, Yen, Rajkumar & Tomochko, 2011; Lynch, Nyaga & Whipple, 2009). In order to sustain this environment of trust and commitment throughout the product lifecycle, it is important to include oportunities in the collaboration process for the partners to evaluate the process. By including evaluation processes, partners can have the opportunity to voice positive feedback or possible issues. This way partners that want to part ways with the product can do so and make room for new partners that have more aligned incentives. Therefore, the last requirement is to include evaluation of the collaboration process steps in the designed process map.

2.8 Analysis Conclusions

This chapter focused on exploring the different parts of the collaboration process through a literature review and informal meetings with partners of the circular extension.

The first section focused on answering the first research sub-question to identify the design parameters for the circular economy product. Technical, Supply Chain, Business model and Value Retention Processes are identified as the CE designed parameters. These models and VRPs play the role of the variables in the process. By changing one of the variables, the collaboration takes a different form. By presenting four circular components and how these projects aim to achieve their objectives, the same focal points are identified. Through the use of technical design, use of circular supply chains, innovative business models and use of VRPs, these models represent the design parameters that will be used as an input during the synthesis phase. The next section focuses on how this design parameters fit the circular extension.

The following section focuses on answering the second sub-question. In order to define the long term collaboration process design parameters, a literature review was conducted. The literature converged that collaboration requires to have some characteristic such as trust and information sharing. Looking forward to the synthesis chapter, some design parameters are required to create the collaboration processes. Therefore, a tool is identified that will be the base for the design parameters. This tool is the design for collaboration by Simatupang & Sridharan (2008). This tool is consisted of five elements, Collaborative Performance System, Information Sharing, Decision Synchronization, Incentive Alignment and Innovative Supply Chain Processes. However, these elements where not made originally for a circular economy project and do not contain all necessary characteristics that are identified in the literature review. Therefore, each element is analyzed and converted to fit the circular extension project.

The last two sections focus on answering the last question, the requirements that the long term collaboration process needs to fulfil. By having informal meetings with the client and contractor of the circular extension, a better overview of the product was given, as well as the individual goals of each partner and how this converts into creating a profit through circularity. Moreover, with a literature search, the requirements that the collaboration needs to fulfil are identified, namely efficiency, effectiveness, profitability and feasibility.

Lastly, the goal of this chapter was to provide the necessary information for the research to continue. The next chapter, the synthesis, will use the answers of the first two questions so the design of the different collaboration processes can be conducted. Furthermore, the answer of the third question provides the conditions on which the partners will evaluate the proposed designs.

3. Synthesis

In this chapter, the synthesis phase is presented. Specifically, the what, how and why with all the relevant findings will be presented.

3.1 Introduction

The synthesis presents a challenge to the research. Even though the base information is presented during the analysis chapter, the synthesis chapter seeks to create design variants with all the relevant information. In order to finally achieve the collaboration designs, a series of research sub-questions need to be answered.

The first step is to understand how to create three different collaborations designs. This will lead to the creation of the main relationship grid that the design will be based on. This will be achieved by observing how the design parameters set the collaboration. Therefore, the following research sub-question is devised:

Sub-question 4: *How does the design parameters set the characteristics of the different collaboration designs?*

The second step of the synthesis is to develop the collaboration designs. This will be done by grouping all the information provided by the analysis chapter and the information established by answering the above sub-question. Therefore, the last step is to answer the following research question:

Sub-question 5: *What are the different long-term collaboration variants for the circular extension?*

The aim is to create different layers of information that will be set together to create the collaboration designs. The first layer will be the relationship grid: time in the form of product lifecycle and relationship between involved parties in its step. The second layer of information will be presented in the form of the collaboration process map. This process map will be the backbone of the design variants. In order to better illustrate the differences between each variant, each step of the process map is presented individually with the approach for each design variant.

3.2 Setting the stage

In this section the first step towards to collaboration design is made. The idea is to use the collected information during the literature review and start the design process.

The two most important actors of the collaboration process are the client (Eigen Haard) and the contractor (ERA Contour). According to the requirements of these actors in the initial steps of the product lifecycle, the collaboration is set. These requirements come in the form of the CE design parameters that were set in the analysis chapter. The design parameters are a set of characteristics that shape the collaboration between the product stakeholders.

Each design parameter is consisted of different schemes. By selecting a different scheme, a variety of different collaborations are created. Hence, firstly the design parameters are explored and how they define the collaboration process.

3.2.1 Technical Parameter

As stated, the technical parameter aims to facilitate circular economy design practices in the form of narrowing, slowing and finally closing the material loop. The main tools to achieve these goals are through the use of modular design and the use of recycled materials, during the design and maintenance phase of the product (Bertram et al., 2019). Therefore, the main aspects that formulate the Technical Parameter are identified as Modularity, Recycled Material, Off-site Construction and Legolization.

Modular design aims to develop a product consisted of physical detachable units called modules, for fast product development, easy of assembly, services, reuse and recycling materials (Hashemian, Sosale & Rivin, 1997). Since, the circular extension is designed in modules, modularity is a core characteristic of the project and does not change. Therefore, modularity will be a constant factor through-out the collaboration processes.

Recycled material refers to the use of recycled materials during the design construction, and maintenance of the project. Due to the CE principles of the circular extension, recycling materials is a core characteristic. Hence, recycled material will not change and will remain a constant factor for the design of the collaboration process.

Therefore, the technical parameter remains constant in all the different design collaboration processes. This is due to the fact that core technical specifications such as modular construction and the use of recycled materials remain a constant core characteristic that makes the extension circular. Due to the use of modular construction the opportunity is given for each client to adjust the layout of the product according to their own specifications.

3.2.2 Supply Chain Parameter

In the previous chapter it was concluded that the supply chain model design parameter aims to enable circular economy practices by adapting innovative supply chain methods. Since the research is looking into long-term collaboration, the supply chains have to promote collaboration. These long-term supply chain methods are introduced in the form of Closed Loop supply chains. Furthermore, it was determined that these Closed Loop supply chains could be adopted in three different configurations: Closed-Closed Loops, Closed-Open Loops and Open-Open Loops (Farooque, Zhang, Thürer, Qu & Huisingh, 2019). Due to the fact that the research is examining the long term collaboration process in these supply chains understanding these configurations is important. Moving onwards, each supply chain model is presented with the projected pros and cons that will provide the collaboration process. These pros and cons are based on the knowledge acquired during the span of this research by the author.

Closed-Closed Loop refer to the supply chain that utilize mainly partners that have a preexisting relationship with the contractor. These configuration provides the opportunity to reintroduce materials in the same project or another project that the supply chain partners are operating.

- The pros: By using existing partners to retain material value, the supply chain remains small in size, trust and information sharing processes are already in place with existing and faster communication routes which can save time. It is the easiest and least costly of the three configurations.

- The cons: Due to the fact that the supply chain is limited, there is a limited number of partners which results in a limited amount of materials that can be reused. Hence, there is a limitation on the use of recycled material which may lead in not achieving the fully circular goals of the product.

Closed-Open Loop refers to the supply chain that utilizes also organisations outside of the existing supply-chain. Therefore, materials can be exchanged between partners on different situations. For example, wood extracted by a renovation project in Amsterdam can be used in a re-construction in Delft by another company.

- The pros: Due to the fact that organisations are within the same sector, exist a form of communication channel. Moreover, communication is easier conducted since organisations speak "the same language" within the same sector. Materials that one contractor finds no use, another can find value. This form of closed loop supply chain is already in use and the product may greatly benefit from environmental perspective.

- The cons: On the other hand, due to the fact that organisations are within the same sector, opportunistic behavior may arise due to organisations being direct competitors. These creates a problem for collaboration, since trust and information sharing will take a considerable amount of time and resources.

Open-Open Loop refers to the supply chain that utilizes partners outside of the existing sector as well as outside of the BE sector. E.g. a grid provider provides an organisation with old used cables that will use this to create a modular bus platform (Bus Boarder Platform).

- The pros: This is the most innovative profile of a loop supply chain. There is minimum loss of material value since materials are interchangeable between an array of sectors. This form of open loop supply chain is the most promising, and can create the foundations for a fully circular product.

- The cons: In contrast, due to the differences between the organisations, collaboration is hindered. New communication channels must be created, therefore trust and information sharing, decision synchronization will severely burden. Hence, this profile presents a challenging environment for the collaboration between partners.

Hence, it is concluded that Closed Loop Supply chains have three different configurations. Closed-Closed Loop was identified as the configuration that creates the frame that enables the partners to collaborate in a familiar environment. However, this comes in the cost of future potential lower environmental performance. Closed-Open Loop is a more inventive form of Closed Loops and creates the potential for collaboration to be more straightforward between new supply chain partners. Moreover, Closed-Open Loop supply chain enables the potential for high environmental product performance. Lastly, the Open-Open Loop supply chain presents the most promising supply chain model to create a fully circular product, however the collaboration between the partners may phase challenges.

3.2.3 Business Model Parameter

Business Model parameters are defined as the strategies that are concerned with defining the competitive strategy through the design of the product or services it offers to the market. Moreover, business models for the circular extension must enable the value creation and retention of materials. To fit the circular profile of the project, Product-Service Systems (PSS) are selected as promising business strategies. A PSS is defined as a system of services and tangible products designed so that jointly are capable to fulfil specific customer needs (Tukker, 2004). Three models emerged from the literature: Product-Oriented Services, User-Oriented Services and Result-Oriented Services.

Product-oriented services: The first model is a traditional take of business models in the BE. The contractor designs and builds the product according to specifications of the client. Therefore, the ownership of the product and its materials remains with the client. Maintenance and decommissioning services can be offered to the contractor.

- The pros: A traditional way of creating a project, specifications can be identified in collaboration with the client. Therefore, collaboration between contractor and client is necessary to achieve the scope envisioned by the client. However, the contractor lacking incentives since there is no involvement for the rest of the product lifecycle.

- The cons: The main cons of this model are the lack of environmental practices. In case the client is an individual or small housing association with no or limited supply chain, the reintroduction of the materials during the operation phase and the repurposing phase may not exists at all.

Use-oriented services: The second model has a more innovative profile. Design is conducted in collaboration with all involved parties to include all possible views. Second, construction is performed by the contractor and ownership is passed to the client. However, maintenance services are conducted by the contractor and when the product reaches the End-of-Use, the contractor retakes ownership of the product and conducts the decommissioning.

- The pros: The main pro of this model is that the contractor is involved with the maintenance and decommission of the product. Therefore, the contractor is incentivized to realize the maximum scope requirements of the client. This results in an extensive collaboration process between the parties to design the product. Furthermore, maintenance and decommissioning services are conducted by the contractor. This results in an extensive supply chain being available for material exchange.

- The cons: Possible cons may appear in the form of legislation. In many EU countries legislation, including the Netherlands, requires a capital tax to be paid in order to transfer ownership of an asset (Rijksoverheid, 2021). By having ownership of the product transfer two times, there is an economic disadvantage which may dissuade either customer or contractor to opt for a business model like that. However, by creating a product that does not fit the criteria of (non-movable asset) the fee can be avoided.

Result-oriented services: The last strategy is the most innovative of the three and has seen limited use in the BE. The client provides a set of specification for the required product and the contractor fulfils them in the form of services. During its lifecycle the product is owned by the contractor, from designing to decommissioning. The client enters in a lease or rent contract with the contractor in order to be able to use the product.

- The pros: Since the product is designed and owned by the contractor, there is an incentive to create a product that will produce value. In this case the contractor is incentivized to create a product that will require minimum maintenance and maximize the recovered material during the repurposing phase.

- The cons: On the other hand, since the product is provided in this particular format, it may create collaboration issues. The requirements of the customer may increase the production and maintenance costs, which comes in direct conflict with the economic goals of the contractor.

To conclude, business model parameters come in three different models. Product-oriented services, Use-oriented services and Result-oriented services. Product-oriented services enables collaboration since its only in the design phase. However, it comes in the cost of the circular goals of the product.

Use-oriented services present a balance between collaboration and CE goals of the product. Lastly, the Result-oriented services is the most innovative model, and can contribute immensely for the product to be circular. However, this comes in the cost of collaboration since the interaction between client and contractor is minimal.

3.2.4 Value Retention Processes

The circular extension product is created with CE principles from beginning to the end of the product lifecycle. Typically, projects in the BE lose material value throughout their entire lifecycle. However, the two phases with the highest exposure are maintenance and decommission. On the previous chapter, Value Retention Processes were identified as processes that enables the capture of material value otherwise lost. In total nine VRPs were identified that span during the whole lifecycle of the product. The aim of these section is to identify which of these VRPs are set and which can be adjusted. As explained in the previous chapter, only the Short Loops processes and Medium Long-Loop processes are explored since the Long-Long Loop processes fall out of scope of the circular extension.

Shortest Loops refer to the first R imperatives, Refuse, Reduce, Resell, Reuse, Repair. These loops exist closer to the consumer and can be linked to commercial or non-commercial actors engaged in extending the life span of the product (Reike, Vermeulen & Witjes, 2018). Also characterized by many scholars as the most preferable “Rs” in the CE, these can have a great impact on the maintenance phase of the circular extension for circularity, as well as for collaboration between the partners.

Medium Long Loops refer to the next three “R” imperatives, Remanufacture, Refurbishment and Repurpose. According to Reike, Vermeulen & Witjes (2018), a small number of researches mentioned Repurpose, since its repurposing material can be done either by repairing, reselling or reuse. Therefore, repurpose is not going to be used during the design of the collaboration processes. On the other hand, Remanufacture and Refurbishment have a direct impact on collaboration, as one is recreating the existing component with the design specifications and the other is trying to implement new innovative concepts into the existing design.

- Refurbishment: It refers to the replacement or repairment of components, which results in an overall upgrade of the product in the state-of-the-art profile. This means that new techniques need to be implemented during the maintenance to improve circularity. Therefore, collaboration between partners is important to keep up with the new innovations. Hence, it requires a high collaboration performance between the partners. On the other hand, by implementing state-of-the-art innovations, there is a potential lower material value retention performance since new designs will require new material.

- Remanufacture: The aim of remanufacturing during maintenance is to repair or to replace material and modules that will bring the product to its original designed state. The result will be to retain the same levels of material circularity as during the design phase. This can have potentially low circularity of materials since the maintenance phase will be in ten to twenty years. However, bringing the product to its original state does not require a big effort for collaboration since it has been done before.

Concluding, VRPs are distinguished into two categories, short and medium long activities. These activities aim to narrow and close the material loop. Short loop processes, are integral to the circular extension and therefore will have constant presence through all the different processes. On the other hand, medium long loops are composed by two different processes. Even though both processes aim on narrowing the material loop, each process has a different approach. Refurbishment aims to create an overall innovative product that keeps up with the advances of CE technologies. On the other hand, remanufacture aims to use recycled material to bring the product to its original state.

3.3 Identification of the Design Variants

3.3.1 Relationship Grid

The previous section provides valuable information over the characteristic of each design parameter and the different modes this design parameters can adopt. As stated during the requirement, the collaboration process map has to adapt according to the changes in the design parameters. Moreover, another requirement that the process map has to fulfil, is that it should span the whole lifecycle of the product. Therefore, we have two sets of data, the lifecycle phases and the design parameters.

Table 3.1 Product Lifecycle Phases

Initiation	Initiation is the first stage of the product lifecycle. In this stage the conceptual idea is formed alongside with the first essential requirements of the products, and an initial roughly sketch of how the product will look like.
Design	During the design phase intense studies are conducted to include as much of the scope as possible as to maximize all the requirements. The design has multiple phases that narrows down the requirements and finalizes the product design. This process is intensive and is a product of many parties. The main initiator of the design is the contractor, with construction experts and client being able to participate.
Assembly	The construction of the product takes place during the assembly phase. The contractor again is the main initiator, alongside the supply chain partners and the experts are involved. The client can participate also during the assembly phase as to create a better understanding of the product and create a base knowledge that will be usable during the maintenance phase.
Maintenance	The next phase is during the operation of the product. Since the product aims to be circular, the maintenance phase has two main functions. Remanufacture or Refurbish. The contractor and client can be involved individually or jointly, depending on the VRP that is chosen mainly.
Repurpose	The last phase of the product is the repurposing of the material. Since, the product has a CE profile all the material will follow one of the R imperatives. There must be an assessment of the material and according to the future needs of the product owner (client or contractor), the materials follows one of the R imperatives.

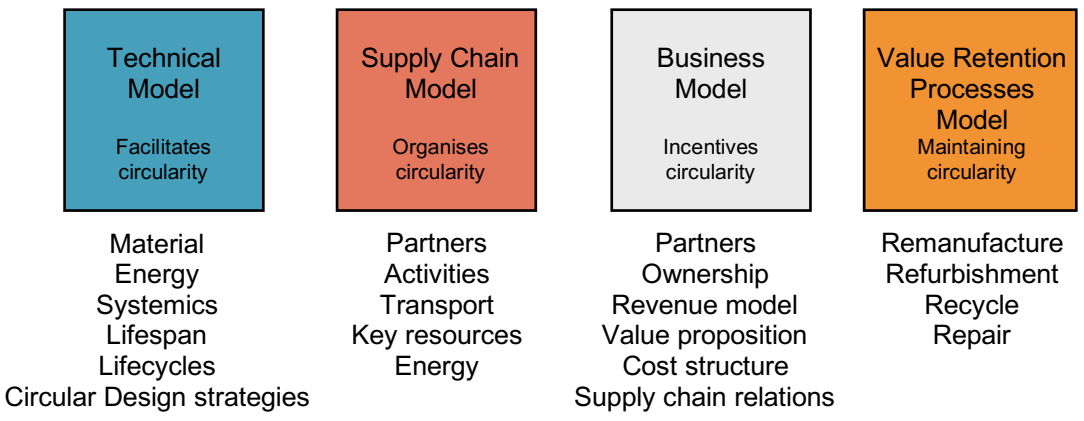

Figure 3.1 Design Parameters of the Circular extension

By combining the two sets of data and the main stakeholders involved, the relationship grid is created. The main stakeholders are the client, the contractor and the supply chain partners that participate in the development of the circular extension. The aim of the relationship grid is to identify the different ways that the collaboration process can take in during the product lifecycle. These distinct collaboration paths that will be created will be foundations of the different collaboration design variants. This grid is created by the author and is based on knowledge acquired during the span of this research.

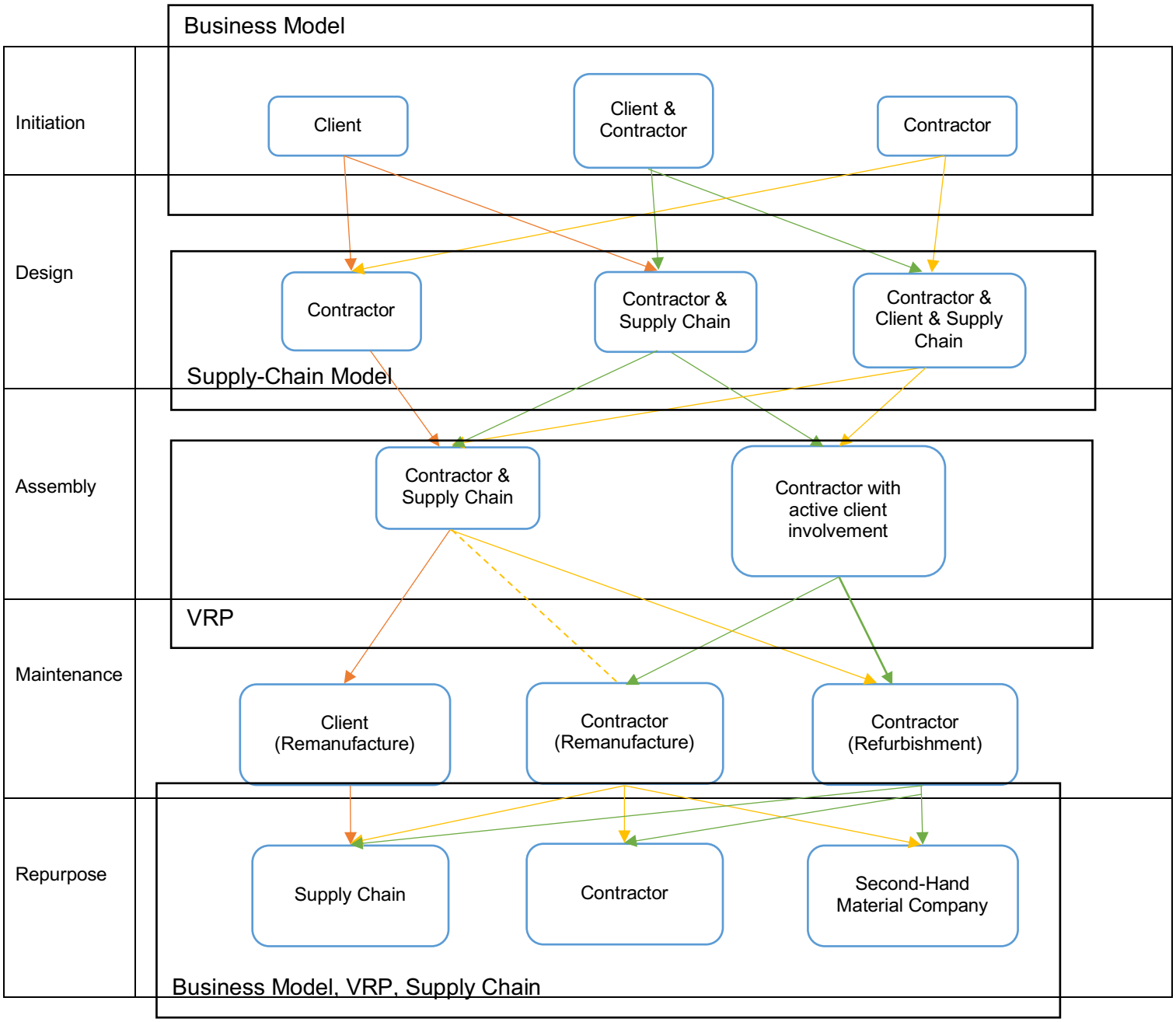

Figure 3.2 Relationship Grid

The above figure illustrates the relationships between the main stakeholders during its lifecycle. During the initiation the most important design parameters that determines the relationships between partners is the Business model. During the business model there are three different ways to start a project: client, client & contractor, contractor. These refer to the three Product Service Systems explained during section 2.3.3. Therefore, it is clear that there are three ways that the relationship moves. Orange path refers to a more traditional approach of design/build/maintain, while yellow is the most innovative approach of lease/rent, and green a more balanced approach where all parties are involved.

Following the orange line, the client provides the design phase to the contractor and is not involved, furthermore the client or contractor can require the presence of supply chain experts during the design phase. This will result in additional expertise to help with the decision-making process. Moving on to the assembly phase, only the contractor with the supply chain can carry out this action. If the client during the maintenance phase has an established supply chain that can carry out the maintenance of the modules, he carries out the maintenance. On the other hand, if the client is a private individual with no supply chain, the contractor assumes the maintenance phase to upkeep the circular goals of the product. Finally, the client can utilize the supply chain to re-introduce material back to the production loop.

Next, following the yellow line, the contractor is the main initiator of the product. Development and design can be completed by the contractor or with the help of the client and the supply chain experts. This decision is taken primarily by the contractor in collaboration with the client. The assembly follows a similar path of being able to be conducted by the contractor or the contractor with the active involvement of the client. During maintenance, the contractor can either opt to refurbish or remanufacture the product. This decision is taken according to the most economical advantageous prospect for the contractor. Finally, the contractor can use all of the available sources to re-introduce materials back to the production loop.

Lastly, following the green line the contractor and client initiate the product together. During the design phase, all the involved stakeholders participate in the decision-making process. During the assembly phase the contractor can include the client in order to bring added knowledge in the process. During the maintenance phase the contractor together with the client decide on the main VRP remanufacture or refurbishment. Finally, the contractor has the ability to use all available sources to re-introduce material back to the production loop.

3.3.2 Design Variants

Following, the paths illustrated in figure 3.2 it is clear that there are three available paths. The characteristics of each path provide the information to create the three different design variants. It is observed that the design parameters come in three main forms: Traditional, Innovative and Balanced. The following table presents the design parameters and the forms that represent.

Table 3. 2 Design Variants

	Traditional	Innovative	Balanced
Supply Chain	Closed-Closed Loop	Open-Open Loop	Closed-Open Loop
Business Model	Product-Oriented	Result-Oriented	User-Oriented
VRPs	Remanufacture	Refurbishment	Refurbishment

The first design is called Traditional design (Orange Line), due to the fact that it relies heavily in using existing relationships between organisations to base the product development. In the BE this is a standard practise that has been in use for many years. The product is using a product-oriented business model that focuses only on the product and has limited services. Lastly, the use of the safer remanufacture VRP as main VRPs during maintenance furthers the traditional profile of the design variant.

On the other hand, Innovative (Yellow Line) design aims to incorporate the most innovative forms of the design parameters. These forms are quite innovative and have seen limited use hence the title. This design variant adopts Open-Open supply chain loops, meaning partners outside the BE sector. Follows, a result-oriented business model that focuses on providing the product as a service to the client and lastly aims to refurbish the modules during maintenance phase to the most innovative profile.

The Balanced design (Green Line) aims to incorporate traditional and innovative forms in order to create a more realistic collaboration design that can be performed currently. The design parameters for the balanced design variant have been used, therefore there are real life examples. The balanced variant is using a Closed-Open supply chain loop that incorporates partners with no prior pre-existing relationship. It is a User-Oriented business model that focuses on the product and the long-term services that follow it. Lastly, by choosing refurbishment of the product as main VRP during maintenance the product has the potential for high circularity.

These three variants are selected in order to broaden the range of the variants. Since the research is following a RtD methodology, a number of variants are required to be simulated in order to create a knowledge base. Hence, the choice of three different settings for the collaboration process to adapt in: a traditional model that illustrates the first steps of the BE in the process of transforming from linear to circular, balanced for the situation that is currently going in the BE like the collaboration process that took place for the circular extension, and finally the future prediction of how the collaboration for circular components will take place in the future.

3.4 Collaboration Process Map

After the identification of the design variants on the previous section, the next step is the creation of the process map. The relationship grid was created to identify the design variants. The important stakeholders together with the design parameters and the product lifecycle phases where combined to create the relationship grid. The next step is to add to that grid the collaboration elements of the Design for Circularity (DfC).

By adding the collaboration elements, the collaboration process map is created. The process map is created by the author of this research with the knowledge derived by the literature review as well as during the synthesis phase and the interviews with the partners of the circular extension. The morphological scheme was inspired by the co-creation map by Chiosea (2021).

The map illustrates the steps that are required to be taken for the collaboration process of the circular extension during each phase of the product lifecycle. These steps are a mix of elements of the DfC and processes that the partners have to carry out in order to create a circular economy product.

The goal is to observe how each design variant tackles each step. There is a mix of steps that are taken the same way by all variants and steps that are taken in a different way. When there is a difference between the steps, the differences are presented together to better understand the differences between each design variant.

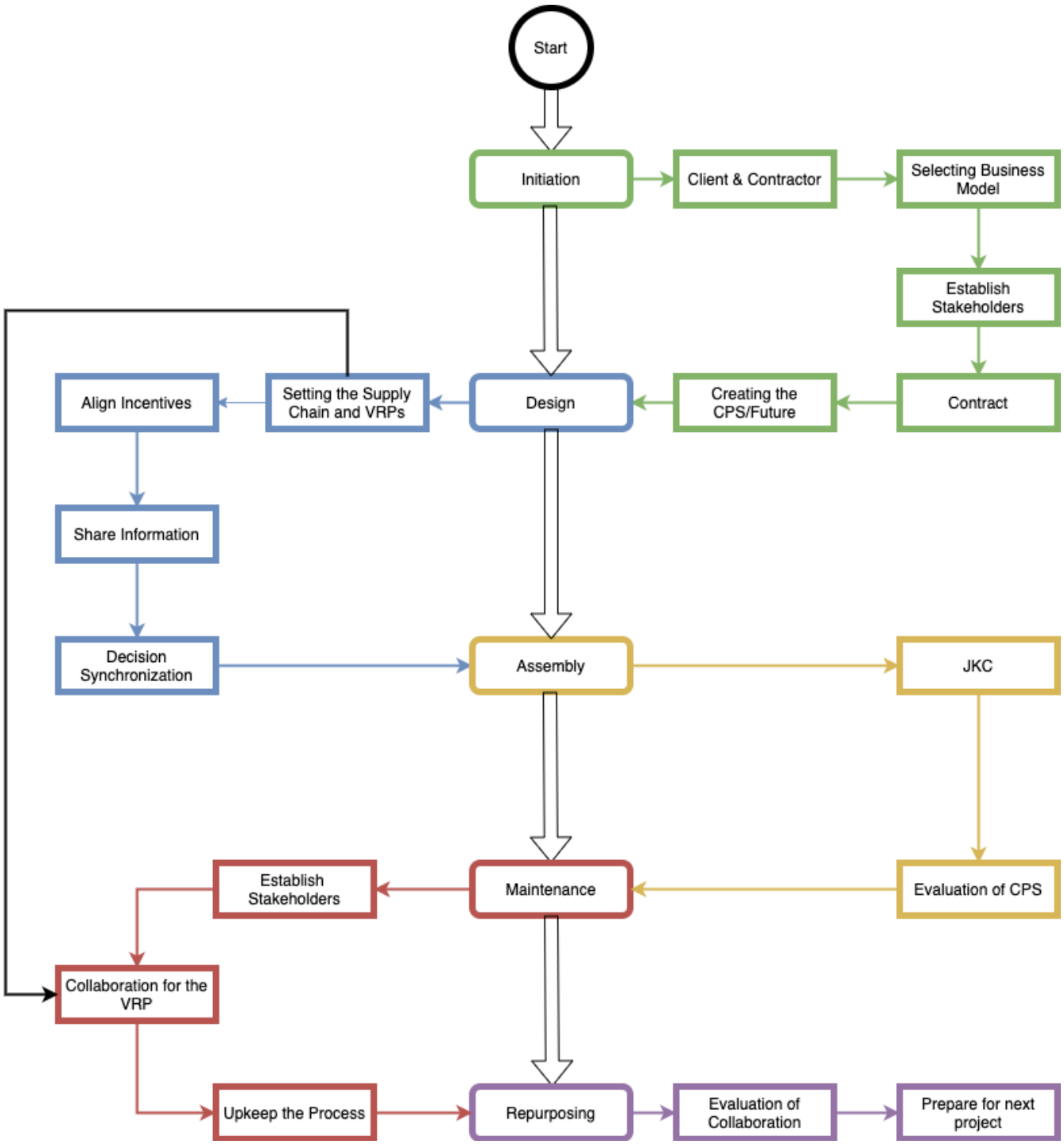

Figure 3.3 Collaboration Process Map

3.5 Collaboration Process Design Variants

The next step is to incorporate the DfC elements into the basic relationship grid and create the collaboration designs.

3.5.1 Introduction

The first thing to explain, is that collaboration is not one single process that occurs once. It is a continuous process that simultaneously takes place through the product lifecycle. The first three phases of the lifecycle (Initiation, Design, Assembly) generally occur in a short time period compared to the total length of the lifecycle. For example, the client from the interviews stated that the initiation to the assembly of the first circular extension occurred within two years. However, he also stated that the client may start the maintenance on the frame in twenty years and finally repurposing in hopefully fifty. Therefore, collaboration that is set and created during the initial phases cannot go unchanged in twenty years into the future, as new technologies are introduced and new partners may take part in the product life cycle.

The following approach is chosen in order to present the design variants. The main collaboration points remain constant in all design variants. The difference lies in how each design variant approach these steps. Therefore, in order to better understand the differences of each design, the process map is followed from beginning to end. In each point the differences between the design are shown in order to create a better understanding.

3.5.2 Collaboration Process Map Designs

1. Initiation

The first step of the project is the initiation. During this phase the first steps towards creating the design of the circular extension takes place. The first step towards setting the collaboration process is contact between client and contractor. The second step is setting the business model of the product. The third step is the identification of all the relevant stakeholders. Fourth, a contract needs to be set to regulate the process and finally to establish the Collaboration Performance system.

1.1 Client & Contractor

Collaboration takes two or more entities working together in order to achieve a goal (Martinez-Moyano, 2006). Therefore, the first thing is the connection between the main involved parties. The client, either a housing association or a private individual, has a need. In this case the need is to create an extension which will add space to the existing building. Through the designs this remains constant as the client and contractor are the main initiators.

1.2 Selecting Business Model

Business Model selection is one of the most important steps towards collaboration. By selecting a business model, the client and contractor set the final goal of the project. This will provide the change of creating profit from selling products to creating profit from the transaction of materials over time (Bertram et al., 2019). As stated, there are three different business models, one for each design. Each business model selection process is illustrated for each design variant.

The Traditional design follows the path of a Product-Oriented business model. In a product-oriented method the client procures the project to a contractor, the contractor design and builds the product. Ownership of the product is with the owner and maintenance can be procured to contractor.

On the other hand, during the Innovative design a Result-Oriented business model is selected. The client contacts the contractor with the need for a product. The contractor develops, constructs, maintains and owns at all times the product. The only involvement of the client is during the operation of the product.

The Balanced design variant is based on the User-Oriented business model. The client is the initiator of the product, the contractor designs, builds and maintains the product, where the client is the owner and upon reaching the product End of Use time the contractor assumes solo ownership.

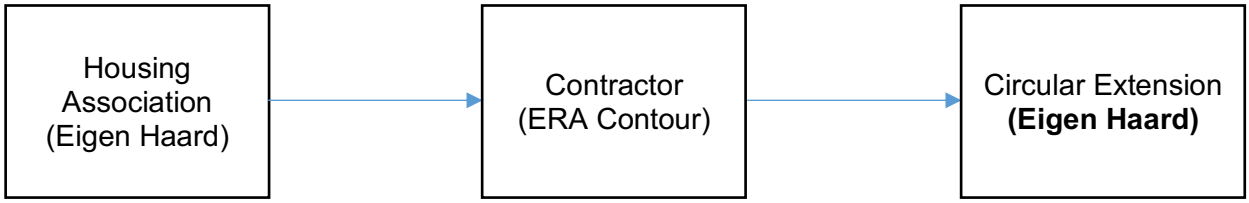

Figure 3.4 Traditional Model

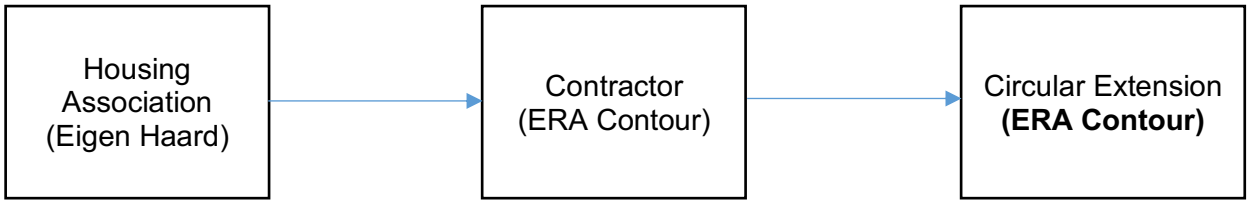

Figure 3.5 Innovative Model

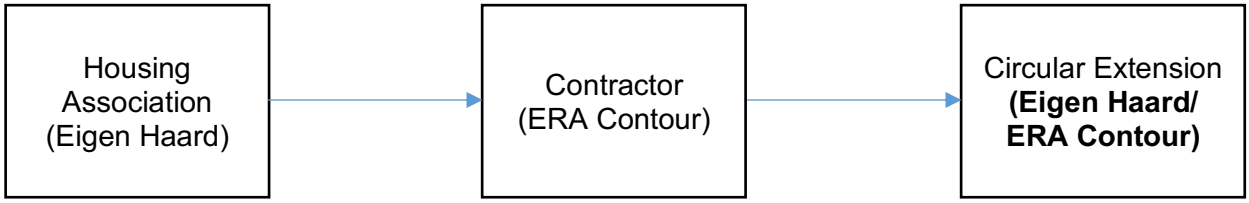

Figure 3.6 Balanced Model

1.2 Establishing Stakeholders

The second step involves the stakeholder identification. The main goal is to involve all the relevant stakeholders in order to achieve the goals set by the client and contractor (Leising, Quist & Bocken, 2018). Stakeholder identification is a lengthy process that takes place early in the product lifecycle and it is not part of the research. Each design involves different partners in different stages of the product. However, the process of establishing stakeholders remains the same throw-out the designs. The following scheme is derived from the first interview with the client.

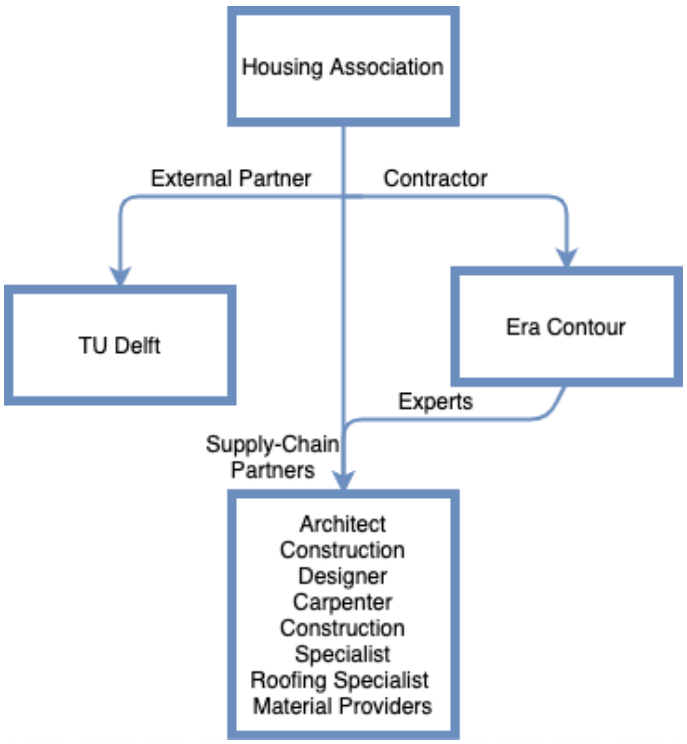

Figure 3.7 Stakeholder map

1.3 Contract

The next step after the identification of the stakeholders and the selection of the business models is the formulation of a contract. Cooperative, long-term trusting exchange relationships are often formalized in detailed contracts (Poppo & Zenger, 2002). Hence, the importance of a well detailed contract that will guide the collaboration between all partners.

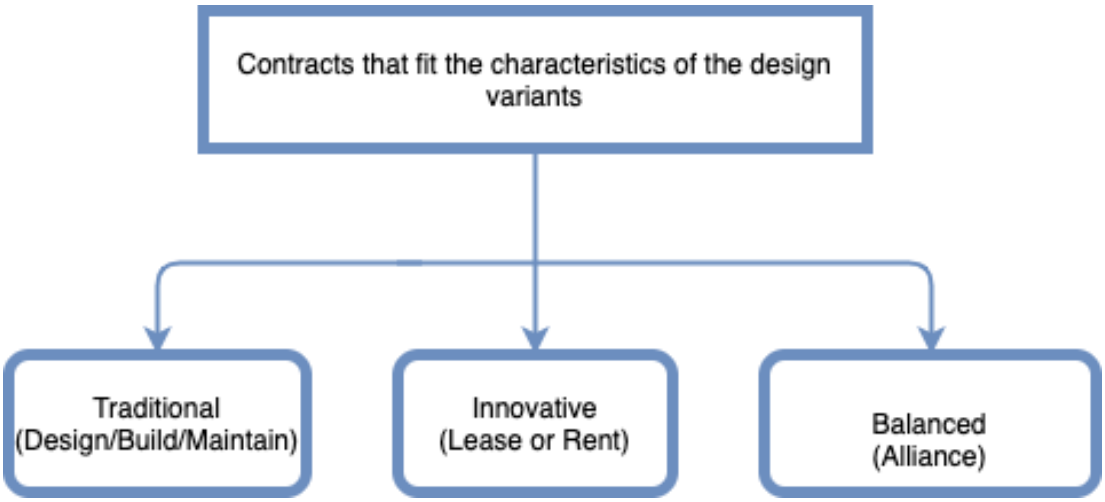

Figure 3.8 Contract Selection Path

The traditional design variant is selected to have a design/build/maintain contract. This contract provides the client with an organisation that has the knowledge to design, build and maintain the product. In the BE it is common practise to use contracts such as Design/Build (Rowlinson & Walker, 1995). The maintenance is added in order to maintain the circular goals of the product. In case that the client has an established supply chain that can support the material needs during the maintenance phase, the contract can be opted for Design/Build.

The innovative design variant is opting for a lease or rent contract. This is in line with the business model that the contractor and client have selected. The client has no active role within the development of the product, and instead of doing a one-time down payment to buy the product, a fee is payed for use and maintenance of the product.

For the balanced design variant an alliance contract is selected. The alliance contract has been used in order to stimulate collaboration performance between supply chain partners (Davis & Love, 2011). In the past, these contracts where used because there was a limited amount of knowledge on a very specialised construction project. The same applies for the circular extension since there is a limited available knowledge within the Dutch BE. All the organisations come together to create a shared pool of information and create an environment that will promote the creation of new knowledge.

1.4 Establishing the Collaborative Performance System (CPS)

With the establishment of the business model, stakeholders and contract, the next step is to set the collaboration goals of the project. This is done by creating the collaborative performance system (CPS). The CPS is consisted of five key elements that the stakeholders have to establish jointly. Each design variant will be setting different collaboration goals since each variant has specific characteristics. However, the process of setting these goals remains the same throughout the design variants. The aim is of the CPS is for the partners to establish in collaboration goals. These goals will be assessed in the end of each phase to observe how the collaboration process functions.

Environmental Performance: The involved parties define the environmental goals of the project in collaboration. According to the supply-chain format and business model, the environmental performance varies from design to design. According to section 3.2, the traditional variant has potentially low circular performance.

Economic Performance: The economic performance of the product is set by the chosen business model and contract. Therefore, client and contractor goals play a key role in defining the economic performance. According to section 3.2, the traditional variant has potentially high economic performance.

Operational Performance: The Supply chain model and VRP model set the operational performance. For example, by choosing for a Closed-Closed Loop and a Remanufacture VRP, the operational performance can be achieved relatively easy since all partners have established relations. According to section 3.2, the traditional variant has potentially high operational performance.

Logistics Performance: Logistical performance is set according the supply chain that is chosen. An Open-Open supply chain model will have a lower logistical performance than a Closed-Closed Loop, since more parties are involved. According to section 3.2, the traditional variant has potentially medium logistical performance.

Organisational Performance: The green image of the product is set by the supply chain chosen and business model. For example, the traditional design variant will inhibit the green image of the product since there is a small number of partners involved. According to section 3.2, the traditional variant has potentially low organisational performance.

Marketing Performance: Creating a satisfactory relationship between partners is key for the circular extension. Hence, the marketing performance remains constant through-out the designs and it involves both client and contractor. According to section 3.2, the traditional variant has potentially adequate marketing performance.

Figure 3.9 CPS for Traditional Design

2. Design

The next major phase of the project is the design. During this phase it is important to create a good establishment of the collaboration process. Collaboration during design has a vital role since all partners come together to develop a new product. Communication and trust are put to the test in this phase. Firstly, the supply-chain and VRP are chosen, secondly the base for Information Sharing, Decision Synchronization and Incentive Alignment are set. In the case collaboration fails in this phase, there is a high chance that the product will also fail.

2.1 Setting the Supply Chain and VRPs

The first step of collaboration during the design phase is setting the foundations for the maintenance phase. Since the maintenance phase plays a key role in successfully creating a circular product, it is of important to set the VRP profile of the project and the supply chain that will support it. Each design variant follows different supply chains with different VRPs. The following scheme represents the selection process.

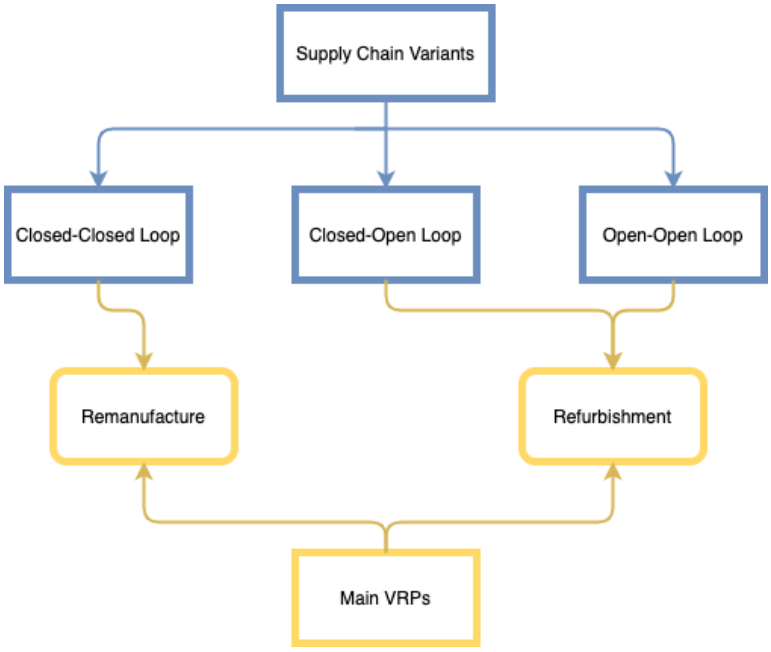

Figure 3.10 Setting Supply Chain and VRP

During a meeting for the research, Anne van Stijn stated that there can be two ways to approach this process. One way is to have a clear goal set during the design process of how the VRPs are going to be conducted during the maintenance phase. This will aid the partners to prepare for the future e.g. by incorporating material and techniques that will make the maintenance of the circular module not as difficult. On the other hand, the maintenance phase can be left undetermined during the design phase, meaning that the partners trust that the maintenance phase will be conducted in the future with the highest standards and with circularity as the final goal. However, this does not always match the reality. Moreover, due to the nature of the long-term maintenance phase of the product, it introduces a number of variables that can contribute in the failure of circular maintenance completion. Therefore, it is decided that the VRP is decided from now with clear goals to what each partner has to fulfil.

2.2 Align Incentives

Incentive alignment is one of the three key core characteristics of the DfC by Simatupang & Sridharan (2008). Moreover, by aligning incentives there is an increase of integration and cross-functional collaboration as stated by Norrman & Naslund (2019). Therefore, the collaboration design variants build in the same three elements to create alignment of incentives.

Contract: The contract between the partners is set in the initiation phase. The only difference between the three designs is the business model.

Information: All involved parties create an environment of shared information that will benefit the component design and maintenance. Information is key to collaboration and therefore it remains constant throughout the designs. Information can be shared by establishing workshops to share ideas on the design on the spot. Moreover, creating a BIM model of the design that can be accessible by all members at any moment presents a great tool to share information.

Trust: The final Element is trust. Trust is created between partners by sharing information and engaging in shared activities. Workshops, meetings and the use of information sharing technologies are key elements to create trust for the collaboration to be based on.

Figure 3.11 Incentive Alignment Pyramid

2.2 Share Information

According to Maskey, Fei & Nguyen (2020), information sharing is split into two main categories: Operational and Strategic Information Sharing. Operational information sharing involves a short-term period, but on the other hand strategic information sharing refers to long-term operations. Operational Information sharing takes place by workshops, shared activities meetings and information sharing technologies. In the circular extension lifecycle this is conducted during the design phase.

Strategic Information sharing takes place in the form of information that will guide the project to achieve its long-term circularity goals. Moreover, strategic information targets information that will help other products in the future. This takes place between the contractor and the experts in the Inter-organisational Dimension. Information sharing is easily established since there are pre-existing communication channels between partners. Using the information by Maskey, Fei & Nguyen (2020), information sharing is consited of four dimensional factors:

- Relationship dimension: which focuses on the adhesive actions such as trust, commitment and personal connection that bound the actors that share information.
- Intra-organisational dimension: which focuses on information sharing within the organisation.
- Inter-organisational dimension: which focuses on information sharing with partners from other organisations.
- Environmental Dimension: which focuses on external factors that cannot be affected by the organisation.

According to Maskey, Fei & Nguyen (2020), each dimension is of paramount importance in order to create an environment of sharing information. Moreover, the relationship dimension remains constant through the design variants since it represents the core of the information sharing activities. However, small changes take place between each design:

- The Traditional design variant focuses more on the Intra-organisational dimension, since there is a limited number of external partners.
- On the other hand, the Innovative design variant focuses more on Inter-organisational dimension since the majority of the supply chain is consisted of external partners, some from other sectors.

2.3 Decision synchronization

Decision synchronization takes place in the existing communication channels that exist between partners and the supply chain. This take place in the form of workshops, meetings and information sharing technologies.

In the previous chapter it was concluded that decision synchronization requires a good level of trust, information sharing between partners and someone that will coordinate and monitor the process (Simatupang & Sridharan, 2008). Each design involves different partners from different levels of the product lifecycle. Therefore, decision synchronization is different for each design variant.

For the Traditional design variant, decision synchronization uses the contractor in the centre of the decision-making process. The client provides the requirements to the contractor, then the contractor initiates the decision-making process with the experts and supply chain partners. Upon completing the decision-making process, the contractor updates the client who then gives feedback upon the decision.

On the other hand, for the Innovative design variant the client is not so involved. The contractor is the main initiator of the decision-making process and the one coordinating the information and decision process. Since the Innovative design variant has a lease contract at its base, the client is not actively involved and only provides the requirements that the product has to fulfil.

The decision synchronization map for the Balanced decision variant changes shape. The client is active in the decision-making process. The contractor is not the main initiator, as all of the partners are involved equally in the decision-making process. The most important decisions are being made in workshops that all partners attend. This is to better facilitate decision synchronization across the partners.

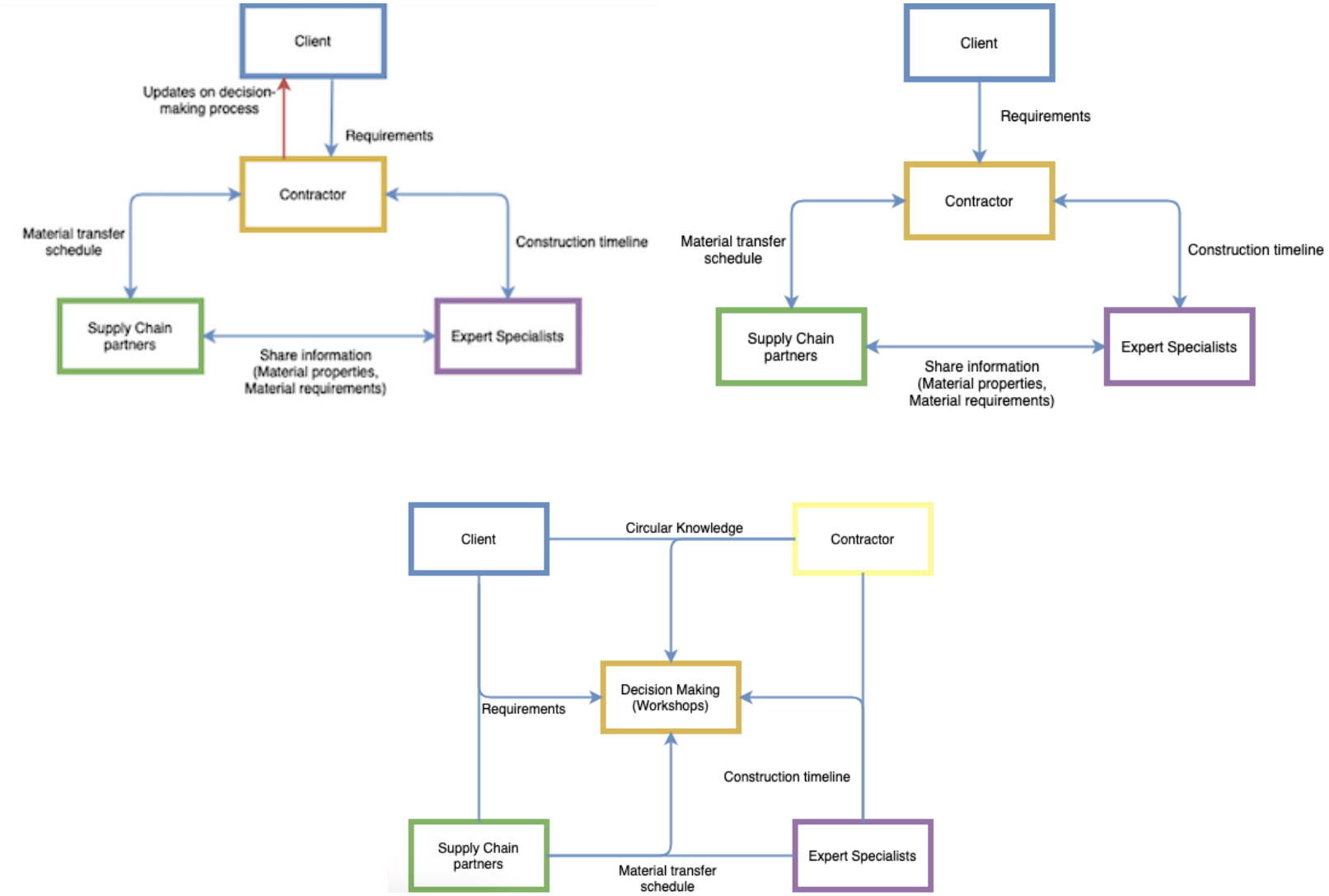

Figure 3.14 Balanced design variant decision synchronization map

3. Assembly

The next phase of the product is the Assembly. During this phase the product is constructed. Collaboration takes the form of applying the knowledge that was created during the design phase. Moreover, new knowledge may surface during construction which can be valuable for future endeavours. The assembly phase mainly plays the role of evaluation for the collaboration process. Collaboration between partners during the assembly process is set during the design phase. Therefore, collaboration between partners is set and remains constant in all collaboration design variants.

The first action of collaboration is to collect the knowledge created during the design and assembly phase. The second step involves the evaluation of the CPS. And lastly, is setting the collaboration process for the maintenance phase.

3.1 Joint Knowledge Creation

Knowledge created during the design phase is implemented in the assembly. Partners such as the construction specialist that directly implement the new knowledge can give direct insights of the assembly for future use. This information can be channelled through the use of BIM model.

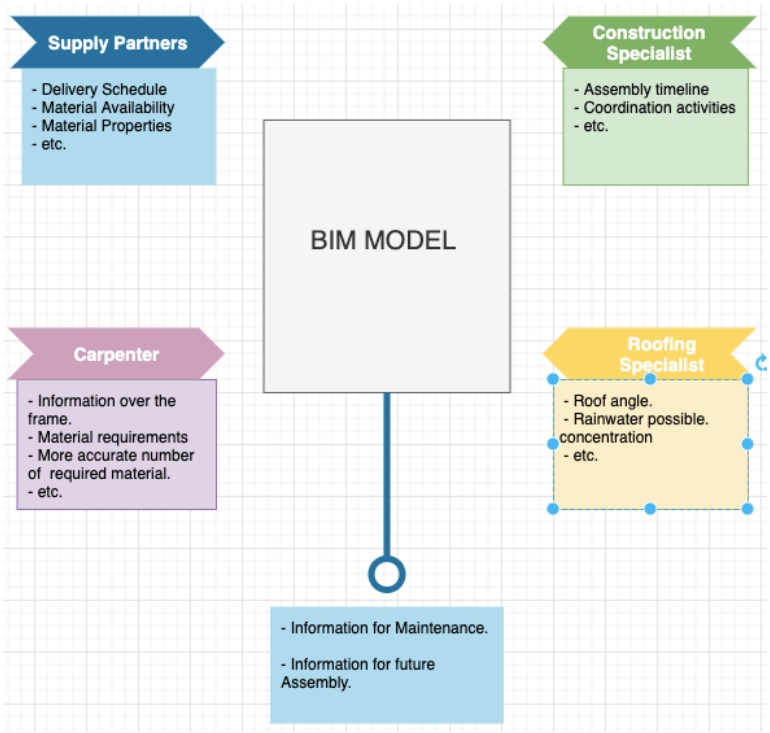

Figure 3.12 Joint Knowledge Creation model

Joint Knowledge Creation is a fundamental part of the circular extension project since this is a highly innovative product. Following the definition of JKC by Cao, Vonderembse, Zhang & Ragu-Nathan (2010), there are two activities that form the knowledge creation: knowledge exploration and knowledge exploitation. Knowledge exploration is done during the design phase and exploitation conducted during the assembly phase when the product is constructed. All collaboration design variants explore and exploits knowledge. Even though this knowledge may vary from variant to variant the process of creating it and exploiting it remains constant in all design variants.

3.2 Evaluation of Collaboration Performance System (CPS)

An important part after the competition of the assembly of the circular component is the evaluation of the CPS. This process is conducted after the assembly of the product with all involved parties. The aim is to examine the performance of the product according to the initial goals of the CPS. Evaluation of collaboration according to Berriet-Solliec, Labarthe & Laurent (2014) is consisted of three steps: to measure, to understand and to learn.

1. Measure: In this case measuring is conducted for each of the five elements that consists the CPS. Environmental, Organisational and Marketing performance can be difficult to evaluate since the product has been through the assembly phase of its lifecycle. However, performances like Economic, Operational and Logistic can provide a number approaching to reality.

2. Understand: The second step involves the partners understanding. This is conducted by jointly analysing the data acquired during the first step and identifying if the goals set during the initial phase where reached. This requires that the measuring was accurate and there are no biases from the partners. This understanding will provide the strong and weak points of the CPS for each design.

3. Learn: The third step involves the learning process. By understanding the strong and weak points of each design the partners can act. To promote the strength of each design and possibly create added value. Secondly, to take mitigation action for shortcomings or even terminate a partnership.

The evaluation of CPS is a key process of collaboration and remains constant in all three collaboration variants. The reason being, that the design parameters that shape the process variants do not affect the evaluation process. The input and output are different but the process remains the same.

4. Maintenance

The next phase of the product is maintenance. This phase is the longest phase of the project and the most uncertain for collaboration since circular economy projects are quite innovative. Moreover, maintenance is a key phase to the circular goals of the product, since the VRPs take place. By sustaining a good collaboration level between the partners, a prosperous environment is created to achieve the circular economy goals of the product.

4.1 Establish Stakeholders

The first part towards the collaboration is to establish the stakeholders that will actively participate during the maintenance. The establishment of stakeholders closely corelates with the evaluation of the CPS. During the CPS evaluation, partners have the opportunity to evaluate their involvement in the product. Partners that wish to continue with the product remain, and partners that do not wish to continue, withdraw. Therefore, new partners are established to participate in the maintenance phase. Every design variant has a different process of selecting new partners.

- In the Traditional design variant, the client remains as the owner of the product therefore remains constant. The contractor can either choose to withdraw or to continue with the maintenance. In case the contractor wishes to withdraw, the client collaborates together with the contractor in order to identify a suitable contractor to continue with the project. On the other hand, if the contractor is responsible for the supply chain partners and experts, the contractor is responsible to find a replacement.

- With the Innovative design variant, the contractor remains constant as the owner of the product. There are two differences between the innovative and traditional design variant.

First, the client can choose to remain or terminate the contract. In case of termination, the product is decommissioned and the materials are extracted to be used in another project. The second difference is the supply chain partners. Supply chain partners extend beyond the BE sector. Finally, the expert's selection process remains constant as with the Traditional design variant.

- In the Balanced design variant client and contractor do not change. The difference with the other variants is that all the partners are equally involved. Therefore, the selection for new stakeholders is conducted jointly by all partners and not only by the contractor.

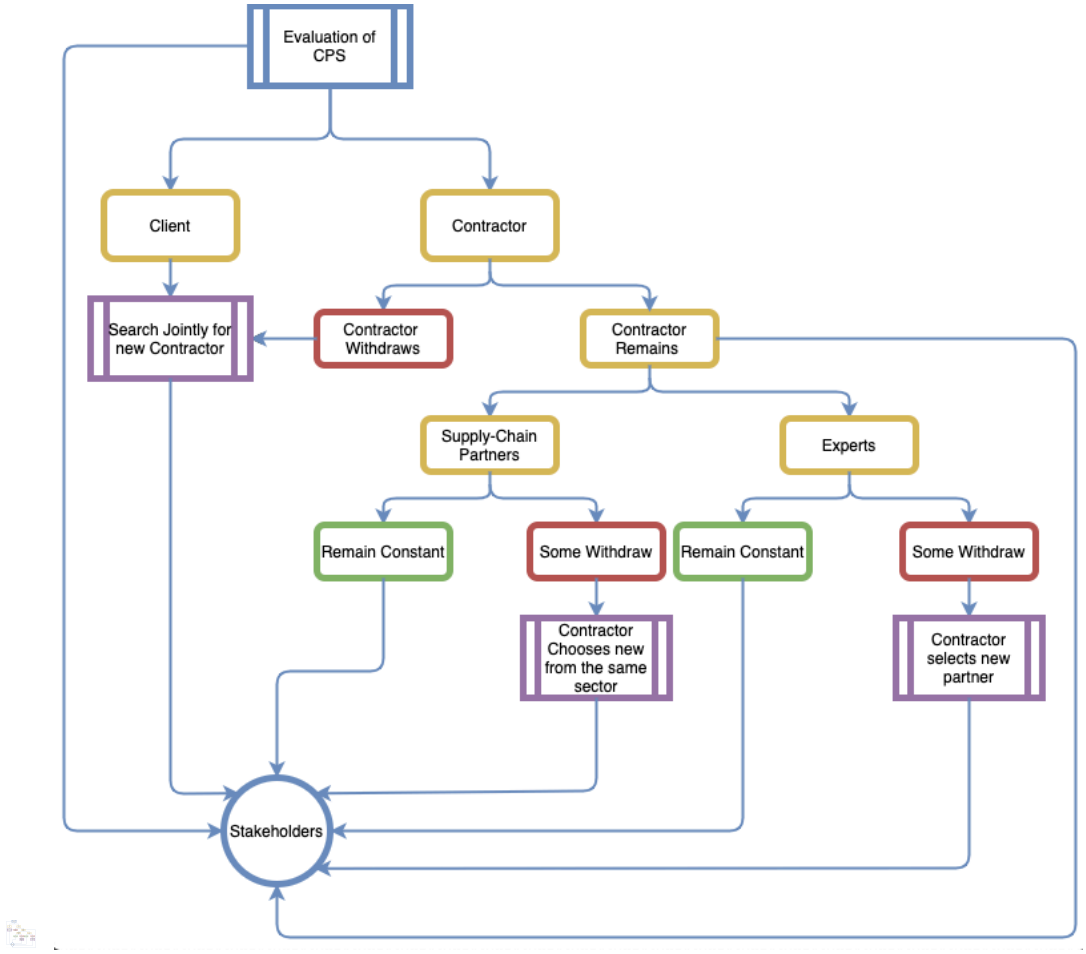

Figure 3.13 Stakeholder selection map for the Traditional design variant

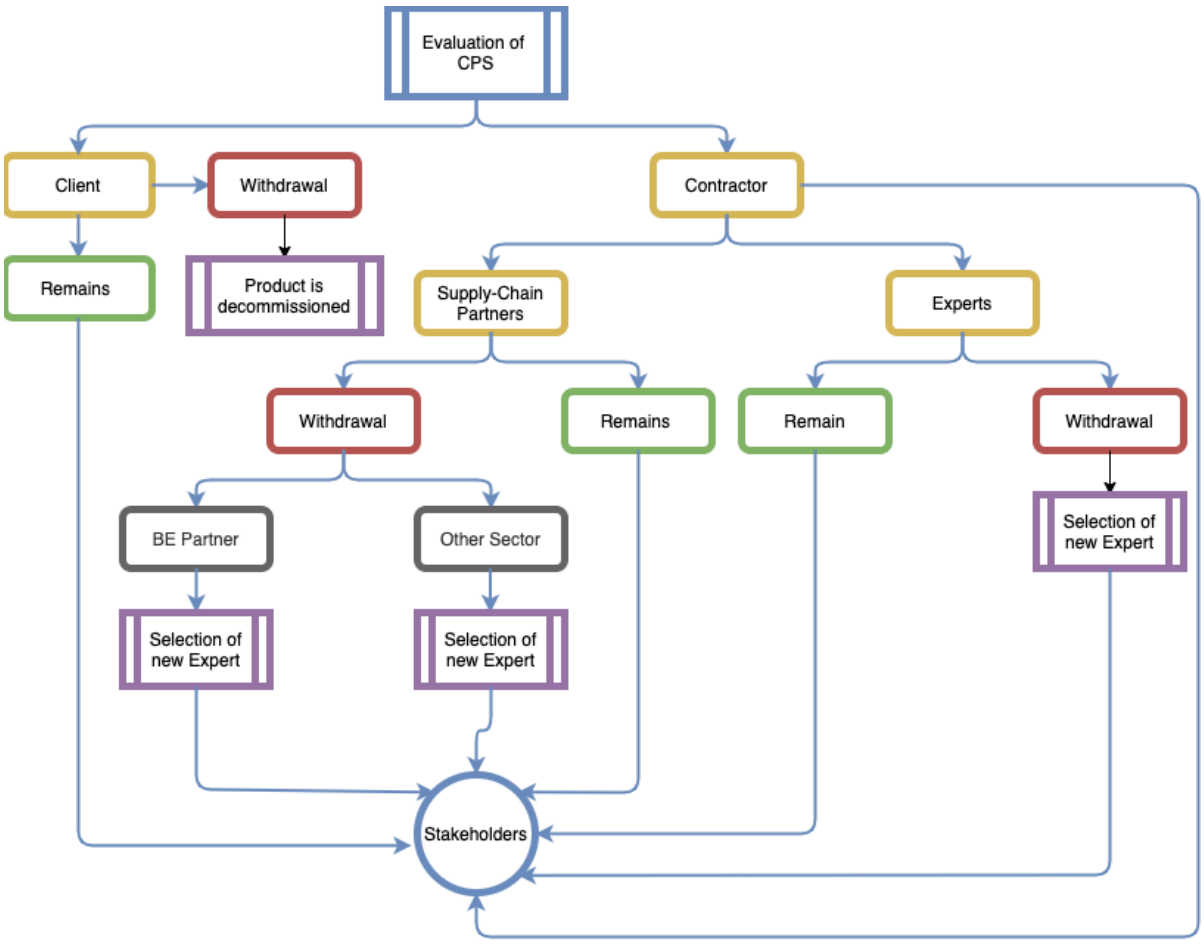

Figure 3. 14 Stakeholder selection map for the Innovative design variant

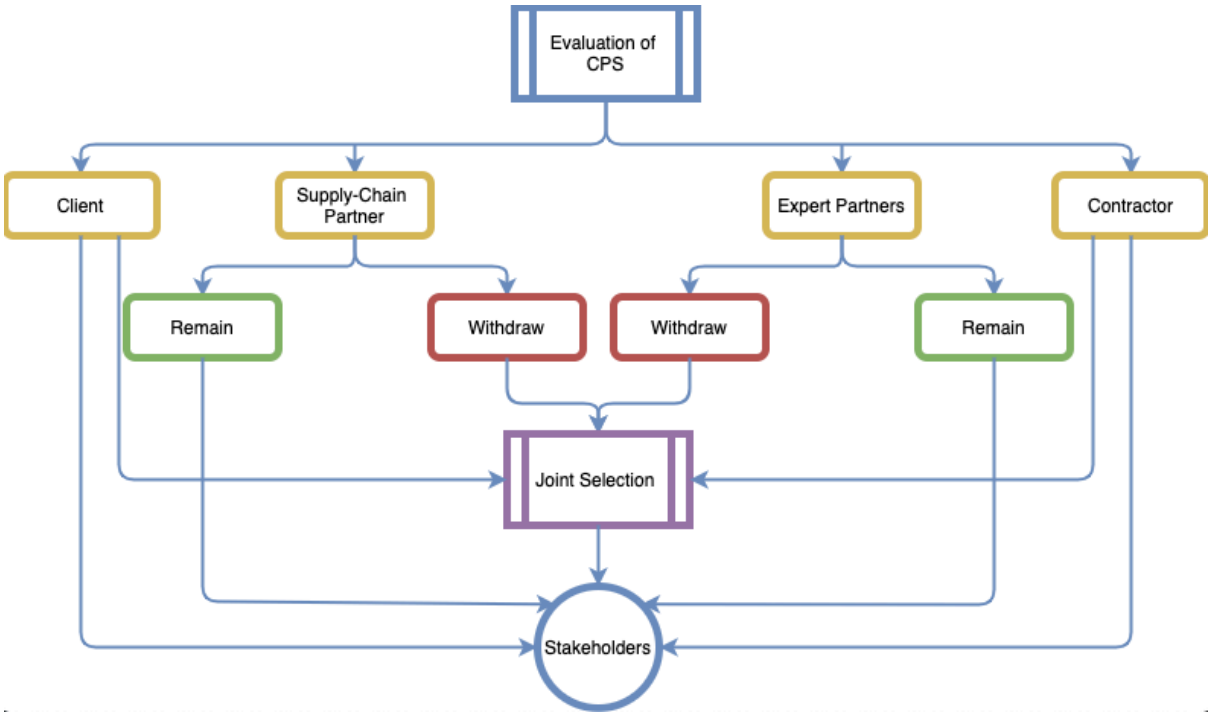

Figure 3.15 Stakeholder selection map for the Balanced design variant

4.2 Collaboration map for VRP

The next part after establishing the maintenance stakeholders is establishing the collaboration map for carrying out the maintenance of the product. Since the circular extension is a circular economy product, the maintenance phase aims to create added material value through the use of Value Retention Processes.

Each collaboration design variant involves different stakeholders in different levels of the maintenance with different communication paths. Therefore, it is logical that the establishment of the collaboration map during the VRP will be different for each design variant. The created process map is derived by the knowledge accumulated through literature research.

The collaboration map is divided into six main steps:

1. Issue Report
   As the name suggests, the first step is reporting the issue. During the Traditional design variant, the tenant reports the issue to the housing association since they are the owner of the circular extension. The housing association then contacts the contractor.

   On the other hand, with the Innovative design variant the client is not involved in the reporting process since this is a lease contract. The tenant reports the problem in an online system that is directly linked with the contractor.

   Lastly, on the balanced design variant the tenant reports the issue in an online system accessed directly by both client and contractor. This is due to the fact that the client is more involved in the maintenance process with this design variant.

2. Inspection
   All design variants follow the same inspection path. The reason behind this is that the inspection of the problem is not affected by the different approaches to collaboration and is a standard procedure.

3. VRP Selection
   The VRP selection process between the traditional design variant has a simple clear VRP selection, since the remanufacture process is selected. On the other hand, the VRP selection for the innovative and balanced design variant is altered. More steps are included since new innovative solutions are incorporated in the process.

4. Receiving Material
   The next step is consisted of receiving the materials from the supply chain. The traditional design follows a Closed-Closed loop supply chain. Therefore, only partners that have collaborated prior to the project are included in the supply chain. The innovative design variant follows an open-open loop supply chain. This means that partners from the BE sector and External sectors are included in the supply chain.
   Finally, the balanced design variant follows a closed-open loop supply chain. This indicates that partners from the BE sector are involved but have no prior collaboration with the contractor before.

5. Maintenance
   The maintenance procedure remains constant through-out all collaboration design variants. This is due to the fact that collaboration does not affect maintenance as an operation.

6. Residual Material

The last part is the residual material created by the maintenance procedure. During the Traditional design variant, the residual materials are evaluated if they can be reused with the same function or different function. If they can be reused with the same function, they are taken by the contractor to be reused. If not, they can be resold to the supplier.

The Innovative and Balanced design variants follow a similar path. The main difference is that during the selection process the residual material that are dimmed unfit for reuse or resell are recycled. The recycling process is conducted by a second-hand material company.

The following figures illustrate the collaborating for VRP map for each design variant.

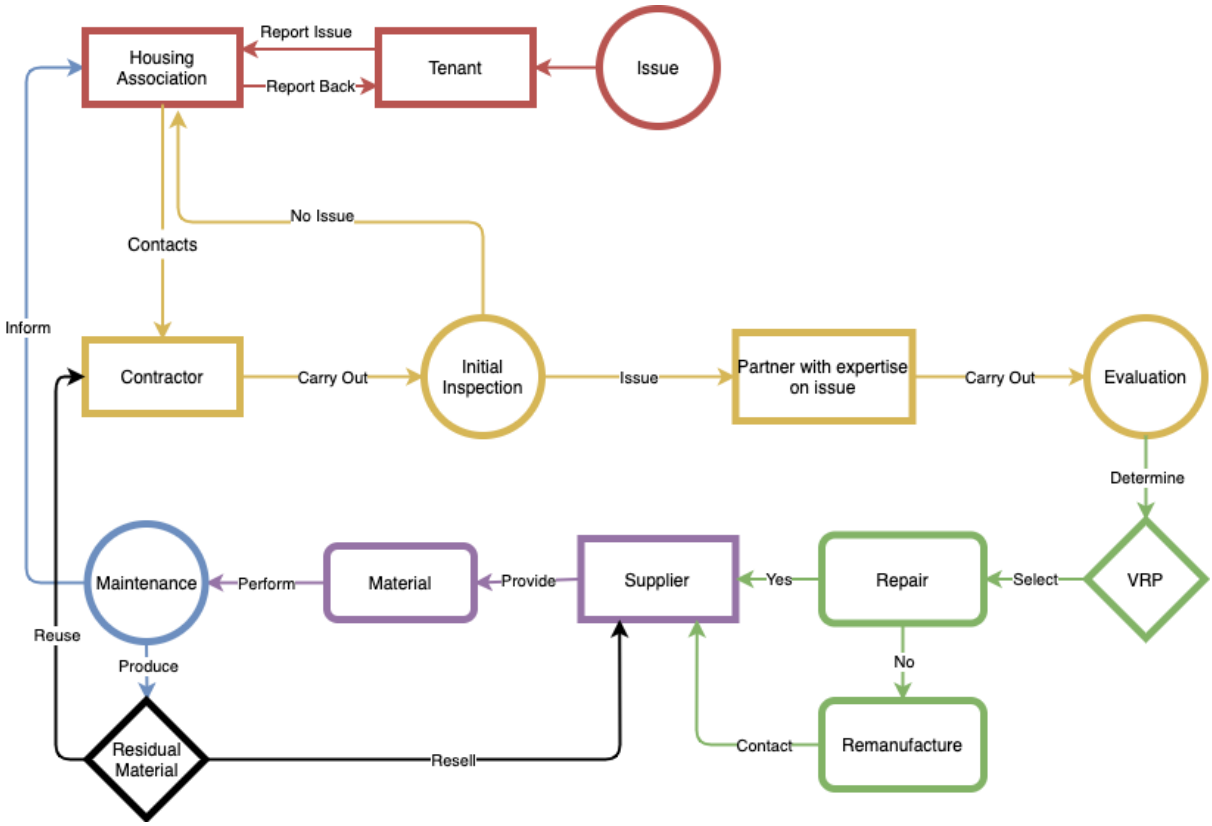

Figure 3.16 Traditional Design Variant VRP Collaboration Map

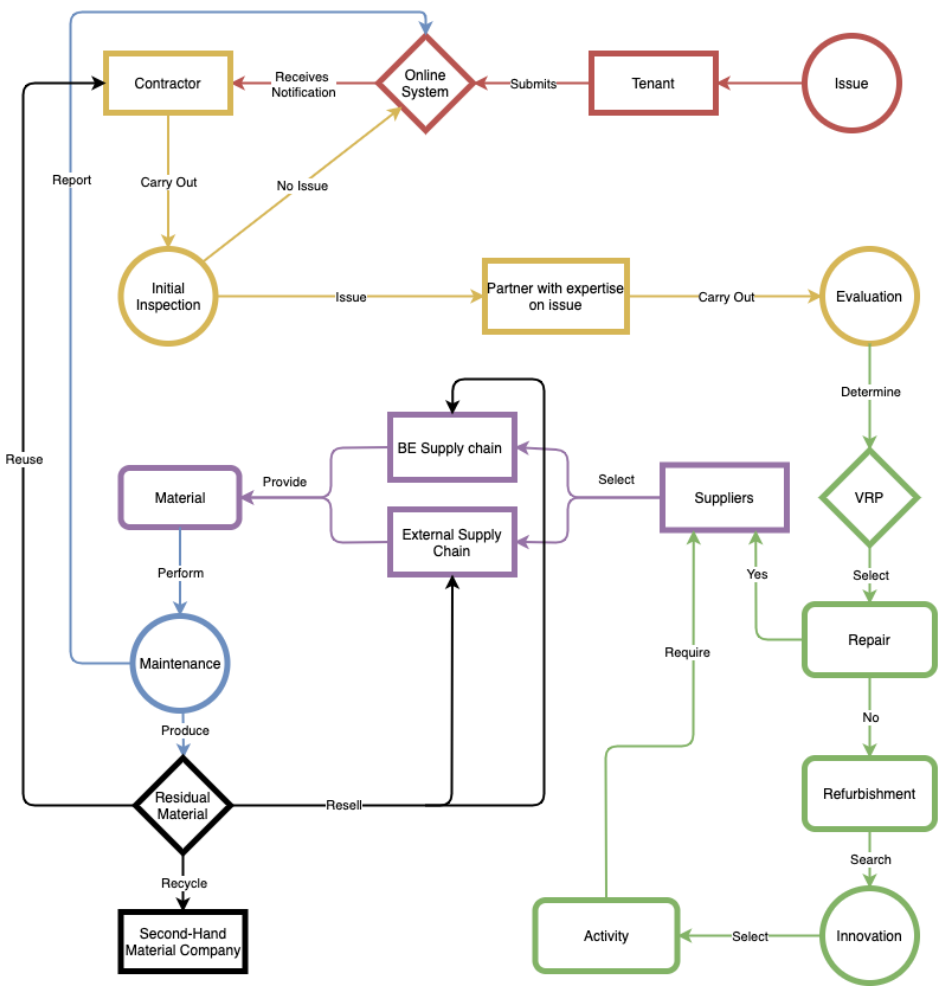

Figure 3.17 Innovative Design Variant VRP Collaboration Map

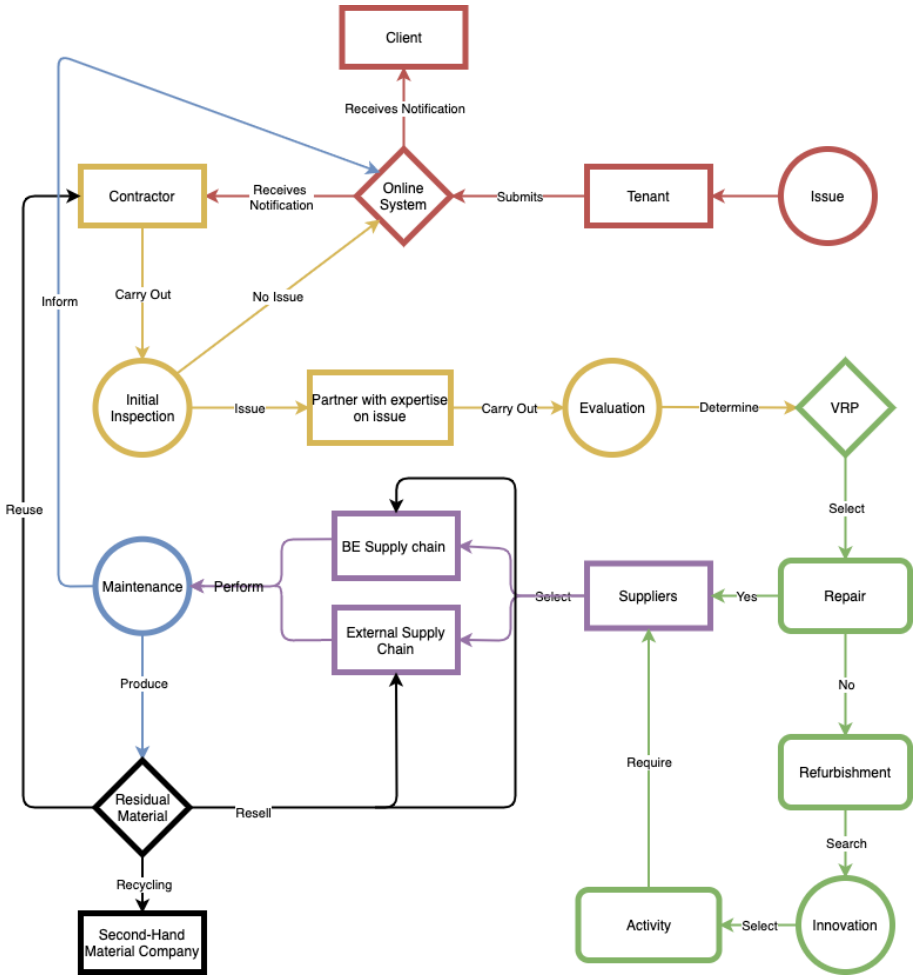

Figure 3.21 Balanced Design Variant VRP Collaboration Map

4.3 Upkeep the process

The maintenance phase is the longest phase of the project lifecycle. During the initial introductory meeting with the client, it was stated that the product is developed to withstand fifty years of use. Therefore, the collaboration for VRP will be spanned for a long time period, which can be straining for the collaboration. To maintain the same construct for collaboration, the DfC is used. In order to facilitate the upkeep collaboration between the partners, the same three core elements of the DfC by Simatupang & Sridharan (2008) are adopted.

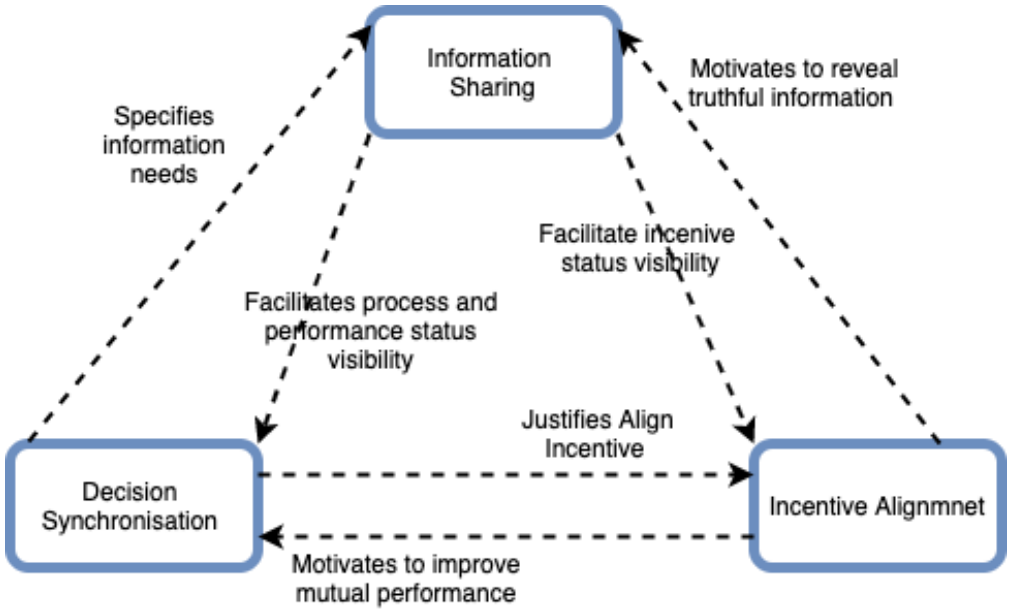

Figure 3.18 Part of the "The architecture of supply chain collaboration: the interplay between its five elements by Simatupang & Sridharan (2008)

To maintain the long-term collaboration, the partners need to adhere to the three core elements of the DfC: Information Sharing, Decision Synchronization, Incentive Alignment. The first action is to establish constant open lines of communication that will be active for each stakeholder to use at any given moment. Furthermore, workshops are established in intervals according to the wishes of the partners. These two actions set the base for the upkeep process and provide the stakeholders with information sharing opportunities. Partners can share new information that has invented. By sharing information, partners maintain and enhance the level of trust established during the design phase.

Furthermore, these meetings will provide the opportunity for partners to share their views on the collaboration process. This process will reveal the level of incentive to the product by each partner. In case that partners are not on the same level of incentive, partners can take actions in order to bring the level of commitment to equilibrium. The upkeep process remains the same for all collaboration design variants. This is because the upkeep process is a fundamental part of the collaboration process and is not influenced by the design parameters.

5. Repurposing

The final phase of the product lifecycle is Repurposing. During this phase the product has reached the end of use and according to the business model the contractor or client assumes ownership. There are two main activities. The first involves the collaboration and partner selection for future endeavours. The second involves the future of materials.

5.1 Evaluation of Collaboration

The evaluation of the collaboration is consisted of a number of steps. The goal is to observe the collaboration process and identify the partners that will stay in the supply chain list for future endeavours.

Figure 3.19: Evaluation Map

Firstly, the final assessment of the CPS is completed. This assessment will highlight the benefits and pitfalls that where faced during the product lifecycle. Moreover, this information will guide the partners in deciding upon future collaborations.

Moving on, general comments are collected by each partner during the product lifecycle. These comments are gathered and shared with all partners. This process is based upon trust and sincerity between partners. The third step is the discussions between partners. This discussion is aimed to identify how each partner experienced the collaboration, the gains and losses created and if they are willing to collaborate in the future. The fourth step is the partner selection. It is natural that not all partners will be content with the collaboration process. The aim is to identify the partners that will be willing to collaborate in future endeavours.

The evaluation of collaboration process remains unchanged between the collaboration design variants. The reason being that the characteristics of each design variant does not affect the evaluation process.

5.2 Renew the material loop

The second part is to determine the future of the materials used during the product lifecycle. Each design collaboration variant utilizes different business models and different supply chains. Therefore, each design variant is using different stakeholders and different CE activities to reintroduce the materials back to the loop.

During the Traditional design variant, the client is the sole owner of the product. Therefore, the client can either keep or sell the modules. Keeping the modules lead to two possible options: re-use and store. It is established that the client cannot repair the modules, therefore the modules can be re-used in another site or stored for a future project. The selling option leads to two possibilities: sell the modules to a second-hand material company to recycle the material, or sell the modules to the contractor. Either way the client creates a stream of added revenue.

During the Innovative design variant, the contractor is the sole owner of the product. The first action of the contractor is to determine the state of the modules. If the modules can be reused, the modules can be stored or immediately reused. In case of repairs, the extend of the repairs is assessed. If the repairs are not economical feasible, the materials are collected and resold in collaboration with the supply chain, or be recycled through a second-hand material company.

During the Balanced design variant, the contractor assumes ownership of the product in the last phase of the lifecycle, the repurposing. The contractor has the same options with the Innovative design variant.

4.6 Conclusion

This chapter focused on developing the three long term collaboration process design variants through the use of information gathered during the second chapter. The first section focused on setting the stage for the design phase. In the analysis phase it was presented that the design parameters can take different profiles. During this section, the analysis of each profile, the aim was to identify the pros and cons in relation to collaboration and circularity. The goal of the section was to answer sub-question 4 and identify how the design parameters set the characteristics of the different collaboration designs.

The next section examines how the different design variants are formed. Observing the information analysed in section 3.2, it is observed that some design parameters can be more beneficial towards collaboration and other towards circularity. Therefore, in order to identify the different design variants, the relationship grid was formulated. The grid combines the design parameters and main stakeholders in relation to the product lifecycle. The aim of the grid was to provide the characteristics of each design variant.

The following section explores the development of the different design variants. Firstly, the collaboration process map is created. The process map provides the necessary steps of collaboration through each phase of the product lifecycle. Hence, by applying different design parameters the three collaboration process design variants are created. Each variant approaches the collaboration steps in a different way. The aim of this section is to answer sub-question 5 and design the different long-term collaboration process design variants for the circular extension.

4. Simulation & Evaluation

4. 1 Introduction

The simulation phase is the data gathering phase of the research. As stated during the first chapter, RtD utilizes a different research approach from qualitative or quantitative methods. RtD applies a method of designing a number of potential processes based on the current situation and evaluate the designs based on the critical approach of individuals that have a direct link to the research. For this research three collaboration process variants were designed. These designs were presented to partners of the circular extension for evaluation. The evaluation process was conducted in the form of semi-structure interviews. The aim of the interviews was to examine how the partners observe the collaboration process variants:

Sub-question 6: *How do experts perceive the usability and feasibility of the different collaboration process design variants?*

The next step is to analyze the answers of the interviews. A number of partners were included in the interviews and provided valuable information on the usability and feasibility of the collaboration process variants. Hence, these answers are analyzed in order to identify important statements and possible correlations. The aim is to identify lessons that can be learned for the collaboration process:

Sub-question 7: *What are the lessons that can be learned for the collaboration process of the circular extension?*

All in all, this chapter is the last chapter of the RtD methodology. The input of these phase is the long-term collaboration process design variants developed during the synthesis phase and the output are the lessons learned by the interviewees. From these lessons the main research question is answered and can be stated if the research goal is achieved.

4.2 Interview structure and participants

As presented during section 1.9.3, during the simulation phase the evaluation of the collaboration process design variants is conducted by semi-structured interviews with parties that participate in the circular extension project. The interviews utilized closed and open questions. The aim of this format is to create a base of solid questions that will have to be answered by the interviewees in a similar way (closed question) and open question that will stimulate knowledge sharing that otherwise would not be given during the closed questions.

The interviews had two phases, during the first phase the interviewer conducted a small presentation. The presentation contained the research goal, as well as the collaboration process design variants. The aim of the presentation was to establish a base knowledge for the interviewees in order to answer the questions. At the end of the presentation and before moving on to the second phase, the interviewees could ask question to the interviewer about the research topic. Moving on, the interviewee carried out the questions. The time was limited to one hour per interviewee due to the lack of available time of the interviewees. However, this time was adequate to ask all the questions and take a satisfactory amount of information.

To keep in line with the initial interviews, the same individuals were approached for the next interviews. This was due to the fact that these partners have a prior existing knowledge of the research and would be able to provide more acquired information over the topic. The following table illustrates the information over the interviews.

Table 4.1 Information over the interviewees

Name(s)	Company	Project Role	Position(s)	Date
Fred Springintveld	Eigen Haard	Client	Project manager	27-10-2021
Nils Vanwesenbeek & Saskia van der Weerd	ERA Contour	Contractor	Project leader & Concept developer	4-11-2021

4.3 Summary of Answers

The following section presents the answers for each question in a summary. The summary is a scaled down version for the answers all participants gave. The aim of this summary is to provide the reader a short version of the answers, the full transcript of the interviews can be found in Appendix C & D.

4.3.1 Evaluation of Usability

The first three questions aimed to evaluate the usability of the collaboration process design variants. Starting from the first question:

1. *Does the process map include all the information needed to support the collaboration process of the development of circular extension? Which information would you exclude or is missing?*

Starting with the client, Mr. Springintveld initially stated that the collaboration process map (Figure 3.3) contains all the necessary steps to conduct the long term collaboration process. He added that “Eigen Haard is now using the balanced side of the presentation”. Furthermore, he added that the client aims to create a team of experienced partners that are incentivized to work together towards the completion. In order to achieve this, the interviewee stated that more evaluation steps are needed. Specifically, each lifecycle phase is required to have an evaluation of collaboration step to avoid creating a product that in the end doesn’t function. Quoting from the interview, “This way you can pull the plug if the collaboration is not working.”

The partners from the contractor also mentioned that the steps presented during the collaboration process map are quite complete. However, Mr. Vanwesenbeek stated that the re-establishing process is not visible in the map and this is the reason the Traditional design variant is not so innovative.

2. *Which process design variant would you use and why?*

Mr. Springintveld stated that currently and for the next ten years the Balanced design variant presents the best choice between the three variants. Currently there is a lack of knowledge on the topic of circular components in the BE, and by using the Balanced variant all partners are incentivized to work together and create a knowledge base for the future. Furthermore, he provided an example of an organisation promoting a circular project which did not include any of the circular design parameters, and concluded that the involvement of TU Delft is of paramount importance to help identify partners that are actually using circular design parameters. Furthermore, the interviewee stated that after ten years, when the contractors have created a knowledge base on constructed CE product, the Innovative design variant will be the optimal choice.

The interviewees from the contractor also agreed that the Balanced design variant is the optimal choice currently, due to the fact that there is less risk involved since more partners are involved in the development process of the product. Moreover, the constant evaluation promotes the optimal output which minimizes the risk of working in “loops”. Furthermore, the interviewees stated that when the contractor in the future has a long term relationship with the client and they know the needs and requirements, the Innovative design variant can be a good solution.

3. *Do you think that the engaging actors would be able to implement the designed processes? Why or why not?*

The client stated that currently something comparable with the Balanced variant is implemented for the circular extension. Hence, the Balanced design variant is applicable to real life products. Moreover, the interviewee stated that the next step is to continue working for example with the contractor, and trust in the knowledge that has been created during the current collaboration. Therefore, to use the Innovative collaboration process variant.

The contractor interviewees also stated that the Balanced design variant has real life implementation in the circular extension currently. Hence, it is applicable because of its characteristics. However, the interviewees stated that the housing market is constantly changing, hence there is a high amount of uncertainties. The interviewees stated that the housing market has a number of variables such as price, materials and technologies that affect the market and hence it is difficult to observe in the future.

4.3.2 Evaluation of Feasibility

The last two questions aim to evaluate the feasibility of the collaboration process design variants. Beginning with the fourth question:

4. *Do you think that the traditional, innovative and balanced the collaboration process and implementation of VRPs would be economically feasible?*

Mr. Springintveld stated that the Innovative would be the most economical feasible design variant. That is because it represents a “Turn Key Project”: the contractor presents the design to the client, and the client gives a go or no go. This way allot of time is saved, and by time the interviewee means money. With the Balanced design variant being the least economic feasible, due to the fact that allot of time is put into the development from all involved actors.

The contractor interviewees agreed that the Innovative design variant is the most economical feasible. There is a high amount of risk involved during this variant since the contractor has to develop the product to fit the needs of the client. To mitigate risks, the contractor may ask for higher premiums. Moreover, the interviewees stated the importance of existing relations with the client will help the contractor to correctly develop the product according to the client’s needs.

5. *Could you highlight any strengths and weakness of the developed designs, in your opinion?*

The client interviewee began with pointing out that the Traditional design variant is not so innovative and it presents an inadequate collaboration process to achieve the 2050 circular economy goals. Moving on to the balanced design variant, the interviewee stated that the Balanced design variant is the optimal collaboration process in the current situation to bring all involved parties together and to create a circular economy practices knowledge base.

Finally, the interviewee stated that the innovative design variant has the potential to be in use in ten years. Though not currently, since contractors lack the expertise to develop products such as the circular extension without the help of other organisations.

The interviewee presented an example that in the future heat pumps will be placed by organisations in a lease or rent contract without the client having to be involved. Furthermore, the interviewee stated that in the Innovative design variant the contractor will incorporate the best material and practices as to minimize maintenance cost in the future.

The contractor interviewees also started by stating that the Traditional design variant is not promoting innovation since the contractor is not more involved in the repurposing phase. Then the interviewees identified the strength of the innovative design variant, that is “when the contractor develops something that the client really wants, then the product is a success”. However, if the product does not fit the needs of the client then it can have an immense cost on the part of the contractor since it is a risky endeavor.

4.3.3 Additional Comments

The client interviewee made also some additional comments. He mentioned that more and more organisations following the 2050 goals set by the Dutch government are moving towards circular economy practices. However, there is a lack of available recycled material currently in the BE sector. The process of removing, refurbishing material and reselling them is currently more expensive than just buying a new product. Furthermore, he gave an example of how Eigen Haard is removing old toilets during renovation and reusing them in new projects. But this is a practice that now is starting to happening in the BE. To mitigate this, he presented a solution where the largest DIY chain stores in the Netherlands should have two racks of steel beams. One rack with old steel beams removed during deconstruction of buildings, and one rack containing new steel beams. This way costumers are presented with the choice of choosing recycled material, something that is currently not the case.

4.4 Correlations between answers

In order to identify possible correlations between the answers that were collected during the interviews, the following table was devised. The table illustrates quotes by each interviewee for each question. These quotes represent the core answer to each question and are used to create possible correlation between the answers.

Table 4.2 Answers of interviewees and possible correlations

Questions	Client	Contractor	Correlations
Does the process map include all the information needed to support the collaboration process of the development of circular extension? Which information would you exclude or is missing?	"I think it has all the ingredients for this road map. I think this is the way you would do it." "More evaluation during the process would be great. I think that is very important."	"I think it's quite complete, actually." "Yeah, re-establishing the stakeholders is not visible in the chart. That's what I mean. Because that's one of the reasons why the traditional way is not so innovative."	All interviewees agreed that the collaboration process map includes all the necessary steps for the long term collaboration process. With the addition of more evaluation steps during each phase.
Which process design variant would you use and why?	"Personally, I like the balanced one" "I think the coming ten years balanced is by far out the best way."	"Yeah, I agree. I think the balanced way is the best way to work together." "And in a process, this looks less risky."	All interviewees agreed that the best design variant implemented currently is the Balanced, and in the future the Innovative.
Do you think that the engaging actors would be able to implement the designed processes? Why or why not?	"So, for now balanced and traditional and then in ten years innovative." "A lot of people say we are circular or we are working like this, but they don't have a clue what it exactly is."	"The balanced way, we already do it like that." "The moment it's going to be maintained, is in about 10 years or something and nobody can see that far in the future."	All interviewees agreed that the Traditional design variant does not offer any innovation, hence can't be implemented. The Balanced is currently in use, and the Innovative in 10 years.
Do you think that the traditional, innovative and balanced the collaboration process and implementation of VRPs would be economically feasible?	"I think at the end the innovative. It looks a bit like a turned key project. So we say we want to renovate this building, you make the plans, you create everything you show to us and then we give a go or a no-go. So that saves us a lot of time."	"With the innovative decision making process, I think it's more about large numbers. If you have something the client really wants, and it's you who developed it all the way with your supply chain partners and experts, and then you can make the same thing a lot of times, then you can put the margin. So, you can make more money".	Both client and contractor agreed that the innovative design variant is profitable for both parties for different reasons. For the client there is no involvement hence no time spend on the development. For the contractor there is a high risk on such projects, there is also a high premium.
Could you highlight any strengths and weakness of the developed designs, in your opinion?	"I think the traditional is less innovative and is still low profile." "The balanced is the way at this moment." "I think it is too early for innovative now. I see in our company Eigen Haard that lease contracts are not done."	"I think the traditional there's no sense of innovation." "Then innovative, I think it could be really smart, if you develop something the client really wants, but that's the risk."	For all interviewees the traditional design variant presented the least innovation. The balanced has the strength of shared knowledge but with high cost for the client. The innovative is the best option in the future for both parties but with higher risk for the contractor.

4.5 Analysis of the interview's answers

This chapter aims to evaluate the usability and feasibility of the designed long term collaboration process variants. The analysis will provide knowledge to identify the lessons learned from the interviews and finally answer the main research question.

Looking at the answers of the interviewees, one thing becomes clear: the balanced collaboration process variant is the best variant that can be currently implemented in the development of the circular extension. Both contractor and client agreed that little has changed in the BE, even though the 2050 net zero goals set by the Dutch government back in 2016 (A Circular Economy in the Netherlands by 2050, 2016). Firstly, the knowledge to create circular components in the BE is in a primitive stage. This results in situations were a number of organisations form an alliance to co-op with the innovations. The best collaboration variant that supports these situations is the Balanced design variant.

1. *The partners believe that the Balanced collaboration design variant is currently the most feasible process of the three.*

The next obvious lesson is that both contractor and client observe that the innovative design variant will be more feasible in ten to fifteen years. As more and more CE projects and products are completed in the Dutch BE, the contractors such as ERA Contour will accumulate more and more knowledge on the topic of CE retrofits. This will provide the opportunity in the future to create a lease based contract that will exclude the client from the development process of the product. This is beneficial for both contractor and client for different reasons. For the client it is more beneficial due to the fact that the client is not purring resources, which in the end equates to less costs. On the other hand, the contractor is incentivized since the product can be scaled and create the potential for a higher premium that will not be shared with other organisations.

2. *All interviewees believe that the Innovative collaboration design variant will be the optimal process in 10 to 15 years' time.*

The following observation is also made clear from the answers of the interviewees. The Traditional collaboration design variant is the least Innovative of the three variants. More specifically the client stated that the Traditional design variant does not offer the level of innovation required to move towards circularity. The contractor also observed that the Traditional design variant is not feasible, because instead of taking a step forward towards circularity, a step back is taken towards linear economy.

3. *The Traditional collaboration process design variant is not feasible in the context of circular economy housing retrofits.*

During both formal and informal interviews, the client and contractor mentioned how valuable the participation of TU Delft was in the development process of the circular extension. The involvement of Anne van Stijn provided valuable information over circular economy practices, and how to implement them on the product. The literature for collaboration in circularity mentions the need for a specialized partner that will assist with the development process.

4. *The development of circular economy products requires the involvement of a circular economy consultant to aid the parties during the development process.*

Looking more specifically towards collaboration, during both formal and informal interviews all partners mentioned trust and a good level of communication as key factors in the implementation of circular economy retrofits. Both, client and contractor stated that is more beneficial for both to terminate the collaboration rather than risk the continuation of the product when there is a lack of trust or bad communication between the parties. Furthermore, it is clear by the answers that both factors play a key role in the Balanced design variant, but also in the Innovative design variant, where the contractor must know in depth the needs of the client in order to create a product that fulfils the client's needs. This follows in fact the literature in collaboration, that states trust and communication as the core elements of collaboration.

5. *Trust and good communication are key factors for the long term collaboration process of a circular economy retrofit, regardless the business model, supply chain model, VRPs and technical model.*

The next lesson is a less obvious one. During the interviews the interviewees had the opportunity to observe the collaboration process during maintenance. This flowchart is an important piece of information for the research and the collaboration process of the circular extension. However, all interviewees did not provide any insights on the topic and the reason is spread all over their answers. As the name suggests, the long term collaboration process is spanned in the future. According to the client the circular extension project is a fifty year project. The BE is a fast evolving market with a high number of uncertainties that can change fast. Moreover, the partners stated that maintenance is far in the future and they do not know what may change until then. This is in line with something that Mrs. Van Stijn said during one of the research guidance meetings: “Partners can plan how to conduct the maintenance during the design phase, or trust that in the future partners are going to conduct the maintenance with circularity as the main driver”. Hence the following lesson is derived:

6. *Due to the ever changing characteristics of the BE, it is still early to establish a clear maintenance collaboration process during the design phase, that will be used far into the future.*

Analysing the interviews, it is noted that the clients strongly correlate the business model with the collaboration process. The interviewees observed that the relationship between client and contractor is built upon the contract profile. Moreover, in the innovative design variant the interviewees closely correlated collaboration with the chosen business model.

7. *The most influential design parameters on the collaboration process, especially for the Innovative design variant, is the business model.*

At last, after the analyses and the identifications of the lessons learned from the data collected during the interviews the main research question is answered:

Is it possible to develop a feasible and useful long-term collaboration process for development and implementation of the circular extension product?

The evaluation of the collaboration process design variants is based on the two aspects mentioned above: usability and feasibility. It is evident that the design variants are still to be tested in practice. The interviews with the client and contractor demonstrated that the long term collaboration process map provides the necessary knowledge to develop the collaboration process for the circular extension. Moreover, both interviews showed that the balanced design variant is currently applicable and therefore feasible. Furthermore, the interviewees stated that the innovative design variant will be feasible in the future in ten to fifteen years from now. The reason being that knowledge on developing and implementing circular economy product in the BE is currently limited and that collaboration of many parties including the client is necessary. To summarize, based on the answers of the interviewees, it can be concluded that it is possible to develop a feasible and long-term collaboration process for the development and implementation of the circular extension product. Hence, the main research question is successfully answered.

5. Validation

5.1 Introduction

This research is not using one of the standard methods of qualitative or quantitative methodology, but rather employs a different method. Research through design better suits the needs of this research due to the nature of the topic as explained in section 1.8. However, due to the abstract nature of RtD, the validation of the research cannot follow the typical research validation process. Therefore, in order to guarantee the scientific validity of this research, two fellow CME students were approached to help with the validation process. Andrei Săceanu that completed his research on the topic of circular supply chains for housing renovations with the REHAB project, and Denis Chiosea that completed his research on the topic of co-creation process on the circular extension. Both topics share similarities with this research and the authors have relevant knowledge on the topic, as well as on the research method and strategy as CME graduates. Hence, the students are suitable to conduct the validation of the research.

The validation session consisted of two parts. First, the author gave a small presentation of the most important parts of the research, such as the research gap, research question, methodology, strategy and every phase of the research. During the second part of the session, the fellow students were asked to validate the problem statement, method, strategy and results of the research. This was done by asking five open questions. These questions were provided during the section 1.9.4. The following answers are a summarized version of the answers, the completed answers can be found in Appendix E.

5.2 Validation Session

As stated, during the first part of the validation session a presentation was given to the students. Both students had questions that had to be answered to create a better understand over the topic, deliverables, method and strategy. Overall, the students found the presentation good and to the point. Staring from the first question:

1. Do you consider the chosen knowledge gap and problem relevant?

Both students agreed that the knowledge gap and problem statement is relevant to the topic. Andrei personally stated that in his opinion, “Allot of people talk about moving towards circularity, but think only about the front end of the product lifecycle, but not the back end.” Hence, he agrees that the long term collaboration process tackles this problem. Moreover, Denis used a similar research gap for his research and agreed that the knowledge gap and problem statement are relevant for the long term collaboration.

2. Do you consider the chosen methods appropriate to fulfil my design goal and research goal?

Both students agreed that the methodology chosen was appropriate to fulfil my design goals. More specifically, Andrei used RtD for his research and found that RtD is appropriate in the case of this thesis research as well. Furthermore, Andrei stated that the analysis and synthesis part of the research were not so hard, but the simulation part was the hardest for him. The simulation used in this research was adequate to extract valuable answers to answer the research question. Denis also agreed that RtD was a good methodology for this research. Furthermore, Denis focused on the limitation of the research topic in general of circularity. However, he stated that if he had to do the same research he would use the same methodology.

3. Do you consider that the results I got during my research fulfil my research goal and fills the identified knowledge gap?

Both Denis has done research on a very similar topic and really believed that the design variants and the simulation provided the relevant results to fulfil the research goal, and start to fill in the identified knowledge gap. Andrei on the other hand, stated that he agrees with the results. However, he would create a clearer connection with the supply chain business models as his research focused on that topic.

4. Do you consider that the developed design variants describe the collaboration process clearly?

Denis clearly liked the design variants and how they were set up. Moreover, he stated that the collaboration steps are clearly illustrated and easy to follow. However, the only comment that he made was that he missed a stage before the initiation phase called “setting up the arena”. During this stage, the stakeholder’s selection process would take place. However, this is a laborious process and is out of the scope of this research, therefore the stakeholders are derived from the circular extension. Andrei also stated that the design variants described the collaboration process clearly. He was more focused on the differences between each design variant. He stated that the differences between each variant covers an adequate part of the collaboration process. However, by adding more variants there could be a better range of results.

5. How would you improve the developed designs?

Starting from Andrei, he connected the three design variants with his five design variants and preferred to see more about the different supply chain methods of Closed or Open loops. More specifically, Andrei suggested to study the relationship in depth between each stakeholder and the contractor in the different supply chain models. However, he stated that he understands that this is not the scope of the research and that this can be done in future studies. Denis, also stated that he found the design variants to be short and to the point. Furthermore, he stated that he finds the simplicity of the steps highly intuitive and easy to implement in real life project.

5.3 Additional Comments

There are additional comments made by Denis and Andrei throughout the session. Firstly, both students agreed that the topic of circular economy product in the BE is new and requires further research in academia. This results in both students identifying a number of limitations for this research. The first is the number of design variants, however both stated that more would be out of the scope of the research. The second is the limited number of interviews, however both students had the same difficulties reaching partners to conduct the interviews. Thirdly, the limitation on the topic in general by using an ongoing product as the circular extension as a case study which is not finished. However, both students stated that further research is required in general on the topic of circular economy in the BE.

On the other hand, both student liked the research methodology, strategy, and the design variants with the results. More specifically, Denis really liked the simplicity and the intuitive way of the process map and the design variants. He stated that it would be easy for partners to implement in real life project in contrast to his design variants. On the other hand, Andrei really liked the relationship grid and how the connection between lifecycle stages, main stakeholders and design parameters was conducted.

6. Discussion

6.1 Researcher interpretation and academic implication

The aim of the research was to fill the knowledge gap that was identified in the collaboration literature, and particularly the mapping of long term collaboration process for the circular extension. The research results are the three long term collaboration process variants and the lessons learned from the evaluation process.

In line with the main research question, it is clear that the balanced design variant is a feasible long term collaboration process variant that can be currently implemented by the stakeholders of the circular extension. This is in line with the indications that the researcher had from the literature, as well as the informal interviews with the partners. Moreover, it is clear that the innovative design variant provides a good bases for the long term collaboration process for future stakeholders to create a circular extension. Contrary to the researchers' initial beliefs that the traditional design variant could be a feasible process, the interviews illustrate that the experts do not find it feasible. The three different design variants were chosen in such a way that would provide a variant using past techniques, a variant highly innovative but untamable currently, and a variant in between. The lessons learned verified the initial assumption of the researcher.

From the answers of the interviews it was clear that each client and contractor had their own incentives. The incentives vary from partner to partner, but both client and contractor had strong feelings about them. The client wanted to create an advantage from being able to scale the product to other locations. The contractor wanted to be able to maximize revenue while minimizing risks. . This is in line with findings (Leising, Quist & Bocken, 2018) that without strong personal ambition, collaboration in circular supply chain is very challenging to be established. Interpreting the answers furthermore, there is a clear tendency, especially from the contractor, to focus highly on the financial aspects of the product. This is in line with findings from other publications (Bocken N. M., De Pauw, Bakker & Van der Grinten, 2016; Leising E. J., 2016; Leising, Quist & Bocken, 2018). The strong knowledge creation incentives coupled with strong financial views resulted in the business model being the most important design parameter of the collaboration process map.

The most important lesson is that it is too early to establish the long term collaboration process from the design phase. To answer if the executed research realized to create a feasible and usable long term collaboration process that was set to achieve, a two-sided answer is needed. As it is clear that academia and the partners of the circular extension really believe that collaboration is a key part on achieving circularity, it can be stated the research created a feasible and usable long term collaboration process. Furthermore, the design variants illustrated that by collaboration especially between partners from different sectors, can result in a higher circularity potential. On the other hand, is clear from the lessons learned that it is too early to establish a feasible long term collaboration process during the design phase. Hence, the research did not achieve its goal. However, the author believes that the research still provides valuable information on the topic of long term collaboration process. Firstly, by providing a framework that illustrates to partners the parts of collaboration, the key elements that are required to be taken, and the ability to create a collaboration guideline that future partners can follow. Secondly, the research illustrates that through good collaboration within the supply chain there is potential for a higher material circularity, especially during the maintenance phase. This is illustrated by the use of extended supply chain outside the BE that can result in a higher amount of materials being able to return into the production loop having the same or different function. Lastly, this research aimed on creating a clear long term collaboration process map for future partners to follow that currently, is not feasible. However, a plan of action designed to achieve a long term goal "strategy" can be feasible. Future research can adopt the information collected within this research to create a strategy, which can be adopted by the circumstances and needs of the partners. The researcher truly believes that this is an interesting research to pursue and will create extra benefits for future projects and the transition from linear economy to the circular one.

What does this mean for the circular extension product? As stated, the circular extension project is an innovative project that has as its main goal knowledge generation on the topic of circular practices for all partners. Even though the research identified that long term collaboration is not feasible at this moment, the partners of the circular extension have developed a good collaboration process to date that benefits all partners. By maintaining the values that consist the successful collaboration (trust, communication, incentive alignment, etc.) the circular extension project can create an outline of the long term collaboration process.

What does it mean for the Built Environment and its circular economy goals? The BE sector of the Netherlands is fast adopting circular economy practices to meet the requirements of the Dutch government. Furthermore, the housing sector, one of the biggest portion that consists the BE, is greatly centralized with housing associations owning 75% of the available housing for rent. This means that development of new housing and renovation projects are conducted by partners that own a large number of assets. These partners can greatly profit by introducing circular economy practices that can be standardized and fit any building. Hence, even though the research concluded that currently a long term collaboration process in not feasible, partners have the incentive to create a successful collaboration in the future since it can create an economic benefit. On the other hand, countries such as Greece that the housing market is greatly decentralized, individuals can build a house with a small amount of capital. These individuals will not benefit the same as a corporation with the introduction of circular economy practices. In instances such as this, the introduction of strict governmental requirements that will force individuals and contractors to use circular economy practices is dimed beneficial. This way partners will have to create a successful collaboration in order to maximize profit.

6.2 Limitations

Surely, there is a number of limitations that affect the research results. The first limitation lies in the number of developed design variants. It is clear that more collaboration process variants could be designed. The reason that only three were chosen was to not increase the complexity of the research that could derail the already extended research timeline. Furthermore, increasing the number of variants would complicate the simulation phase as more time would be required to conduct the interviews, which would further demotivate partners from participating.

The next limitation is the evaluation of the design variants by interviews. According to Galvin (2015), data saturation can be largely achieved after twelve interviews. This research conducted two interviews with three individuals in total, a far cry from the optimal of twelve to produce reliable set of data. The reason being that after the first initial interviews, only these three individuals replied to invitation emails to conduct interviews. Therefore, the same partners were chosen to conduct the semi-structured interviews as they already had a knowledge base on the research topic and could produce more reliable data.

The next limitation comes from the interviews themselves. The interview with the client produced a good set of clear data that were very valuable. On the other hand, the interview with the representatives of the contractor did not produce the same amount of data as the researcher expected based on the literature. The main reason is suspected to be that the interviewees did not comprehend the research designs and goals clearly. It is noted that the interview with two individuals was much shorter from the interview with the representative of the client.

The next limitation is derived directly from the circular extension. The interviewees have been collaborating in the development process of the circular extension for the past two years. By looking into the interview's answers, it is clear that the client and contractor have a good relationship based on trust and good communication. On the one hand, the answers validated the need of the collaboration factors that were derived from literature for a successful collaboration. However, it presents a limitation on providing information in case that collaboration was not successful. Moreover, this limitation is closely correlated with the number of interviews conducted.

Finally, the biggest limitation is time. The long term collaboration process is looking into the far future of the circular extension lifecycle. However, there is a high uncertainty of how the long term collaboration process will look in the next ten to twenty years. New methods and techniques can have a drastic effect on how collaboration in the BE is conducted. With the introduction of BIM models and data management and collaboration, the collaboration between partners has moved from real life to information modeling.

6.3 Recommendations

In the future studies could improve the developed design variants by applying the collaboration process in the development of another circular extension with partners that have no prior relationship. This will provide more concrete information on the progress of the collaboration process and what happens in case a partner is not satisfied and departs the process. Furthermore, by conducting a higher number of interviews from different partners and interviewing the supply chain as well, a more reliable data set can be drawn.

A big limitation of the research was the time frame. As the name suggests, long term collaboration spans into the future, where the client aims the product to be in use for the next fifty years. However, setting the collaboration process for the maintenance phase so early in the product lifecycle gives a small chance of creating a successful long term collaboration that will be followed by the partners. This research is intended as the stepping stone for future research to conduct a collaboration research during the maintenance phase of a circular economy product.

Moreover, observing the answers of the interviews it is clear that both client and contractor believe that the innovative design variant presents the best option out of the three in ten years' time. Hence, it would be logical for future research to conduct further studies in the innovative design variant and identify the economic and environmental benefits. This way both contractors and clients can be further incentivized to utilize lease or rent contracts that will further benefit the circular economy practices.

Lastly, future research can focus on establishing and developing a long term collaboration strategy for circular economy retrofit housing projects. This strategy will provide a more volatile path that partners can follow from early stages of the product and establish the core characteristics of successful collaboration. This means providing future partners the framework to continue the successful collaboration by adapting new techniques that are still to be discovered in CE, as well as adapting changing needs of the sector.

7. Conclusion

With the conclusion of the analysis phase, three designs of long term collaboration process map variants were developed. These variants were evaluated by expert partners of the circular extension and learnings were derived. The research was guided by the following main research question:

Is it possible to develop a feasible and useful long-term collaboration process for the development and implementation of the circular extension product?

The first steps of the research started with the analysis of the collaboration and circular economy literature to draw design parameters for circular products. The literature was conducted by investigating CE projects that have been conducted in the BE and other sectors. This analysis provided the design parameters for circular economy: Technical Model, Business Model, Supply Chain Model, Value Retention Processes.

Following, the analysis of the circular extension took place. This analysis was based on information provided in the form of documents. The design parameters were defined with each parameter able to adopt three different aspects. The next step was the identification of the collaboration elements: incentive alignment, collaborative performance system, information sharing, decision synchronization and joint knowledge creation. These elements were adjusted to fit the CE profile of the product.

Finally, the informal interviews with the partners, together with the literature review provided further information that resulted in a list of requirements that the process map has to fulfil:

1. The collaboration process map design variants are required to span throught the product lifecycle.
2. The collaboration process maps should be based according to the profile of the CE design parameters.
3. It is required that the process variants include a step that will require the stakeholders to engage in a upkeep process of the collaboration during the maintenance phase.
4. Lastly, it is required to include a evaluation of the collaboration process steps in the designed process map.

The synthesis phase begun with setting the stage by identifying the pros and cons for each different aspect of the design parameters. This was conducted to understand the relationship between the partners by choosing different design parameters. The next step was to connect the design parameters and the main stakeholders with the product lifecycle to create the relationship grid. This grid provided the bases for the different characteristics of each design variant. The next step was the creation of the collaboration process map. This map illustrates the step that the collaboration has to take in relation to the product lifecycle. After that, the three design variants where developed illustrating how each design variant tackles the collaboration steps, namely the Traditional, the Innovative and the Balanced design variant.

The next phase was the simulation. Semi-structured interviews were conducted with partners that participate in the circular extension product. The interviewees were asked to evaluate the usability and feasibility of the design variants. The Balanced design variant was viewed by the interviewees as the most feasible variant in the current situation of the BE. Moreover, the interviewees stated that in the future the Innovative design variant will present the most feasible choice, when contractors have established an extensive knowledge base on the development, maintenance and decommission of CE products. On the other hand, the interviewees stated that they found the Traditional design variant to be outdated and that it is not feasible currently, and not will be in the future. All in all, it can be concluded that it is possible to develop a feasible and long-term collaboration process for the development and implementation of the circular extension product. Hence, the main research question is successfully answered.

Analysing the interviewees' answers and comparing them for correlations, the following learnings were derived. This learnings could be suited for circular building components during retrofit.

1. The partners believe that the Balanced collaboration design variant is currently the most feasible process of the three.
2. All interviewees believe that the Innovative collaboration design variant will be the optimal process in 10 to 15 years' time.
3. The Traditional collaboration process design variant is not feasible in the context of circular economy housing retrofits.
4. The development of circular economy products requires the involvement of a circular economy consultant to aid the parties during the development process.
5. Trust and good communication are key factors for the long term collaboration process of a circular economy retrofit, regardless the business model, supply chain model, VRPs and technical model.
6. Due to the ever changing characteristics of the current housing market, it is early to establish a clear maintenance process during the design phase.
7. The most influential design parameters on the collaboration process is the business model, especially for the Innovative design variant

The lessons learned could possibly be applied not only on the case of the circular extension, but on other circular building components. By creating a process map, partners now (Balanced design variant) and in the future (Innovative design variant) can "plug in" the desired design parameters of the developed product and can observe how the long term collaboration process will unfold. Subsequently, by answering the research question, this research contributes to the domain of long term collaboration and partially fills the gap on the domain of collaboration knowledge linked to the housing retrofits and particularly the circular extension component.

Observing the research as a whole, an additional number of conclusions can be made. Firstly, it is observed that circularity is still in its initial steps in the transition to circular economy. Even though circular economy projects have been completed in the Netherlands, this are unique projects that focus creating a green image for big corporations. However, following the answers of the client, little has been happening in the housing sector. The housing sector has seen an immense rise the last four years, with housing prices and demand skyrocketing. Therefore, more regulations should be taken by the government towards requiring added practices of circularity in the housing sector. These regulations can target all stakeholders in the BE, from client (housing associations) to contractors, manufacturers and even users. Now is the time that CE practices can be established to create a circular housing market for future generations.

Secondly, from financial perspective both interviewees stated that it is still cheaper to create a new product than to use recycled material. However, at the wake of the COVID-19 pandemic, a combination of factors such as increased demands on the global supply chain, failure of a large number of natural gas wells and most importantly the decrease of investment towards fossil fuels has driven gas, oil, coal and subsequently electricity prices in record highs (Alvarez & Molnar, 2021). This trend will aid the transition towards CE as new materials will require more costs to manufacture which will increase the prices. Moreover, further government subsidies on the use of recycled material with further aid the transition to a fully circular economy. Practices, such as the implementation of material passports will greatly contribute in the reusability of modules.

The transition of the Built environment from a linear economy to a circular is a highly complex issue that still requires further research to be conducted. This research aims to be a stepping stone that will aid future researchers and practitioners to implement circular economy practices in housing retrofits.

8. Reflection

So, it seems my long journey of completing my master research report is coming to an end. Hence, it is time to reflect on the graduation process and identify the lessons learned during this 1,5 year.

This has been a rollercoaster of a journey. My first one and a half year of studies had been quite successfully with some minor exceptions. I completed almost all (except one) of my compulsory courses and it was time to start searching for a graduation research topic. In my mind, I had a clear topic (or so I thought at the time) of what I wanted to do. However, after researching for a month and creating an initial research proposal I could not find any member to join the committee, due to the fact that all of the professors I contacted where unavailable to take more students. I dusted myself off, and went out to find another topic. The second topic I found was not connected to my studies and it was out of my expertise. Nonetheless I needed to start my graduation research as time was passing. Covid-19 hit the Netherlands and professors were not replying to emails. I heard of fellow students that lost their research topics because companies fired them. So, I continued on this unfamiliar topic for two months with a professor, who in the end told that it was not his domain of expertise and I needed to find another supervisor. After consideration, I decided to drop yet another topic and search for something new, and just like that I met Anne. The first meeting was quite good, I had a good feeling about it, even though I had no prior knowledge on circular economy building components or collaboration. In the beginning it was hard to read and identify relevant information on the topic. The failed research topics aided me already in information identification. However, Anne provided a list of publications. This list was a crucial tool that helped me hence the first lesson is: how to correctly determine and choose information relevant to your topic.

The second lesson was how to write a research. Of course, through my bachelors I knew that a technical report is about giving the information in the shortest possible way. However, the bachelors thesis did not begin to compare in complexity of a masters research. Starting from the identifications of the research gap all the way to managing all the information to designing collaboration processes. It is to lose yourself chasing leads that are of no interest to the topic. Furthermore, I have to admit that writing is not my forte and I believe that I still have big room for improvement. However, through the guidance of Anne, Gerard, Tuuli and of course Henk I want to believe I became a little bit better.

Furthermore, one of the most important things, I take away from these research is the knowledge I acquired on the topic of circular economy. More specifically, not only the knowledge I can apply in my future career, but information on more personal level. I consider myself to be more sustainable conscious, I have stopped eating red meat, minimized the consumption of dairy products, try to reuse everything that I can and consider to update my current six years old phone with a Fairphone.

However, the biggest lesson I learned during my research period is the following. Because of a number of personal reasons, I found myself highly demotivated. Most importantly, psychologically I was in a very bad place for a very long time. I was taking hit after hit that left me in a state of emotional denial which highly contributed to the extension of my studies by a year and a half. I was battling with stress on a daily bases, to the point of having panic attacks. Least to say, this has been the worse two years of my life. But during these two years I overcame a big personal challenge and personally talking about it to other people helped me a lot. So, my last and most important lesson from this journey is that when you feel down, holed up in the dark corners of your soul, you **have** to talk to someone. In my case, I talked with my friends, supporting people that did not judge me but helped me overcame my hardships.

So, I hope my research will help the collaboration process between the partners of the circular extension to complete the circular extension. Finally, I want to end with a phrase that has guided my life the last five years:

“When you want something, all the universe conspires in helping you to achieve it”

Paolo Coelho, The Alchemist

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Appendix A: First informal interview with the representative of the client

Stefanos *So, I have this meeting with you because I want to hear also from your perspective as a client. I also went with the contractor perspective, I talked with Niels. Because as understood, Niels told me that now you, as you think of the collaboration, the circular extension is more like the first business model that I showed you. The design, build and then maybe maintenance in the future. And first, I want to ask you what are the main values of the circular extension? What do you aim to accomplish by creating this circular extension?*

Fred you Are we talking about our thing we have accomplished in our project, de 'uitbouw'. Do want to talk about what we accomplished in our project?

Stefanos *Yes.*

Fred We built something at the back of the house. It was something old and we put it in a circular new one. And you want to know what our ideas are about this in the future?

Stefanos *Yes.*

Fred which Okay. We're still learning at Eigen Haard. This is one of the first real time projects in we have circularity. By keeping it small, we can accomplish something on short notice for now. Which is a good thing for our project. But we designed it on a grid of 60 centimeters, so we can extend it for use with other buildings. So it's scalable. That was one of the biggest challenges, which for us was very important, so we can use it on other projects. In several parts of Amsterdam, our renters built a lot of stuff on our house, but it's not ours. But when this is not registered well, then our lawyer says, you don't have it on paper.

Stefanos *Yes, you have no permit.*

Fred problem. So now it's your problem. So what the other person built or our house is now our

So I find it very important that we create something that we can easily pick up from our project on a specific street and put it somewhere else where we have to replace such a thing. At the same time, we want, probably in the future, not a small building at the back of the house, but over the full length of the house so your living room can become bigger. This is very important for us, and then we looked at the materials, how do we build it? What can we reuse easily so it doesn't downgrade, the whole thing is screwed together.

Stefanos *It's like LEGO.*

Fred so this Yes, completely. So everything is replaceable. The skin is all wood from the Pergola, is a reuse of old materials, which normally would go to some burning factory for energy to get electricity. And now everything is reused and can be replaced and can be reused on every detail of the building. That is very important for Eigen Haard to

know how this is working and how we can pick something up from these buildings and put it somewhere else in Amsterdam. That was the main course of our interest.

Stefanos easy, 60 by *So first, you say it is economical. You fix something modular that you can make*

60 grid, and then use it in another place. You want to create something like a material bank, but that you can use. And then together with environmental perspective, again, your first is economical and then the ecology comes. Because we also have the 2030 50 percent of circular economy. And now there are very strict rules imposed about the new levels of sustainability in refrigerators and air conditioners. Now there are new levels two weeks now that they're very strict before you had an A-plus plus. Now, to date it's C.

Fred which is Now at Eigen Haard, we think with every project, we take one piece of the project,

small and we try to make it circular. But it must be scalable to other projects. We try to take small parts with us to another project, then recreate something new. And this one we put in our project, and this one we take to the other. And there we create something new. So it's like a snowball. It is little when you roll it in front of you, it's getting bigger and bigger. And we hope to be ready in 2030. We have a lot of things sorted out that we can use in our projects, no matter what the project is and where it is.

Stefanos circular *Oh, nice. And do you have like a time frame of how many years you have one*

extension for use? Do you have it for 10, 20, 30 years or you haven't defined the time frame yet?

Fred think. Our goal is to get ready in 2030. And 2050 is so far away, but it goes faster than you

Yes. Yeah. I don't know if this is the answer to your question.

Stefanos use, *I'm more interested to know if you have a timeframe. How many years it might be in*

because you have a circular extension now, you put it now..

Fred The thing we create, how long we keep it?

Stefanos *Yes.*

Fred think this We have a renovation for these houses, for the coming 40 years. The extension, I

is the part we are talking about. The house on its own is for another 40 years, but we know the extension can't make it with the old wood we used for skin. When everything goes well, I think the extension will be okay for 40 years, the construction. But the skin, I think, must be changed, perhaps after 20 years. It is very good wood, it's very hard, tropical wood. When it's good preserved, I think perhaps also another 20 years, so perhaps it can be 40. Also with the building together, but we have to see if it remains the same time.

Stefanos *Yeah, it's a lot of different parts you have. It's a lot of small, different parts.*

Fred for Yes, but I think the construction is okay for 40 years. Like the building itself. It's okay

another 40 years. There's no problem. The construction of the extension, for another 40 years. No problem, but the skin I think maybe 20 years, and we want something else. But it's possible just to remove the skin and put on another one.

Stefanos *The timberman does this?*

Fred No, no painting needed, it's plain wood.

Stefanos *Oh yes, because it's inside after the isolation, you don't see it.*

Fred told me ERA Contour took the design, and the implementation, the construction. And Niels

that you were in close collaboration during the design. How did you experience this?

Stefanos makes I think that's very important to work together with a constructor with a factory that

the frames. Anne was very important. In Holland we say a paper is patience. So everything

you put on paper is very easy, but it has to be made. So you need someone who is able to translate our paperwork in something real. You have them in your collaboration from the very first time. So it's very important to have all those people together and think about how are we going to make this? We had several times that we thought, OK, it goes like this. And something completely else happened, because it was not possible. It's very important that you think about what do you want. I think it's very important not to get something so big that it's not possible to create something because it's too big. And all the people who work or who have to do something about the extension must be thinking together. We have sessions all together on one table, with drawings, a whiteboard, so we can create with each other. That is very important.

Stefanos *Yes, that's also what Niels said. That there were a lot of sessions together and you've made a lot together. Also, from ERA Contour, they have their own contractors and timberman and the people. Everyone had a say to create the design. You know that I also talked about the supply chain. Because now I think it's mostly that I do not know how it is going to be maintained because that's what I am looking more towards to maintenance. How are you going to maintain the supply chain that you're using right now or what you're thinking of using. What kind of supply chain?*

Fred Well, the frame was made from new materials, but the door was from somewhere else. The windows are from our project and the skin, the wood, is from our project. So we try to make the most parts from our own materials. At Eigen Haard we have almost 60000 units, apartments. So we have a lot of materials. If you think about what stands in Amsterdam on the streets in material, it's insane what we have on materials. So we're very busy as well to get a list of all our possessions, all the things we have on materials. So we know when somewhere else in Amsterdam another renovation is going on, we know which materials come out so we can use it in another place. So this is something we are working on.

Stefanos *Yes, because you have a lot of locations.*

Fred Yes.

Stefanos *Up until now, I think the business model that you are using and you are going to use is the circular extension?*

Fred We're also looking forward. What is the best solution for that? And now with the extension we know it's ours. ERA Contourbouw thinks it is okay, because it's a part of the house in a part of Zero on the Meter. We're doing everything electric because everything is a low temperature warming in the house. The isolation and everything that comes with it must be in good shape. Otherwise it isn't possible to keep zero on the meter. It has to be maintained. ERA Contour has to keep it in perfect shape.

We own it and now they keep it in perfect shape for us. But we're also thinking maybe this is not the best solution. Maybe the contractor should be the owner of the extension and we rent it or something like this. We're not sure for Eigen Haard what is the best way. When I look to myself, I like to own stuff. When I buy a car, I want it to be mine. I don't like to rent my car. That's something in my head which must change for the best. And we are open to all possibilities at Eigen Haard.

Stefanos *Yes, it's quite hard. Because then if you own the product, then you can always keep it and it's always perfect, you always have it in the top condition. If you rent it from someone else, you have to make sure they come and keep it perfect. But it has a lot of potential, I think. Also for Eigen Haard. How I see it, the business model, it is mostly because you are a big organisation, you have the materials, you have the connections. You can take material from yourself and from other organisations. If you were a smaller organisation, you did not have so many connections. Maybe it was easier to lease or rent it.*

Fred That is what I hear from smaller corporations with less houses. They say for us it is easier to rent the stuff they do for us. It's cheaper for us like this, because we have a lot of personnel. People working for Eigen Haard, so we can control it ourselves. And smaller companies can control all of the things outside, so they say, OK, this is our house, it must be OK. You do it and we hear from you what it costs. But we don't close that book. We also look at it like this. There are small projects that we try to do as well. To rent service.

Stefanos *I think there are quite a lot of possibilities inside in renting, especially in the building environment it is a bit hard. It's not like you take a car, you lease a car or you go and you rent a boat. It's a bit different. For example, in Samos. I know now they meet people with money. They rent a house and they make it a hotel for 50 years. For 50 years they rent it, they say we have a contract for 50 years. I fixed it and I turn it into a hotel, and I get money from it.*

Fred It has potential.

Stefanos *Are you involving the people that live inside your house, inside your apartments now? Do they also get involved or is it more standardized from you? Because I understand you want something to be accessible for all houses, but each resident is different from the other one Maybe they say, I don't like it, mine is the same with the next owners, or we don't like it that it's the same. Do you have complaints or not in my backyard?*

Fred In this project people weren't that interested in what we did. They had a lot of complaints from the residents about the draught. Wind coming inside from the outside. Moist. They couldn't get it warm enough, and in the summer it was too warm. So there were a lot of complaints that we recognized from other projects. The people say they want us to fix it, and how we do it, they don't care if it doesn't cost them too much. So it's very difficult and what I see is that the people living in our apartments are not so involved with the environment and circularity and climate.

They only think about their wallet. 'What is it going to cost me?'. That is their main business.

Stefanos *It's the Netherlands. Always, it is about the money.*

Fred Yes, it is a big issue. Let's not forget that we are for social housing. For the people who don't have that much money. So every euro is one for them.

Stefanos *And with your partners, I do not know if you can say. What kind of contracts do you share? Design and build mainly? Or design, build maintenance?*

Fred For not so long ago it was designed and built. But we're making a switch to design, building, maintenance. We think in the end, it's better. The contractor puts in better material when he has to maintain it, then when you say 'okay, it's finished, bye bye'. So we slowly make a switch to maintain as well.

Stefanos *And how many partners do you have? I know it's Eigen Haard, you and ERA Contour in the circular extension project. I do not know how many other partners do you know of?*

Fred For circularity?

Stefanos *Yeah, for this project for the circular extension.*

Fred For this project, especially? We have a timber factory who makes the frames and puts in the windows and the door and makes it as a whole. For the extension, I think these are the most important three companies who made it.

Stefanos *So you, ERA Contour and the timber factory?*

Fred We worked with ALBA concepts. It's a company who can calculate how circular the product you make is. How much CO2 did it cost to make it? What is the value at the end? So we also have to calculate differently than we did before. A circular product costs more than a regular product. This will change over the years. It takes a while, but we have a good circular product at the end. If there's more value, there's some you have to demolish and burn and throw away. So within Eigen Haard we have to change to a strategic more long-term view. We have to calculate differently from what we do now.

Stefanos *Yes.*

Fred This is also something we are starting out with our financial colleagues. This is how we do it now, it costs some more. But at the end, it is more valuable, so there must be something else we have to calculate otherwise because it's not okay like this. That is also a big issue at Eigen Haard.

Stefanos *Because finance people say money now it's more valuable than money in the future.*

Fred It's very easy when something costs two euro, but you can get it for one euro. They say, why don't you get it for one euro? We say, this is a circular project. It is better for the environment, better for this and in the end it has a better value. The financial people have to make this switch within Eigen Haard.

Stefanos *This is good information. Because it's still a bit early, all of this, it's quite innovative. So it's still a bit to change the mentality. It's hard.*

Fred You must think about the long term. Not in short parts of 10 years, but with 30, 40, 50 years, maybe. And it's very difficult to make this switch. It's a lot of mindset as well. Because it's so far away, we don't know what will happen then. They think short term. A short term profit.

Stefanos *I don't have another question. I do not know if you want to say something? If you think you have something more to say to me about this particular extension*

Fred I'm very glad we managed to build this one so quickly. We started talking to Anne in 2019, I guess. In 2020. We got all the people together and talked about circularity. In one year, we had a circular extension. I'm very proud that in the short term, we have created something which is scalable, which we can use on other projects. We learned a lot from Anne, really. At first when I met Anne, my manager said, great Fred, we're going to do some circularity. And I was like 'What is this? Give me a normal project' But it gives a lot of energy when you see that things are possible and things can be changed. And when I look at my son, my son is sixteen now, we really must change so he can also see his son grow up. If you ask me, it's going to slow. Big companies like Eigen Haard have to take our responsibility. Say 'okay, we are a big company, we are healthy and we can give a lot of money when we create something'. So, get it done, get it quicker. 2030 is only nine years away. What are nine years in a lifetime? Nothing. The scale must be bigger. I also work with Eigen Haard in project groups. Now we are talking with our project group with the board to make them understand that we have to get it in our system that everything must be circular. More and more and that we must invest now to get it done on time. I think we're going to slow.

Stefanos I think it's always like this a bit in the built environment. It always goes a bit slow. As you just said, it is design and build contracts. And these contracts were for how many years now to design and build? It's the traditional contract, which for so many years they have. It hasn't changed. The construction sector hasn't changed for one century and the last 100 years had always the same processes. But now, I think it's going to be like a snowball effect that you said before. In the beginning it is going to be hard.

Fred But once it is rolling, it's getting bigger and bigger and things are going quicker, I hope. Also very important: when I ask you to build me a house, and say nothing more than that. You buy new beams in the store, because it's cheaper than thr one used. So what if I say to you I want you to build me a house, but I want you only to use refurbished or used materials. And as long as we don't do that, the contractor will take new beams, because it's quicker, it's clean, it's cheaper. There are no nails in it, so I can use it quickly. But we have to change our mindset and say you can work for us, but I only want you to use this or I only want you to use that. And this, I think that's also a big change for the markets. The market must be inspired to think otherwise than they are doing now.

Appendix B: Second Informal interview with the representative of the contractor

Stefanos	So, I would first like to ask you, what do you think that the requirements of the projects are from your perspective? Are the end goals economical, ecological, societal factors. What would you think that this project aims to fulfil?
Saskia	Well, I have to think about it,. You mean the end goals and you mean all the parties involved in it ? Or for ERA Contour? We have different goals, our standard goals are gone is gone, the ecological, but it also what the market asks for. So we think it's important, but it's also a question that comes from the the owner of the building.
Niels	And we respond to their questions. And it's important for us to learn what is the best response for their problems or questions which could be to develop circular extension for me? And the reason we said it is okay, is because from the start, we knew it's part of a larger project, and it's going to be paid for. And in combination with Anne van Stijn we saw the opportunity to take this within our project and learnalong the way from somebody who was really into it. So it's a pretty low risk for us to do this.
Saskia	We made an investment, we pay TU Delft, we pay her for four years, but we get a lot of knowledge from it.
Stefanos	So you would say that the main goal is associatal, but you also want to get a competitive advantage in the market. So it is economical in the end.
Saskia	Well, it's both because it's ecological, because we think it's important. For our future, of course. We think the market is going to change, eventually. It's very slow. But that is always in construction, but we think it's going to change. And this was, as Niels said, a great opportunity with the TU Delft.
Niels	We wouldn't have done the same if we were asked to develop a new fuel engine or something. It needs to be ecological. Nobody is going to ask us again for a new fuel engine, but we think in the future, housing owners are going to be asking more questions about circularity. Then it's also good for us in this way.
Saskia	We have an advantage to our competition, to other construction agencies.
Stefanos	*In a competitive advantage coming into circular technology.*
Saskia	Yes.
Stefanos	*Let's go to business models, or actually, let's go to contracts. I do not know if it's possible for you to share any small information, like what kind of contracts do you have with the partners?*
Niels	It's split in two actually. We are asked to do the development and building or renovating it. So design and build. And optional is maintenance.
Saskia	But that's not in the contract, the maintenance.

Niels Not yet. But could be.

Saskia Yeah, could be, but not for now.

Stefanos *And do you have a specific business model that you're going for? Let's say for example, for the circular extension, are you trying to go for a business model in which you create the product? You build it, you give it to the user, and then the user aims for a service from you, which can be the maintenance, and then in the end of life, you can have a buyback option, which then you can take back all the materials that you use for the circular extension.*

Niels No, I think we are best at development and building. And I think, as other parties are better at maintenance or different business models, with the buyback option for example.

Saskia That's something we're still analysing, because we're not so far in circular extension. We have to have more information to make a decision about what we're going to do. Is that something for ERA Contour to do? The service and the maintenance and its extension, but we're not that far yet.

Stefanos *This is extend to other partners also?*

Saskia Yes, and how ERA feels about it, because what Niels said, this is not something we do. Normally, we don't do that. So we don't have much experience. So it's difficult for us to do. But it's always important when they ask for it, well, you get more done. That's strange.

Stefanos *So maybe you have a bit more about the technical model also. Because I would like to know, for example, how many modules per unit are used? Or would you like to talk a bit more about the technical model for the circular extension? Can you give a small overview of how you see it?*

Niels I think it is split into three parts. One is the design and technical specs of the module. The second is the materials, which are being used in the module. And the third would be how to maintain it. And the first one is more design wise, we made an extension which is also modular in itself, because it's easy to make it a double circular extension, in depth, or in width. It's really easy to extend it, or really use it somewhere else. And that's because it's built from smart parts. And we thought about making it at a factory and not on site. So we can move it by crane and place it and also pick it up later. And all measurements are taught off, it's in a grid of 60 centimeters at 60 centimeters, which are measurements we also see in the materials we are using. So we have less waste when we make it. And it's practical, because also other things, outside buildings are also sort of like in these measurement systems, for example, and washing machine is also 60 by 60 when you look on top o of it which makes it easier to use for the end user which is the habits. And the second thing is what what kind of materials are we going to use to build this thing and this is where we thought of two things we need to reuse what we can reuse from this project itself or other sources which are available which is for example the woods On the outside is from the project itself, and also the windows and the doors from another renovation project from us. But we also asked repurpose to search for wood, which we could use in the components, which could also be wood which we reuse from somewhere else where we don't know off. We also did this with the isolation. And then for all the new materials, we searched for low impact on the climate. That is two and the third would be maintenance. The ideal thing for maintenance would be low cost, low labour and easy to repair.

Stefanos *So using the modular design.*

Saskia And not to glue it, but to screw it.

Niels So you can easily take it apart if you want to fix one component, for example. If it's broken or worn down.

Stefanos *Yeah. So youŕe already thinking during the design what you are going to do for the maintenance?*

Niels But this is not our focus area. In operation we don't really do maintenance. We do renovation projects, but we do have an eye for lower maintenance costs in the future after renovation, which is for this circular extension. But also as the whole for all the other components in the project

Stefanos *And are you using the you know, for example, for the materials you're using something like material passports or materials certification of such in?*

Niels We use the NIBUD database for example. That is a database for the environmental impact of materials. Anne van Stijn has a whole lot of knowledge about this. Do you find the impact of certain materials or components? Anne van Stijn really a whole lot of knowledge about this. Do you find the impact of certain materials or components? Yes.

For example, for the materials, you're using something like material passports or material certification of such in.

So if you, at some point, you're going to think about what board am I going to use for the floor? And then some are really practical, for example, and then you're left with three options. And then you check on this website what is the environment impact? And you're gonna choose the lesser one. If it's within budget range.

So for this project, you're not a part of the maintenance?

We could be, but it's optional.

And do you know, how many partners are already?

How many partners we would need to maintain this circular extension?

Yes, because I can understand that ERA Contour has a specific set of skills, but maybe other partners are needed.

I think it would only be three. I think somebody to do the painting of the doors, the windows and the frames. A partner which will do the roofing. And then we need a partner, which could also be us to do I think the carpenting. Am I missing one?

No, I thought about the one who puts it together.

Yeah, which is also just a carpenter. But it doesn't necessarily have to be debt copter.

That's yeah. Can be someone else.

Its better that it's the same person who built it. Who can do the maintenance,

But there are more parties with this skill set.

And I understand that, Niels, probably you know better the different parts of the circular extension as if you have if you can divide the circular extension is there roofing the walls and windows and yet what are the different.

modules modulus? Yeah, yeah. Yeah. Well, you you you said it already. I think the roof the walls the floor. Yeah, by hearing

Yeah, it's is the construction of steel where the circular extension is set on. That foundation Yeah, exactly. And then the there are the components floor, facade, and roof. And then there is a component which is the frame for the door and the windows And then the rest is outside the outer facade of the of the circular extension which is the roofing and the roots from with on the outside which we have reused out of the project and there are some Foley's.

I don't know the way to fully to the material to get a water you put because of the

idea that water drainage in

the vertical route roofing material.

Yeah. What are they? That's tricky. Like that. No, no, no,

not the pipe

is also a component by the way. Yeah,

that's. Yeah. But yeah, you have big components and they exist of the smaller. It's called waterproofing. Yeah. Yeah. Yeah, like clothing.

Yeah. So you do something like waterproofing on the outside already? In the facades?

Yeah, yeah, it's behind the mood. Yeah, you have the component. And then you have water resistant layer. And then there is the outside facade, which is, which is the reused boots from out the project, which is not waterproof. But it's in the layer behind it.

And then a lot of the components, or materials are also from other projects. So you, you talked about water, for drainage, drainage. That's from another project of verse, And we using it in Kosova. That's also for the door, the doors we use from other projects. So we're looking for the materials, secondhand, but

good enough.

Yeah.

Nice. I have another question. Now, you're collaborating with other partners? Yeah. And how would you say that you are having an information sharing? How would you describe how you share information? Do you share information with other partners? First of all?

Yeah, our partnership is corporator.

Yeah. And the roofing specialists? Yeah. Specialist. Architect. Construction designer.

Now we Yeah, and we the knowledge we share with them. And we have a lot of meetings, workshops to come to the, to this. She Claire extension.

Yeah. Yeah. Because I think it's integrated. Yeah. So things like development decisions. So we do all at once, together with our partners, because it could influence someone, which isn't there. So we like to do it at at workshops and at one time.

So you'll have an open, you can say about information sharing with those partners. You are to have.

Yeah, it's open and be open. Yeah, yeah. So yeah. Ordnance I think because otherwise you can't have this results. Yeah.

I would take you longer later as a result.

Yeah. So we did most about defining the scope in the beginning as best as possible by including all the partners, stakeholders, that the design process.

Yeah, yes. Yeah. Yeah. And also the clients, in this case, the I heart, it's important that they are involved also. So that what we make, it's what they want.

And maybe it's also important. The parties we work with, have the same motivations as we do. We have which we talked about at the start of this interview. So we all told them, This is going to take you a lot of time. But it's you're going to learn from it because we're going to do it together. That should motivate you to get together on this team. Yeah.

So you'll create. You incentivize all the all the decisions. Yeah. Yeah. And how you do all together?

Yes. They have to say motives. Yeah. Together definite fans, which with the competition and the motive to do things, ecological or sustainable. Competitive goals? In the first question, it's important to have the same goal. Yeah. And most parties we work with, we like to have the parties we work much more than with we have long term relationships with Yeah.

I want to give burnish a bit of time also. I do not know if he wants to buy something.

Yeah, basically, I have a couple of questions. Yes. They appeared only during during this meeting. Yes. So about the supplier, you basically about the carpenters. So how hard would it be to change some player? How many problems for the bring to you? The change the sparkler? is the bottleneck of the project, or No.

It doesn't have to be the bottleneck. But I think it's better that you have the same party, the same supplier, because they know how its bills. And but when when well, it can happen. And then it's important to have the information they need. Yeah, did they know what they have to do? So in the development phase, it's really hard to, to, to step over to another machine and start again, actually, no, during the development, it isn't possible.

It's not possible, but then you have an end project, which could easily be copied, like Ollie Express does the square when you take a Tesla apart, it's not that hard anymore, how it's made. And then by the end, anybody can copy it. But in the development phase, you need each other and you need each other's insights to get to go, the thing you're making.

And my second question is I so on, I can hurt both sides that there is going to be built a exemplary house or renovated exemplary house and users are going to be asked what they think about it. And for stuff like this. So how do you think users could be involved in the process? And especially if you just discussed the maintenance and you discovered you would like to make it as simple as possible do consider users to be involved in the maintenance phase.

But you, sir, you mean the owner of the residence? Right? The residents? Yeah. Well, in this case, I don't think you we can expect too much of them. Because they're just hiring the house. Yeah. And they're not really involved. They're not really involved. And Neil's had, as talked to all the residents, so he knows best who lived there. But I think I expect that there aren't as many residents who are showing forced to be a part of that.

I have a question for that. Will you, for example. Employ in a way and putting the residents inside? The maintenance process shows you the instead of having a group that goes and checks the house, the mayor, the tenant can give a notification to you Both of these needs to be changed. So you involve the tenant in site maintenance process.

Yeah, yeah, that's important. And so we have, we ask feedback from the residents after half a year, when they live in it. So then we want to know, what they think of it. What's, what are problems, what can we do better what. And that's also for a circular circular extension.

And this is the the other system is when something is broken, or needs to be repaired from the circular extension. They call the owner. And then then he needs to fix it, because it's part of the surface of the surface or the higher from the from the building, the higher from the corner.

And I have also another follow up in this, have you consider it, then creating a platform of having the each individual parts of the building or the circular extension, that the tenant can go inside in a web website, for example, and say that I have this problem in this specific part. And then this is what it is wrong. So you already know what is wrong, and you don't have to send someone to check and then 40 permits go a second.

Yeah, yeah, we we do that. But as a consumer, we have a system, people can also make a photograph of the problem and data loaded up in the system. So we know what's, what's the problem? We don't have to go there two times first to see what what there is, and then come back with the materials to repair it. But yeah,

yeah, but but we are actually in the second line. Problem is first going to go to the housing owner, and then it's going to go to us. There's no direct connection with the tenants. And so for Dennis, would you have another question?

Basically, I said, but you just thought, Oh, I'm sorry. Do you have any other question?

So far? I think, no, ever all of the questions they had they knew me for previous meetings.

About Do you have any knowledge? I want to ask for the circular extension. Do you have any knowledge about supply chain management and general generally across the supply chain? Because understand you're in the design phase? And before you might not know so much about supply chain?

During the supply chain,

yeah, the supply chain for the construction of the circular extension? And for the maintenance phase, for example, the materials that they're going to be used from the partners and

lighting I think Neil's is in the development phase. He Yes, but he also decides decides where where the supplies come from, what are the materials when he makes the decisions?

So do you have any color management tool? Or do you have any requirements from the supply chain? You used not only the ecological that you already set, but do you have any other events?

Well, there are a lot Most parties we work with, we already know them. So that's our supply chain, I think. Yeah.

And behind the carpet, he has contracts with the ones who literally would have the materials but what kind of words we would use. Those choices are made within the team in these workshops.

Yes. So you give you gave yours, yours your suppliers for example, in this candor, case, carpenter the specifications that you want. Now.

Now we decided within the team. Yeah, yeah,

so we have a couple of options, and the carpenters most experienced. So he would, he would lay down the options because this is best. And he shares his experience and knowledge about why he would use these are these are these. And then together, we would take the decision which one we would use, and sometimes we, we also shed light on it. And then we check for the advisement impact, we check costs. And we check at maintenance costs. But where the decision making is, I'm responsible for it because I met and the spider in the web, for example. But this decision making is from the team out.

And this is also how you share responsibilities, responsibilities with the housing owner. So he knows why things are the way they are. And he comes along in the process where you can see what is what choices are being made, which influenced the cost by for the end project product.

Yes. Yes. Yes. You have a yes or no is in southern Patrick. Yes. Okay. Yes. But we have they, because I've done some courses from them. It's a big difference. We get we get a lot of contracts and a lot of collaboration, procurements. Yeah, procurements? Yeah. And they they dive in a bit into a bit of the management but from an architecture perspective. Okay. Yeah. which colors to use with proper fabrics.

Yes, this is why the, the circular extension is I think from the architecture because it's innovative. It's a bit different. Yeah. Yeah, we don't have we don't have such a circular

Appendix C – Semi-structured interview with the representative of the client

Fred: I don't know what your questions are, but when I see this I think Eigen Haard is on the balanced side of your presentation. Because everything is new, we're looking for new partners - or new constructors, I don't know how you want to call it. Because it's a learning process for us as well. When we are a bit further in our learning phase, the innovate picture is the thing we want to go to. That's further away in time.

Stefanos *Let's start with the questions. Does the process map include all the information needed to support the collaboration process of the development of the circular extension. Which information would you include or is missing?*

Fred: I think it has all the ingredients for this road map. Do you make it like this, I think this is the way you would do it. Of course you hope at the end you have a good team, so you can go to the next phase or the next project, and keep experienced people on board. And I think when something is not going well, you should evaluate earlier in the process. So let's say the contractor does not do what he has promised, or in his first conversation with us, he says 'well we are going to do that, and I am great in that', but then you find out it doesn't work or we are not able to work together. You must pull the plug and say 'this is enough, this is not working for us'.
More evaluation during the process would be great. I think that is very important. To evaluate every milestone. Is it what we expected, is it what you expected, is everybody with the process? Something like that. Or can we improve our collaboration or something else or get another partner to help us? So I think it is important to have these evaluations often.

Stefanos *So you believe evaluation should be done after the assembly? As well as after the repurposing phase, but also during the design and maintenance?*

Fred Yes, every step is an important step. It is what you show. First the green phase, then the blue phase. Every phase has its own dynamic and purpose to go further in the process. So I think it is important to say 'okay now we are done with the green phase.' What have we learned? Are we happy? Is it going according to plan? I think that is very important.

Stefanos *Alright, so more evaluations.*

Fred You don't want to have a very difficult way to come to the end and then say well, it doesn't work. Then you put a lot of time and energy in something which doesn't work.

Stefanos *Next question, which process design variant would you use and why?*

Fred I think I already said this. Personally, I like the balanced one. Right now we need all the deep layers on board. And I want to learn from them, and they can learn from us. So it is one big learning process at the moment and there's no company I think personally who can be the contractor in the innovative column.

Stefanos *In the innovative design variant?*

Fred I think it's too early to go like this right now. All the people build infrastructures, people who make projects to build something. All are needed on this moment on the table of the balanced design.

Stefanos *Because it is that either the contractor doesn't have the knowledge. So a lot of contractors don't have the knowledge yet for circular economy projects. To do this kind of projects that they can rent or lease.*

Fred Funny, we had a conversation yesterday with a contractor. And he says 'well, we are very circular building now'. And he showed a picture and the core of the building was concrete and the rest was wood. So he said, 'yes, this is circular'. So I said, 'what is circular about this?' He replied, 'because we use a lot of wood.' Yeah, so?
I expected that he would say that the construction is completely removable and on another site we can build it in the same way. But in his opinion this was circular, but it doesn't work like that. So I think it is very important to have the TU Delft on board. People that have knowledge on how this works and what circular actually means.
We also learned a lot from you during our conversations on the TU Delft with Anne, and the other professors. That was very learnful for us as well as it was learnful for them. As it works in real life. I think the coming ten years balanced is by far out the best way. And after ten years the people are motivated and understand what it means to do this on their own, but not right now.

Stefanos *Do you think that the engaging actors would be able to implement the design processes? And for this I would ask you for each one. Do you think that the actors can be implemented if the client contractor forms your perspective can they implement the traditional, the innovative and the balanced?*

Fred I don't understand the question.

Stefanos *If you could already use it right now in a new project.*

Fred Yeah, sure. If I understand the question correct, can you use each one of them. I use the balanced one right now.

Stefanos *But could you use the - for example - traditional right now? Where you don't take so much part in the decision making process.*

Fred I think the project we did with ERA Contour. You spoke with them as well. The next project with ERA Contourbouw we can use their knowledge, because they are already one step further then the rest of the builders or contractors. They already have this learning phase with us, so the next step could be, let them do it, and tell us 'this is your building this is what we can do with it, like this or that'.

Stefanos *Because now you said you can implement the balanced. So you can use it, but you can't use the innovative right now, but in ten years for example. But the traditional is more a step back.*

Fred I think that it can be the next step for example for ERA Contourbouw. Because they already know what to do and where to look and what circularity means. That is what I was trying to say with my story before this one. A lot of people say we are circular or we are working like this, but they don't have a clue what it exactly is. So, for now balanced and traditional and then in ten years innovative.

Stefanos *Do you think that each one of these design variants are economically feasible? And which one would you say is more economically feasible in your opinion?*

Fred What do you mean by economically feasible?

Stefanos *Which would be more economically advantageable for you. From money perspective which one would be the best for you as a client?*

Fred I think at the end the innovative. It looks a bit like a turned key project. So we say we want to renovate this building, you make the plans, you create everything you show to us and then we give a go or a no-go. So that saves us a lot of time. When the contractor is involved, and if they have good knowledge about this, they must proof they've done it before and also for us. If they have several projects for Eigen Haard, then definitely it will be less expensive.

Stefanos *I understand, because on the balanced you put a lot of time and effort yourselves.*

Fred Yeah, and also the other partners. They will have the same input in the innovated style, but we don't have to control it. The contractor has to control all that, and I think he also goes to the subcontractors, he chooses the firms which proved themselves. So, you get an efficiency.

Stefanos *The last question, could you highlight any strengths and weaknesses in the developed designs?*

Fred I think the traditional is less innovative and is still low profile. And it stays like this. When innovative goes like that, the traditional goes less steep. It takes a lot longer to get where we want to be in 2050.
The balanced is the way at this moment to get all the contractors and other parties who are working for us on this level. And at the end that must be the way with lease contracts or things like this. I think it is too early for that now. I see in our company Eigen Haard that lease contracts are not done. We still like to own the stuff and then choose parties to maintain.
For example, the heat pomp, we own it, but the service on this object we give to a party that does that for the coming ten years. They have to design it, they place it and then maintain it for us. But the heating pump is still ours.
Over 10-15 years the heat pumps will be from the company who is placing it and we will lease it for an amount per month or year – I don't know. Because when they own this part of the building, they put in the best materials for a long period of time, so I don't have to come every year to maintain it. At the very end it is better to do this. It is more circular then to own everything.

Stefanos *It is also, if you as the partner, you are leasing a product. They have to have a circular economy practice. They need to have a contract, because again, you think if they lease it, of course they want to go for the most economically valuable solution. And then usually circular economy, as of now, it's more expensive then linear.*

Fred What we see now, there are parties that go circular, but you can't buy circular products, because there are too few. We have to do this a lot more to create circular project chains. There are a few products on the market right now. So now it's more expensive, but there are several projects, for example the toilet. We will it take out of the building when it is still okay. We clean it, refurbish it and then comes back. This is going on for a while now by Eigen Haard and it went from zero to 500 houses per year we provide for refurbished materials. And we have this from toilets, from sinks, doors, handles. So there are a few products and a lot of companies that have to go into a building and have to renovate it. They call the company that get's it from the building site, refurbish it, put it on the site and they can buy it for less money than a new one. In the beginning everybody was, refurbished toilet seats? Are you crazy? I want a new one. When you go for a new house, when you rent a new house, the toilet stays the same. It would be

the same as every time someone new comes into a house you would put a new toilet in it. It is a mindset also.

Stefanos *It is a mindset. For me it is more a capitalistic way of everything new. New is always better, so it is better to make more money for the big organisations. I want a new tv, my washing machine is broken, I want a new one. It is cheaper to buy a new one than repair the old one.*

Fred Yes, when we go to the building market, you should have two units: one with new beams and one with second hand beams. That should be the way. When I need beams in my home to make a floor. Why do I need new ones? There is a floor going over them, I will never see them again. So why not? But there is no building market who has second hand materials.

Appendix D: Semi-structured interview with the representative of the contractor

Stefanos So do you think that there is something missing in the collaboration process?

Nils So each phase - or actually assembly and maintenance and repurposing, there could all be different parties involved?

Stefanos Yes. So, you start together, but during assembly for example, someone leaves. And then during maintenance you have another partner, so you have to re-establish the stakeholders.

Nils Yeah, this re-establishing the stakeholders is not visible in the chart. That's what I mean. Because that's one of the reasons why the traditional way is not so innovative.

Stefanos During the traditional way the collaboration is going to be easy, but the collaboration doesn't give you so much opportunities to create a fully circular project. Innovative on the other hand gives you quite a big advantage to create a circular economy product, but it makes it very hard for all the parties to collaborate, because you have a lot of different contractors. The balanced uses partners from the building environment and we don't expand to other sectors. The collaboration is easier, but of course it is in the middle from the traditional and innovative. I tried to created three points: the lowest, the extreme and in the middle. Do you think that anything else might be missing on this chart?

Saskia I think it's quite complete, actually.

Nils I think so too.

Stefanos Essential to what Fred said, and I quite agree with him, is that he required more steps of re-evaluating the collaboration. Fred said that in each specific phase you need to re-evaluate the collaboration, so you can have a healthy relationship with all your partners.

Nils That's true. You can then choose if you want to proceed to the next phase or not or create new contracts from assembly to maintenance.

Stefanos Then we move on to the next question. Which process design environment would you use and why?

Nils The balanced one.

Stefanos And this is because?

Nils There is more knowledge coming together. And in a process, this looks less risky. There is a continuous evaluation, because you're working together on the same project. You don't work in loops, and you can have the best output. That's what I think.

Saskia Yeah, I agree. I think the balanced way is the best way to work together.

Stefanos And do you think that in the future, the innovative way is the one to go? Because, for example, Fred said that everyone is using then balanced now, because no one has the knowledge to create or to be able to support lease or rent contracts. Do you think that in the future the innovative way is going to work?

Nils Now there are, for example housing models, which are developed by the contractor and its partners. We all think this is what the client wants, but it happens many times that he also wants to tweak it a bit. And then then you get in the process again. It's hard not to involve the client.

Saskia I think maybe when you have a long term relationship with your clients, you know better what they want. Then the innovative way is a possibility, but I think that is really necessary. Do you know each other very well? And at this moment we don't do the last steps yet as a contractor. These are the maintenance and repurpose. Maybe in the future, but there are some risks the contractor doesn't want to take yet.

Stefanos Do you think that the engaging actors would be able to implement the design processes and why or why not? Do you think that the actors - you as a contractor, Eigen Haard as a client - that you can implement this design variant?

Saskia We already do it like the balanced way now.

Nils Yes.

Stefanos So this is what you are already using?

Saskia More or less, yes.

Stefanos And do you think that you go towards the innovative? That if you know the client?

Nils It is pretty hard. With the circular extension, for example. The moment it is going to be maintained is in about 10 years or something. That is pretty far away. The moment it is going to be refurbished is about four years away from now. And nobody can see that far in the future. And that's the hard thing with housing, I guess. It changes in these years. All ideas about working together and about working with what kind of materials change, and maybe prices change, everything changes. It’s not the same environment, in collaboration from now or in ten years.

Stefanos This is why I'm using also this way of researching the research gap, because nothing exists in collaboration, because the circular environment has only been around for the last five years. And during maintenance, as Fred mentioned, he said the product may go 40-50 years. Then you look so much into the future.

Nils. It makes it hard. How do you evaluate what you designed, and then in 50 years?

Stefanos Yes, how do you evaluate the collaboration process? You go towards the goals again?

Nils And then it are such long terms, it's easier with for example a phone or something,. In two to five years it's done and then it goes back and you can still find the same guy who developed it. That's not that hard. But here I think it's harder.

Saskia Also because we don't do everything ourselves. There are a lot of partners involved for the installation or something.

Stefanos The next question. Do you think that traditional, innovative and balanced collaboration processes and the implementation of the value rotation process would be economically feasible?

Saskia Sorry, can you explain the question again.

Stefanos If they can become economic quickly advantageous or if they can be done economically speaking from your perspective. So for example, like you are the contractor and you take some risks of course, because you are the one that develops. You are in the middle of everything right now. Do you think that, for example, the balanced is economically feasible for you right now? If you're doing it right now is it making money? So during the innovative, for example, you have a lot of risk that is on you. Do you that in the future it is actually going to be worth to make money from his collaboration process?

Nils The innovative decision making process is more about things with large numbers. If you have something the client really wants, and you developed it all the way with your supply chain partners and experts, then you can create the same thing a lot of times and you can put a margin and make more money. Once it's good, it's good. You don't have to do the process of development every time again or not completely. That also saves a lot of money.

Saskia The risks need to be paid. That's a little bit of the problem, I think. When we take a lot of risk, we ask for more money. Because we want to be sure we will not lose any.

Stefanos So the more risky from your perspective is the innovative?

Saskia Yeah, I think so.

Stefanos And the less risky is the balanced maybe?

Saskia Yes, because you are in it together. But it needs to be a transparent collaboration with your client. You need to be open about the problems.

Stefanos The last question I have for you, is if you could highlight any strengths and weaknesses for the developed designs in your opinion? So any strengths and weaknesses for the traditional, the innovative and the balanced?

Saskia You told a lot of about this already, I think.

Nils I think that there's no sense of innovation in the traditional one. You are not responsible for the next phase, so it is just what it is. The innovative could be really smart if you develop something the client really wants, but that's the risk. You need to develop something the client really wants or else it dies easy.

And then there are a lot of costs there. The balanced one takes a lot of time to develop everything like this. And who is responsible for keeping it together? Maybe this time it was us or the contractor. The decision making workshops, who is responsible? I don't really see it in this scheme.

Stefanos On this part it is the contractor, but its more about the in between, because the contractor can have ties with the supply chains and the experts. You have more communication channels so you may even have pre-existing relationships with a lot of your experts. It makes it easier for the contractor to be the initiator.

Nils It would really help to get the client involved a lot. The supply chain partners and the experts can also give information straight to the client and not only through the

contractor. That would really help, if everyone was really working together all the time. Now for example with the circular extension, a lot of workshops are without the client. We did a workshop without the client and then we would inform him on how we were doing. and we cut it in pieces the process like the sketch design premature design, final design,

Saskia It was more than just inform. They were more involved than just informing the client.

Nils No, it was reflecting. Is this what you want? Are we going the right route and are we following the right process? So, they could also give their input.

Saskia What is missing, is that we don't do the maintenance and repurpose part by the circular extension.

Stefanos And which of these three variants can build up a lot of trust? Because as I understand the balanced one needs way more trust than the innovative.

Saskia I think that the client is more involved in the balanced one than the innovative. When they see how you work and how you do it, the trust will grow. In the innovative way you need to know the contractor as a client before you trust them. You need some experience together before you trust each other. That's a whole process.

Appendix E: Validation Session with Denis Chiosea and Andrei Săceanu

Stefanos The first question, do you guys consider the chosen knowledge gap and problem relevant?

Andrei OK. After you explain, I understood that it was relevant. Obviously, this knowledge gap starting from the phase of construction and going through the operation, the maintenance that like the exploitation phase of construction and specifically for you have the circular extension and going till the end of the of the end of the lifespan. Yeah. And after that restart in the loop, I think that there is for me and also my thesis, I note, is that that there is the most important thing because people are discussing very much about how to make it so circular from the beginning that people are not writing like in in the scientific papers, how to what you are doing at the end, because there are a lot of articles that I found out on recycling. And as you know, from the butterfly, blah blah recycling is not the best. You have to go there. So exactly where you pointed out the end of life, I think is revving up. Yeah.

Stefanos And yeah, it's like, this is also like the long term collaboration I said inside that is used as a means to enhance circularity.

Denis Yeah, I also completely agree, because basically, first of all, I will say I use pretty similar a knowledge gap, and I established myself too. And the main question is like when they research the literature, you have something like, Yeah, let's go circular or, yeah, we have we can implement business in this business model. And this supply chain. But the thing is, it's still pretty new area, and we're like examples of how it could be done in the long term. So basically, the main question is how does it look in the long term i agree.

Stefanos Yeah. And yeah, these of what they want to be and who knows? OK, so question one, done. Question, two. Do you consider the chosen methods appropriate to fulfil the design goal and research goal research through design? What if I remember something? Andrei, you wrote about in the end, our show already heard something about that issue.

Andrei I realize that some of the limitations of this, yes, but it's very important to mention it's a methodology, not the method. Yeah, OK. I really consider that t for your thesis here and also for my results for Denis thesis just this method worked in the end it, which I consider to be one of the most challenging part. It's how you simulated. The simulation part of all these things, because talking from discussing from my personal experience, the simulation part of the synthesis is not that hard. A simulation, even synthesis be the main focus of this is because they're created. But as we know, because we are talking about scientific, scientific paper, what you're creating here, how you simulated and how you discuss it is more important in the end, even if you're creating for variance. If you speed nicely, you're going to have it, then. But if you're going to have the best solutions in the world but don't simulate it properly and you don't discuss it further, there might be a problem. But as I consider, I consider it very relevant and pointed out the focus on the simulation part because I'm very curious to see how you how you simulated

Stefanos How I did. You mean the semi-structured interviews? Yeah, I know. But what knowledge are obtaining from the interviews, because their knowledge? Yeah, this is also yeah, this was more about this is I followed what you did and then Dennis it and then I copied it also a bit. I did usability and visibility. I did not do transferability. So, if you can use it,

if it's usable and feasible, that's what they asked about the three variants. So first I asked, how do you find it if there is any knowledge gap or any steps in the first map that you would actually follow and then I asked whether you find pros and cons for each party on economical protocols and if you believe that is doable now and then in the future?

Denis To clarify one thing. So basically, your design goal was to develop collaboration process map, right? Yeah, OK, but I want to ask about lessons learned. I mean, like lessons learned from development of long term collaboration process map or a lesson learned from basically a collaboration.

Stefanos The lessons learned from what I learned from the partners on the collaborative process. And then is focusing on collaboration, not on the map specifically, yeah.

Denis So, can I give a give a comment about that? Not his feasibility, but like method chosen, then it's appropriate. Is it appropriate? I would say something like it is definitely appropriate for development of the collaboration map. But the question is about, I would say, the it's not even like not appropriate. It is a limitation of current reality that you, you look forward to defines the lessons learned from the collaboration. But the thing is to still something like collaboration in the middle of collaboration. And so, we still don't have all of the lessons. And I would say this is the main limitation. And it is a limitation not only of your process, map, limitation of topic in general, because basically, as I was saying before, the topic is still in progress. It is still in development. And so, yes, here it's just like all of us do not really have choice. We worked on the basis of this project. But if I was proposing this topic as myself today, I would suggest something like that. We should take some kind of project that is already finished and try to introduce the people from a finished project because it could give more insights. So, I would say something like this.

Stefanos Yeah, yeah. I also agree that this is also what I don't think the limitations. But first of all, yeah, very little interview scientists because, you know, no one else wants it, so it's not actually replicable. And that's the thing. That's the only thing. The variants also limitation, but no more time to make it more complicated and that this is still ongoing, like a lot of this topic in general is still ongoing, and it's because this is the biggest. Limitation of my research also in general, that this is makes it maybe it's work a little bit in a way, but not all the way. It did not work all the way. So, it's just that it's the biggest limitation that you don't have actually a circular, fully circular economy, all that that has sparked all of the life cycle so had gone through the maintenance operation. And disassembly assembly and the use of the materials. But we haven't had a big project with a lot of parties involved that has successfully gone through all of these stages. So, it's something for the future, for future researchers to really confront. And should we move on to the third question?

Stefanos OK, I. Do you consider that the results I got during my research fulfil my design research and goal, and the identified knowledge?

Denis I will say once again in terms of collaboration process map, it's really feels, and I really like it because what I like, like you said that you don't like is that you couldn't do it more complex. But I will say, first of all, I like the simplicity because it's like it looks more like real guidelines because you can in the same time. See common process. So, I would say for collaboration, for a real collaboration, it is more useful than mine because, for example, what I did, I would say it's more appropriate for something like presentation in front of stakeholders. Yeah. And I think for that, for actual collaboration, it's really useful and feasible and thoughtful. Your design and research goals and about the identified but once again, one of your research goals says identifies the lessons to once

again be here. Have some limitations, but you showed us lessons. But I think so far, yeah, it's you did a good. My applause.

Stefanos Thank you.

Andrei Okay. Yeah, definitely. One of your research goals was clearly touched, which is the map. But I would like to refer more on the on the lessons that that you got from there, because they're a little bit. You know, we have also to say negative stuff. It's important for you for your validation also. Yeah, yeah, yeah. Yeah. So there on the lessons I would I will try to connect you more clearly with the with the supply chain business model VRP, you know, to be directly focused on that one. Yes. Because if you remember, this is how a guideline my thesis on that structure. Yeah, but otherwise I really consider it actually exactly also in the format that you have. I would also add that part. Yeah.

Stefanos Did you, Andrei? Can you remind me that you choose also from your designs? For example, I found out that there were all the interviewees were going towards a business model a little bit more as a main design parameter. For me, for example, it was a business model that identified.

Andrei For me, it was a slightly different because in all my interviews, I was starting from the business models. I was calling circular supply chain barriers.

Denis I think Andrei can interrupt you for a second. Yeah, I think you found this. You were speaking about what I wrote that to mainly during interviews, people were speaking about economic visibility and they didn't really look into circularity. Yeah.

Stefanos From what you said, yes, from on your report. Yeah, what I did, yes, but on my own.

Andrei I also have I also had this part and I also know this because I was if I remember, I was touching some points, also economic feasibility. I was touching the supply and the resource efficiency. I think these things and obviously everybody is talking with businesspeople. They were focused on an economic part all the time on circularity. They're saying, yes, it's good to be good, to not be bad. Something like that. Yeah.

Stefanos Yeah, it's yeah. Because for example, I did my interviews with a project manager of the client of the housing association Saskia the of what process goes from a contract. She was also something about she was always talking about money, everything she talked about. But yeah, she talked about money and in the end, it in the end. And then it all became all about money, of course.

Andrei But this is this is good because you see how people are thinking the industry is our thesis. It's way too theoretical, even at you. They're way too theoretical, and it's normal to see their point of view, whether that matters in the end.

Stefanos Yeah, it's all about the money. Yeah, OK. And so, you feel fulfiled with that question.

Denis Yeah, it's like short summary. It just fulfiled in terms of process map. It is partly fulfiled in terms of lessons, but it still serves the research that's required so that you can further research the lessons that you draw.

Stefanos Yeah. And did you consider that the developed design variants describe the collaboration process clearly by what you believe? So, yeah.

Andrei Yes, can you show us again?

Stefanos Let's see. Let's see. I would think that if you think that all the steps followed here. Are relative, or can you think, for example, another step that can fit inside the main process map? So, the first part is the client is a contract and then business model, the established stakeholders and then seems to have a business model as stakeholders. You create the contract and then you establish the goal of their collaboration before you start it, actually before you go into the design, what you want to achieve and then you go to the design. You set the supply chain and what VRPs you want to choose. You align all the incentives of the other partners through contract, trust and something that I don't remember and then shared information you have to make a specific channel to share information and then you have to decision to create a decision synchronization process that I showed you with the three.

Denis OK, so this are the variants, right? Yeah, but it's variants and so it's mostly like, for example, in the beginning, all variants will follow these steps the same, no matter what, the different variants.

Stefanos Go back with the slide that with the colors, I think it's better for us to see. But for example, here each variant will go differently. You can create a decision synchronization model called they will collaborate to achieve a decision. So, for example, this one, the traditional variant the client talks with everyone else's mediator and then says back to the client and the client gives back its feedback. I like it. During the innovative, for example, the client is not involved and the contractor has to create the product that the client likes if she doesn't like it. Good bye. You don't afraid they're going for this design process. And then the balance that everyone works together holding hands.

Denis And I ask you to go through each slide holding staying on each side for like one second. Yes, from, you know, from the bigger picture show that from the bigger picture here and stay for like five seconds, it's just like, OK. OK, I have basically like quite a short notice. I think it describes the collaboration clearly. But I will say it from my perspective of a person who was doing pretty, very, very similar. Think I missed something in the initiation in the taste, something I would call setting up zero arena something like this. Yeah. So basically, setting up the initial caliber because you jump straight to contract and initiatives. But the thing is how do you even set up this arena? I would say I missed something like this, but that is I also didn't have it. But I was going through some papers that were describing this, and I didn't have it because I was saying that my starting point of my thesis is when there is already collaboration going on. Yeah, but I but I would say that some something we should also think about this how do we even set up the arena?

Stefanos I think this the first part for me, the first part is shaping up there in because you first. You have the client and the client. You have declined a contractor meeting. Which is and then they speak with each other and then they decide what is going to be, especially with a business model. So what relations they will have with each other? And then they establish the stakeholders that they want to go in to take with inside the process. And then they all together, they create the contracts and then since, all of them are together and then create the contracts. The last part for the collaboration is that they create the collaboration performance system. So, they say that, oh yes, we are together all together, and then we have where it is here. You have environmental, economic and operational logistic organisation and marketing is five describing the bottom with the faces. Yes, by various these five areas in which, according to what the different supply chain model business model, you can have a better environmental

performance. For example, if you have an opened up and supply chain, look because you have a bigger variety.

Denis If you explain it like this makes sense.

Stefanos Yes, yes, and then but operationally, it's not good because you have people, the partners with completely different language, talking with each other, making no sense. So, it's very hard to create a collaboration. So, at this this way, I say this the whole part, the initiation part is like setting up the collaboration. It's you. I use the life cycle product. What do you do on the collaboration part? What's not on the product as a product? Yeah, I think I do not know if you like my answer.

Denis You see, I like it, but then at the same time, I'm I still miss some things. I would say something like I was talking more about how to choose the stakeholders. How do you involve them? Basically, how does it work? Yes, it is something innovative and innovative, and you cannot just like find a contractor and say, Oh, you have such a large experience in this you need to find. I would say something like minded individuals or like-minded companies and to just it is also quite the challenging part. And I would maybe say something about this and your limitations, because otherwise you could be asked this question. I was asked something like this during my thesis, but my safe, safe, safe point was that my process map describes the process from the point of actual collaboration happening. But you also need the safe point. Yeah, yeah.

Stefanos Nice.

Andrei OK, I'm ready. I think you have. You have chosen very interesting this these three, these three types of the same design. Yeah, because you chose the traditional one. The balanced one, which is like a moderate one. And the innovative one, which is a bold one. A progressive one. Yeah. OK. And in this from your choice, you are covering your covering largely these three broad possibilities. And this is nice because this is how you can analyze it. You can have an interesting analysis. On the other hand, you have only three variants. And these, like Denis said you might have a limitation here because by having only three, you are not. You are covering largely, but you are not very, very specific on any on any of these things. But obviously, you can have 100 variants or more by changing any. For example, I saw one of the stakeholders was the expert or something like that. You can have a lot of possibilities what the export might do in each of them. But this is very important in this and this is a recommendation to do as Denis set right in the limitation that you have only three of these. And obviously everybody understands this is a thesis. This is not. This is not a comprehensive research. And you have to show them that you are aware of the fact you cannot be very specific with that with all of this. Yeah. To be honest, I will do the same as you did. Yeah, if I remember, I had the five. Yeah, it was. It was simple for me because it was different than those of certain specific. But one, on the other hand, very good job with them.

Stefanos Thank you. Yeah. But this is also what they said. That limitation that yeah, it's only that only three. You can play with a lot of things and especially I do a recommendation about the innovative part because apparently all of the interviewees believe that in the future this is going to work. This is how we are going towards the future. So, I said, yeah, there are lots of different possibilities. Future research can do different variants from the innovative.

Andrei But have you discussed in your interviews to rate these variants of specific points like I don't know which one is the best.

Stefanos Yes, because the economy, they are agreed. All of them are agreed from the lessons that I have it here that the balance, the balance variant is what is feasible now right now at the kind of the markets, what the balance.

Andrei Not the traditional?

Stefanos No, not the traditional, we decided that it's not feasible. No one like this. The balance is what everyone lives up for now and said that this is how we are going to do it all together because there is not so much knowledge acquired around a circular economy. But in the future, for example, when a contractor has done some projects and has their knowledge to himself, he can create the product according to the specifications of the clients and then give it as a lease contract. And then you don't have all of this collaboration, because collaboration is money. When you have a lot of people collaborating, it's a lot of time and time is money, and neither client and or contractor want to do this. But now they have to, because there's it's quite innovative, but it's money. This, that's what they said.

Andrei That's nice. Yeah, OK. I think I'm done with this question.

Stefanos And with the last one. How would you improve them?

Denis I mean, they were really short in terms of design. They wouldn't change anything. It is simple and intuitive and easy to follow and like, maybe, but it's also like you don't put it together in one picture. But yeah, but you call it later on, though, I wanted to say something like it's not even about the design, it's about your presentation. You can take this middle column. Yeah, and put it. For your presentation on something, Klopp throws a past where you explain each of the step one somewhere on the left and highlights the path, you are currently explaining something like this. Yeah, yeah. Oh, it would be even more intuitive in terms of the design as content. I mentioned the only things that I'm missing, but you can write it not as the things that you are missing, but that's the limitation here. I would say it depends a lot on as you wish. So basically, that's my comment.

Andrei Okay, how are they going to develop design? Can you go back, you had the picture with her. I forgot it. Go back a little bit to the previous slide. No, go up to that one. Yes, exactly. Exactly. Exactly this one. OK. How will they improve it? I can. I can notice that, for example, I'm going to connect directly with the supply chain because I did my thesis on the supply chain. I noticed that you said close closed supply chain. Open open supply chain. I consider that one way to improve it is to analyze it more from the perspective of each stakeholder, which one is close, which is open, for example. In this case, I'm not talking about the client. Obviously, I'm talking about the contractor, the experts. I'm talking more about the also the people who are doing the maintenance. Yes, I can see the refurbishment if the refurbishment can be open or closed in manufacture and so on. This is my point of view here. And obviously, you can add more, more business model. This is how you can improve it. But from my point of view, what you created already now they're very nice to analyze because you are going with each variant through initiation, design, assembly, maintenance and repurpose, which is good to see them. How the how the how they behave, which is their behavior in time through all the construction phases. And also, that I would like to congratulate you for that. You made this team, which is interesting because I can see all of them in parallel now. And you and you because I haven't thought about this when my two to go back going to be back. Yes, I'm talking about this picture from the right way. AM simultaneously. How was the behavior in that? So yeah. Yes. The only improvement is to work more on it, obviously. But this is not the yeah, this is not and not in this call.

Stefanos	Thank you for your time and effort guys, I was really glad to see you again and I hope one day we can do the Circular BBQ we wanted to do.
Andrei	Nice to see you guys again, until next time.
Denis	It was very nice guys, until next time.