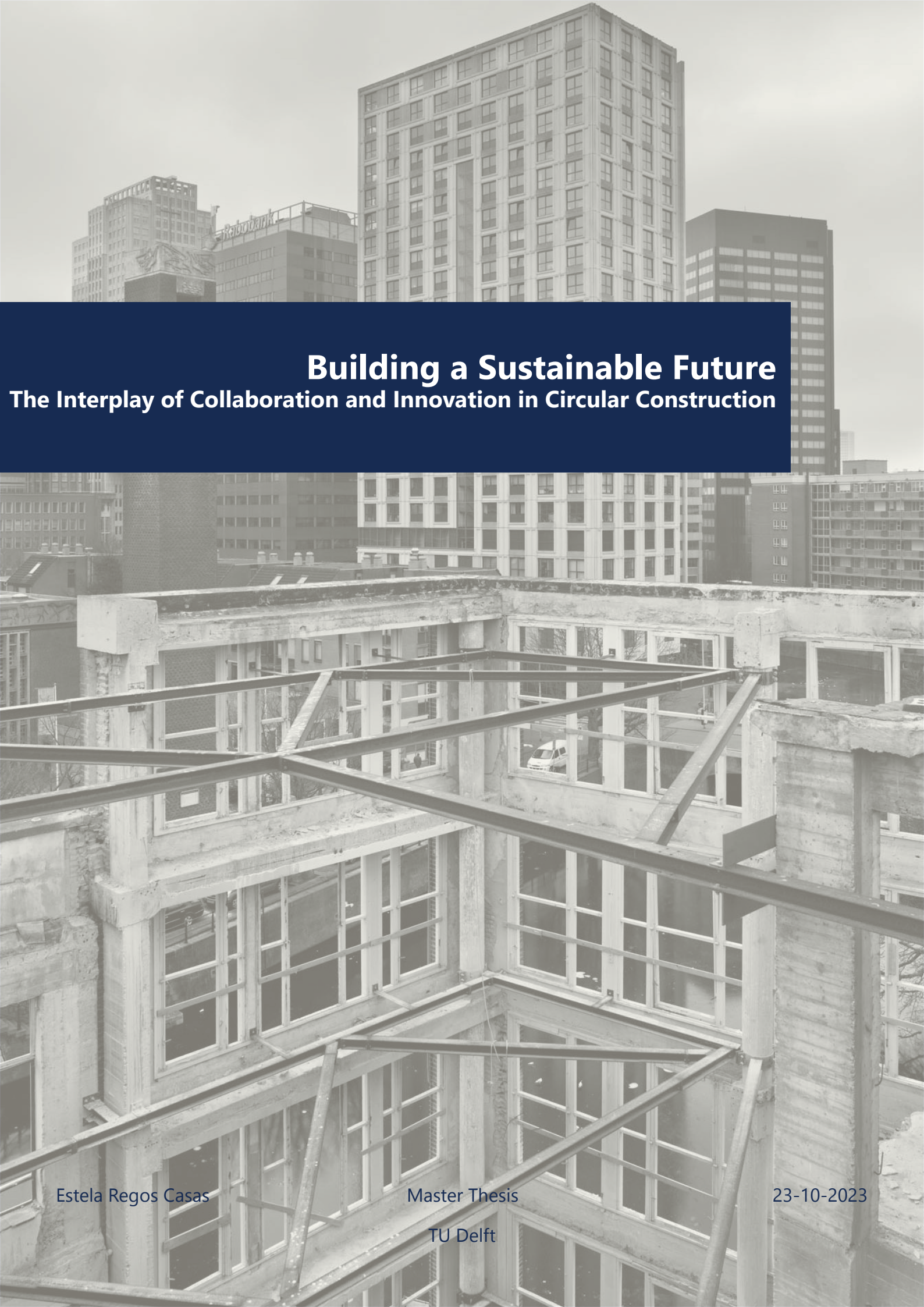

Building a Sustainable Future

The Interplay of Collaboration and Innovation in Circular Construction

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Preface

This research endeavour was conceived as an integral part of my academic journey within the Master's program in Management in the Built Environment at Delft University of Technology. It is the result of an insatiable curiosity about circularity in the construction industry.

The reason for choosing this research topic emerged from personal interest and the recognition of the necessity for a shift from our linear society towards a circular one. There is still insufficient focus on the circular transition, particularly in the conservative construction economy. With this thesis, I hope to contribute my share to accelerating this transition

I am deeply grateful to all those who contributed to the realization of this thesis. I would like to express my gratitude to my parents and family for their continuous support of my educational, personal, and professional development. I would also like to thank my friends and fellow students for a creative and enlightening time as a student in Delft. Finally, I would like to extend my appreciation to my mentors, Karel van den Berghe and Paul Chan, for their time and guidance that provided inspiration and insightful moments.

Abstract

This thesis will focus on the relationship between collaborations and the innovation of the circular construction industry. The reason for choosing to investigate this topic is because the construction industry is one of Europe's largest waste producers and energy consumers. Therefore, it can also make a big impact when the circular economy is implemented as efficiently as possible. According to het Planburea voor leefomgeving (2019), there is very little innovation in the circular economy, which does not favour the efficiency of the circular economy. On the other hand, the literature states that collaborations will be beneficial for implementing circularity in the construction industry. However, companies in other sectors that mainly work in-house (no collaborations) are frontrunners in the innovation of the circular economy. An example of this in the car industry is Tesla. They are a frontrunner in terms of electric cars and do 80% of the process internal (Benam, 2020). Out of this emerges the main question of this thesis. What is the relationship between collaboration and innovation in the circular construction sector? To support the main question, the four sub-questions will be answered first: RQ1: What kind of innovations are there in the circular construction sector? RQ2: What are the different elements of collaboration in the circular construction sector? RQ3: What are the factors that drive and prevent collaborations in the innovation of the circular construction sector? RQ4: Who are the stakeholders with whom collaboration should be established to facilitate innovation in the circular construction sector? The research method that will be used for this research is an exploratory study and the data collection will be done with the help of five case studies.

Keywords

Circular construction sector, Collaboration, Innovation, AEC industry

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2 | Introduction

2. Introduction

This thesis examines the relationship between collaborations and the innovation of the circular construction industry. In this chapter, background information on this topic is given. In addition, the literature gap is mentioned and a problem statement is drawn up.

2.1 background

2.1.1 consumption and waste

The construction sector consumes around 50% of all energy that is produced in Europe, and it is responsible for 50% of all raw material extraction, 40% of greenhouse gas emissions as well and 30% of all water waste. Besides, 36% of all solid waste in Europe came from the construction industry in 2016 (Heisel & Rau-Oberhuber, 2020). The construction industry is not only responsible for a large part of resource extraction in Europe but consumes a quarter of all raw materials worldwide (Richardson, 2013). Therefore, a focus on circularity in the construction sector could have a major impact on resource extraction and pollution. In addition, the infrastructure of the built environment such as roads, bridges, dykes and sewers consists of large quantities of often heavy, materials, such as stone, concrete and steel. The extraction, processing and transport of these materials leads to excessive strain on the earth (Faes, 2021).

Legislation

The EU wants to have a fully circular economy by 2050. They have this goal to reduce pressure on natural resources and to halt biodiversity loss (EU, n.d.). Since the Netherlands is an EU member state, they have a target of having a fully circular economy by 2050 as well. They set the additional requirement of having a 50% circular economy by 2030 (Ministerie van Infrastructuur en Waterstaat, 2022).

2.1.2 Circular economy

The economy that is prevalent in Europe at the time of writing is a linear economy. This is an economy where resources and energy are readily available (MacArthur, 2013). To ensure the supply of raw materials and decrease the strain that economic activity has on the environment, the linear economy needs to transform into a circular one. Like the circular economy, circular construction is about closing a loop. According to Ellen MacArthur et al. (2015), a circular economy is:

An economy that is restorative and regenerative by design and aims to keep products, components, and materials at their highest utility and value at all times, distinguishing between technical and biological cycles.

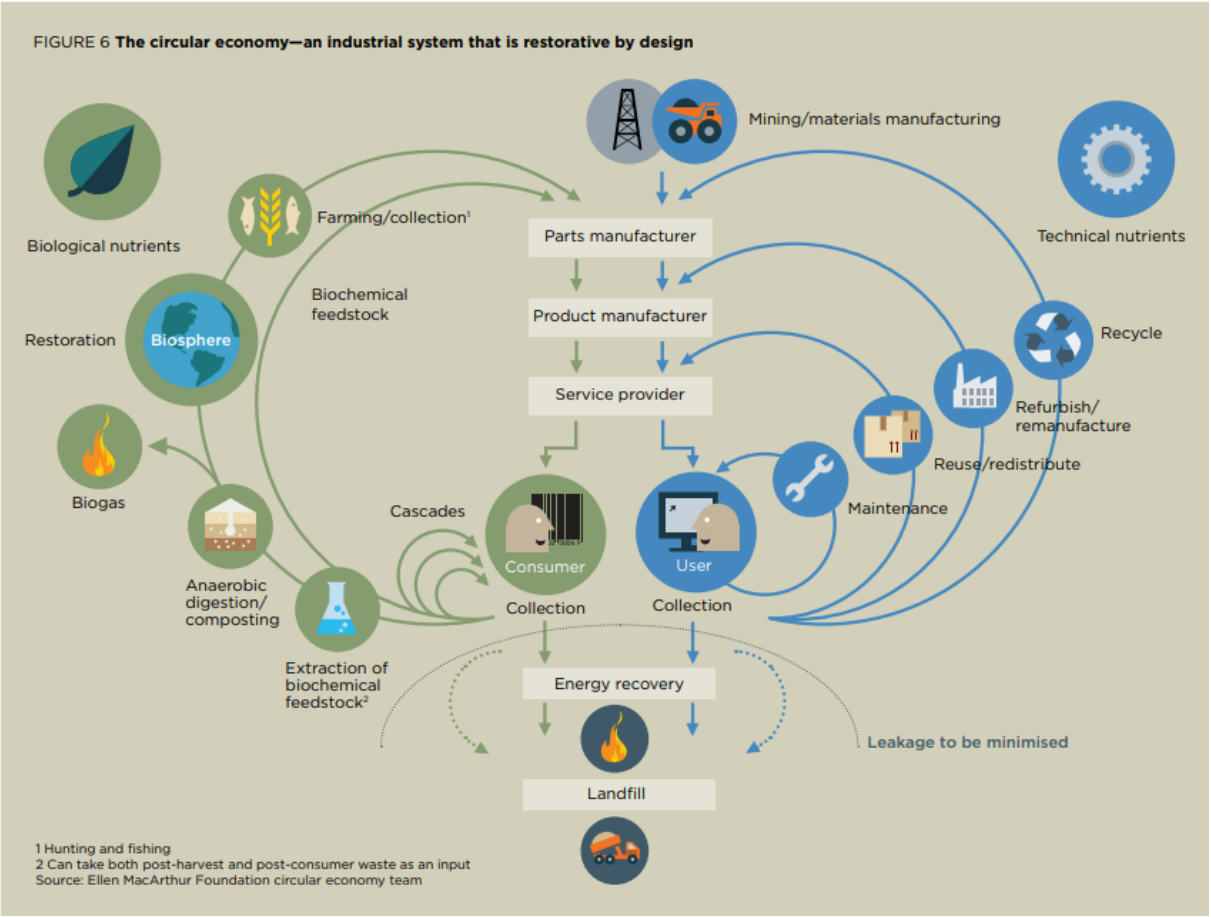

Figure 1. A framework for the circular economy is the butterfly diagram by the Ellen MacArthur Foundation (2015)

Figure 1 shows a framework for the circular economy. In this framework a division between biological nutrients on the left and technical nutrients on the right. Both sides show a loop being closed. The technical circle is mainly about materials and products that remain in circulation through maintenance, reuse, refurbishment and recycling. In the biological circle, nutrients from biodegradable materials are kept in a loop by returning them to the earth (MacArthur et al., 2015). The loops aim to keep resources at their highest use value at all times. The technical circle is designed for non-biodegradable materials. The circles of maintenance and reuse are the most effective within the technical circle. In this process, the value of the product remains and its lifetime is extended. If a product can no longer be reused, it is still possible to keep the value of the product by refurbishing or remanufacturing it. If this is not an option for a product, it can be recycled. When this happens, the product itself loses its value, but the value of the materials is maintained (MacArthur et al., 2015). On the side of the biological circle, products are renewable by nature. However, value can be added to this circle by cascades for different applications in different value streams. When materials in this circle can no longer be used, they can be composted or anaerobically digested. In this way, usefulness can still be obtained. (MacArthur et al., 2015)

When looking at the technical nutrients side, downcycling can be placed here as well. Downcycling is part of recycling. However, this is not recycling, as it involves downgrading in material quality (MacArthur, 2013). This is something that occurs frequently in the Dutch construction industry. Downcycling of construction and demolition waste is already widely used, more than 95% (Het ministerie van Infrastructuur en Milieu et al., 2016). An example of downcycling is the processing of construction waste into granulates that can be used as foundation material.

Not only released materials should be reused in the highest possible quality but also building products and (parts of) construction works. This is a huge task given that in the current practice, only 5% to 7% of the weight of all building products that make up a building are found to be highly reused (Faes, 2021).

2.1.3. Innovation and collaborations

As can be seen in figure 2, only 2% of circular activities are innovative initiatives. Figure 2 also shows that a variety of innovative initiatives do exist, but innovations beyond recycling are still not common. An example of recycling in construction is roads made from recycled plastic. However, innovation in the reuse or repair of products is quite rare. Innovation must occur in the higher forms of circularity, as these are also more effective than recycling (Planbureau voor de Leefomgeving, 2019). As discussed in *2.2.2 Circular economy* circularity aims to keep resources at their highest use value at all times. Recycling is the last option and the one that retains the least value of a resource (MacArthur et al., 2015).

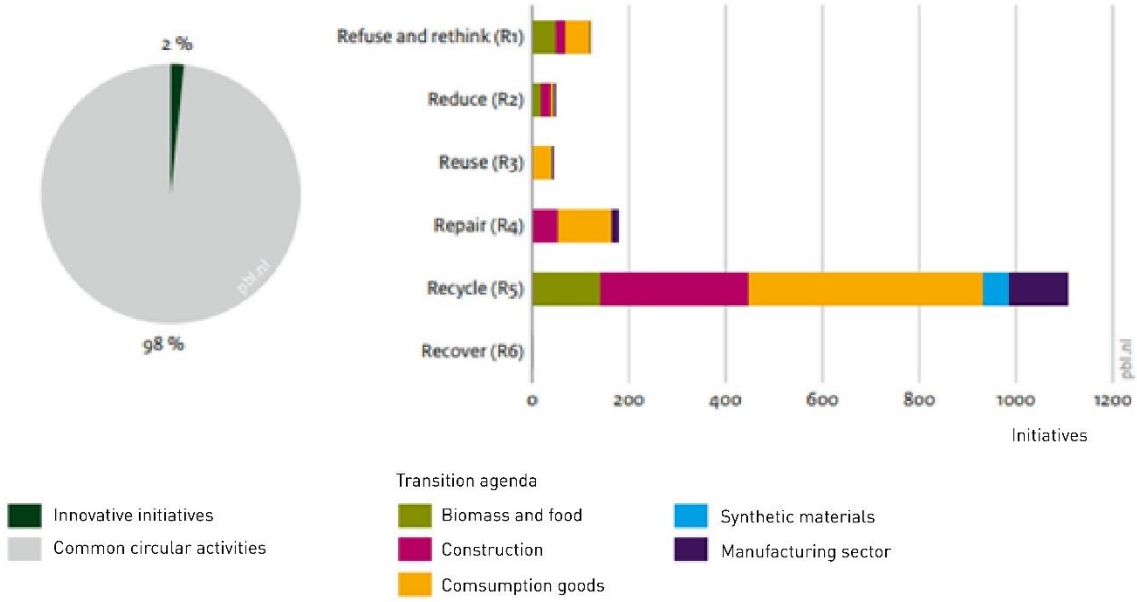

Figure 2. Innovative Circular Initiatives (Planbureau voor de Leefomgeving, 2019)

More attention is being paid to innovation and collaborations between organisations. Nowadays, external actors are mainly used to obtain new ideas for innovation, technologies and resources. In addition, knowledge obtained internally is often commercialised to external parties. However, it is often ignored that such collaborations and the relationship between the external and internal knowledge sources are very complex and can cause the neglect of innovation performance (Gkypali et al., 2017).

There is a consensus in the literature that collaboration is necessary to implement circularity in the construction economy. However, according to the Planbureau voor de Leefomgeving (2019), supply chain cooperation is seen as a barrier to new circular initiatives.

Circularity in the construction industry is a challenge, as there are many stakeholders involved and there is a serious lack of knowledge (Çimen, 2021). A circular economy makes the construction industry more complex, which slows down their implementation. Barriers like the adaptation of design and technology, material information and additional investments are

created when applying circularity (Çimen, 2021). At this moment financing also plays an important role in terms of the willingness to implement circularity in the construction industry. The increased complexity of circular projects increases the costs, which tends to demotivate companies to apply circularity (Lica, 2019).

In addition, there is a large quantity of literature highlighting the importance of collaborations for implementing the circular economy. However, there are few, if any, platforms that facilitate these collaborations (Çimen, 2021). Secondly, the literature does not discuss these collaborations in depth (Koolwijk et al., 2018). The architecture, engineering and construction (AEC) industry has generally been highly conservative. This is because collaborations in the construction industry are defined by power, which makes it difficult to implement changes (Kooter et al, 2021). The complicated part about collaborations within the AEC industry is that these collaborations are for the short-term. This is because these collaborations are often only during a specific project. During this period of collaboration, there is often intensive collaboration. However, collaborations within the AEC industry are important because it is not possible for companies to do the whole lifecycle of a project on their own (Han et al., 2018).

This thesis will investigate the relationship between collaborations and innovation in the circular construction sector. Are more or other kinds of collaborations needed to implement innovative circularity in the construction sector, or does collaboration act as a barrier to innovation, as concluded by the report of the Planbureau voor de Leefomgeving (2019)?

2.2 Problem Statement

The circular economy makes the construction industry more complex (Çimen, 2021) and more costly (Lica, 2019). According to the Planbureau voor de Leefomgeving (2019), more innovation is necessary within the circular economy, as only 2% of circular initiatives are innovative. They also state that collaboration acts as a barrier to applying circular innovations. However, it is often mentioned in the literature that increased collaboration in the construction sector will be beneficial for the implementation of the circular economy (Çimen, 2021). On the other hand, Koolwijk et al. (2018) have noted that collaborations in the circular construction sector are rarely examined in-depth. Therefore, exploring collaborations in the circular construction sector in greater detail is essential. Finally, the construction industry is very conservative, which is not beneficial for the process of normalising the implementation of innovation of circularity in the construction sector (Kooter et al., 2021). These different perspectives create a gap in the literature. To address this gap, this thesis examines whether collaboration is beneficial or disadvantageous for the advancement of innovation of circular construction practices.

2.3 Societal and Scientific Relevance

This research carries substantial societal relevance due to its potential to drive the transition towards a more circular economy. The adoption of circular practices is vital for environmental sustainability and the conservation of raw material resources. The construction industry, which stands as one of Europe's largest consumers of energy and materials, also significantly contributes to waste generation. As a result, the implementation of the circular economy in the construction industry can make a significant difference in terms of climate, biodiversity, and pollution. However, according to Het Planbureau voor Leefomgeving (2019), there is insufficient innovation in the circular economy. Therefore, by examining the relationship between collaboration and innovation in the circular construction sector, this research provides insights that can potentially enhance innovation in the circular construction sector. Moreover, the research aligns with the global call for sustainable development, emphasizing the

significance of such research in addressing environmental challenges and fostering a more sustainable world (Waarom een circulaire economie, 2016).

From a scientific perspective, this research advances the understanding of the intricate dynamics between collaboration and innovation within the circular construction sector. By exploring this relationship, the study contributes to closing existing gaps in the knowledge regarding collaborations and innovation in the context of circularity in the construction sector. It not only expands the academic comprehension of the key drivers and challenges associated with fostering innovation within the circular construction industry but also provides nuanced insights into the unique role of collaborations. This scientific relevance extends to various domains, including construction management, innovation studies, and sustainable development. The findings of this research will be valuable for scholars, policymakers, and industry practitioners in comprehending and navigating the complexities of fostering a circular construction industry.

Moreover, the scientific relevance of this research carries practical implications. It can guide governments and funding bodies in making informed decisions regarding where to allocate resources and investments to drive circular innovations effectively. Understanding the specific areas in which collaborations are most impactful for innovation within the construction sector can help public and private sectors strategize resource allocation, aiming to promote innovation aligned with circular principles.

3 | Research questions

3. Research questions

Main question

What is the relationship between collaboration and innovation in the circular construction sector?

Sub-questions

RQ1: What kind of innovations are there in the circular construction sector?
RQ2: What are the different elements of collaboration in the circular construction sector?
RQ3: What are the factors that drive and prevent collaborations in the innovation of the circular construction sector?
RQ4: Who are the stakeholders with whom collaboration should be established to facilitate innovation in the circular construction sector?

3.1 Conceptual framework

Figure 3 illustrates the conceptual framework of this thesis. It is bifurcated into two primary concepts: Collaboration and Innovation, both of which fall within the circular construction sector. RQ1 will be addressed through the right side of the framework, while RQ2 will be addressed through the left side. Next, RQ3 will be addressed by examining both innovation and collaborations in the circular construction economy. RQ4 will be addressed by examining the relationship between collaborations and innovation, as it constitutes a part of the collaboration elements. The main research question will be answered by interlinking RQ1 and RQ2, in combination with RQ4.

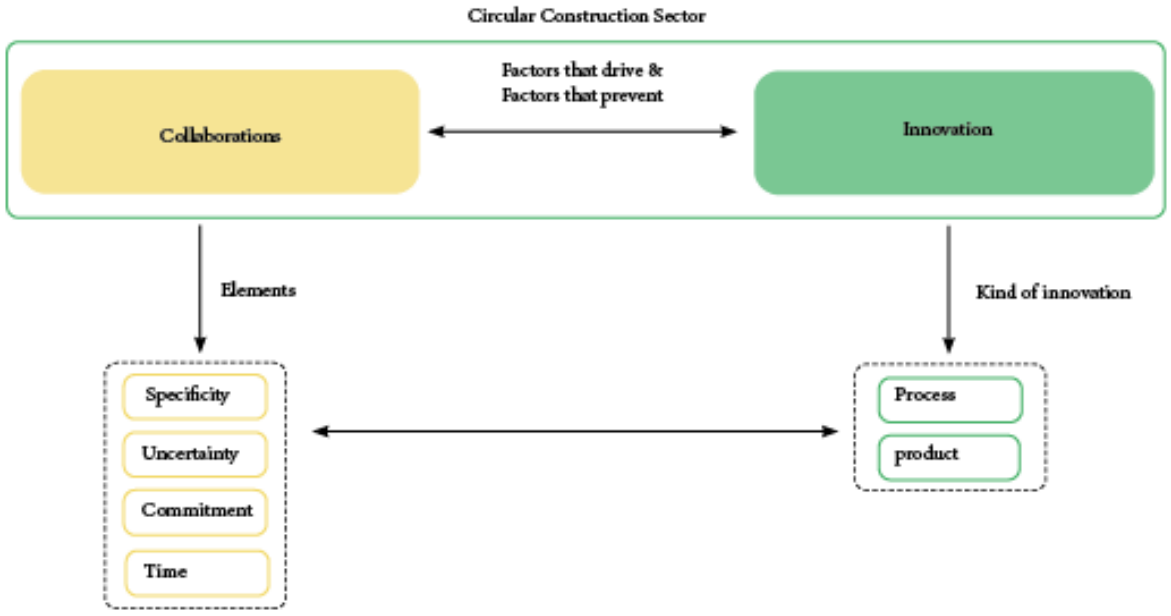

Figure 3. Conceptual framework (own elaboration, 2023).

4 | Literature study

4. Literature study

The literature study is divided into four chapters. The first chapter provides a more in-depth discussion of innovation. The second chapter gives an overview of how collaborations are discussed in relevant literature. In the third chapter literature on the circular construction sector is reviewed. The fourth chapter presents a literature synthesis that creates an analytical framework comparing companies that develop innovations internally, and companies that do so externally.

4.1 Innovation

4.1.1 What is innovation?

Innovation is stimulated by knowledge to create new products and processes. Product innovation is when a new good or quality of good is introduced which an external user or market is not yet familiar with (Damanpour & Gopalakrishnan, 2001; Hage & Meeus, 2006). Process innovation involves the implementation of new elements that have not been previously tried within a specific industry to manufacture a product or deliver a service (Damanpour & Gopalakrishnan, 2001; Hage & Meeus, 2006). In turn, knowledge is important for a company's competitiveness. Often, competitive companies are looking for new knowledge and also want to retain this knowledge. Innovation occurs when different types of knowledge are converted into value. Innovation is not only seen as a way to generate economic value but also as a means to qualitatively improve processes and promote the well-being of the people in the larger ecosystem. Scholarship in the field of knowledge management has increasingly come to recognize the importance of descriptive, conceptual, and common-sense knowledge for driving business innovation (Pinto et al., 2023).

Innovation happens when entrepreneurs and established organisations develop and launch new technology-based products and processes. New outputs in the form of new goods, new quality goods, new sources of supply or new markets are created by innovation. However, innovation is sometimes also seen as social changes rather than technological changes (Pinto et al., 2023). In other words, Innovation is driven by sources of knowledge that are both technological and economic. This can incorporate the formation of new processes, products, services, and various organizational and social practices. For these sources to be embraced, there must be a specific level of cultural openness, social networks, capabilities, and organizational structures in place. These components are the basis for the acknowledgement and usage of information sources, both inside and outside the business (Pinto et al., 2023).

Size is also an important factor in innovation. Often small firms are more effective when it comes to innovation than larger firms. Studies showed that smaller firms relatively tend to invest more in product innovation, while large firms tend to invest more in process innovation. Innovation is internal when it emerges from in-house research. Innovation is external when it emerges from technical literature, existing patents, customers and parent firms or cooperative research. Firms often use internal aspects as the main source for knowledge and innovation, even though there frequently is a balance between internal and external aspects (Pinto et al., 2023).

Technology intensity is an important concept for innovation in companies. It refers to the level of knowledge incorporated in firms' products. Technological intensity plays a fundamental role in the competitive and innovation opportunities at which a firm assimilates and applies innovation. High-technology-intensive companies also tend to have more innovation (Pinto et al., 2023).

Sharing knowledge promotes growth. Sharing this knowledge ensures that technology advances faster. However, it is not yet clear whether openness ensures increased performance. There is still a lack of clarity in the literature as to whether external knowledge

plays a major role in fostering innovation, or whether the knowledge for innovation should mainly be acquired internally. Although it is known that human capital and skills are major factors for success when it comes to innovation and economic performance (Pinto et al., 2023), there is no general way to apply innovation within a company. Different factors such as age, size, resources and capabilities affect how a company should apply and create innovation (Schmitt et al., 2018).

4.1.2 Innovation in AEC

Investigating innovation internally ensures the exploitation of innovation combinations. When working externally, this ensures more innovation in the industry as a whole. The research by Han et al. (2018) shows that state-owned enterprises and universities are the bodies that promote innovation within the AEC industry. Universities have the most influence when it comes to implementing and spreading innovation (Han et al., 2018).

Furthermore, applying innovation in the circular construction sector is highly complex. This complexity stems from the inherent intricacies of the traditional construction process, which involves multiple actions in a complex sequence. The success of a project relies on all participants understanding the intricacies of the traditional construction process and knowing what is expected of them. When innovation is introduced, it transforms this familiar situation (the traditional approach), necessitating the acquisition of new knowledge and skills to bring the project to a good end (Davidson, 2013).

According to Pries and Dorée (2005), the construction industry remains inward-looking, often failing to failing to acknowledge societal as well as customer need. Furthermore, it becomes evident that governments play an important role in promoting innovation through new regulations. Since 1975, approximately 40% of all innovations in the Dutch construction sector have been attributed to the introduction of new regulations.

It should be considered that innovation in the construction industry can be categorized into two types (Davidson, 2013):

> Type 1: Innovations that affect a single stakeholder.
>
> Type 2: Innovations that affect multiple stakeholders, including those beyond the sphere of the original innovator.

The first type of innovation follows the conventional innovation path and is relatively straightforward. In contrast, Type 2 innovation is more complex and requires a systemic approach for implementation. In the conventional innovation path, the focus is on the internal structure and strategy of an organization. In the construction industry, the presence of multiple stakeholders involved in a project results in a multi-organizational context. Additionally, the construction industry lacks continuity due to its project-based nature. As a result, when implementing innovation in the construction sector, a systemic approach becomes necessary. This systemic approach is associated with major innovations. When considering Type 2 innovation in construction, a re-engineering of the entire construction process is required, involving all participants in the project, either explicitly or implicitly (Davidson, 2013).

4.1.3 Innovation in circularity

Other than recycling, innovative circular initiatives are rare, and there are few innovative collaborations within the circular economy. Generally, circular initiatives are developed internally, and companies work on changing their business model rather than collaborating or aligning with other parties (such as suppliers or customers). According to Het Planbureau voor de Leefomgeving (2019), cooperation between companies in setting up new supply chains is seen as a barrier to circular initiatives. When attempts do take place to create a supply chain around a circular product, this often involves problems such as differences in culture, difficult communication and diverging interests. In addition, different levels of ambition could cause friction within the cooperation. Creating new collaborations within industry organisations is tricky. These parties often focus on traditional collaborations and are not open to new ones. This means it takes a lot of time and effort to convince them, which slows down initiatives (Planbureau voor de Leefomgeving, 2019).

It is also more difficult for investors and governments to work with (new) production chains rather than individual companies. Banks, for instance, are used to finance individual parts of production chains. In a chain cooperation, investments in one company can lead to savings in other companies. This makes it difficult for investors to assess how to deal with risk sharing and joint investments (Planbureau voor de Leefomgeving, 2019).

4.1.4 Collaboration and innovation

Collaborative innovation occurs when organisations collaborate with other organisations to develop or commercialise a joint innovation. This is achieved by the different parties sharing resources, information and knowledge to develop that project. After the project ends, the different parties remain independent (Vivona et al., 2022).

The literature focuses on the fact that external collaborations together with internal knowledge provide the enhancement of innovation within a company. External collaborations allow access to more collaborations, however, there are still doubts about the influences of external collaborations on innovation. External collaborations entail additional costs. Research by Gkypali et al. (2017) shows that investing in internal research and development (R&D) has a positive effect on companies' innovation performance. The research also showed that a diversity of R&D collaborations has an indirect negative effect on innovation performance. In other words, taking over knowledge from external collaborations is a difficult and inefficient process, because it is often difficult for companies to manage, absorb, store and (re)use knowledge (Gkypali et al., 2017). However, it should be noted that this research is based on companies in Greece, which are often not financially stable.

4.1.5 Costs of Collaborative Innovation

inter-organisational collaborations can in some cases be detrimental to companies. This is because collaborations can involve large costs. Collaborations cost money, time and resources. This can mean that when collaborations are established to innovate, they result in minimal returns. It is difficult to calculate these costs. This is because the nature of innovation activities is uncertain, making it difficult for organisations to fully calculate the costs (risks) and benefits of innovation (Vivona et al., 2022). These costs mainly arise from searching, coordinating, managing and exchanging knowledge. It should therefore always be carefully weighed up whether it is worth incurring these costs in contrast to the gained knowledge. These costs can increase even more when management mechanisms have to be applied so that innovations do not leak out to other partners (Gkypali et al., 2017). When a collaboration is done systematically, it can cause collaboration costs to drop. When cooperation collaboration costs are too high, it could still be advantageous to enter into the cooperation, as the collaboration costs will decrease over time (Gkypali et al., 2017). However, it should be noted

that in certain sectors such as the AEC industry repeating collaborations could reduce innovation (Han et al., 2018).

4.1.6 Costs of circularity

Applying circularity often has cost barriers. This is because using virgin materials is often cheaper than using circular materials (Guldmann et al., 2020, Hart et al., 2019). Secondly, there are also high upfront investment costs, which currently cause organisations to wait for others to invest in circular knowledge, to adopt this knowledge (Kirchherr et al., 2018, Hart et al., 2019). Other financial barriers are the poor business case and unconvincing case studies. Often the case studies used to recount information are poorly articulated and poorly explained (Hart et al., 2019). Finally, there is limited funding for circularity within the construction industry (Hart et al., 2019).

4.2 Role of collaborations

4.2.1 What is collaboration?

Generally, collaboration is seen as 'working together' (Longoria, 2005). However, collaboration is a diverse concept that is difficult to explain. Most theories do agree that collaboration occurs when two or more stakeholders have a relationship together where they interact with shared rules, norms and structures. Stakeholders can include individuals, groups, organisations or entire societies (Longoria, 2005). The goal of collaboration is to obtain better outcomes for both parties than what is achievable separately for each party. (Brown et al., 2018). In addition, the relationship has to include a bounded structure with systems properties (Longoria, 2005). The benefits of collaboration arise when different parties have different perspectives, knowledge, capabilities and problem-solving approaches. This creates more and different ideas for innovation, value creation and engagement of different markets. However, a few requirements need to be met during collaboration for a positive outcome. Generating trust is what makes collaborations complex. Trust depends on many different factors, such as communication, actions and behaviours between the different parties. Also, there must be an agreement on vision, organisational identity business relationship management strategy and capabilities (Brown et al., 2018).

4.2.2 Alignment of interests

Alignment of interests and behaviour between organisations are two key factors on which collaborative relationships depend. There are also several factors on which partner selection and interest alignment depend. These are factors such as the partner's place in the supply chain, capacity to be influential and their negotiation power, physical proximity and location. Partner trust and commitment are influenced by the degree of alignment between the perspective of economic values and partner judgement. However, power asymmetry can prevent trust from being built in the relationship. Power asymmetry depends on the position that companies have in the supply chain. Organisations often use their power for their benefit, which decreases the ability to jointly solve problems with other organisations (Berardi & Brito, 2021).

An important aspect of collaboration is the ability to share. This involves developing a joint solution and complementary resources between organizations, which can be achieved through the sharing of information and knowledge by the collaborating agencies. However, there is the possibility of opportunism by focusing on power asymmetry and alignment of interests. This can compromise partners' ability to work together. In practice collaborations of this type are uncommon (Berardi & Brito, 2021).

4.2.3 Inter-organisational collaboration

Generally, collaborations between companies are perceived to be positive. Inter-organisational collaborations arise when there are collaborations between different organisations (Longoria, 2005). These relationships are often beneficial because they allow businesses to share resources and maximize efficiency. This creates more aggregate knowledge which in turn creates more innovation. Inter-organizational relationships also create new growth opportunities, create networks for new ideas, and develop strong partnerships that can help an organization succeed (Klessova et al., 2020).

Inter-organisational collaboration is often encouraged because of its potential benefits, however, they are not always efficient. Inter-organisational relationships can lead to fiscal waste and inefficiency (Longoria, 2005). The behaviour of individuals during collaborations can fail due to tension, ill-intended behaviours, opportunistic behaviour and unethical practices. Another common disadvantage of collaborations within sustainable development is interpersonal conflicts. Examples include unwillingness to compromise, unrealistic expectations, other values and goals, inability to cooperate and not willing to understand others (Escher et al., 2020).

There are several factors contributing to effective inter-organizational collaboration. These elements encompass members of collaboration, time considerations, available resources, and the nature of the collaboration itself.

Inter-organizational collaboration entails the participation of two or more independent *members* (Schreijer, 2020). It is important that these members exhibit commitment, possess expertise, and have access to information and resources. Furthermore, it is essential for each member to be individually engaged and personally devoted to resolving the issue at hand (Schreijer, 2020). There is no definitive optimal number of members for fostering effective collaboration. The foremost consideration is that these members possess the capability to address and resolve the issue or provide the necessary resources for its resolution. Criteria of significance in selecting members for a productive collaboration include commitment, a willingness to engage in early discussions, openness to novel information and ideas, and a disposition that values listening, communication, and collaboration. Additionally, it is important that the organizations to which these members belong extend their support in terms of time, effort, commitment, and the implementation of decisions. Members' interest and capacity to participate in the collaboration are of paramount importance (Greer, 2017).

Secondly, *time* represents another critical aspect of successful collaboration. Collaborative attempts are time-consuming since they necessitate the establishment of communication practices, the cultivation of relationships, and the delineation of processes. The most substantial challenge encountered in effective collaboration is the time and effort required by members for discussions, definitions, construction, and the implementation of all requisite elements for collaboration. Collaborations are characterized by temporary, delicate structures. Consequently, time constraints can impede efficiency in collaboration or lead to its termination. Longer durations of collaboration yield enhanced effectiveness owing to increased participation (Greer, 2017). Extended periods of collaboration among parties result in clearer roles and objectives, thereby promoting stability in collaboration (Schreijer, 2020).

Thirdly, *resources* are of paramount importance for successful collaboration. Resources manifest in various forms, including funding, time allocation, support from home organizations, competencies, and expertise to facilitate desired outcomes. Through collaboration, resources can be identified, exploited and distributed as shared resources. The sharing of resources plays a crucial role in providing legitimacy and equitable outcomes as perceived by stakeholders (Greer, 2017). Parties involved possess diverse resources related to a shared

issue or topic but are mutually reliant on each other for the resources possessed by the other (Schreijer, 2020).

Lastly, various *forms of collaboration* exist. Diverse collaboration methods can be categorized into the following collaboration types: vertical collaboration, encompassing collaboration channels with customers and suppliers; horizontal collaboration, involving collaboration with competitors of the focused enterprise; partnerships with public R&D entities, comprising universities and government research organizations, and; engagement with consulting firms and other private R&D entities. These collaborations also vary in terms of their intensity (Greco et al., 2020).

4.2.4 Collaboration in AEC

AEC are short-term and have a period of high collaboration. There is increasing demand for larger and more complex AEC projects. This is due to the high demand for more urban inhabitants, but also, for instance, due to the rise of circularity (Han et al., 2018). AEC projects therefore call for many collaborations with specialised expertise. Also, better coordination between the owner, engineers, architects, contractors and stakeholders is needed throughout the project life cycle. Another reason why collaboration is important during AEC projects is because an organisation cannot carry out the entire project lifecycle on its own (Han et al., 2018).

Even though the construction industry is very conservative and not open to change, we have seen more efforts in recent years to apply more technology and circular applications due to the growing demand for more urban environments (Han et al., 2018).

4.2.5 Supply chain

Nowadays, companies want to be flexible and responsive to be prepared for changing market demands. To achieve this, many companies have started decentralising their value-adding activities. This is done with the help of outsourcing services. As a result, integrating suppliers and partnering firms into supply chains becomes even more important (Gunasekaran, 2004). Collaborations are viewed as the drive within successful supply chain management (Min et al., 2005). For this thesis, Huo's (2012) definition of supply chain management is used:

The degree to which a focal company strategically collaborates with its supply chain partners and collaboratively manages intra- and inter-organizational processes.

Several studies are showing that supply chain integration (SCI) has performance improvement in terms of customer service, operations, finance and profits. However, this can vary greatly depending on business conditions. SCI should therefore be implemented in different ways in different industrial contexts (Eriksson, 2015). SCI can be applied to two different types of industries. In manufacturing industries, where continuous exchanges take place or project-based, where discontinuous exchanges take place. Supply chain integration is especially challenging when it is on a project basis. This is because it is a discontinuous demand, which ensures that projects are unique in terms of technology and financing (Eriksson, 2015). There is uncertain demand and the suppliers are highly specialised but interdependent. As a result, buyers often assume competitive tendering, keeping the project costs as low as possible. However, this creates a disjointed supply chain (Eriksson, 2015). The AEC industry is considered a project-based industry (Han et al., 2018).

The life cycle of successful products is divided into four different stages. These can be seen in figure 4.

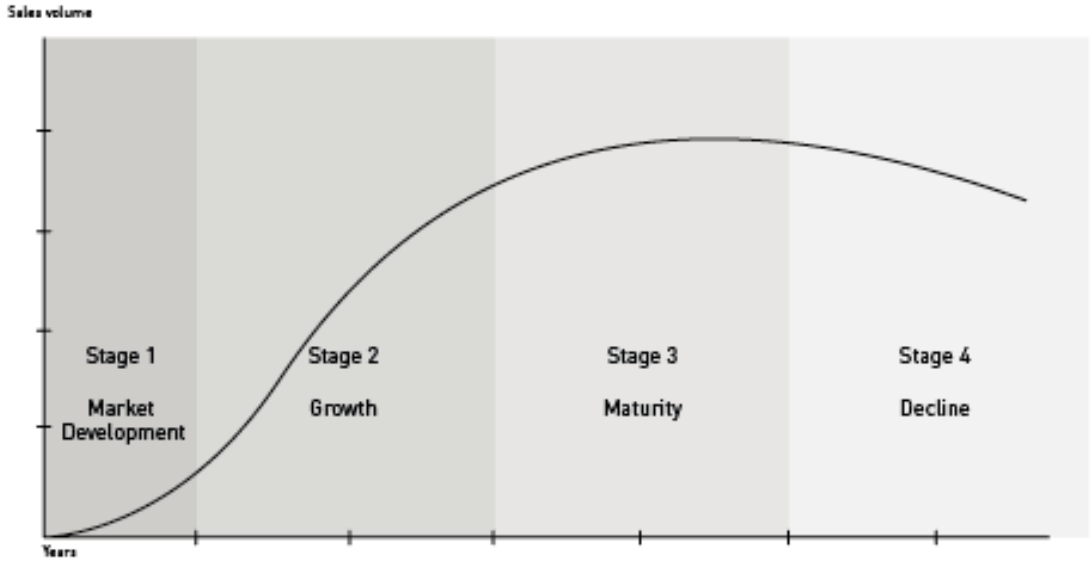

Figure 4, Product life cycle (Levitt, 1965)

The different stages consist of market development, growth, maturity and decline. These take place in chronological order. The speed at which each product moves through this cycle depends on market demand and the marketing tools used, among other things. The duration of each stage also varies greatly from product to product (Levitt, 1965).

Stage 1. Market Development
The first stage is the market development, which involves a new product that has just entered the market. Sales of the product are still very slow at this stage, but there is an increase in sales. Bringing a new product to the market is often uncertain and linked to many unknowns. Often the demand for a product has to be created, however, this varies greatly from product to product (Levitt, 1965).

Stage 2. Market Growth
At this stage, demand for the product starts to grow strongly and the market for the product increases rapidly. This is also the point where competition arises, and others put the same or similar product on the market. A battle for the consumer then ensues. All brands then do their best so that consumers prefer their brand. However, at some point, brands will lag in technology and therefore offer cheaper prices (Levitt, 1965).

Stage 3. Market Maturity
During this stage, the demand for the product begins to level off. This is the point where market saturation occurs. At this stage, most consumer companies or
households own or use the product. This ensures that the growth of the product parallels the growth of the population (Levitt, 1965).

Stage 4. Market Decline
In this stage, demand for the product begins to decline. As demand falls, few companies can overcome competition. Product overcapacity arises and prices and margins are reduced (Levitt, 1965).

4.4 Circular Construction Sector

4.4.1. Implementing the circular economy

The circular economy cannot be achieved by individuals, but can only be obtained with a systemic change in companies, industries and economies. For this change to occur, there must be a major change in societal values, norms, and behaviour (Suchek et al., 2021).

Implementing the circular economy requires changes in the way organisations work. However, changing incumbent organisations is more difficult than has been assumed. This is because the changes involved in implementing the circular economy are perceived as cumbersome and unattractive. However, not implementing the circular economy within organisations also has risks, due to changes in the public discourse and through competition that may arise when other companies do adopt circularity. As mentioned before, implementing a circular economy can often have less attractive financial consequences. In addition, implementing the circular economy is correlated with innovation. Incumbents are often not attracted to innovation, as innovation frequently happens in fringe markets (Kuhlmann et al., 2022). This ensures that innovation within incumbent parties is not often applied. Startups are generally considered more effective for implementing innovation and circular solutions, as they are more flexible (Guldmann et al., 2020). In addition, other reasons are mentioned in the literature as barriers to applying circular economy. For instance, a lack of incentives, resources, knowledge and competencies could also be seen as an obstacle when applying a circular economy (Kuhlmann et al., 2022).

According to Kuhlmann et al. (2022), four aspects hinder the implementation of circular innovation within incumbent companies:

- Cultural barriers: Top managers need to be more culturally open to make decisions about circular innovation. This can be done by a conscious new set-up with its own culture, this can overcome scepticism in an organisation regarding circular innovation (Kuhlmann et al., 2022).

- Changes in competencies: circular innovation frequently has consequences beyond the concerned company. Often it affects the value chain as a whole, and this value chain may require different skills than the company currently possesses. This makes it important that companies think about how they can secure such skills (Kuhlmann et al., 2022).

- Separating organisational structure: separating the structure in organisations allows multiple cultures and identities to emerge within a company. This allows companies to evaluate which competencies are needed to implement circular innovations. It also allows competencies to be reconfigured to remain competitive in a circular future (Kuhlmann et al.,2022).

- lack of a deliberate innovation strategy: by having a deliberate innovation strategy, ambitions to apply circularity can be encouraged (Kuhlmann et al.,2022).

4.4.2 Circular Construction Economy

As mentioned above CE is obtaining more attention, but the circular economy for the construction sector is lacking. On the side of the construction sector, the focus has been more on problems like energy use and energy efficiency. In 2010 buildings were responsible for one-third of the global energy use, but on the other side, the construction industry is responsible for consuming 40% of the raw materials. And only 20% to 30% of these materials are being

recycled or reused. In other words, there is a huge need to implement more CE in the construction sector. CE offers an important step in the construction industry to create more financial, social and environmental value. Using circular interventions, the impact of constructions on the environment can be significantly reduced (Leising et al., 2018).

There are different barriers to the implementation of CE in the construction sector. The government has a big role in the implementation of CE in countries. This is because of the upfront costs that are needed to implement CE (Bilal et al., 2020) In addition, there are also many barriers for companies themselves to apply CE, such as the lack of awareness, higher costs when CE is applied and often little attention to the end-of-life phase (Bilal et al., 2020).

Another problem that comes with implementing CE on the construction level is that buildings are generally one-off projects. Buildings are complex projects, where each material used has its specific life cycle. Secondly, buildings are often designed to have a long life cycle and the whole life cycle is often not known during the initial phase. The average lifespan of a building is between 60 and 90 years (Pomponi & Moncaster, 2017). Buildings often change function during their life cycle or are modified and renovated at some point. This also brings uncertainties about what might happen to the materials in the future. The CE currently focuses mainly on products with a short life cycle and not on the complexity and longevity of buildings (Pomponi & Moncaster, 2017).

Furthermore, we observe that the circular economy in construction often remains stuck in pilot projects. New circular products are indeed implemented, but they don't scale up to a larger extent (Billé, 2010).

According to Pomponi and Moncaster (2017), It is necessary to combine different disciplines to implement CE at the building level as can be seen in the framework in Figure 5.

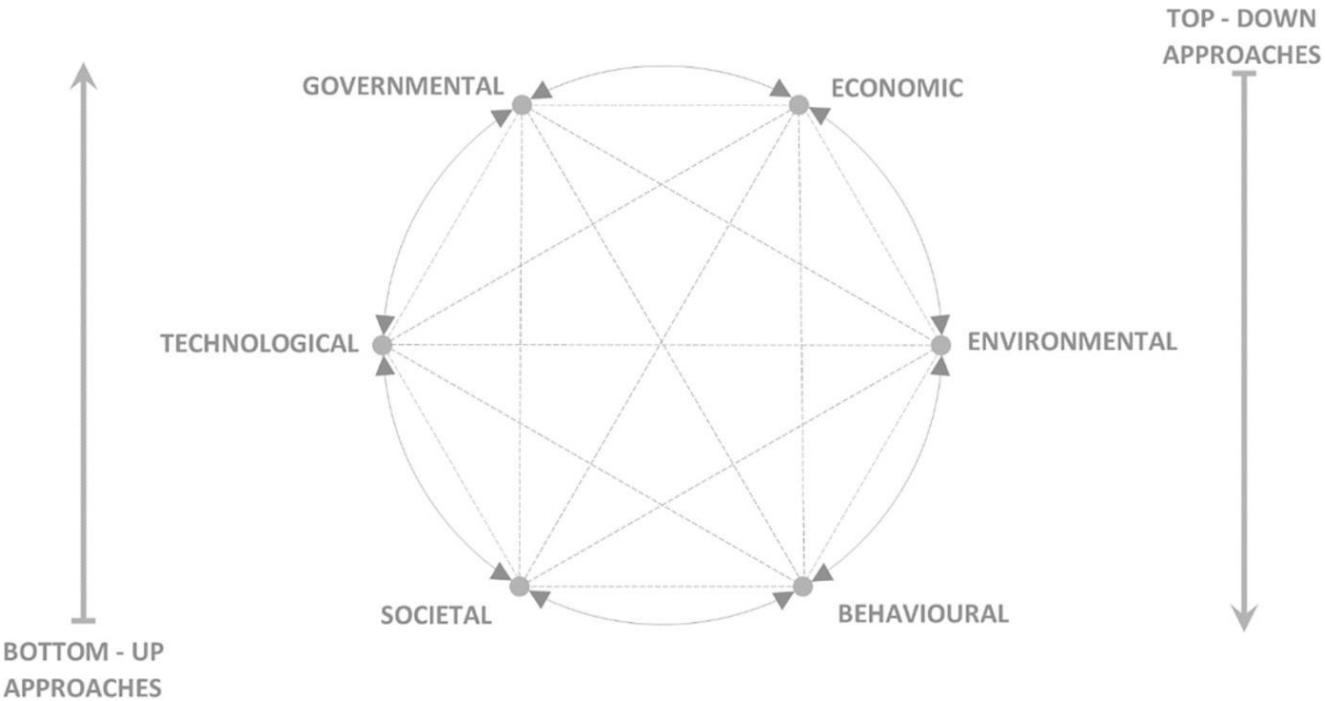

Figure 5. different disciplines in the CE (Pomponi, Moncaster 2017)

The arrows show the connections between the different components. Here, the cooperation between the different pillars is important. The bottom-up approaches and the top-down

approaches represent the impact of innovation and progressive public policies. Both of these are equally important. All the six pillars will be discussed below.

Governmental
There is a high demand for government policy for implementing CE in the built environment. An example is the steel industry. The price of steel is currently so low that it is not profitable to reuse it. It is therefore important to make national policy, for example, implementing tax breaks for reusing materials. This will encourage the reuse of materials since they become financially viable this way (Pomponi and Moncaster, 2017).

Economic dimension
There is a demand to reshape the ownership model to develop a new thinking framework for profitability. Currently, people often choose the lowest-price bid. However, it is better to work with cooperation models between all contractors involved. This way, there is more honesty about information and therefore more feedback, which promotes EC (Pomponi & Moncaster, 2017).

Environmental dimensions
All environmental indicators must be taken into account. At the moment energy and carbon are the main indicators that are considered. This may cause other environmental indicators to be overlooked (Pomponi & Moncaster, 2017).

Behavioural dimension
People's behaviour towards the CE will have to change to make it more accessible. People have an aesthetic appeal and often choose the new option. However, we also see differences in material and more research will need to be done on this (Pomponi & Moncaster, 2017).

Societal dimensions
The societal aspect is very important in the CE. A CE requires various partnerships and collaborations. Networks need to be created to share recycled materials. Education also plays an important role, as new ways of designing and building need to be taught (Pomponi & Moncaster, 2017).

Technological dimension
Technology plays an important role in enabling the CE. This is because supply and demand need to be matched. This requires processing a large amount of data. In addition, technology also plays a big role in innovations in the CE (Pomponi & Moncaster, 2017).

4.4.3. Construction sector

Demolition

Constructing a building produces waste throughout its entire life cycle. During this end-of-life stage, construction and demolition waste (CDW) is produced. CDW creates the largest waste stream worldwide, so it has a major environmental impact. As can be seen in figure 6 CDW has a large contribution to the composition of solid waste (Ruiz, Ramón, Domingo, 2020).

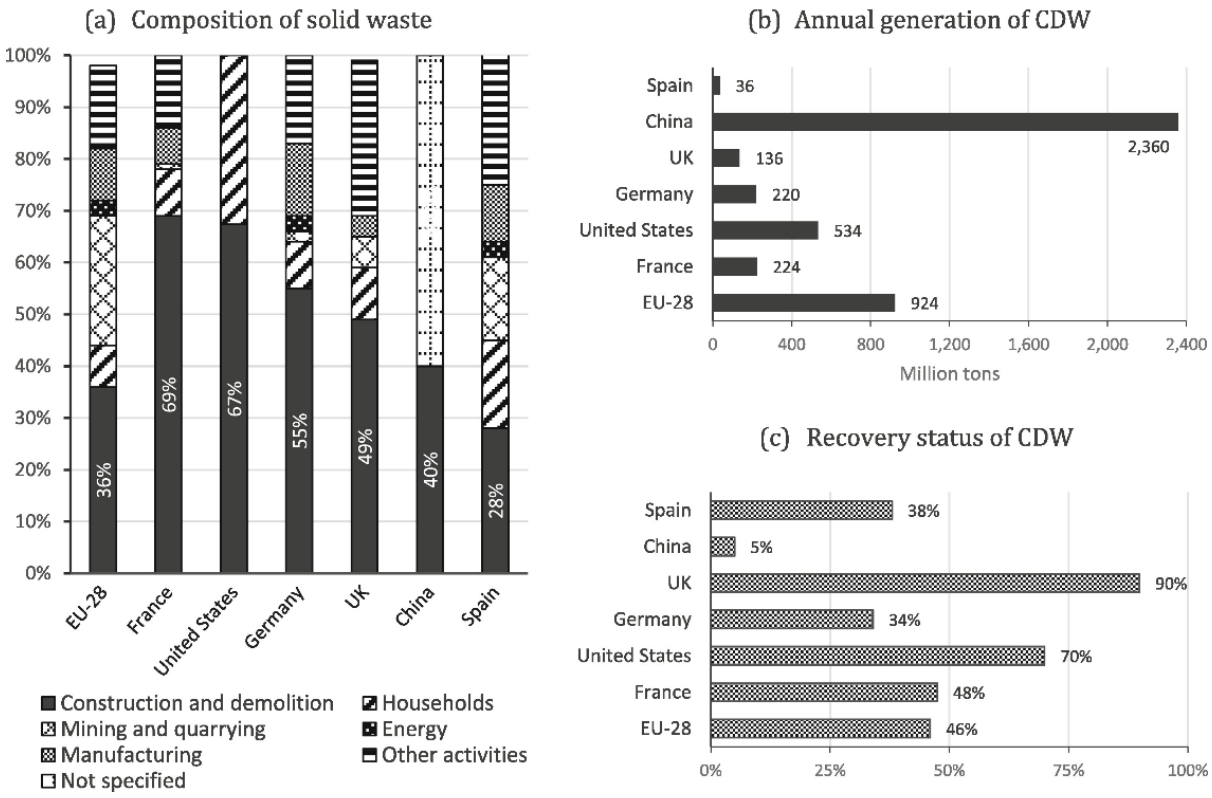

Figure 6. Construction and demolition waste (Ruiz, Ramón, Domingo, 2020)

Related negative environmental effects due to the CDW are:

- Land degradation
- Landfill depletion
- Carbon and greenhouse gas emissions
- water pollution
- high energy consumption
- resource depletion

There is a growing interest in recycling the CDW. However, the extent to which this happens varies greatly per country. As shown in figure 6, the recovery status of the CDW varies from 90% in the UK to 5% in China. The global average for this is only between 20% and 30% (Ruiz, Ramón, Domingo, 2020).

The solution to reducing CDW is to apply the circular economy in the construction industry. However, major changes are needed to apply this, and it is therefore a big challenge (Ruiz et al., 2020).

Procurement

To understand what circular procurement is, it is first necessary to explain what procurement is. According to Chao-duivis et al. (2018) procurement is:

The process leading up to the award and conclusion of the contract. Procurement law deals with how a public body selects a party with whom it wants to enter into a contract.

Circular procurement is about purchasing products or services that contribute to closing the energy and material loop within supply chains. This helps reduce negative impacts on the environment. However, circular procurement is linked to many activities, such as design, procurement, production, logistics, use, reuse and waste of companies. Therefore, economic,

environmental and social impacts must also be taken into account in circular procurement (Sprakel, 2022). By applying CE procurement, the principles of price, quality, time and value for money will change (Farooque, 2019).

Managing Inter-organisational relationships is an important factor when implementing circular procurement. Here, the strategies for engaging suppliers are very important. A change from control and compliance activities to development and cooperation activities is then required from the suppliers (Meehan & Bryde, 2011).

Construction

There is an increasing focus on the circular economy at the city level. Cities like Paris, London and Amsterdam are examples of cities with great ambitions in terms of circular economy policy. In this context, the built environment plays a significant role in both the consumption of virgin materials and the generation of waste in cities. (Van den Berghe, 2021). To achieve a successful circular city, it is necessary that the entire supply chain, including production, consumption, and waste management, is reconfigured into a circular system. This is not only about matching the demand for materials, but also the remanufacturing of these materials must be taken into account. In an ideal world, the demand and supply should match perfectly. In practice, there is often a time gap between supply and demand, and materials may need to be stored temporarily before reuse. One solution is to create material hubs, which serve as temporary storage facilities for recovered materials (Van den Berghe, 2021). However, a significant challenge to material reuse is that materials from demolished buildings typically require modification or even complete remanufacturing, of such as metal and concrete components. (Van den Berghe, 2021).

Circular supply chain

When waste is reused, the output also becomes the input, creating a circular material flow. As a result, the production or construction chain transforms into a re-supply chain. The difference between a circular and linear supply chain is that in a circular chain, a location can act as the supply of materials at one moment and as the demand for materials at another moment, thus creating a circle and a circular chain (Van den Berghe, 2021). It is even possible for a location to be both the supply and demand at the same time, as is the case when renovating a construction. Reusing materials on a one-to-one basis is often challenging due to fitting and time constraints. To address this issue, experiments with circular material hubs are being conducted, providing temporary storage for materials. Nevertheless, the problem of fitting materials persists, as these hubs cannot frequently adapt materials (Van den Berghe, 2021).

4.5 Conclusion

A lot of information has been obtained from the literature that has been discussed in the previous sections. Here it is noted that there are many contradictions within the literature regarding innovation, circularity and collaborations.

Innovating circular projects is necessary as there currently is little innovation and circularity is mainly stuck with recycling (Planbureau voor de Leefomgeving, 2019). However, inter-organisational collaborations have been found to have a negative effect on innovation performance (Gkypali et al., 2017). Collaborations cost money, time and resources. This can mean that when collaborations are established with the goal of innovation, they result in minimal returns (Vivona et al., 2022).

On the other hand, when a collaboration is effective it leads to knowledge and knowledge in turn leads to more innovation (Klessova et al., 2020). However, inter-organisational collaborations can also be detrimental to a company. The reason is usually the behaviour of individuals due to tension, ill-intended behaviours, opportunistic behaviour and unethical

practices (Escher et al., 2020). However, AEC projects do require many inter-organisational collaborations. Especially as projects become increasingly complex, more parties are involved (Han et al., 2018).

In addition, collaborations are viewed as the driver of successful supply chain management (Min et al., 2005). However, supply chain integration is challenging when it comes to project-based work, such as AEC projects (Eriksson, 2015). It is also challenging to create a supply chain around circular projects. This is because problems often arise around differences in culture, difficult communication and diverging interests. Furthermore, different levels of ambition could cause friction within the cooperation (Planbureau voor de Leefomgeving, 2019).

To conclude, effective inter-organisational collaborations lead to more knowledge and more knowledge leads to more innovation. However, when these collaborations are not effective they can have a negative effect on innovation and therefore also on innovation within circularity. This is especially the case when the supply chain is project-based, which is generally the case in AEC projects (Eriksson, 2015). Yet, it is not possible to state that for more innovation within the circular construction economy, it is better not to have collaborations. This is because the construction economy is so complex that companies are incapable of carrying out projects without at least some collaboration (Han et al., 2018). In addition, the circular economy is about closing loops and buildings often change functions during the life cycle, which creates uncertainties about what to do with the materials in the future. Buildings have a life span between 60 and 90 years (Pomponi & Moncaster, 2017). On the other hand, the average life span of a business in 2023 is 19.1 years (Statista, 2021). In addition to the large number of specialisations that are necessary within companies, most companies will therefore not be around anymore to reuse their product and close the loop.

4.6 Analytical framework

As mentioned above, there are doubts about the benefits of engaging in collaborations for innovative circular construction projects In other words, there is uncertainty within companies about doing services internally or externally. In this case, external is linked to collaborations and internal services to no collaborations and working in-house. The section below will elaborate on how the analytical framework is set up. Filling in the case study quotes within this framework will allow conclusions to be drawn regarding the relationship between innovation and collaborations.

When an internal business strategy is adopted, as many services as possible are performed by the company itself. When a company's business strategy is external, various services are performed by a third party (Hansen et al., 2020). There are major differences between these two models. Which model is preferable for a company depends on company circumstances, culture and activities in which the company is engaged. It is therefore not possible to apply one model for all companies, and companies can change over time as well. Limited research on circularity and working internal or external has been done, so there is no academic consensus on the topic. Also, research mainly focuses on the manufacturing context and not on services (Hansen et al., 2020).

4.6.1 Internal

Doing processes or product innovation internally means that most of the steps are done within the main company. While there are generally still other suppliers, for example for materials or certain parts, cooperation with other companies is kept at the minimum. When a process is done internally, it facilitates the information flow in a company. In addition, there is more innovation in terms of technology, product and organisational levels (Hansen et al., 2020). Working internally is often found to be a good strategy when there is a lot of uncertainty and

the supplier is expected to have opportunistic behaviour (Sayed et al., 2021). In addition, it is apparent at the product level that internal processes have a higher degree of loop closure within the circular economy. This involves enabling a higher degree of recycling, remanufacturing/refurbishing, reuse, and repair (Hansen et al., 2020). In addition, high-concentration companies are also more likely to adopt a strategy that is internal when it comes to innovation and new concepts. Keeping these processes internal to the company creates a market advantage for the company. This is because this company specialises internally, thus delaying or preventing imitation from other companies (Sayed et al, 2021).

4.6.2 External

Contrary to the working internally, when companies opt for working external, they adopt the services of other companies for certain parts of their business. Companies generally opt for an external strategy for certain functions because the company to whom it is outsourced can often offer a better quality and cheaper service (Doran et al., 2020). An external strategy has many advantages, but also some disadvantages. Its advantages are that experts in certain areas can be accessed and it ensures that internal research does not have to be carried out. Furthermore, it is beneficial for transaction costs. However, if a project is very specific, it can in some cases lead to higher costs. This is because collaboration and working together can create higher costs if it does not happen effectively. In those circumstances, it is better to carry out the process internally. An external strategy may cause innovations within the company to be missed. Secondly, internal skills on the topic that is done externally may be lacking within a company, so the externally created products cannot be properly evaluated for their quality. (Doran et al., 2020).

4.6.3 Analytical framework

Based on the previous literature, the first part of the analytical framework is created (See figure 7). The this framework is divided into two extremes. On the left, this is internal (no collaboration), on the right this is external (collaboration). However, it is important to keep in mind that companies are never fully internal or external (Benam, 2020).

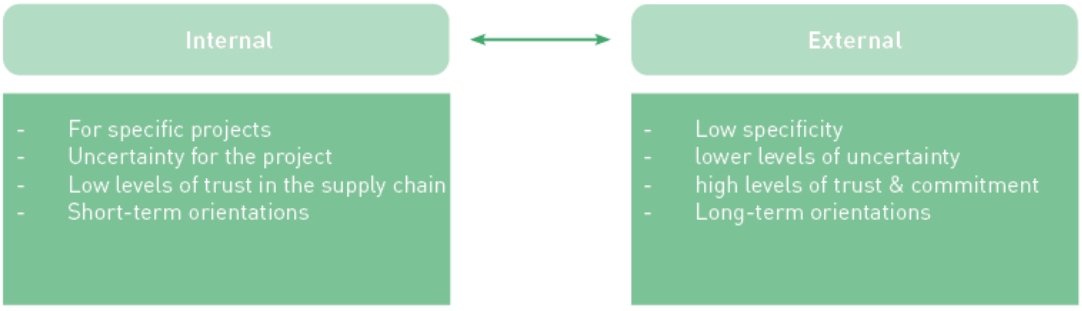

Figure 7. framework Internal and external (Own elaboration)

As the second section of the analytical framework, the innovation component will be incorporated. As previously mentioned, a distinction can be made between process and product innovation (Damanpour & Gopalakrishnan, 2001; Hage & Meeus, 2006). Finally, this will be linked to the various stages in the product life cycle (Levitt, 1965). This stages can be seen in figure 8.

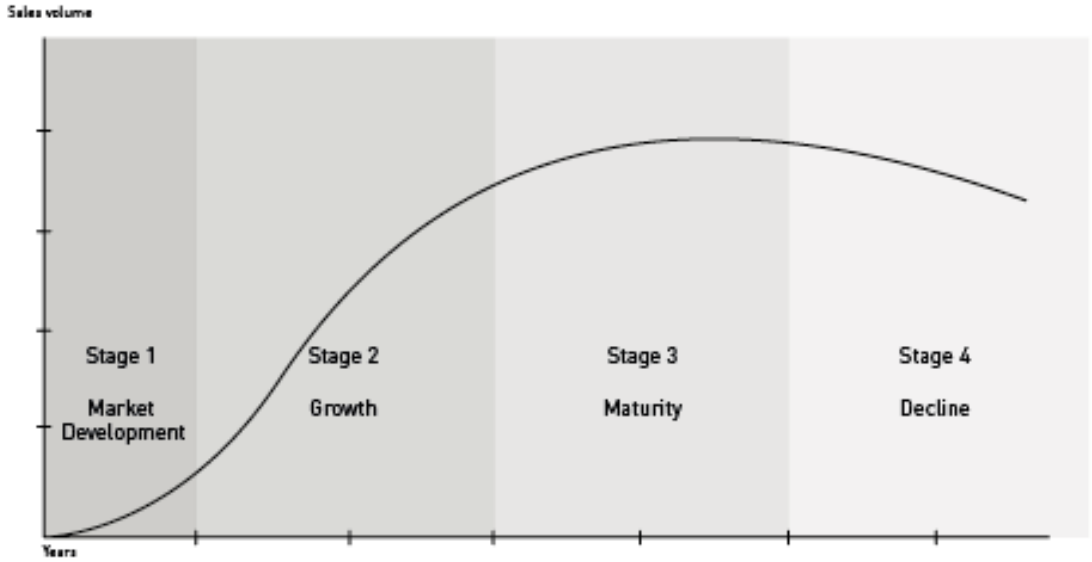

Figure 8 product life cycle (Levitt, 1965)

By consolidating all the preceding information, we can create a table that functions as an analytical framework. This table is illustrated in figure 9 for this thesis, the position of the manufacturing party will be adopted to populate the table. On the vertical axis, the four stages of the product life cycle are displayed: Market development, Growth, Maturity, and Decline. These stages are further divided into internal and external, enabling an assessment of the extent of collaborations in each stage. On the horizontal axis, four attributes of internal and external are placed: Level of specificity, level of uncertainty, level of trust and commitment, and time frame. Furthermore, these attributes are subdivided into product and process. This segmentation allows an examination of the type of innovation applicable to each stage.

Characteristics Collaborations / Stages Life Cycle		Level of Specificity		Level of Uncertainty		Level of Trust & Commitment		Time Frame	
		Product	Process	Product	Process	Product	Process	Product	Process
Market Development	Internal								
	External								
Growth	Internal								
	External								
Maturity	Internal								
	External								
Decline	Internal								
	External								

Very much
Many
Normal
Few
Very few

Figure 9 Analytical framework (Own elaboration).

In the empty cells, quotes from the case studies can be inserted, after which these quotes can be color-coded to indicate the extent to which they are applicable to the respective cell they are placed in. Once this is accomplished for all case studies, an examination can be conducted for each case study to determine where, in the product life cycle, there is a greater presence of either product or process innovation. Additionally, it can reveal the stages in the product life cycle where internal and external (collaboration with many or few parties) can be situated.

5 | Methodology

5. Methodology

This chapter will discuss the methodology of the research. The adopted research method is a qualitative case study. The purpose of the study is to obtain and explore information about the relationship between collaborations and innovation in the circular construction sector.

A case study has been conducted for the research. There are three different types of case studies (Yin, 2013).

- Factual or descriptive cases – A description of the specific case is given and information is obtained through this.
- Explanatory cases This makes the research writer an expert on the subject. The study ensures that the research becomes comprehensible to readers.
- Exploratory cases – that explore a new terrain.

The type of case study that is conducted during this research is an exploratory case. The advantage of case studies is that they can be used with unstructured data coming from a dynamic and ambiguous organisational process (Yin, 2013).

The first research tool that has been used was a document analysis. Documents from the different projects are used to gain an overall knowledge of the case studies. Next, interviews have been conducted to gain more in-depth knowledge about collaborations and Innovation in the construction sector.

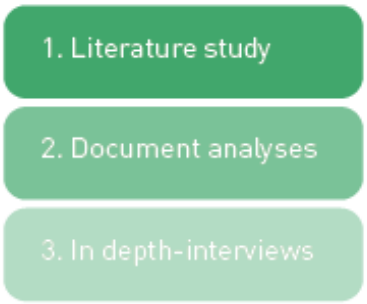

Figure 10. Structure of research (Own elaboration)

5.1 Research design

A case study can be executed with several projects which are investigated in depth (Blaikie & Priest, 2019). Since there are a limited number of projects built fully circular, this is a good method to research this topic.

The method of investigation is a multiple-case study method. The aim of this is to do an individual case study of different projects and then compare them, making the whole a multiple-case design. Generally, a multiple-case study is found to be more compelling (Yin, 2013). Since a case study generally consists of few samples, choosing the case study should be done carefully. The study will involve comparing five projects.

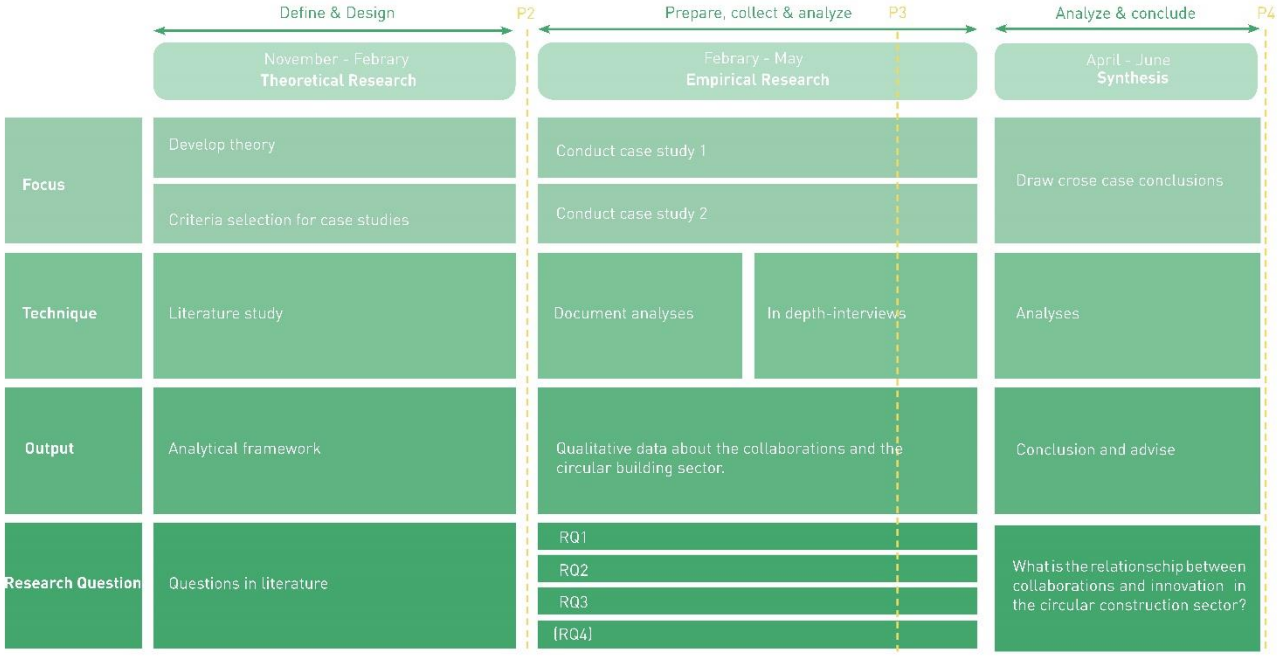

Figure 11. Research framework (own elaboration)

Figure 11 shows the research framework that will be used to carry out the research. The research will be divided into three parts. First, the theoretical research will be conducted. Here literature will be studied and an analytical framework will be made. Second, during the empirical research, five case studies will be conducted. The qualitative data found here will be used to answer the four sub-questions. Finally, a cross-case comparison will take place to analyse the data and draw conclusions to answer the main question.

5.2. Theoretical research

Before the case study, literary research will take place. Relevant articles will be searched using keywords related to the research questions. This will allow relevant information and prior knowledge to be gained before starting the research and answering the questions. The most common keywords used for the literature study are Collaboration, innovation, Circular construction economy, Circular construction sector and circular supply chain. To find literature Scopus, Google Scholar and TU Delft's repository were mainly used.

5.3. Empirical research

Two different research instruments will be used to conduct the empirical research, which are documentary analyses and in-depth interviews. The elaborated versions of the interview protocol can be found in Appendix A.

Document analyses

The research will first start with a documentary analysis. Here different documents will be examined as sources of data to investigate what collaborations and innovations took place for each case study. Within document analysis, three types of documents can be examined (Lincoln & Guba, 1985).

1. Written texts e.g., reports and contracts
2. Digital information e.g., social media and websites

3. Visuals e.g., videos and pictures

This research will focus on written texts. Contracts, briefing documents and reports will for example be examined. These documents will be obtained by contacting companies that have been involved in developing the chosen case study projects and by searching on the internet. Because official papers will be examined, it is assumed that the credibility of the documents is high. Links between different companies and cooperation between them will be the main focus of the analysis. Document analysis aims to find as many collaborations and connections as possible. Information not found after conducting the document analyses will be requested during the interviews.

In-depth interviews

Secondly, interviews will be held with various stakeholders of the projects. The questions for the interviews will arise from the literature study and document analyses, among others. The in-depth interview method was chosen because more detailed information is needed on which collaborations and innovations exist, what kind of collaborations there were and why they are important for the innovation or why were they not. In an in-depth interview, the questions are loosely structured. To conduct the interview properly, an interview protocol will be set up. This can be used as a guideline during the interview. There is space within the interviews for the interviewee to tell his/her story. The interviews will be held face-to-face, but when there is no time or opportunity for this, they will be done via teams.

For the sample, people who have worked on the projects will be interviewed. The minimum sample size for interviews is 10 (Shetty, n.d.). For this research, an attempt will be made to conduct 11 interviews if enough people can be found.

5.4. Data collection

Primary and secondary sources will be used to obtain the data. The secondary sources are the ones that will be obtained through the literature study. The primary sources are the data that will be obtained by conducting the case studies (Bryman, 2016).

During the case studies the method of data collection will first be based on documentary research. Later in the process, interviews will be conducted with the different stakeholders of the projects. By doing an interview afterwards, new insights can be gained about which collaborations were still missing or went wrong and how innovation was applied in the project.

5.5. Selection of cases

For selecting a good case study, they must meet certain criteria. The criteria found are based on the literature study.

five different case studies will be conducted for the research. For this purpose, a distinction has been made between the criteria for all case studies and the criteria for the specific case studies.

Criteria for all case studies

- The project has to be innovative. A project is innovative when a new good or quality of good is introduced that an external user or market is not yet familiar with or the implementation of new elements that have not been previously tried within a specific industry to manufacture a product or deliver a service (Damanpour & Gopalakrishnan, 2001; Hage & Meeus, 2006).

- The project has to be circular. For doing the case, it is chosen to examine projects where reuse of materials has been used. The reason for this is that reuse is very little used in construction compared to other sectors. In addition, it is important to move higher up the r-

ladder above recycling. After conducting several case studies, it was found that innovation in the field of reuse primarily focuses on process innovation rather than product innovation. Therefore, during the research, a decision was made to include a case study on product innovation as well. For this purpose, a bio-based product was researched.

The chosen case studies are:

Project	Hoogstraat 168-172
Innovation	Donor load-bearing structure
Circular	Reuse of steel
Type of project	Building
Interviewees	- Engineering firm (IMd) - Architect (R) - Municipality (G) - Steel inspection (N) - Contractor (C)

Project	Fortbrug
Innovation	Donor steel beams
Circular	Reuse of steel
Type of project	bridge
Interviewees	- Engineering firm (A) - Municipality (Ams) - Structure inspection (N2)

Project	The Hof of Cartesius
Innovation	Reused construction materials
Circular	Reused construction materials
Type of project	Area development
Interviewees	- Architect (Hof)

Project	Beelen Next (Demolisher)
Innovation	Reusing wood
Circular	Reusing wood
Type of project	Reusing wood
Interviewees	- Innovation and New Business Manager (B)

Project	Seawood

Innovation	fibreboards made from brown seaweed
Circular	Biobased material
Type of project	Material
Interviewees	- Founder (SW)

5.6. Data analysis

The research will take place in three parts. The first part is a literature study, the second part is a document analysis and the third part is interviews. The document analysis and the interviews will be analysed with the help of Atlas TI. This is a tool that helps with qualitative analysis and analysing large amounts of data (Atlas. ti, n.d.). By coding texts or transcripts, the information is organised, making it easier to analyse. The codes that will be used for this research have been divided according to the research questions:

RQ1:

How can collaborations be designed/ facilitated

RQ2:

What are the innovations in the circular construction sector

RQ3:

Factors that drive collaborations

Factors that prevent collaborations

Factors that drive innovation

Factors that prevent innovation

Other factors that drive circularity

Other factors that prevent circularity

RQ4:

Different parties between whom collaboration should be established

5.7. research ethics

For the research ethics part, we will use Chen's (n.d.) framework. It consists of the five principles: Do not harm, confidentiality, informed consent, trustworthiness and data protection.

Do no harm

Research can contribute something good and give benefits to people, however, one should always think about the people who might be harmed by the research. Therefore, efforts should be made at all times to minimise this harm.

Confidentiality

The identity of the people contributing to the research, such as the interviewees, must be protected. Keeping the interviewees anonymous protects their identity. During the research, data will be known about the interviewees, such as where they work, what their position is, their names and email. When the research is completed, the names and emails of those participating will be deleted. However, the information about the functions and company where they work will not be deleted. These details will also be mentioned in the thesis. This is necessary for the credibility of the research.

Informed consent

The people participating in the research must know what the purpose of the research is and participate voluntarily. It is therefore necessary to give information about the research to the participants before the research has started. The interviewees will have to sign an informed consent before the interviews. To ensure that all interviewees are aware of what will happen with their information, they will sign an informed consent form before the interviews. Also, before the interview starts, it will be explained what their data will be used for.

Reliability, validity and (mis)representation of data

To ensure the quality of the research, the reliability and validity of the research will be taken into account. To guarantee the reliability of the research as much as possible, certain requirements have been drawn up for the case studies (see 5.4). If the research were to be conducted again, there are fixed requirements that the case studies must meet. The validity is ensured by using theory, among others, to find the case studies. All aspects are covered by doing five different case studies, with different requirements.

Data protection

It is important to store the data obtained from the research in a safe place. As this research is part of a thesis to be conducted by an individual, the information will be stored on a computer. To make it possible for further research to access the results, the anonymised research results will be stored in the repository of TU Delft University after the research is completed.

6 | Empirical findings

6. Empirical findings

6.1 Case Study Introduction

In this chapter case studies are conducted to gather empirical evidence on the relationship between collaboration and innovation in the circular construction economy. The case studies will be explained in detail in this chapter. After introducing the cases, the data obtained from the interviews will be presented. The acquired data will be discussed per category, divided into three categories: collaboration, innovation, and general aspects.

Hoogstraat 168-172

The first case study that would be conducted is the case of Hoogstraat 168-172. This project consists of three existing buildings. These have been completely transformed inside and connected to form a residential and retail complex, with the option of one large store. Only the facades, originating from Rotterdam's reconstruction period, have been preserved. The original concrete shell, on the other hand, was no longer adequate and was replaced with steel beams and columns from other buildings: a donor skeleton (Herontwikkeling Hoogstraat 168-172 Rotterdam | Rijnboutt, 2023).

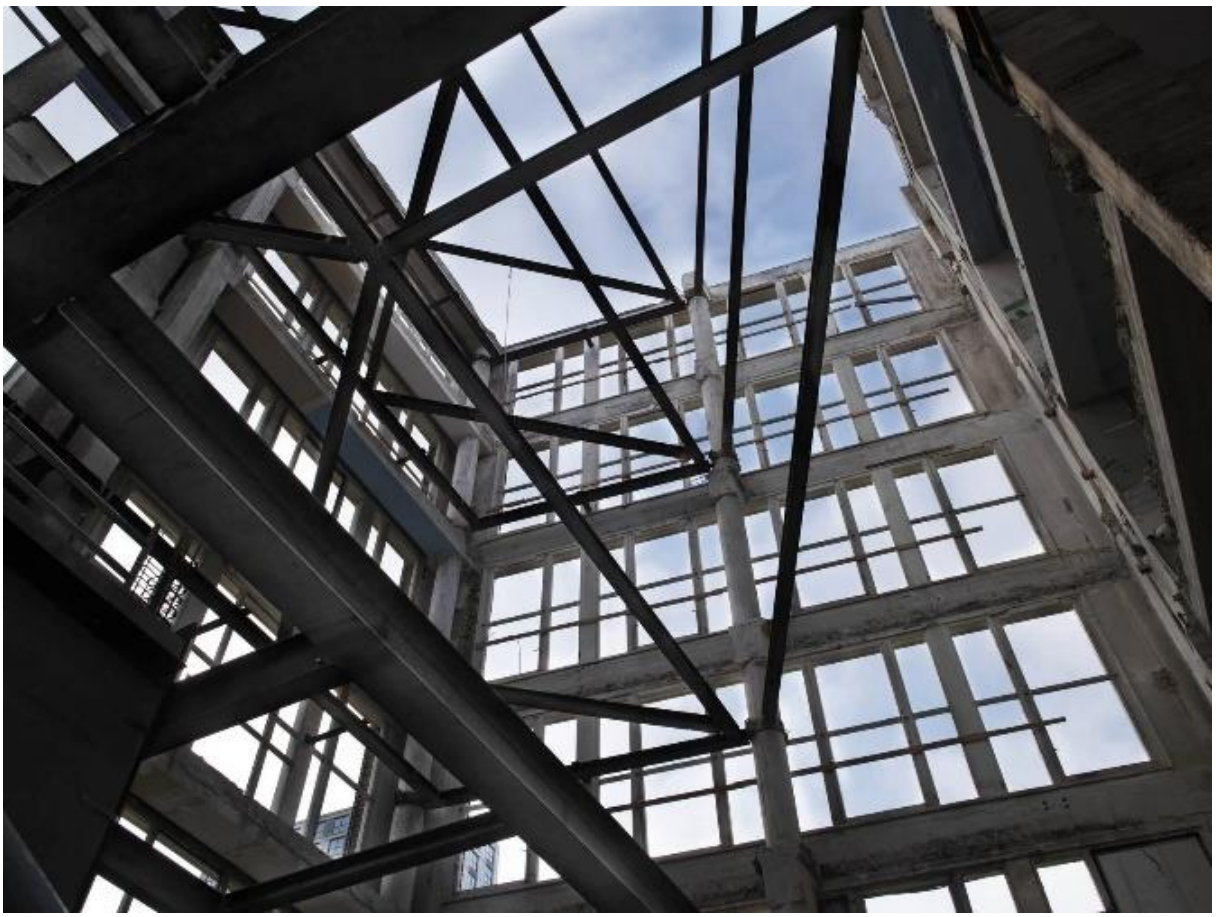

Figure 12. Donor skeleton (Herontwikkeling Hoogstraat 168-172 Rotterdam | Rijnboutt, 2023).

The three buildings, built between 1950- 1954, in the heart of Rotterdam, each with a separate load-bearing structure, had a forest of columns and different floor levels. As a result, the buildings could not be connected unless the structure was removed. Except for the post-war facades and basement, therefore, almost the entire concrete load-bearing structure was

removed and filled in with a steel structure. This allowed higher floors to be built within the overall height and greatly reduced the number of columns (Peters & Relker, 2019).

Figure 13. Donor skeleton (Herontwikkeling Hoogstraat 168-172 Rotterdam | Rijnboutt, 2023).

The construction of the new building consists of a steel beam-column structure combined with a steel slab-concrete floor. Stability is ensured with a steel gantry in the store, a precast concrete stairwell and a wind bracing against the adjacent building. A special feature of the steel structure is that it consists of reused steel. Because the supply and demand of reused materials in construction is very difficult, the available structural elements have to be used creatively. A good example of this transformation is the "fork beam". A new steel structure would simply use a larger beam. This was not available. It was therefore decided to use three lighter sections and connect them like a fork (see Figure 14). Of course, with this alternative, care must be taken not to (excessively) increase the amount of material. Not only because of construction costs but also to maintain the advantage of environmental impact. After all, that is the higher goal of the Donor Skeleton (Peters & Relker, 2019).

Figure 14. fork construction (Herontwikkeling Hoogstraat 168-172 Rotterdam | Rijnboutt, 2023).

This project was chosen to research because applying a donor skeleton at this level was a first during this project. The donor skeleton is a good example of the complex reuse of materials in construction. Because the load-bearing structure of the building is reused, the task becomes more complicated than if, for example, floors or doors were reused. For the load-bearing structure, more requirements must be met before it can be applied. In addition, the project won the 2020 National Steel Sustainability Award.

Het Hof van Cartesius

Hof van Cartesius is a circular business park located in Utrecht that focuses on sustainability and innovation. The park provides space for start-ups and other companies involved in circular business (Dé fysieke proeftuin voor de circulaire economie | Hof van Cartesius n.d.). The buildings at Hof van Cartesius are constructed using various circular building materials, such as wooden pallets, train parts, and old windows. The design of the buildings follows the principles of the circular economy and incorporates modular elements, making expansion easier (Jansonius, 2022).

The emphasis on circularity at Hof van Cartesius extends beyond the use of building materials. The construction process considers the circular ladder approach, encompassing steps such as refuse, reduce, redesign, re-use, repair, refurbish, remanufacture, repurpose, recycle, and recover (Het Hof van Cartesius, 2020). Flexibility and collaboration play a crucial role in the development of Hof van Cartesius. The project requires cooperation among various stakeholders to ensure its successful completion. The ability to incorporate newly available materials reflects the park's commitment to innovation and experimentation (Jansonius, 2022).

Hof van Cartesius prioritizes the integration of green spaces and nature within its design. Offices are arranged around green courtyards, serving as common areas for meetings and fostering social interactions (Awada et al., 2021). By eliminating corridors and maximizing the use of common spaces, the design reduces material usage and enhances the connection with nature (Awada et al., 2021). The collaborative nature of Hof van Cartesius extends to its occupants. The cooperative model requires renters to contribute their time to the care of shared spaces and the collective's well-being. The garden team, consisting of renters, actively participates in designing and maintaining the green spaces, strengthening the sense of belonging and shared responsibility (Awada et al., 2021).

Hof van Cartesius is a part of the Werkspoor neighbourhood, which is a hotspot for sustainable urban development. The collaboration and experimentation within the neighbourhood contribute to creating a green, sustainable, and healthy area (Awada et al., 2021).

By emphasizing circularity in building materials, flexibility, collaboration, nature integration, community engagement, and alignment with the broader sustainable development context, Hof van Cartesius serves as a leading example of a sustainable and circular business park (Awada et al., 2021; Het Hof van Cartesius: the circular hotspot for circular action, 2020; Jansonius, 2022).

The reason for selecting Hof van Cartesius as a case study is its abundant opportunities for experimentation. The project has been ongoing for several years, and incremental progress is made through the application of acquired knowledge.

Beelen Next

Beelen Next was chosen as a case study to analyse, in order to investigate a material flow rather than just projects. The focus was on examining the wood flow of Beelen Next, a demolition company that is dedicated to reducing waste and residual flows by making waste streams transparent with data, designing processes intelligently, and reusing materials during construction. NEXT-Use Hout is an initiative of Beelen Next that focuses on the circular reuse of wood. NEXT-Use Hout aims to promote the reuse of wood and to create a closed wood cycle. This is achieved by dismantling and sorting wood that is released during demolition and renovation work as much as possible. The sorted wood is then processed into high-quality products, such as furniture, flooring, and facade cladding (Hegeman, 2019).

In the effort to protect forests worldwide, the reuse of wood plays a vital role, particularly as there is growing attention towards building with wood. Although waste wood is often recycled into pallets or engineered wood products like chipboard, Beelen NEXT has taken a step towards higher-quality reuse by establishing its woodworking facility. Depending on the size and quality of the waste wood, it is processed into a variety of products, ranging from picket stakes to beams and planks, thereby extending the lifespan of the wood and preventing deforestation (Hegeman, 2019).

De Fortbrug

The Municipality of Amsterdam is planning to replace the current Fortbrug due to its inability to withstand the imposed loads from the traffic it serves. Restrictive measures have been implemented, and a temporary bridge is being constructed to address the issue. In line with sustainability and circularity goals, the municipality has chosen to reuse beams from another bridge for this project. The feasibility of this reuse is currently being assessed separately (MEM –002, 2023).

The project intends to be prepared and executed in the form of a construction team (Bouwteam). The SOK contractor will be engaged through PBK based on a yet-to-be-finalized construction team agreement (offerteaanvraag, 2023).

Under the framework contract ROK IDCC, the Municipality of Amsterdam has requested the replacement of the Fort Bridge in Weesp. This project serves as a pilot for circular replacement, where the new bridge will be constructed using components from the existing bridge BRU1920 (CFW, 2023).

The municipality has made a deliberate decision to collaborate with parties that have experience in reuse and with whom they have previously worked. This choice was made to ensure a successful project outcome.

The reason for selecting this particular project is that it is the first bridge being constructed by the Municipality of Amsterdam using reused beams. Additionally, this project is currently underway, which means that the rationale behind specific decisions is still fresh in the minds of the various stakeholders.

Seawood

Finally, the Seawood project is analysed. In contrast to the other projects, this involves a new biobased material that is currently being developed and tested. The material is a 100% natural substance composed of seaweed. Seaweed is a rapidly growing crop that requires no freshwater, land, fertilizers, or pesticides, while also sequestering significant amounts of CO2. Sea-Wood materials comprise a range of panel products made from local seaweeds combined with byproducts from the timber and paper processing industry. Using the natural binder found in the seaweed itself, these materials are pressed into soft board, MDF, or particle board, serving as clean and circular construction materials. The material can be utilized for interior construction purposes such as non-load-bearing interior walls, decorative, acoustic, insulating, and fire-resistant finishes, as well as furniture. (Geperste zeewier panelen - The Exploded View, 2021) The reason this product was chosen to investigate is because the innovation in the other project seemed to be mainly in process innovation and not within product innovation.

6.2 Interviews

In the following section, the obtained interview data will be discussed. This chapter will be divided into four parts. The first three are about the findings of the interviews and will be built up as follows:

1. Innovation
2. Collaboration
3. The relationship between innovation and collaboration.
4. Analytical framework

6.2.1 Innovation

Several findings about innovation emerged during the interviews. These findings included both factors that drive innovation and bottlenecks for innovation. In the Methodology section, you can find which interviewees were associated with the sources referenced in the chapters.

Factors that drive innovation

To drive innovation, stakeholders must take action. Endless discussions on how to achieve something will not yield quick results. It is important to actively try different approaches, learn from what works and what doesn't, and not be discouraged by failures (B, R, IMd, C). In other words, more experimentation is needed. Discovering the best way to do something requires time and energy. This was exemplified by Beelen Next, who noticed significant wood waste during demolition and started experimenting with ways to reuse the wood. They conducted tests to determine the time required to remove nails from a piece of wood and when it would be more efficient to cut off a section. During experimentation, it is crucial to accept mistakes and demonstrate the lessons learned. Share these experiences with others who are embarking on a similar path (C).

Yes so with innovations is the party that has that passion that has to stick its neck out and it really has to go for it (IMd).

Implementing a circular economy and driving innovation within an existing company can be challenging as it often involves experimentation. There may be instances where you fail multiple times before achieving success, and this can create a perception within the company that circularity doesn't work. Therefore, it can be beneficial to establish a separate entity or company dedicated to experimentation and innovation (B).

Innovation is driven by knowledge. Having a deeper understanding can lead to even smarter solutions, which is why it is important for companies to expand their knowledge base (R).

During the innovation process, it is crucial for the municipality to be open and actively engage in discussions. Often, innovative solutions do not align with existing regulations, so collaborative efforts are needed to find ways to obtain the necessary permits (R, IMd, C). For instance, while the strength and safety of new materials may be well understood, reusing materials may pose uncertainties.

It is essential to focus on innovation efforts. Not all innovations are suitable for widespread use or have market demand. For example, the 3D-printed Canal house, which may look appealing, but constructing a house using plastic is not practical (IMd, N). When pursuing innovation, consider the specific focus and potential impact of the innovation. Invest energy in areas where significant impact can be made. It is also important to innovate in the right areas. While a certain technological aspect may already be proven by the Delft University of Technology, the challenge may lie in innovating economic value or collaborative approaches (N).

Innovation requires thinking outside the box and proposing initiatives that may initially seem unconventional or illogical to others. However, these ideas need to be embraced and championed within the organization. In the civil engineering sector, this is often a challenge because of the mindset of "we've always done it this way." If people are not motivated and encouraged to think differently, innovation will not occur (A). It is important to think beyond the rules. If you have a great idea but people are solely focused on adhering to existing rules, it will be difficult to implement (A).

To achieve volume in circular innovations, it is crucial to be competitive with existing products on the market. Companies may need to invest more money or increase their level of innovation to make this happen (B). By offering products or solutions that are economically viable and attractive to customers, companies can generate the necessary volume to drive the adoption of circular practices.

Bottlenecks for innovation

Many companies have heavily invested in linear production lines and other facilities, making it challenging to transition to circular practices. The entire business model may need to be restructured to accommodate circularity (B). Furthermore, circular products often have higher costs compared to conventional products, making it difficult to achieve volume as consumers tend to opt for the cheapest option (B, R). This necessitates smart approaches to reduce costs associated with circular innovations. One example is Beelen Next's wood sawmill, where they train young people with employment barriers, supported by subsidies to offset costs (B).

However, it is worth noting that in some cases, circularity can ultimately be more cost-effective than linear practices. For instance, using less electricity in a building or realizing the residual value of materials can result in long-term cost savings. The challenge lies in ensuring that the parties investing in circular initiatives are the ones reaping the financial benefits. Additionally, the return on investment may take several years to materialize in certain cases.

The point is that people build a building now and then you can say, in 100 years you can take it apart and then you will make a profit because those materials have more residual value but of course, it is still very uncertain whether that is so. That's an issue that is not directly of interest.

In some cases, individuals within a company may have a strong desire to implement circular economy practices, but they do not receive support from upper management. In such situations, even if an individual is enthusiastic about adopting circular practices, the lack of support makes it difficult to succeed. Conversely, the same principle applies when an organization wants to embrace circular economy initiatives, but individuals within the company are not willing to invest the necessary effort. In both scenarios, the alignment of individual and organizational motivations is crucial for the successful implementation of circular economy principles (N, hof).

And there is no connection between the political party who supported you and help and helps you to start this project, maybe also moving some money support from and the technician from the same municipality that come to cheque during the process and say yeah, but this is not OK (hof).

To achieve significant progress, it is advisable not to rush the process. When implementing a large-scale innovative circular project, the timeline can be extensive. Therefore, it can be more beneficial to start with small steps. Given the complexity of circularity, beginning with a specific component allows for learning from that project and gradually advancing towards a circular economy (Ams, A). An illustrative example is the Fortbrug, where the reuse of beams is

implemented. Although the beams represent a small portion of the overall bridge, they hold significant importance within the construction. Considering the substantial concrete and reinforcement involved, its environmental impact is noteworthy.

6.2.2 collaboration

Factors that drive Collaboration

During the interviews, it was evident that collaboration was highly valued within the circular construction economy. It was frequently mentioned that a linear economy is primarily based on offering the lowest price.

It is important to encourage circularity from multiple perspectives. For instance, when material producers set a requirement for products to be detachable for future reuse, it stimulates other parties to adopt circular practices. Similarly, if the client for a project emphasizes the importance of circularity, it should be implemented throughout the project (B).

When a product is made or reused circularly, collaboration with product customers is crucial to determine the requirements the product should meet. This is because they are the ones who will ultimately use the product. An example of this is the wood sawmill at Beelen Next, where they worked with the consumer to identify the products that could be made from reclaimed wood and establish the quality standards for the wood. It is also important to know when to reject a piece of wood and when not to (B).

but also when it comes to quality requirements, it's at the level of how many nail holes are allowed in a linear metre. These are things I'm not going to come up with on my own. I really need a party that knows a lot about wood for those things, so cooperation is very important there too, even though we now ultimately do it ourselves.

Given that circularity is not yet mainstream, it is important to collaborate with specialists and individuals who have idealistic goals. By working with parties that have extensive knowledge of circularity, you can acquire knowledge yourself. Additionally, this approach allows you to build a network of partners with whom you can collaborate on circularity-related initiatives (R).

Sharing knowledge among stakeholders is crucial. This mutual exchange can greatly strengthen the overall efforts. Keeping knowledge in-house and not sharing it internally is inefficient for the circular transition (R).

If you are all trying to invent the wheel yourself then. Yes, then you are very inefficient.

Collaborating with the municipality is crucial. As circular interventions are often new, there is currently no specific legislation in place for them. The municipality needs to be open to this concept and careful consideration should be given to how permits are granted (R).

Collaborating in areas where you lack knowledge or expertise is beneficial as it allows you to acquire new knowledge and skills across different domains. By engaging in collaborative efforts and learning from these experiences, you can build a repertoire of reference projects to draw upon (AMS). In the context of product innovation, partnering with educational institutions can provide valuable insights. However, to successfully bring a product to market, it is essential to also consider the market's needs and preferences (SW). Additionally, penetrating the construction industry with new products can be challenging due to strong existing networks. Collaboration becomes crucial in establishing a presence, gaining visibility, and proving the effectiveness of your product (SW).

I think collaboration is the only way to innovate, especially in complex sectors like this.

Collaboration is crucial in a circular construction economy due to the interconnectivity of different stakeholders' phases. In a linear economy, each stakeholder carries out their distinct phases, whereas, in a circular economy, these phases overlap and intertwine (Hof). It is essential to establish effective coordination and alignment across various dimensions, including structural aspects, static considerations, and the overall process, to ensure successful outcomes in every stage of the process.

Finally, in the construction industry, collaboration is essential due to the multitude of disciplines involved. A single company cannot possess expertise in all these areas, making collaboration a necessary and integral part of the process (Ams).

Bottlenecks for collaboration

The traditional construction economy follows a highly phased approach where a project moves from one party to another, with each stakeholder carrying out their phases before passing it on to the next. In contrast, the circular construction economy involves much more overlap between these phases, fostering collaboration that is not typically seen in the traditional construction economy (B).

Often, when introducing something new, you have to do it independently. Once you have demonstrated its feasibility, others may be more willing to join. However, the initial burden lies in proving that it is truly possible (B).

Collaborations do not materialize because it is difficult to find partners willing to collaborate. This was the case with Beelen Next, for example. As no one wanted to collaborate with them, they had to undertake the project themselves (B)

Moreover, it is not advantageous to have an excessively large group collaborating. More actors mean more opportunities and more risks. When these are combined, it leads to diminished opportunities and increased risks, making it challenging to focus on a specific goal (IMd).

The contract structure of a project must allow for collaboration (A). While individuals working on a project may be open to collaboration and circularity, being bound by a contract that prohibits collaboration hampers the project's outcome.

To foster effective collaboration, everyone involved must be motivated. It is sometimes observed that individuals try to avoid actions or shift responsibilities to others. However, everyone in a project must be motivated to prevent missed opportunities (A).

6.2.3 The relationship of innovation and collaboration

In this section, relationships between innovation and collaboration will be discussed. These include which parties should collaborate to create innovation and how these collaborations should be designed. In addition, it will also discuss what the bottlenecks of innovation are within the collaboration of the circular construction economy.

Parties between whom collaboration should be established.

In the context of the circular economy, it has been emphasized that collaboration with various stakeholders is crucial from the outset. However, there are a few specific parties that deserve extra attention.

Firstly, the buyers or consumers of products play a significant role. As they are the ones purchasing the products, it is important to listen to their requirements and considerations regarding product quality (B, SW). Defining quality standards, determining acceptance criteria, and setting guidelines for approving or rejecting products are essential aspects in this regard.

Producers, on the other hand, serve as a vital link in the circular economy. They possess the product knowledge and production facilities necessary for implementing circular practices effectively.

Collaborating with parties possessing expertise in circularity is also essential. By working with knowledgeable partners, we have the opportunity to learn and establish valuable networks for future collaborations. This approach applies to various domains, including modular timber construction and biobased building materials (R).

Furthermore, engaging with local municipalities is crucial, especially considering that circular interventions often lack existing regulations. The municipality's openness to embracing circularity is necessary, and careful consideration is required when discussing permit procedures and approvals (R, IMd, C).

For innovation and introducing new products to the market, establishing connections with educational institutions is important. This is particularly valuable when a company does not have an in-house research and development department, as collaborating with educational partners can significantly reduce associated costs and provide access to valuable resources and expertise.

Lastly, when reused materials are utilized in new construction projects, the entire construction process undergoes restructuring. This gives rise to a new mode of collaboration known as the "flexible dynamic design." Within this framework, there are three primary teams: the building team, the design team, and the urban miner team. These teams may involve various stakeholders such as demolishers, architects, urban miners, materials testers, and contractors. What makes this approach unique is the overlap between these distinct roles. These three teams must collaborate from the project's beginning. As mentioned above, cooperation with the municipal authorities is also of paramount importance in this context. This is because, in the flexible dynamic design, an initial sketch design is created. Subsequently, a permit is requested from the municipality. Following this, the reused materials are searched for. Then, the design is adjusted to accommodate the mined materials, and the permit is updated accordingly (Hof).

How can collaborations be designed/facilitated?

It is advisable to collaborate with parties who possess specific knowledge relevant to the aspects you want to implement. This allows for mutual learning and the establishment of a network through repeated collaborations (IMd). For a circular innovation project, working with experienced partners and those with whom previous successful collaborations have taken

place is a sound approach. An example of this is the Fortbrug project, where intentional choices were made to collaborate with specific parties who had prior experience in circular projects, including one partner who held a framework contract with the municipality (AMS).

Collaboration is highly dependent on individuals, and it is important to recognize that project outcomes, both in terms of circularity and in general, are influenced by the collective effort of individuals. Therefore, effective collaboration is essential (N).

Incorporating various areas of expertise from the outset by working in a multidisciplinary team, such as a construction or design team, is a recommended practice (Hof). Additionally, involving the material dismantler or harvester from the beginning is beneficial. Proper disassembly techniques should be applied to ensure materials are not damaged and can be appropriately reused in their intended locations (A). It is also important to consider engaging parties like the inspecting authority of the municipality. Informing them in advance about any deviations from existing regulations allows for their preparation and active involvement in the process (G).

Collaborating to share knowledge is not only beneficial with advisory parties but also with suppliers and subcontractors who provide circular products, as they possess extensive knowledge in this area. A construction team approach can be a good option for a circular project. This is because involving multiple parties from the outset allows for effective coordination of the design and other aspects from the beginning (IMd, Hof, Ams, N).

We involve all stakeholders from the earliest possible stage. Make sure that your ambition becomes a shared goal and that everyone is okay with the approach. Ensure that everyone is confident before starting because otherwise, you will get discussions on the job, which can make the project go sideways (N).

Aligning these aspects is also a crucial factor in successfully completing the project. It is essential that all parties embrace the circularity principle, including the client, architect, suppliers, and subcontractors (IMd). By doing so, you establish a way of working that minimises the need for constant discussions during the pre-project phase and provides a solid foundation to rely on (N). Involving everyone from the outset and ensuring clear coordination of tasks also helps ensure that each individual knows their responsibilities throughout the project (Hof). Maintaining open and honest communication among all stakeholders from the beginning of a project is a priority. This requires personal commitment and organizational readiness. Such an approach enables early commitment and support from individuals and organizations, ensuring that the right people are involved in the project (N)

An open learning environment can be a way to promote the implementation of the circular transition. In this setting, knowledge is shared among all parties involved in the value chain, including academic institutions, clients, engineering firms, and contractors. Within this open learning environment, various thematic lines are explored, ranging from business and value cases to materials, technology, and data. These thematic lines serve as avenues for addressing circular challenges. Some focus more on technical aspects, while others are more oriented toward organizational aspects (N).

It is good to motivate individuals from higher up to apply circular economy in construction. People who can think out of the box and come up with initiatives that might not initially be thought to be logical should be listened to. If this is not supported within the organisation, it is also much harder to be innovative. So people need to be motivated and stimulated to do this from and within themselves, but also from higher up, and only then will an innovation emerge.

What are the bottlenecks to innovation in the circular construction sector?
During the process of reusing materials, it is crucial to make a careful assessment of whether it is worth the time and energy investment. There comes a point where it may no longer be economically or practically viable to salvage a particular material. An example of this can be seen in the reuse of wood at Beelen Next. When dealing with wood that contains a significant amount of nails, there comes a moment when a decision must be made regarding whether it is worth investing substantial time and effort to remove the nails or simply discard that particular piece by cutting it away.

If you are going to put too much time and energy into trying to get every piece of metal out, you are going to spend infinite amounts of time with every piece of wood

One of the barriers to innovation in the circular construction economy is the uncertainty surrounding future developments. Construction projects are often designed to last for several decades, and since we cannot predict what will happen in the future, this uncertainty can make certain decisions quite challenging. For instance, when constructing a 9-story building surrounded by 12-story buildings, one must consider whether to design the structure with the potential to add three additional floors in the future. This decision involves weighing the additional material and cost implications against the uncertainty of whether such an expansion will be necessary or desired in the future (IMd).

What do you do now to ensure that circularity and why is that difficult? It's difficult because, of course, we can't look 10, 20, 50 years from now. And that's really a challenge.

Another example is the forked construction created in the project at Hoogstraat. In this case, additional material was used to accommodate three adjacent beams. However, more material also means increased environmental impact. Therefore, a decision must be made whether to use a new beam or three reused beams, taking into account the environmental considerations (IMd).

Lastly, another aspect to consider is that reused materials are often not readily available for reuse. They may require cleaning, repairs, or removal of rust, which adds time to the process. Additionally, multiple transportation trips may be needed, further contributing to the negative environmental impact (IMd).

6.2.4 Analytical framework

In this section, the completed analytical framework will be shown. For each case study, quotes will be placed in the analytical framework. These quotes will then be color-coded to indicate their relevance within the designated cell. The tables in this chapter will solely feature the color-coded cells without populated quotes. Tables containing the quotes can be can be found in appendix B.

Seawood

Seawood's focus is on product innovation. The table has been filled out from the perspective of the project founder. In figure 15, the completed framework for the Seawood case study is presented. From this, several results can be derived. Firstly, we will examine the insights obtained from the horizontal axis. The initial observation indicates that process innovation commences later than product innovation. Furthermore, it is evident that process innovation exhibits lower specificity compared to product innovation. Additionally, the time frame for process innovation is longer than that of product innovation.

Turning our attention to the vertical axis, we observe that for the external dimension, both product and process innovations are less specific compared to when they occur internally. Moreover, a notable disparity exists in the level of trust and commitment between internal and external dimensions. Internally, a higher degree of trust and commitment is evident.

Furthermore, it is noticeable that for this case study, no quotes can be inserted into the maturity or decline stages.

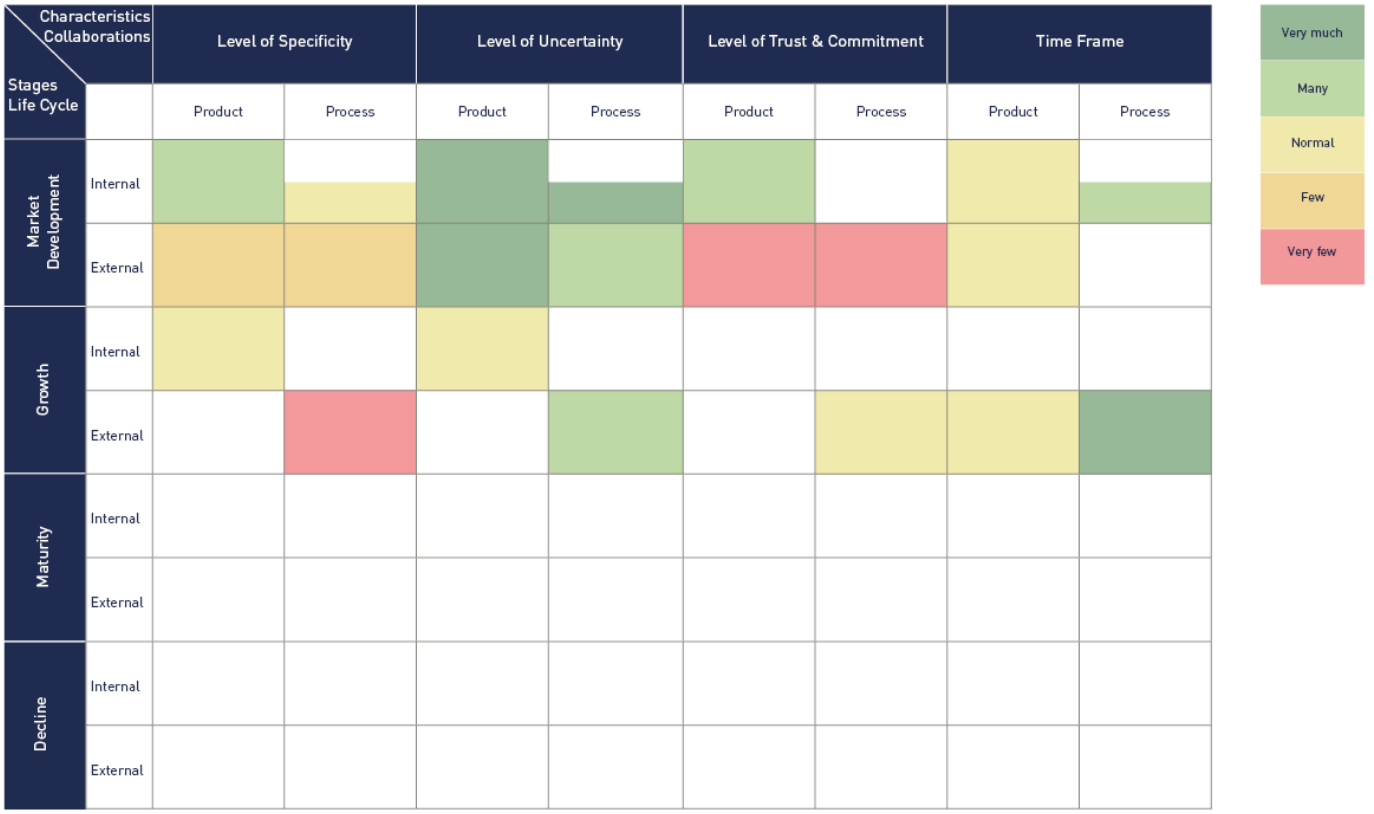

Figure 15. Analytical framework Seawood (Own elaboration).

Beelen Next

The focus of Beelen next is on the manufacturing of reused wood. The table has been filled out from the perspective of the innovation manager. In figure 16, can be seen that this case study primarily emphasizes process innovation. As a result, conclusions can only be drawn for the points on the vertical axis. It is observed that as we progress further in the product life cycle, process innovation becomes less specific. Additionally, a trend is noticed where uncertainty decreases as we move further in the life cycle. Conversely, there is an increase in trust and commitment as we approach maturity.

Figure 16. Analytical framework Beelen Next (Own elaboration).

Hoogstraat 168-172

The focus of Hoogstraat is on process innovation. The table has been filled out from the perspective of the engineering firm and the steel inspection firm. In Figure 17, it can be observed on the horizontal axis that there is also an initial product innovation before the introduction of process innovation. However, the process innovation commences earlier in comparison to the Seawood case.

Similarly, the vertical axis reveals that the level of specificity decreases as we progress further in the product lifecycle. Secondly, it is evident that the level of uncertainty decreases as we move deeper into the product lifecycle. Thirdly, there is an increase in trust and commitment as we advance in the lifecycle. Notably, internal trust is greater than external trust. Lastly, it is that the time frame gradually shortens as we progress.

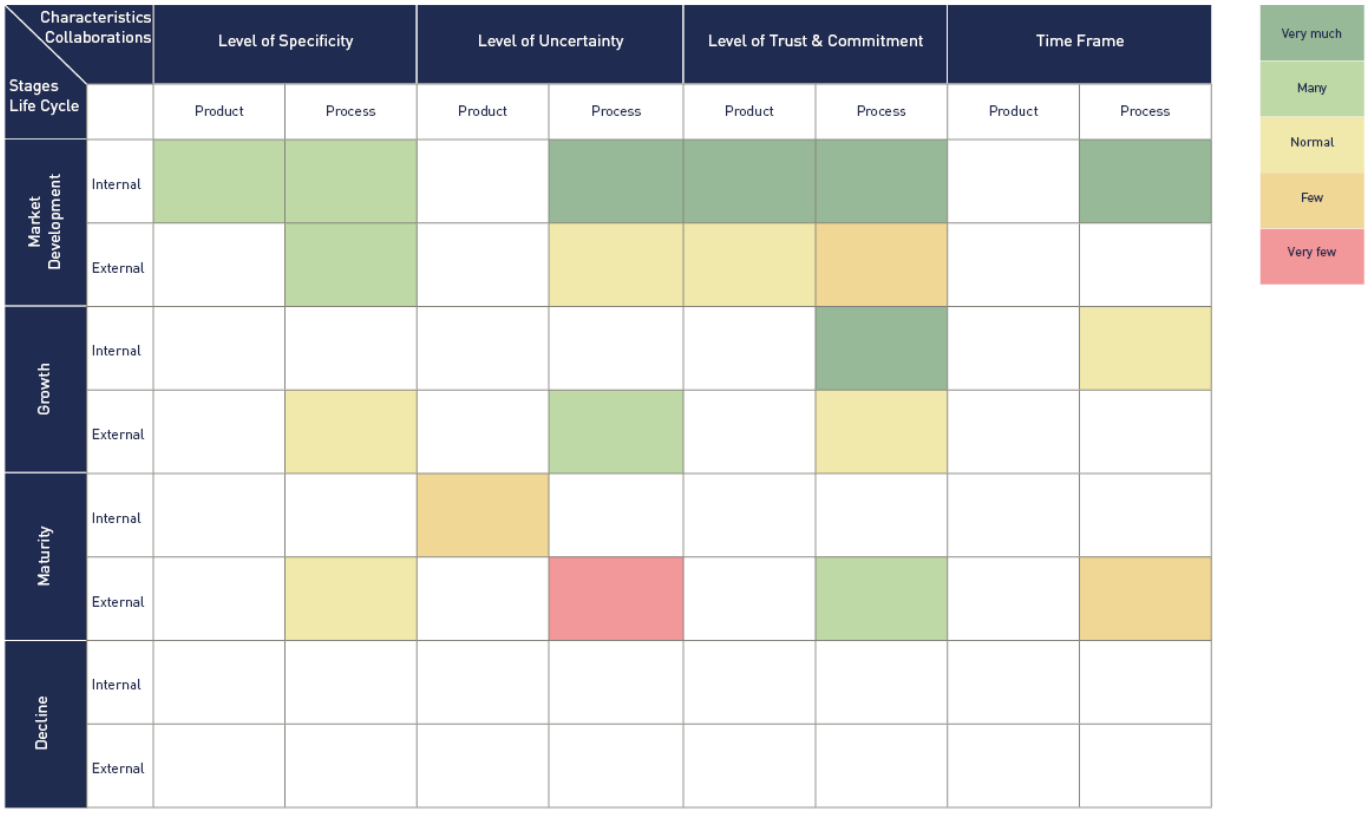

Figure 17. Analytical framework Hoogstraat 168-172 (Own elaboration).

Hof van Cartesius

The focus of the Hof van Cartesius lies within the construction process.

The table has been completed from the perspective of one of the architects and a community member. When we examine the case study of the Hof van Cartesius, we observe a different pattern compared to the previous case studies. In figure 18, it is noticeable that the level of specificity increases as we progress further in the product life cycle. Conversely, the level of uncertainty experiences a slight decrease.

One similarity with the other cases is that the level of trust and commitment is greater for internal aspects compared to external. However, there is also a decline in trust and commitment as we advance further in the lifecycle.

Figure 18. Analytical framework Hof van Cartesius (Own elaboration).

6.2.5 Discussion of the findings

In this chapter, the most important findings of the research will be clustered and explained. The chapter will be divided into the following sections:

- Process and product innovation
- elements for collaboration
- Counter-intuitive
- Specific condition
- Contradiction
- Those that are challenging the status quo

Process and product innovation

One of the key findings is that there is a distinction between product innovation and process innovation in the circular construction sector. This distinction is influenced by the parties involved and the timing of these collaborations. The research reveals that in the case of product innovation, closer collaboration with universities can be beneficial, particularly in the initial phase of product innovation. The advantage of such collaboration lies in gaining access to different disciplines that are not present within a company's team, thus acquiring additional knowledge and involving more individuals in the process. Furthermore, universities offer the advantage of cost-effective access to knowledge, which is particularly beneficial for startups. In contrast, larger companies often possess dedicated R&D teams and more resources, making collaboration with universities less essential than for startups.

Compared to product innovation, in process innovation, we see collaboration including bigger numbers of stakeholders. However, the collaborations here vary a lot depending on the process and the objective of the process. Important stakeholders in cooperation during process innovation are market players and government agencies. Collaboration with market players is essential to determine the demand for implementing the product innovation. For instance, Seawood serves as an example where prior product innovation had resulted in the development of a material resembling wood from seaweed. Collaboration with market players was crucial to identify potential applications for this product. Subsequently, it was necessary to assess compliance with regulations, as the material was novel and lacked established legal frameworks.

An important finding is the interconnection between these two forms of innovation. Product innovation often leads to corresponding process innovation, aimed at integrating the newly developed product into existing processes.

Several elements regarding collaboration have come forward in the interviews. Collaboration arises from several stakeholders who perform different activities. Furthermore, it varies when collaboration happens and how intensive this collaboration is.

In addition to the distinction between product and process innovation and the elements of collaboration, it was also observed that the findings from the interviews could be clustered into various groups. The first group is labelled as "Counter-intuitive," encompassing findings that yielded outcomes contrary to what one would initially expect. Subsequently, this study will illuminate the most prevalent specific conditions governing the relationships between collaboration and innovation in the circular construction sector. The interviews revealed numerous contradictions, thus warranting a dedicated section. Lastly, the section that

challenges the status quo will delve into aspects that distinguish the circular economy from the conventional construction economy.

Counter-intuitive

During the interviews, several counter-intuitive observations were made, which are instances contradicting initial expectations. For instance, it was noted that not everyone should collaborate at all times. Collaboration is often depicted as a constant necessity; however, it is not required at all stages of a project. Beelen Next, for instance, initially engaged with a wood consumer when establishing its lumber mill. Together with the consumer, they determined specific quality requirements for the wood and identified potential applications for the reclaimed wood. Currently, the wood consumer primarily serves as a consumer (B).

One critical moment emphasized for collaboration is the early phase of a project. Involving all relevant parties at the project's outset ensures that everyone is well-informed about the project's requirements. The advantage of assembling all stakeholders at the project's inception is that each can provide expertise-based advice, reducing the likelihood of surprises or problems later in the project (B). Moreover, it might be advantageous for the circular economy, particularly in this transitional phase where the optimal approach to implementing circular principles in construction is still evolving, to first execute a few projects within a specific group. This approach allows for a better understanding of how to successfully conclude circular projects. As a company gains experience and builds a database of circular projects, it becomes easier to collaborate with others (Ams).

Currently, adherence to existing regulations is still prevalent; however, this approach often hinders innovation as these innovations are frequently not yet incorporated into the current legal framework (A). Within this context, it is essential to sometimes heed advice that may initially seem counterintuitive. Thus, individuals must be intrinsically motivated and encouraged not only from higher-ups but also from within to embrace circularity, as this is the foundation for fostering innovation (A).

It is advisable to start experimenting and avoid long meetings and discussions at the beginning of a project. Experimentation facilitates the accumulation of knowledge along the way. You may not achieve your desired outcome immediately, but step by step, you gain more insights until you attain a final product that meets your satisfaction (Beelen). Furthermore, it is prudent not to rush the innovation process. For instance, in a project, it is not necessary to implement circular practices comprehensively from the outset. Starting with a smaller portion is advantageous because circularity is a multifaceted concept encompassing various aspects. Initiating on a smaller scale, such as reusing only the beams of a bridge instead of all its materials, provides valuable learning opportunities throughout the process. This approach allows for the step-by-step introduction of novel elements with each project (Antea).

It is good to look broader than what costs are covered. Sometimes you have to do things that do not cover costs. Because this creates volume, for instance, or because there are now fewer CO2 emissions. You only create volume by being competitive with new (B, R).

Innovate with a specific focus. It may seem that innovation should be a continuous process applied to everything, but sometimes it is only necessary to innovate a particular component of a product or process. Innovation involves various criteria, including technical feasibility, economic perspective, and... It is prudent to direct your energy towards areas with the most significant impact. For instance, when pursuing development and the innovation has not yet been technically proven, despite various laboratory tests, the challenge may lie more in evaluating its economic value, elucidating its impact, or exploring collaborative approaches rather than in the technical aspects (N).

Specific conditions

When dealing with tenders related to circularity, it is advisable to collaborate with a party knowledgeable in this field. Such a party has a better understanding of the necessary steps, and by working together, valuable insights can be gained (R). Partner with companies experienced in the circular construction economy. It is crucial for everyone involved to be genuinely motivated to implement circular practices (AmsS, R).

For a circular project to succeed, every participant must embrace the circularity principle; otherwise, the project may not achieve its objectives (IMd, A). This holds even when an individual within an organization is enthusiastic about circularity but lacks support from higher-ups (N).

To make a meaningful impact and become attractive in the construction economy, you need to create volume. Companies often engage with you only if they can source products from you regularly or in significant quantities. Thus, growing in volume is essential for new products (S). To generate volume, your product or process must meet market demand. This can be achieved by consulting with market stakeholders to understand their needs and the types of products and processes in demand.

Initially, during the early stages of product innovation, collaboration with educational institutions is beneficial. This facilitates knowledge dissemination and provides cost-effective access to expertise, which is particularly advantageous for startups with limited financial resources (S). Greater knowledge often leads to increased innovation.

The internal structure of a company is crucial for the effective implementation of the circular economy. Having a designated representative for circularity within a company is important for shaping its circular initiatives. This is especially relevant for organizations with limited experience in circularity, as it can be challenging for them to envision and implement circular practices. It helps prevent economic interests from outweighing sustainability concerns, which could otherwise hinder progress (N2).

Contradictions

Careful consideration should be given to circular applications, as they may not always justify implementation. An example of this is the donor skeleton. A fork structure (see figure 14) was built at one spot in the building because there was no donor steel beam long enough to cover the distance at that spot. However, this approach results in the use of more material for a span. In such cases, a thorough assessment is necessary to determine if the application is truly worthwhile (C).

It is not always advisable to collaborate with a large number of people. This is because each party has its possibilities, potential opportunities, risks, and when these factors are combined, opportunities may diminish while risks increase. Often, within an organization itself, circularity is not well-coordinated. An example is the municipality of Utrecht, which provided subsidies to the Hof van Cartesius for circular construction. However, the design was rejected by another department of the municipality because the design was not yet fully developed (flexible design). They did not know which materials would be used in the design (Hof).

Collaboration with new, sometimes unknown parties can be hindered by standard contracts that are perceived as not allowing for flexibility. It is essential to carefully consider how a project is structured. For example, having a generic request for proposals may not be the right approach to foster innovation. The choice of contract format is also critical. Even if individuals to apply circularity come together, if the contract terms do not provide the necessary flexibility, the project may be doomed to fail. Clients play a crucial role in this regard (N).

Those that are challenging the status quo

Previously, assessments in construction projects were primarily based on the lowest price (subcontractor). Nowadays, there is an increasing focus on factors such as the CO2 impact of materials. This shift represents a positive change for the circular economy. During tenders and procurement processes, it is crucial to consider not only the lowest price but also whether the environmental impact justifies the cost. Sometimes, it is beneficial to opt for a more expensive tender if it results in lower CO2 emissions. This consideration should extend beyond the construction phase and encompass the building's operational emissions. For example, a better-insulated building may be more expensive to construct initially but can save on heating costs and reduce CO2 emissions in the long run (B).

Collaborating with suppliers during project initiation is also advisable. Typically, suppliers are seen as sources of materials, but if a supplier has a new circular product, their expertise about the product can be invaluable to the project itself (R).

Challenging the status quo, some material producers are now reclaiming their materials at the end of their lifecycle due to the presence of valuable resources. This practice compels consumers to use materials in a way that allows for their extraction. An example of such a company is Philips, with its leased lighting products (B).

From the project's outset, involving all relevant parties fosters collaboration and ensures that everyone has a say. This collaborative approach establishes a clear goal from the beginning of a project, fostering trust (N, A, Ams).

Currently, the construction industry is highly segmented, with each actor performing its phase independently before passing it on to the next party. In a circular construction economy, these phases often overlap, requiring more collaboration among different parties. These phases eventually converge, allowing products to be returned (Hof, B).

Another change to the status quo is that the traditional sequence of phases may change. An example is the Hof van Cartesius, where various materials are reused. Often, they begin with a conceptual design and then search for available materials. Once the materials are found, the design is completed (flexible design). In the traditional approach, the design would be completed first, followed by the arrival of materials since new materials are always readily available (Hof).

To promote circularity, it is beneficial to execute several projects with the same group of parties. This is because circularity is a relatively new concept. By working on multiple projects with the same parties, you can learn how circular projects are structured. Eventually, you build a library of different projects, making it easier to reference how a project should be executed. This, in turn, facilitates collaboration with other parties (Ams).

Implementing circularity is challenging due to the deeply entrenched traditions within the construction industry, where many practices have remained unchanged for years. Transitioning to a circular business model often entails a significant overhaul, which can be challenging for entities that have invested heavily in linear organizational structures, particularly for manufacturers (B). Therefore, it can be beneficial for a company to create a separate division or subsidiary to experiment within the circular construction economy, allowing them to explore successful business processes (B).

7 | Discussion

7. Discussion

In the discussion, it is imperative to first establish the validity of the research. Subsequently, the significance of the results will be examined, as outlined in this chapter. Initially, a comparison will be drawn between the reviewed literature and the research outcomes. Following this, limitations will be discussed and suggestions for future research will be presented.

7.1. validity

Internal validity

Internal validity concerns the precision and consistency of the research outcomes within the particular context of the study. Internal validity was ensured by initially constructing a conceptual framework based on a review of the literature. Once the conceptual framework was established, the most suitable research methods were determined. The research comprises three main components: a literature review, several case studies and a document analysis. The criteria for the case studies were derived from the literature review. After the literature review, a document analysis was conducted, which, in conjunction with the literature review, informed the development of interview questions.

External validity

External validity concerns the extent to which the results of the study can be applied to contexts beyond the specific circumstances of the research. Generalizing to the population: to facilitate the replication of the research, criteria for the case studies were established. To ensure cross-context generalization, various types of case studies were conducted at different levels within the built environment: urban development, building, bridge, material flow and material. By encompassing a broad spectrum of research, the validity of the study can be extended to the entire construction sector.

7.2. Interpreting results

The problem statement of this thesis is that the construction industry is a significant contributor to pollution and resource depletion. Therefore, it is crucial to implement circularity in the construction industry. However, according to a research by Het Planbureau voor Leefomgeving (2019), only 2% of circular initiatives are considered innovative. The role of collaboration in implementing circular innovations is a subject of debate, with some advocating for increased collaboration (Çimen, 2021) and others noting that inter-organizational collaborations pose a barrier to the implementation of innovation in the circular economy (Planbureau voor Leefomgeving, 2019). Consequently, this thesis examines the relationship between innovation and collaboration in the circular construction sector.

The results of this research indicate that there is a variation in the relationship between innovation and collaboration based on the type of innovation and the stages of the product life cycle.

Analytical framework

In the theoretical background section, an analytical framework was established. Within this framework, the concepts of internal (limited collaboration) and external (more collaboration) were associated with both product and process innovation throughout the product life cycle.

The focus of the various case studies varied, addressing perspectives centered on process, product, manufacturing processes, and construction processes. A common observation across all case studies was the presence of both process and product innovation. Notably, it was

apparent that product innovation was closely linked to a higher degree of process innovation, whereas process innovation was less associated with significant product innovation.

As can be seen in figure 19. the findings indicated that product innovation predominantly played a more substantial role at the beginning of the product life cycle. Additionally, internal collaboration was more prominent at the outset of the product life cycle than in its later stages. A correlation became evident, particularly in the market development stage, where internal efforts primarily concentrated on product innovation. As we progressed through the product life cycle, there was a shift towards increased focus on process innovation and external collaboration.

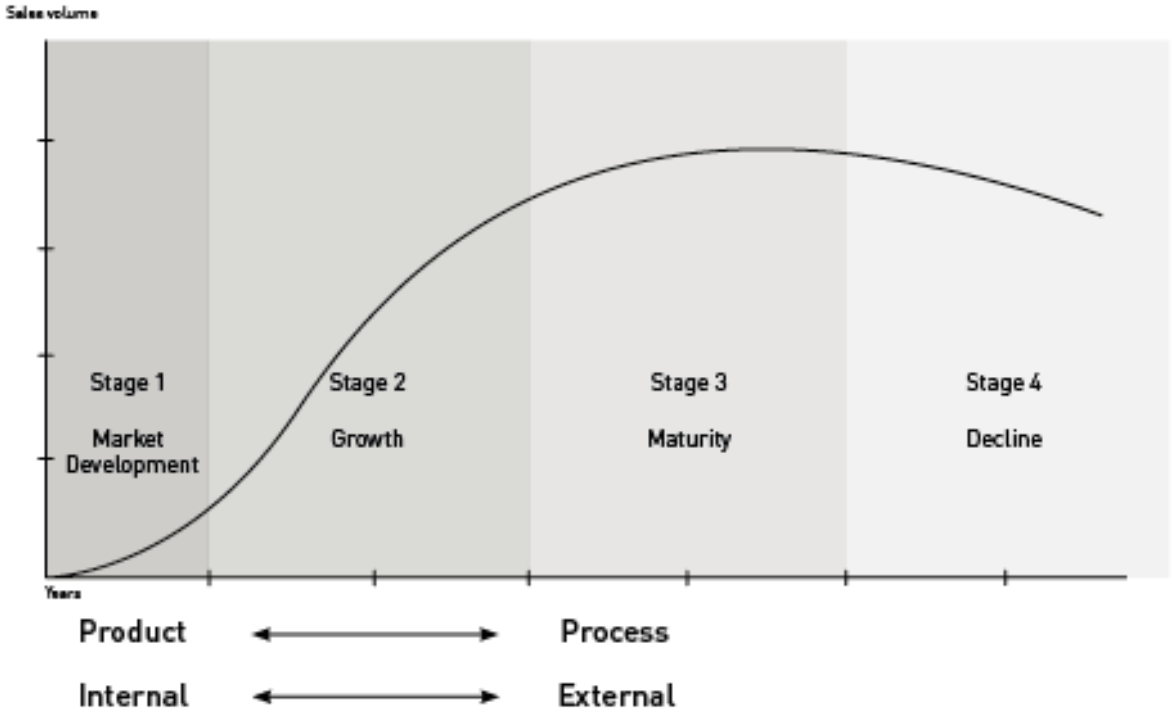

Figure 19. product life cycle linked to product, process, Internal and external (own elaboration).

Furthermore, it was observed that most quotes could not be allocated to the maturity or decline stages. This observation is rooted in the fact that new product and process development is often oriented toward growth anticipation, with limited consideration given to maturity or decline when establishing a new venture.

Additionally, distinct patterns aligned with the literature on internal and external approaches. As previously mentioned in the literature part, the internal strategy is more frequently associated with projects that demand higher specificity, involve greater uncertainty, and exhibit lower levels of trust and commitment within the supply chain. Conversely, when the external strategy is applied, it tends to involve collaborations for long-term orientations. At the outset of the product life cycle, it is notable not only that more quotes were allocated to internal collaboration, but also that the quotes concerning internal collaboration received a higher rating of relevance.

However, there was also the case study of Het Hof van Cartesius in which certain patterns observed in the other case studies did not manifest. For instance, the process became increasingly specific, and there wasn't necessarily more internal collaboration at the beginning

of the product life cycle. Patterns that did correspond with those in the other case studies were that the level of uncertainty also decreases as we progress further into the product life cycle and that trust and commitment are greater internally than externally. Furthermore, this case also aligned with the observation that at the beginning of the product life cycle, more internal work is carried out, and the amount of product innovation decreases as the life cycle progresses, while process innovation increases.

One possible explanation for this exception could be the various types of innovation within the construction industry. These will be elaborated on in the following section.

Innovation

The research has revealed various types of innovations within the circular construction sector. As previously noted in the literature, a distinction exists between product and process innovation (Pinto et al., 2023). This distinction also emerged from the study, revealing differences in collaborations and activities depending on whether product or process innovation was involved.

The research has also revealed that collaborations with various partners differ according to the different types of innovations. As can be seen in figure 20, we observe that product innovation primarily engages in collaborations with educational institutions. However, it is also possible that product innovation is entirely conducted internally if the company possesses sufficient resources for an internal R&D department. In the case of process innovation, there is a predominant inclination towards collaborations with market parties. These findings align with the case studies of Seawood, Beelen Next, and the Hoofdstraat.

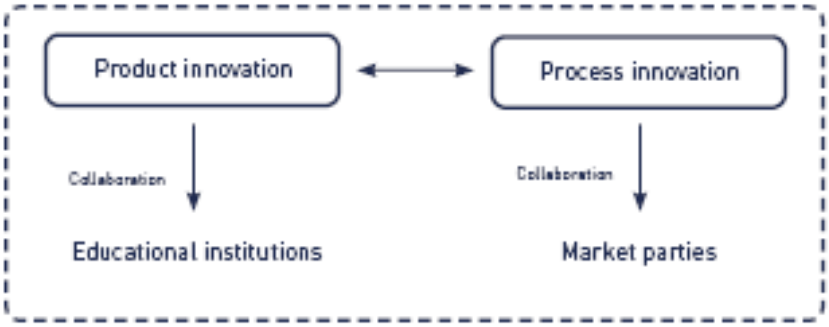

Figure 20. Collaborations in product and process innovation (own elaboration)

The case study of the Hof van Cartesius cannot be accommodated within figure 20. In this case, we observe various collaborations with different parties, leading to a complete transformation of the project chain (see figure 21). This restructuring primarily arises from the fact that, in circular projects, different phases of a project tend to overlap, which can lead to changes in the roles of participating stakeholders. For instance, the role of a demolisher, in the linear economy, primarily involves demolition activities. However, in the circular economy, we observe that the demolisher can also take on the role of a processor of materials or an advisor. Not only do the roles of stakeholders change, but the chronological sequence of tasks also changes. In the linear economy, for example, the process typically involves first creating a design, followed by passing the design to the contractor who then procures the materials and proceeds with the execution of the design. In the circular construction economy, especially in the case of flexible dynamic design: this is when the process begins with a preliminary design sketch, followed by the search for suitable materials. Only once these materials have been identified can the design be finalized.

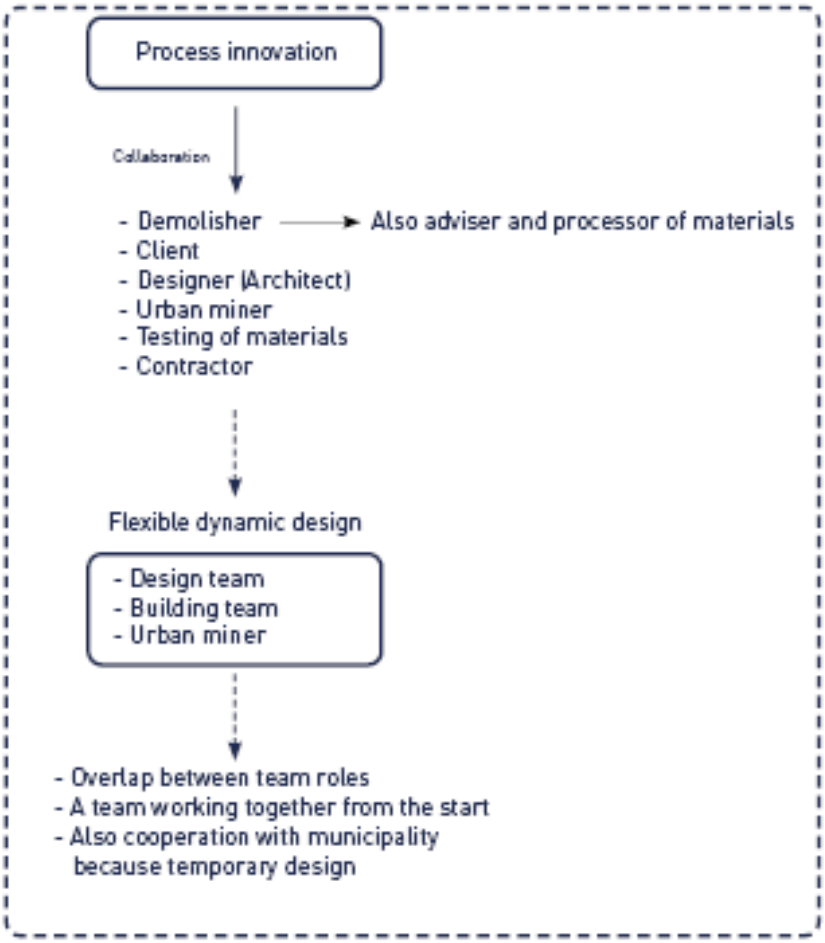

Figure 21. innovation type 2 (own elaboration)

One reason for these substantial differences in the case studies could be explained by Davidson's (2013) literature, which categorizes innovation in the construction industry into two types:

Type 1: Innovations that affect a single stakeholder.

Type 2: Innovations that affect multiple stakeholders, including those beyond the sphere of the original innovator.

A characteristic of innovation type 2 is that when dealing with this type of innovation, a complete re-engineering of the construction process is required (Davidson, 2013). This is also what we observe in the case study of the Hof van Cartesius.

Collaboration

Also, concerning the aspect of collaboration, many parallels were identified between the literature and the research. For instance, the literature emphasizes the significance of alignment of interests in facilitating effective collaborations (Berardi & Brito, 2021; Greer, 2017).

Another point which came up from the literature is the importance of inter-organizational relationships for knowledge sharing, which in turn fosters innovation (Klessova et al., 2020). It is imperative in this context that participating stakeholders have access to information and resources (Schreijer, 2020). During the interviews, it was frequently emphasized that collaborating with parties experienced in the circular construction economy is crucial due to their existing knowledge base. Other critical collaborations mentioned for knowledge exchange include partnerships with universities, which offer diverse areas of expertise, and working with market players who can specify product requirements and conditions, a form of knowledge in itself. Collaboration becomes more complex in the case of process innovation type 2, involving numerous stakeholders, all of whom play central roles in project realization. Each stakeholder possesses unique expertise and has access to various information and resources vital for project success.

Interviewees often stressed the importance of commencing collaboration from the project's beginning. This approach allows alignment of goals with all involved parties. Literature underscores the significance of early interaction and coordination among various stakeholders at the project's outset (Greer, 2017). By collaborating from the outset, there is also more time to build trust within these collaborations. This is also a pattern that resonates in the results of the analytical framework. The further we progress in the product life cycle, the longer the collaborations endure, the more trust has been established. Aligning with Schreijer's insights (2020) that longer-term collaborations result in clearer roles and objectives, thereby fostering more stable cooperation. However, it is also important to acknowledge the downsides of collaboration. Issues can arise when individuals fail due to tension, ill-intended behaviours, opportunistic behaviour, and unethical practices (Escher et al., 2020). This aspect was prominently emphasized during the interviews as well. The interviews repeatedly underscored the critical role of individuals in project success. If an individual lacks faith in the project, there is a substantial risk of project failure. Beyond individuals, the interviews also highlighted the significance of organizational support for those individuals. When organizations fail to support their employees in terms of time, effort, commitment, and the implementation of decisions, it becomes challenging for individuals to contribute effectively to the project, as also noted by Greer (2017).

Conclusion

While formulating the problem statement, a contradiction in the literature regarding whether collaborations are conducive or detrimental to the circular economy was identified. According to Çimen (2021), the construction industry becomes more complex due to the circular economy, implying that more collaborations would be beneficial for its implementation in construction. However, according to the Planbureau voor de Leefomgeving (2019), collaborations are a barrier to the implementation of circular initiatives.

The conducted research provides findings that support both assertions. The case study of the Hof van Cartesius demonstrates that as the project progresses through its life cycle, it becomes more specific and, consequently, more complex. Moreover, this case involves various types of collaborations, as each stakeholder possesses specific knowledge and skills. On the other hand, the Seawood case reveals that there are few collaborations at the outset of product innovation. This case study highlighted that they collaborated with educational institutions, but such collaborations are only necessary when a company lacks the resources for an internal R&D department. During the interview, it was mentioned that they initially collaborated with another company, both working on different aspects of the product. When market interest emerged, the other company withdrew, leading to increased time and effort to bring the product to market. This case study aligns with the notion that collaborations can be a barrier to the

implementation of the circular construction economy (Planbureau voor de Leefomgeving, 2019). Whether more or fewer collaborations are better for the circular construction economy varies depending on the type of innovation and its position in the product life cycle.

According to the problem statement, there is also a lack of innovation in the circular economy. The interviews reveal that innovations do exist but are often confined to pilot projects due to insufficient process innovation. Innovative initiatives are present in the construction industry but are not commonly adopted on a large scale. Interviews with Seawood highlighted their desire to produce on a large scale, given that construction projects often involve significant square footage. To make a meaningful impact in this context, the ability to deliver products on a large scale is essential. It is likely that by paying more attention to the process innovation of these products, the project's chances of success will significantly increase.

Moreover, in various projects, we also encounter challenges related to legal and regulatory compliance. Innovative products and processes frequently do not align with existing laws and regulations. Consequently, this often acts as a barrier to the implementation of the circular economy in construction. It is likely that placing more emphasis on products and processes that do not fall within these legal and regulatory frameworks will be beneficial in expediting the process of implementing the circular economy in the construction sector.

7.3. Limitations

From the document analysis limited information was obtained regarding collaborations. Therefore, most of the results are based on the interviews. The various interviewed parties had different interests during the projects, which could have led to not all questions being answered candidly by the interviewees. For instance, during the interviews, a question was posed regarding whether there were parties they avoided collaborating with. Many of the interviewees responded no, possibly because they did not want other parties to discover that they were avoiding collaboration for certain projects. To mitigate this in the future, it may be advisable to use an anonymous survey for such questions.

During the first case study, the project on the Hoogstraat, it was noted that since the project had been completed in 2018, not all interviewees could recall the project details accurately. As a result, different interviewees sometimes provided varying information, or they answered questions in a more general manner or related them to more recent projects because they were uncertain about the answer. To address this in the future, it might be beneficial not only to consider projects that fit within the scope of the research but also to assess the age of the projects.

Finally, the results obtained from the analytical framework are limited for the maturity stages and entirely absent for the decline stages. This is attributed to the newness of the circular construction economy, as it has not progressed sufficiently within the product life cycle to allow for conclusive statements. Consequently, there is a scarcity of, if any, conclusions that can be drawn regarding these latter two stages of the product life cycle.

7.4. Suggestions for follow-up research

In a follow-up study, the analytical framework could be tested in a sector other than the construction industry. This approach would facilitate the exploration of relationships between collaborations and innovations in the circular economy across diverse sectors. Such research may further aid in enhancing and promoting the implementation of the circular economy in various industries.

Furthermore, a follow-up study could delve deeper into the types of collaborations necessary for different forms of innovation. For instance, it could investigate the most efficient means of

establishing these collaborations, the optimal forms of collaboration for specific cases, and the most effective duration for these collaborative efforts.

Lastly, it would be beneficial to conduct a study that encompasses the final two stages of the product life cycle. Due to the novelty of the circular economy, this research did not yield sufficient results concerning these stages. An innovative process or product that was relevant within its time in the product life cycle could be examined. This research would allow for anticipation of how the innovation life cycle in circular construction processes will unfold.

8 | Conclusion

8. Conclusion

In this chapter, the conclusions of the study are presented. The chapter will be structured by initially providing answers to the sub-questions. These responses will serve as a foundation for addressing the main research question.

Main question

- What is the relationship between collaboration and innovation in the circular construction sector?

Sub-questions

- RQ1: What kind of innovations are there in the circular construction sector?
- RQ2: What are the different elements of collaboration in the circular construction sector?
- RQ3: What are the factors that drive and prevent collaborations in the innovation of the circular construction sector?
- RQ4: Who are the stakeholders with whom collaboration should be established to facilitate innovation in the circular construction sector?

8.1.Innovations

What kind of innovations are there in the circular construction sector?

In the context of the circular construction sector, innovation is a dynamic process driven by the transformation of knowledge into new products and processes. As highlighted by Pinto et al. (2023), innovation involves the conversion of diverse forms of knowledge into valuable outcomes. This process is integral to the circular economy, which is characterized by a restorative and regenerative design approach. The primary objective of the circular economy is to maintain products, components, and materials at their peak utility and value throughout their lifecycle.

this study highlights a fundamental distinction between product innovation and process innovation within the circular construction sector. This distinction is significantly influenced by the composition of collaborating parties and the timing of these collaborations. The research underscores that concerning product innovation, establishing collaborations with educational institutions can yield substantial benefits, particularly during the initial phases of product innovation. Collaborating with educational institutions offers the advantage of gaining access to diverse disciplines that may not be readily available within a company's internal team, thereby expanding the pool of knowledge and involving a broader range of expertise in the innovation process. Additionally, educational institutions provide a cost-effective means of accessing valuable knowledge, which proves particularly advantageous for startup ventures. Conversely, larger companies often maintain research and development (R&D) teams and possess greater resources, diminishing the imperative need for collaboration with universities, especially when compared to startups.

In contrast, process innovation entails collaborations that frequently involve a more extensive array of stakeholders, although the nature of these collaborations varies considerably based

on the specific process and its objectives. Key stakeholders engaged in the process innovation include market players. Collaborating with market players is ecclesial to establish the prerequisites of products.

In addition to regular product and process innovation, there can be a specific type of innovation in the construction industry, known as Ttpe 2 innovation. This occurs when an innovation affects multiple stakeholders and results in a re-engineering of the construction process (Davidson, 2013). This is also the case when flexible dynamic design is employed. This type of process innovation is on a larger scale, involving the process of construction. When innovation is applied in this context, the entire chain transforms. The flexible dynamic design emerges approach consists of three main teams: the design team, the building team, and the urban miners. Within these teams, various stakeholders may be involved, such as the demolisher, architect, urban miner, materials tester, and contractor. What makes the flexible dynamic design unique is the overlap between different roles, necessitating a more intensive collaboration. It is also crucial to establish effective collaboration among all teams from the project's inception. Furthermore, continuous coordination with municipal authorities is essential throughout the project, as this mode of operation does not yet align with existing laws and regulations.

8.2. Collaborations

What are the different elements of collaboration in the circular construction sector?

In conclusion, this investigation into inter-organizational collaboration within the circular construction sector has unveiled various essential elements that contribute to its effectiveness. Responding to the second research question, key elements of collaboration in this sector were identified.

Firstly, Each project has a level of specificity, which corresponds to different resources from various stakeholders. the availability and sharing of resources are vital for successful collaboration. Resources, including funding, time allocation, support from home organizations, competencies and expertise are essential for facilitating desired outcomes. Collaborations enable the identification, exploitation and distribution of shared resources, which contribute to legitimacy and equitable outcomes.

Secondly, the establishment of inter-organizational collaborations often depends on the level of uncertainty associated with the project. When things are uncertain, there are often no or very few parties willing to collaborate with you. This can be due to the lack of parties possessing the required expertise or because the risks are too significant for other parties.

Thirdly, The level of trust & commitment is important for a collaboration. effective collaboration hinges on the composition of collaboration members, emphasizing the importance of commitment, expertise, access to information and resources, and individual engagement. Important selection criteria for productive collaboration members are commitment, willingness to engage in early discussions, receptiveness to novel information and ideas, and a disposition that values listening, communication and collaboration. Organizational support in terms of time, effort, commitment and decision implementation is crucial, and members' interest and capacity to participate are paramount.

Lastly, time management is another critical factor. Collaborative efforts are time-intensive, involving the establishment of communication practices, relationship cultivation, and process delineation. Efficient collaboration requires members to invest time and effort in discussions,

definitions, construction and the implementation of necessary elements. Collaborations operate within temporary, delicate structures, making time constraints a potential impediment.

8.3. Factors that drive and factors that prevent

What are the factors that drive and prevent collaborations in the innovation of the circular construction sector?

The factors that drive and hinder collaborations and innovation in the circular construction sector are multifaceted and critically impact the sector's development. Understanding these factors is crucial for fostering a sustainable and innovative circular construction economy.

Several factors act as driving forces behind innovation in this sector. Firstly, knowledge expansion plays an important role. A profound understanding of circularity is essential for devising intelligent solutions. Companies must continually broaden their knowledge base to effectively stimulate innovation. Another way to acquire knowledge may involve establishing collaborations with parties that already possess expertise in the circular construction economy. Moreover, open communication with municipal authorities emerges as another driving factor. Collaboration with local governmental bodies holds great significance since innovative solutions often challenge existing regulations. An open dialogue facilitates the streamlining of permit procedures and approvals, smoothing the path for innovative endeavours. Focused innovation is a crucial aspect. Recognizing that not all innovations are universally applicable or in high demand, companies must strategically channel their energy and resources into areas with the potential for substantial impact.

Furthermore, embracing unconventional ideas is important. Innovation thrives on thinking outside the conventional boundaries and championing unconventional concepts within organizations. Encouraging a shift in mindset is instrumental in fostering innovation. The competitiveness of circular products in the market is also a driving factor. To achieve prominence in circular innovations, companies must compete effectively with existing products on the market. Economically viable and appealing circular products are more likely to be adopted.

Conversely, various factors can impede innovation within the circular construction sector. The legacy of linear infrastructure poses a significant challenge. Many companies have made substantial investments in linear production lines, rendering the transition to circular practices complex and demanding a potential restructuring of entire business models. Contractual constraints can be a hindrance, particularly when projects are bound by contracts that prohibit collaboration, impeding collaborative efforts essential for circular innovation. Additionally, large collaboration groups can diminish opportunities, elevate risks, and create difficulties in maintaining a focused approach to specific goals. Moreover, uncertainty regarding the long-term impact of circular practices in construction, especially for multi-decade projects, presents challenges due to future uncertainties. Lastly, When it comes to recycling materials and preparing them, problems can be encountered. Reused materials often require cleaning, repairs, or rust removal, which adds time and effort to the construction process. This sometimes makes it difficult to determine whether it is worth reusing a material.

Understanding these driving factors and barriers is essential for stakeholders in the circular construction sector to navigate the complexities and foster innovation while addressing challenges effectively.

8.4. Stakeholders

Who are the stakeholders with whom collaboration should be established to facilitate innovation in the circular construction sector?

The stakeholders with whom collaboration is necessary vary depending on the type of innovation. For product innovation , it is essential to collaborate with educational institutions as this provides access to diverse disciplines. However, this collaboration is not necessary when a company has its in-house R&D department. In the case of process innovation , it is crucial to collaborate with market entities to establish the prerequisites for a product.

Lastly, there is process innovation type 2, which involves more complex collaborations. This innovation entails a complete reengineering of the construction process, resulting in different types of collaborations and structural changes in collaborations compared to the pre-innovation phase.

One instance where this occurs is in the implementation of flexible dynamic design. Collaborative efforts in this context involve a design team, a building team, and an urban miner team. Within these teams, various stakeholders are present, including the demolisher, client, architect, urban miner, materials tester, and contractor. What distinguishes this innovation is the overlap between different roles. For instance, the architect can also be the urban miner, or the demolisher can be the one testing or preparing materials for reuse. It is also vital to initiate collaboration from the project's inception and establish agreements regarding the project's end goals.

Other key collaborations include collaboration with circularity experts enriches knowledge and fosters vital networks in various domains like modular timber construction, biobased materials and suppliers and subcontractors specializing in circular products contribute their extensive knowledge. Material dismantlers ensure proper disassembly for reuse.

Local municipalities hold important roles, especially in the absence of established circular regulations. Their openness and careful consideration of permit procedures are vital for project success.

8.5. The relationship between collaboration and innovation

At the outset of this study, ‘ two concepts in the circular construction sector were investigated: collaboration and innovation. The reason for investigating these two concepts stemmed from the contradiction in the literature regarding the effectiveness inter-organizational collaboration in facilitating innovation within the circular construction economy. This inquiry led to the main research question: *What is the relationship between collaboration and innovation in the circular construction sector?*

The relationship between collaboration and innovation in the circular construction sector is multifaceted and influenced by various interconnected factors. In this thesis, these factors are examined from three different perspectives. First, there are various elements that influence whether internal or external development is more suitable for a project. These elements include the level of specificity, the level of uncertainty, the level of trust & commitment, and the time frame. Internal work involves fewer collaborations, while external work involves many collaborations. Second, different types of innovations exist within the circular construction economy, distinguishing between process innovation and product innovation. It should be highlighted that innovations in the construction process affecting multiple stakeholders can necessitate a re-engineering of the entire construction process. Third, the relationship between innovation and collaborations in the circular construction economy varies depending on the

stage of the product life cycle. The product life cycle consists of different stages, each characterized by varying types of innovation and levels of collaboration.

When these factors are compared, certain patterns emerge in the case studies. In each case study, there is a mix of both process and product innovation, with some showing a more distinct connection than others. Another pattern that emerges is that at the beginning of the product life cycle, the focus is more on product innovation, transitioning to a greater emphasis on process innovation as the life cycle progresses. Additionally, it is observed that at the beginning of the life cycle, more internal work is performed, while the focus shifts to external collaboration later on.

The relationship between collaboration and innovation in the circular construction sector varies depending on the type of innovation and the stage within the product life cycle. By examining these relationships at each stage, a key takeaway can be derived for each stage:

Market development: during the market development phase, a pattern emerges where the level of specificity, level of trust, and level of uncertainty are all at their highest. There is also a more frequent focus on product innovation. The key takeaway for this stage is that starting innovation internally is often the most effective approach.

Growth: in this stage, there is a reduction in the level of specificity and uncertainty, and the focus shifts more towards process innovation. The key takeaway for this stage is that if you've already undergone product innovation, it's essential to consider process innovation. In this stage, both process and product innovation may involve increased collaboration. Many of the quotes in this stage related to process innovation and involved regulations and the application of innovations that do not fit in these regulations. By considering this in earlier stages or by making it easier to implement innovations outside these regulations, the circular economy can be more rapidly integrated into the construction sector.

Maturity: there were few quotes that could be placed in this stage. The available quotes mostly pertained to process innovation and indicated more collaborations compared to the growth stage. The key takeaway here is the importance of considering the maturity stages in earlier phases and thinking about potential collaborations for this phase. Since further along the life cycle, more collaborations come into play. Hence, it may be beneficial to start looking at potential parties to collaborate with in advance.

Decline: no quotes were available for this stage. The reason for the decline is that there is no further innovation. This could be a reason why no results were found for this stage. The key takeaway for this stage is that to avoid entering the decline stages, one must continue innovating. Therefore, it's crucial to consider this in earlier stages.

To address the issue of insufficient innovations in the circular economy, some findings from this thesis can be employed. One potential reason for the persistence of pilot projects might be inadequate consideration of process innovation. Additionally, innovations often encounter legal and regulatory constraints that impede project progress. It is likely that directing subsidies from both public and private sectors more towards process innovation or streamlining the approval process for products and processes that do not align with existing regulations could promote the implementation of the circular economy within the construction sector.

9 | Reflection

9. Reflection

This chapter provides a reflective analysis of the preliminary results of the research and design conducted during the graduation phase, focusing on product, process, and planning. It encompasses reflections on the graduation process, methodology, outcomes, and their relation to the master's program. Additionally, a personal reflection on the graduation process and its outcomes will be presented.

Relation between Graduation and the Master of Management in the Built Environment (MBE)
This thesis contributes to a better understanding of collaboration and innovation within the circular construction economy. It sheds light on how collaboration structures align with various types of innovation prevalent in the circular construction economy. The MBE master's track encompasses a broad spectrum of topics within the built environment. The findings of this thesis can be practically applied to streamline the integration of innovation into the circular construction economy.

Relationship between Research and Design
A continuous feedback loop existed between research and design throughout the project. Initially, research laid the foundation for the design process by providing a structured framework. The literature review further refined the research approach. An analytical framework was developed based on the insights gained from the literature, which was subsequently applied in the research. The literature review also set prerequisites for the case studies. During the case studies, this feedback loop persisted. Additional case studies were introduced to address information gaps, and the literature review was expanded to complement and validate the case study findings. This iterative process led to minor adjustments in the analytical framework and even the research's primary question.

Approach, Methods, and Methodology
The research sequence proved effective for this study. Initiating an extensive literature review provided a solid foundation. However, some challenges were encountered. Initially, the plan was to conduct a comprehensive document analysis before commencing interviews. Unfortunately, not all expected information was available in the documents, and some were delivered late, prompting the formulation of interview questions based primarily on information from the literature review. Nevertheless, the document analysis proved valuable in enhancing the understanding of the case studies and acquiring additional information. In hindsight, some questions in the interviews might have been better addressed through anonymous surveys, as certain interviewees seemed cautious in their responses to specific questions. Additionally, during the interviews, it became evident that one of the case studies had concluded several years ago, resulting in limited recall of details. This was compensated for by conducting an extra case study of a project still in progress.

Academic and Societal Value
As previously mentioned this research contributes to both academic and societal domains in multiple ways. The study addresses a literature gap, providing insights into the relationship between collaboration and innovation within the circular construction sector, a topic that lacks comprehensive coverage in academic literature. However, this knowledge is of paramount importance for societal value, particularly in the current context of an environmental crisis and the increasing significance of circularity. Achieving the goals of a fully circular economy by 2050 necessitates substantial changes. Given the significant environmental impact of the built

environment, this research can contribute to a better understanding of how to transition the construction economy toward circularity.

Transferability
The transferability of this research and its potential for future studies are ensured through the well-established methodology and research framework. Both the research methodology and the criteria for selecting case studies are thoroughly explained in the report. Consequently, replicating this research for different case studies in the future is feasible.

Personal Reflection on the Process
The initial weeks were challenging due to the limited timeframe for selecting a theme that would be the focus for the next year. Initially, the research was centred on exploring collaborations required for constructing buildings with reused materials. However, after conducting a literature review and discussing it with my mentors, the research gradually shifted its focus toward the role of collaborations in the innovation of the circular construction sector. The thematic meetings, where various students gathered, proved immensely beneficial. These meetings offered valuable insights into structuring the thesis and writing it effectively.

Following my P2, it was time to execute the research. However, there were challenges in reaching the individuals I intended to interview, leading to modifications in the research plan. Some individuals did not respond, prompting contact with alternative interviewees. During this period, I also participated in the interdisciplinary thesis lab at the Leiden-Delft-Erasmus Center for Sustainability. This provided an opportunity to gain practical insights for my thesis from an engineering firm, Antea Group, with which I maintained regular contact. This practical exposure complemented my research well. It was also during this time that I realized the need for additional information, resulting in an extra case study.

The final phase of my research was arguably the most challenging. Initially, the obtained information was relatively generic, lacking innovativeness. Fortunately, over time, this issue was rectified.

At the beginning of the graduation process, I set three study targets for myself. I aimed to enhance my understanding of the circular construction industry, improve my planning skills, and gain clarity about my future career direction. I have made significant progress in achieving these study targets. I have learned extensively about circularity over the past year and have a clearer vision of working in this domain after graduation. However, planning remains an area of challenge.

10 | References

10. References

Atlas. ti. (n.d.). What is ATLAS.ti. ATLAS.ti. Retrieved December 17, 2021, from https://atlasti.com/product/what-is-atlas-ti

Atta, I., Bakhoum, E. S., & Marzouk, M. M. (2021). Digitizing material passports for sustainable construction projects using BIM. *Journal of Building Engineering*, *43*, 103233.

Benam, B. (2022, June 13). Why Vertical Integration Made Tesla More Powerful - Behzad Benam. Medium. https://medium.com/@bhbenam/why-vertical-integration-made-tesla-more-powerful-8b33b6aee773

Berardi, P. C., & de Brito, R. P. (2021). Supply chain collaboration for a circular economy transition to continuous improvement. *Journal of Cleaner Production*, *328*, 129511.

Billé, R. (2010). Action without change? On the use and usefulness of pilot experiments in environmental management. SAPI EN. S. Surveys and Perspectives Integrating Environment and Society, (3.1).

Blaikie, N., & Priest, J. (2019). *Designing social research: The logic of anticipation*. John Wiley & Sons.

Brown, P., Bocken, N., & Balkenende, R. (2018). Towards understanding collaboration within circular business models. *Sustainable Business Models: Principles, Promise, and Practice*, 169-201.

Brunner, P. H. (2011). Urban mining a contribution to reindustrializing the city. *Journal of Industrial Ecology*, *15*(3), 339-341.

Brütting, J., De Wolf, C., & Fivet, C. (2019). The reuse of load-bearing components. In IOP Conference Series: Earth and Environmental Science (Vol. 225, No. 1, p. 012025). IOP Publishing.

Bryman, A. (2016). *Social research methods*. Oxford university press.

Chan, P.W. (n.d.). *Quick Guide on Research Ethics*.

Chao-Duivis, M. A. B., Koning, A. Z. R., Ubink, A. M., & Stichting Instituut voor Bouwrecht. (2018). A Practical Guide to Dutch Building Contracts. Instituut voor Bouwrecht.

Çimen, Ö. (2021). Construction and built environment in circular economy: A comprehensive literature review. *Journal of Cleaner Production*, *305*, 127180.

Damanpour, F., & Gopalakrishnan, S. (2001). The dynamics of the adoption of product and process innovations in organizations. Journal of Management Studies, 38(1), 45–65. https://doi.org/10.1111/1467-6486.00227

Davidson, C. (2013). Innovation in construction–before the curtain goes up. Construction Innovation, 13(4), 344-351.

Dé fysieke proeftuin voor de circulaire economie | Hof van Cartesius. (n.d.). https://www.hofvancartesius.nl/circulair

Doran, J., Ryan, G., Bourke, J., & Crowley, F. (2020). In-house or outsourcing skills: how best to manage for innovation?. International Journal of Innovation Management, 24(01), 2050010.

Eriksson, P. E. (2015). Partnering in engineering projects: Four dimensions of supply chain integration. *Journal of purchasing and supply management*, *21*(1), 38-50.

Escher, I., & Brzustewicz, P. (2020). Inter-organizational collaboration on projects supporting sustainable development goals: The company perspective. Sustainability, 12(12), 4969.

EU. (n.d.). *Circular economy action plan*. Environment. Retrieved 25 May 2022, from https://ec.europa.eu/environment/strategy/circular-economy-action-plan_en

Faes, K. (2021). Hoogwaardig hergebruik bouwproducten en -materialen. In Cirkelstad. Cirkelstad. https://www.cirkelstad.nl/wp3/wp-content/uploads/2021/10/GP-Hoogwaardig-Hergebruik-DEF.pdf

Farooque, M., Zhang, A., Thürer, M., Qu, T., & Huisingh, D. (2019). Circular supply chain management: A definition and structured literature review. *Journal of cleaner production*, *228*, 882-900.

Gkypali, A., Filiou, D., & Tsekouras, K. (2017). R&D collaborations: is diversity enhancing innovation performance?. Technological Forecasting and Social Change, 118, 143-152.

Gorgolewski, M. (2006). The implications of reuse and recycling for the design of steel buildings. *Canadian Journal of Civil Engineering*, *33*(4), 489-496.

Greco, M., Grimaldi, M., & Cricelli, L. (2020). Interorganizational collaboration strategies and innovation abandonment: The more the merrier?. Industrial Marketing Management, 90, 679-692.

Greer, P. A. (2017). Elements of effective interorganizational collaboration: a mixed methods study (Doctoral dissertation, Antioch University).

Guldmann, E., & Huulgaard, R. D. (2020). Barriers to circular business model innovation: A multiple-case study. *Journal of Cleaner Production*, *243*, 118160.

Gunasekaran, A., & Ngai, E. W. (2004). Information systems in supply chain integration and management. European journal of operational research, 159(2), 269-295.

Hage, J., & Meeus, M. (2006). Innovation, science, and institutional change: A Research Handbook. OUP Oxford.

Han, Y., Li, Y., Taylor, J. E., & Zhong, J. (2018). Characteristics and evolution of innovative collaboration networks in architecture, engineering, and construction: Study of national prize-winning projects in China. Journal of Construction Engineering and Management, 144(6), 04018038.

Hansen, E. G., & Revellio, F. (2020). Circular value creation architectures: Make, ally, buy, or laissez-faire. Journal of Industrial Ecology, 24(6), 1250-1273

Hart, J., Adams, K., Giesekam, J., Tingley, D. D., & Pomponi, F. (2019). Barriers and drivers in a circular economy: the case of the built environment. Procedia CIRP, 80, 619–624. https://doi.org/https://doi.org/10.1016/j.procir.2018.12.015

Hegeman, H. (2019, December 9). Beelen NEXT presenteert 'NEXT-Use Hout' - Cirkelstad. Cirkelstad. https://www.cirkelstad.nl/beelen-next-presenteert-next-use-hout/

Heisel, F., & Rau-Oberhuber, S. (2020). Calculation and evaluation of circularity indicators for the built environment using the case studies of UMAR and Madaster. *Journal of Cleaner Production*, *243*, 118482.

Het Hof van Cartesius: the circular hotspot for circular action. (2020, November 2). European Circular Economy Stakeholder Platform. https://circulareconomy.europa.eu/platform/en/good-practices/het-hof-van-cartesius-circular-hotspot-circular-action

Herontwikkeling Hoogstraat 168-172 Rotterdam | Rijnboutt. (2023, January 30). Rijnboutt. https://rijnboutt.nl/portfolio/hoogstraat-168-172/

Huo,B. (2012) The impact of supply chain integration on compny performance: an organizational capability perspectiveSupply Chain Manag.: Int. J., 17 (6)

Het ministerie van Infrastructuur en Milieu, Het ministerie van Economische Zaken, Het ministerie van Buitenlandse Zaken, & Het ministerie van Binnenlandse Zaken en Koninkrijksrelaties. (2016, September). Nederland circulair in 2050. In *open.overheid.nl*. https://open.overheid.nl/repository/ronl-a6ce8220-07e8-4b64-9f3d e69bb4ed2f9c/1/pdf/bijlage-1-nederland-circulair-in-2050.pdf

Jacobs, J. (1969). *The economy of cities*. Vintage.

Jansonius, T. (2022, February 9). Het Hof van Cartesius Proeftuin van circulair bouwen #2 scouten en oogsten [Video]. YouTube. https://www.youtube.com/watch?v=qPEtuSpvjJ4

Kanters, J. (2018). Design for deconstruction in the design process: State of the art. *Buildings*, *8*(11), 150.

Kirchherr, J., Piscicelli, L., Bour, R., Kostense-Smit, E., Muller, J., Huibrechtse-Truijens, A., & Hekkert, M. (2018). Barriers to the circular economy: Evidence from the European Union (EU). Ecological economics, 150, 264-272.

Klessova, S., Thomas, C., & Engell, S. (2020). Structuring inter-organizational R&D projects: Towards a better understanding of the project architecture as an interplay between activity coordination and knowledge integration. International Journal of Project Management, 38(5), 291-306.

Kooter, E., Uden, M. V., Marrewijk, A. V., Wamelink, H., Bueren, E. V., & Heurkens, E. (2021). Sustainability transition through dynamics of circular construction projects. *Sustainability*, *13*(21), 12101.

Koolwijk, J. S. J., van Oel, C. J., Wamelink, J. W. F., & Vrijhoef, R. (2018). Collaboration and integration in project-based supply chains in the construction industry. *Journal of Management in Engineering*, *34*(3), 04018001.

Kuhlmann, M., Bening, C. R., & Hoffmann, V. H. (2022). How incumbents realize disruptive circular innovation-Overcoming the innovator's dilemma for a circular economy. Business Strategy and the Environment.

Levitt, T. (1965). *Exploit the product life cycle* (Vol. 43). Graduate School of Business Administration, Harvard University.

Lica, I. M. (2019). The circular economy approach in cities: an evaluation of municipal measures in Brussels. *Cogito: Multidisciplinary Res. J.*, *11*, 180.

Lincoln, Y. S., & Guba, E. G. (1985). Naturalistic inquiry. sage.

Longoria, R. A. (2005). Is inter-organizational collaboration always a good thing. J. Soc. & Soc. Welfare, 32, 123.

MacArthur, F. E. (2013). Towards the circular economy. https://www.ellenmacarthurfoundation.org/assets/downloads/publications/Ellen-MacArthur-Foundation-Towards-the-Circular-Economy-vol.1.pdf

MacArthur, E., Zumwinkel, K., & Stuchtey, M. R. (2015). Growth within: a circular economy vision for a competitive Europe. *Ellen MacArthur Foundation*.

Meehan, J., & Bryde, D. (2011). Sustainable procurement practice. Business strategy and the environment, 20(2), 94-106.

Min, S., Roath, A. S., Daugherty, P. J., Genchev, S. E., Chen, H., Arndt, A. D., & Glenn Richey, R. (2005). Supply chain collaboration: what's happening?. The international journal of logistics management, 16(2), 237-256.

Ministerie van Infrastructuur en Waterstaat. (2022, March 1). *Uitvoeringsprogramma Circulaire Economie*. Rapport | Rijksoverheid.nl. Retrieved 24 May 2022, from https://www.rijksoverheid.nl/onderwerpen/circulaire-economie/documenten/rapporten/2021/10/18/uitvoeringsprogramma-circulaire-economie

Nikerk, M., Starmans, E., & Govaart, Y. (2021, April 13). *Circulair bouwen -"Beginnen is belangrijker dan perfect zijn"*. Cirkelstad. Retrieved October 8, 2022, from https://www.cirkelstad.nl/circulair-bouwen-beginnen-is-belangrijker-dan-perfect-zijn/

Pinto, H., Guerreiro, J. A., & Fernández-Esquinas, M. (2023). Sources of knowledge in the irm: a review on influential, internal and contextual factors in innovation dynamics. SN Business & Economics, 3(2), 57.

Planbureau voor de Leefomgeving. (2019). Circulaire economie in kaart. In PBL.nl (No. 3401). Retrieved January 22, 2023, from https://www.pbl.nl/sites/default/files/downloads/pbl2019-circulaire-economie-in-kaart3401.pdf

Peters, P., & Relker, T. (2019). Donorskelet, second that. In BOUWEN MET STAAL 270. Retrieved February 6, 2023, from https://www.nvtb.nl/images/Circulariteit/Staalbouw/270_donorskelet.pdf

Pomponi, F. and Moncaster, A. (2017) Circular economy for the built environment: Aresearchframework,Journal of Cleaner Production,

Pries, F., & Dorée, A. (2005). A century of innovation in the Dutch construction industry. Construction Management and economics, 23(6), 561-564.

Pronk, A., Brancart, S., & Sanders, F. (2022). Reusing Timber Formwork in Building Construction: Testing, Redesign, and Socio-Economic Reflection. Urban Planning, 7(2), 81-96. https://doi.org/10.17645/up.v7i2.5117

Richardson, A. (2013, 1 januari). *Reuse of Materials and Byproducts in Construction: Waste Minimization and Recycling*. Springer Publishing.

Ruiz, L. A. L., Ramón, X. R., & Domingo, S. G. (2020). The circular economy in the construction and demolition waste sector–A review and an integrative model approach. *Journal of Cleaner Production*, *248*, 119238.

Sayed, M., Hendry, L. C., & Zorzini Bell, M. (2021). Sustainable procurement: Comparing in-house and outsourcing implementation modes. Production Planning & Control, 32(2), 145-168.

Schmitt, J. C., & Hansen, E. G. (2018, July). Circular innovation processes from an absorptive capacity perspective: The case of cradle-to-cradle. In Academy of Management Annual Meeting Proceedings (Vol. 16814).

Schruijer, S. (Ed.). (2020). Dynamics of Interorganisational Collaborative Relationships. MDPI-Multidisciplinary Digital Publishing Institute.

Sprakel, M. (2022). *Circular procurement in a project setting in the construction sector* [MA Thesis]. University of Twente.

Statista. (2021, August 27). Average company lifespan of S&P 500 companies 1965-2030. https://www.statista.com/statistics/1259275/average-company-lifespan/

Sudusinghe, J. I., & Seuring, S. (2021). Supply chain collaboration and sustainability performance in circular economy: A systematic literature review. International Journal of Production Economics, 108402.

Suchek, N., Fernandes, C. I., Kraus, S., Filser, M., & Sjögrén, H. (2021). Innovation and the circular economy: A systematic literature review. Business Strategy and the Environment, 30(8), 3686-3702.

The Ellen Macarthur Foundation. (n.d.). *Circular public procurement: a framework for cities - Circular Procurement for Cities*. Https://Emf.Gitbook.Io/Circular-Procurement-for-Cities/. Retrieved 2022, from https://emf.gitbook.io/circular-procurement-for-cities/

Van Bueren, E., Buizer, E., Van den Berghe, K., Heijkers, B., Meijs, L., Verhagen, T., Dittrich, K.,
Sperecher, B. (2021) Perspectieven op circulaire Gebeidsontwikkeling. *ACCEZ*

Taplin, D. H., Clark, H., Collins, E., & Colby, D. C. (2013). Theory of change. *Technical papers: a series of papers to support development of theories of change based on practice in the field. ActKnowledge, New York, NY, USA*.

Van den Berghe KBJ and Verhagen TJ (2021) Making it Concrete: Analysing the Role of Concrete Plants' Locations for Circular City Policy Goals. Front. Built Environ. 7:748842.doi: 10.3389/fbuil.2021.748842

Vivona, R., Demircioglu, M. A., & Audretsch, D. B. (2022). The costs of collaborative innovation. The Journal of Technology Transfer, 1-27.

Waarom een circulaire economie? (2016, 29 maart). PBL Planbureau voor de Leefomgeving. Geraadpleegd op 16 oktober 2022, van https://www.pbl.nl/publicaties/waarom-een-circulaire Economie

Winch, G.M. (2010). Forming the Project Coalition. In: Managing Construction Projects; An Information Processing Approach. West Sussex, UK: John Wiley & Sons. Excluding case 5 and panel 5.3.

Yin, R. K. (2013). Identifying your case (s) and establishing the logic of your case study. *Case Study research: design and methods*, *25*.

Appendix A

Appendix A

Interview protocol

Hallo goeiedag

Hoe gaat het?

Om te beginnen wil ik u alvast bedanken voor u deelnamen aan dit interview. Ik ben Estela Regos Casas en ik doe nu de master Management in the Built Environment aan de TU Delft. Voor het schrijven van mijn thesis ben ik interviews aan het uitvoeren over de rol van samenwerkingen binnen de innovatie circulaire bouw sector. Door middel van deze interview kom ik er graag achter welke samenwerkingen er hebben plaats gevonden tijden het ontwikkelen van het project… en wat u rol daarbinnen is geweest. Het interview zal rond de 45 minuten gaan duren.

Controleer of informed consent is ingevuld.

Voordat ik aan het interview begin, gaat u akkoord dat ik het interview opneem?

Heeft u verder nog vragen wat betreft het interview?

Zet opname aan

Samenwerking

1. Wie bent u en wat is u rol binnen ….. (organisatie)?
2. Wat begrijpt u onder de term circulaire bouwsector?
3. Wat is u ervaring wat betreft de samenwerkingen binnen de circulaire bouwsector?
4. Wat werkt er goed binnen de circulaire bouwsector? (Welke samenwerkingen, vormen van samenwerking of wellicht geen samenwerkingen)
5. Wat werkt niet goed binnen de circulaire bouwsector?
6. Heeft u mensen/bedrijven vermeden om mee samen te werken? Ja, wie en waarom heeft u deze vermeden?
7. Binnen de literatuur worden ook dingen genoemd zoals…. Is dit niet belangrijk voor u?

Innovatie

8. Hoe is de innovatie van het project aan de Hoogstraat begonnen?
9. Wat was u rol binnen de innovatie van het project?
10. Wat begrijpt u onder de term innovatie en hoe is dit toegepast binnen het project aan de Hoogstraat?
11. Wat werkte er goed qua innovatie?
12. Wat werkte er niet goed qua innovatie?
13. Wat was het moment waarop er doorbraak was binnen het project (tipping point)?

Algemene vragen

14. Wat zou u de volgende keer anders doen binnen het project?
15. Wat zijn u tips voor anderen die een soort gelijke project willen uitvoeren?

Heeft u verder nog punten die u belangrijk vindt om besproken te hebben of waarvan u denkt dat ze belangrijk zijn voor mijn onderzoek? Ik wil u erg bedanken voor u tijd en de deelnamen aan mijn onderzoek.

Appendix B

Characteristics Collaborations / Stages Life Cycle		Level of Specificity		Level of Uncertainty		Level of Trust & Commitment		Time Frame	
		Product	Process	Product	Process	Product	Process	Product	Process
Market Development	Internal	And then aren't specific skills that are needed to work with seaweed, or can you treat it as other Construction material? Or does it require some specific and new skills? For us to manufacture the the material itself. If you know a lot about materials then you don't need new or specific skills. You need to look at the components of the organism or plant in this case, and you have to have basic biochemistry knowledge (SW).	And in the end I tried to make it look as much as possible as the existing materials and in the end I brought it to my first focus groups and then I also had some examples that I wasn't too happy about myself and they all liked it. Because it was different (SW).	OK, so that's I hope it works, yet still a pilot. It's always a risk right (SW).	And one of the biggest challenges is now that we have a product, but in the building industry, before you are working in the built environment, a product by itself is really hard to to enter the market with. So that's why we now collaborate with a project. It will be built in July. It's a complete facade with other people that do the structure and isolation, there's a an exterior and we are then the interior sheet (SW).	We make sure that we contribute to a circular economy and we have future proof solutions. So that's our main mission to transform systems in that way. So we use as much as regenerative feedstock as we can combined with, residual streams or waste from other industries or sectors that are at the moment unused. We focused on seaweed as feedstock because we strongly believe that that's a future proof feedstock and has a rich history, one of the oldest organisms in the world. So it has proven itself as adaptive organism throughout the centuries and we think that might also be the case for the future (SW).		I spent a year in the lab trying out different ways and methods and recipes to do things and in the end I tried to make it look as much as possible as the existing materials and in the end I brought it to my first focus groups and they all were (SW).	Yeah, the interior offers still quite some options for us there will be already eight different products and each product requires 2 to 3 years R&D before you have all the certifications set and your production line. So we totally busy for a while (SW)
	External	OK, depends a bit on the on the Level of the technical expertise that is needed. I would always say education. Especially when you start, if you're a startup. If you're already an established company then you have resource. You have your full R & D team. If you start small then my advice would be to start with education, because the good thing is other people learn. But also you have access to disciplines you cannot afford to have in your team yet, so it also gives access to knowledge and a good set of extra brains that think along with you and different parts of the of innovation. It works both ways I think (SW).	And on the market side, it came later because then I already had the concept and then I quickly started having focus groups trying to find partners who would be interested in the actual application, because if there's no interest there, then yeah, yeah, the whole exercise is bound to Fail. So I knew I had to connect with the market as soon as possible, yeah (SW).	What's Difficult sometimes is that we also had. This system developed with another small company start up and then they disappeared. So we did all kinds of tests and pilots super nice and then actually the market was interested. But then yeah, we had half of the of the system. So yeah then that's a set back, so that's difficult and it's hard to. Yeah, there are quite some options right to collaborate, to know or to have a good gut feeling where what direction to go and it will from the beginning. So that that is a difficult sometimes, yeah (SW).	Yeah, because there you actually need to hold value chain yes. And one of the biggest challenges is now that we have a product, but in the building industry, before you are working in the built environment, a product by itself is really hard to to enter the market with. So that's why we now. Collaborate that starts in. It will be built in July. It's a complete facade with other people that do the structure and isolation, there's a an exterior and we are then the interior sheet (SW).	If the material fails in 10 years and the risk and the suing and the claims are for the contractor. How things are now right range, so yeah, well, why should this person take the risk if there's no real big advantage (SW)?	Yeah, because there you actually need to hold value chain yes. And one of the biggest challenges is now that we have a product, but in the building industry, before you are working in the built environment, a product by itself is really hard to to enter the market with. So that's why we now have a collaboration that starts in July. It's a complete facade with other people that do the structure and isolation, there's a an exterior and we are then the interior sheet. And then you can mean something for the sector, because otherwise it's small party. and the Forces are huge and strong, and the networks in the build Environment and the real estate sector ar big. So to be a player of any significance later on, you need to formpartnerships as soon as possible (SW).	Good point. I started in house in Blue City in the Lab, but since my former profession was partly also being a tutor at the Industrial design engineering. I had from the beginning a strong connexion with education, so I worked with programmes, process and food technology for the chemical procedures, but also because the industrialization was the aim from the beginning. Because we want to create impact. So that means also volume in our case, but then in a good way so we'll talk about the new industrial revolution producing in mass but then not harmful. So first food technology and chemists are worked with. Directly connected with noordsea farmers, which is an organisation I knew because I studied in Delft, the founder of the seaweed company. So we connected quite early (SW).	
Growth	Internal	We actually hope to be able to deliver something that behaves a bit different. So that stays whole because now I have you look at the chips and board. For example, you drill holes in it and you take it, plaster it, etcetera and that's a lot of material waste and it's hard to reuse it, right. So we try to deliver like a prefab element that's already finished and you don't have to damage it to install it. That's what we're going to test in Amsterdam as well. So you can actually take it out as a whole without it having any holes. So it can be used somewhere else. So we did also a test at the green village. I don't know if you're familiar with it. But then in small size, so it was blocks of 60 by. 60 But it was also like a lego system. You could demand the wall and and rebuild it somewhere else so that is in the end for the circular economy better then that we take it back and we grind it and make new materials. So our focus for it for R&D at the moment is if people drill holes for televisions or paintings or electricity. Can we repair that so it can be actually reused and you don't have to throw it away (SW).		So for all the applications, there are typical standards. That you need to comply with. So it depends abit on how you apply it? A ceiling panel has different needs and criteria than a load bearing structure, so to speak. And depends also where you put it. If it's a public building, it's different. If it's an emergency exit the regulations are different. How we work with it, we focus now first on the applications that require the least amount of certifications to just also be able to enter the market and to overcome the the gap that we now as company have to overcome that our costs are high and we're not on the market yet. So we want to enter the market with the product and In our case, it is for interior applications, so it's not in the the construction of the of the building, so the the the building or house has already been built and it's applied later as interior right. So they need to think about wall cladding acoustic panels, those kinds of things and then it depends on. How public the building is and what the setting is (SW).					
	External		I think it's the only way, especially in in complex sectors like this, OK. If you do not have a plug in product that's easy for the market to understand that It's a direct replacement. Then you actually need to develop things together, so that's also how we do it. We developed it up to a certain point and then together with the end user, we do the final part, because then you know how to apply it. How they want to process it with their with kind of machines they use, what kind of context they want to use it in and what that means for the technical properties of the material. So you can also you to predict that and then offer it to the client, but you can also pick your. We do now different pilots in different situations. So we do a kitchen and a wall and furniture all different applicatons. Public buildings, private homes. So we see how people respond and how they interact with the material after it leaves our company and that's where the actual market learning and refines. And I, I do believe that that's where the success or failure in the end will happen (SW).		Yeah, because there you actually need to hold value chain yes. And one of the biggest challenges is now that we have a product, but in the building industry, before you are working in the built environment, a product by itself is really hard to to enter the market with. So that's why we now. Collaborate that starts in. It will be built in July. It's a complete facade with other people that do the structure and isolation, there's a an exterior and we are then the interior sheet (SW).		And then you can mean something for the sector, because otherwise it's small party. The Forces are huge and strong, and the networks in the build Environment and the real estate sector, so to be a player of any significance later on, you need to form partnerships as soon as possible.	And in the end I tried to make it look as much as possible as the existing materials and in the end I brought it to my first focus groups and then I also had some examples that I wasn't too happy about myself and they all liked it. Because it was different.	Yeah, but also if we talk about the build industry, they talk about a lot of square metres, because otherwise there's no sense for building industries or constructors to work with you if they can only do one project with you? Yeah. that's nothing. And so therefore you need to be attractive enough to actually get attention and investment in time to get to know you how it works? What is this new material?
Maturity	Internal								
	External								
Decline	Internal								
	External								

Very much
Many
Normal
Few
Very few

Characteristics / Collaborations / Stages Life Cycle		Level of Specificity		Level of Uncertainty		Level of Trust & Commitment		Time Frame	
		Product	Process	Product	Process	Product	Process	Product	Process
Market Development	Internal	We actually went through it step by step, calculating how much time it takes to pull those nails out and when it's smarter to just cut that piece of wood out. Or to painstakingly remove those three nails and, in that way, we kind of, bit by bit, set up a process. We sought out customers and engaged in discussions with them. We ended up with the idea of making picket fences, thinking, well, there can't be much wrong with it if it's a fraction of an inch thicker or thinner, right? Or if it has one extra paint stripe; nobody really cares. So that might be a nice place to start, and that's when we began making picket fences (B).	We actually went through it step by step, calculating how much time it takes to pull those nails out and when it's smarter to just cut that piece of wood out. Or to painstakingly remove those three nails and, in that way, we kind of, bit by bit, set up a process. We sought out customers and engaged in discussions with them. We ended up with the idea of making picket fences, thinking, well, there can't be much wrong with it if it's a fraction of an inch thicker or thinner, right? Or if it has one extra paint stripe; nobody really cares. So that might be a nice place to start, and that's when we began making picket fences (B).		So, just as I said, stumbling three times, but continuing to try, and eventually arriving at something that works. We also had a bit of luck in that regard, because in the beginning, everyone said, 'Axel, you've gone completely nuts. You'd be better off finding a hobby. You're not going to invest so much time and energy in it that way (B).		So, we still have those circular hubs, which are really the places where circularity is at its utmost. You can see that the people working there are 100% convinced (B).		When that was up and running, three shipping containers quickly became too small, so we added two more shipping containers (B).
	External		We closely examined with them what kind of products we should make, what quality standards to adhere to, when to reject something, and when to approve it. In the early stages, there was intensive communication about this, and you can see that it's now running smoothly. They are one of our customers, but not much more than that (B).				For the first six months, I searched for someone who owned a sawmill and was willing to do this with us. So, I really learned from that. That when you've demonstrated something, everyone is willing to do it, but proving that it can be done, that it works, and that it's not completely absurd, often requires you to do it yourself (B).		We worked closely with them to determine what kind of products to make, what quality standards to adhere to, when to reject something, and when to approve it. In the early stages, there was intensive communication about this, and you can see that it's now running smoothly. They are one of our customers, but not much more than that (B).
Growth	Internal	And eventually, it grew in such a way that I now have a fully serious woodworking shop in Utrecht, where we handle substantial volumes and produce high-quality interior-grade finishing timber (B).	And eventually, it grew in such a way that I now have a fully serious woodworking shop in Utrecht, where we handle substantial volumes and produce high-quality interior-grade finishing timber (B).		You're using wood while competing with large sawmills in Scandinavia and Poland, but the wood prices have, of course, skyrocketed. So, we've been really lucky in that regard (B).				When that was running, three shipping containers quickly became too small, so we added two more shipping containers. And eventually, it grew in such a way that I now have a fully serious woodworking shop in Utrecht, where we handle substantial volumes and produce high-quality interior-grade finishing timber (B).
	External						But also when it comes to quality requirements, it's at the level of how many nail holes are allowed in a linear meter. These are things I'm not going to come up with on my own. I really need a party that knows a lot about wood for those things, so collaboration is very important there too, despite the fact that we now ultimately do it ourselves (B).		
Maturity	Internal				We handle the entire process in-house, but Ommijer and Jongeneel are actually our customers for almost all the construction materials we produce. That's very convenient for us because it means we don't have to maintain any inventory. I'm a bit allergic to holding inventory, so they come to pick up our products every week (B).				
	External						Well, it really depends on the product. In essence, I don't need and don't want to have my own woodworking shop at all. This is definitely not my core business, and it's distracting. Of course, it's a lot of fun, and I enjoy receiving people, and I was there the whole morning today. It's just nice to be there, and we create beautiful things. But I have about 10 material streams in my head, and I can't set up our own production location for all 10 of those material streams. Even if I could, I wouldn't want to(B). I established that sawmill more to prove that it's possible, and I hope that someone will eventually pick it up and say, 'Hey, bring your wood here because I can do it much better and more efficiently than you.' That way, I can finally be rid of it (B).		
Decline	Internal								
	External								

- Very much
- Many
- Normal
- Few
- Very few

Characteristics Collaborations / Stages Life Cycle		Level of Specificity		Level of Uncertainty		Level of Trust & Commitment		Time Frame	
		Product	Process	Product	Process	Product	Process	Product	Process
Market Development	Internal	The first commercial step of ours where a donor skeleton was used, and, of course, reused steel has been used in construction before, but this is on a large scale and also a material that came from a completely different source. You see the same thing in smaller projects or renovations. You have steel lying around in the building. Well, then you can say, I can place it somewhere else and reuse it. So that might have happened, but truly the concept of having structural elements lying or standing somewhere and using them in a completely different building, that's new in this project (IMd).	So, completely rusted, you name it. So, I said, 'Well, maybe we can do something with these.' We had them examined to determine what kind of profiles were there, how much length they had. So, we revisited the shopping list we initially gave to Beelen and went to the construction site ourselves. We found about 80% of what we could reuse in the design. They wanted to get the client on board, so we said, 'We have 80%, and if you're interested, we need to negotiate with these parties on how to do it together, so we need you to come along to make it happen.' At one point, they said, 'You should do that together with the contractor,' because the contractor had already been selected, so we did that with the contractor. The interesting part was that the client said, 'I'm actually a bit disappointed that you don't have 100%, so keep looking.' This motivated us to find even more to reuse. We adjusted the design not at the location but on the profiles we had, so we eventually achieved that 100%. It shows that in the design process, you need to make adjustments. Last but not least, we've written a comprehensive procedure protocol on how to handle the material's quality (Imd).		At one point, we sat down with a demolition company and told them we have a shopping list. Can you find these materials because you do a lot of demolitions, and they also had a history with that client. So they said, 'No problem.' But, like I mentioned when we started with Hoogstraat, they weren't really focused on this aspect at all back then. That was about 10 years ago or so, 8 years ago. They didn't think about it at all. Now, they have actually established a company specifically focused on this. So, you can see how the market has changed over time, and it's nice to see. No, the demolition company searched for these profiles for two years but couldn't find them. So, I thought, 'Well, that's a shame.' That's when we started searching ourselves and came across a demolition company where the materials were just lying in a field. Now, it's common for various parties, including the first demolition company, to call us and say, 'Hey, we have this and that, and we're going to remove it. Can you use it (IMd)?	Yes, the breakthrough of the project came because we took the initiative ourselves. So, when it comes to innovations, the party that wants it, that has the passion for it, really has to take the lead and go all in (IMd).	Yes, the breakthrough of the project came because we took the initiative ourselves. So, in the case of innovations, the party that wants it, that has the passion for it, really has to take the lead and go all in (IMd).		No, for each project we were running at that time, we had to figure out the best way, so it did take time and effort (IMd).
	External		We had a material investigation done in consultation with the client. We also created an inspection table to determine the steel quality, rust formation, delamination, and various other factors. A company conducted this material analysis for us (IMd).		The municipality didn't play a very significant role. However, we collaborated with the municipality on the quality control procedure and calculation system. In innovations, you naturally encounter regulations, and building regulations are known when something is new. But when it's existing or reused, we didn't have regulations for it. We discussed this with the municipality because they ultimately have to give their approval, and we are responsible for the calculations. The contractor is responsible for the execution, ensuring it's done correctly, and ultimately, for the quality of the steel because they took that over from what was in the contract. The municipality then has to say, 'Okay, it's approved, and you will get a permit later (IMd).	The municipality didn't play a very significant role. However, we collaborated with the municipality on the quality control procedure and calculation system. In innovations, you naturally encounter regulations, and building regulations are known when something is new. But when it's existing or reused, we didn't have regulations for it. We discussed this with the municipality because they ultimately have to give their approval, and we are responsible for the calculations. The contractor is responsible for the execution, ensuring it's done correctly, and ultimately, for the quality of the steel because they took that over from what was in the contract. The municipality then has to say, 'Okay, it's approved, and you will get a permit later (IMd).	You can see that clients want it, but they also feel like it has to be determined in a certain way, perhaps from above, like a decision made by the municipality, province, or some other party. However, sometimes the ones who have to implement it aren't necessarily intrinsically motivated about the topic, and that does affect the motivation for cooperation from the client's side (N).		
Growth	Internal						When it comes to collaboration on circularity in the projects where, for example, we incorporate donor skeletons, we find that all parties must fully support and embrace the principle. This means that both the client, the architect, the suppliers, and the main contractor must be on board. We, of course, stand behind it, as we often initiate it as well. But everyone needs to embrace it (IMd).		Similar projects during this project, because it's a project that has had a long duration. But during the project, we've already encountered other works where we've used donor skeletons and reused constructions (IMd).
	External		To create profiles for the construction and then to collaborate with those authorities to figure out how to make it compliant with regulations. Because, of course, regulations are primarily based on new materials, at least at that time and largely even now. So, if you want to make this possible, the whole circularity aspect must be included in, let's say, the building code and other regulations. How to address that (N)		Yes, it's about more sustainable concrete, right? Yes, they have already been involved in several dozen pilot projects. Nevertheless, Rijkswaterstaat hasn't made it mandatory yet. So, it may still need some innovation, but I see this mainly on the side of structuring contracts and providing the right circular criteria that can make such a project a success (N).		When you look at the collaboration for circularity in the projects where we, for instance, incorporate donor skeletons, we notice that all parties must support and embrace the principle. This means that the client, the architect, suppliers, and the main contractor must stand behind it. We, of course, support it regardless, as we often initiate it as well. But everyone must embrace it (IMd).		
Maturity	Internal			Based on our current projects, we have now found a workflow for how to do it, how it can be done. What you can see from that is, if you have a building that's already there and you're going to disassemble it, and then use it for a new building, it has a very high chance of success because you already know everything about it. You know the design, and you don't need to do the design twice because you already have the basis for your design (IMd).					
	External		That's one aspect, and ensuring regulations. So, I am also. This year, the first standard for the reuse of steel elements is being launched. Dutch technical agreements have been established between the Ministry of the Interior and the steel construction industry, and they are set to be launched in June (IMd).		That's one aspect, and ensuring regulations. So, I am also. This year, the first standard for the reuse of steel elements is being launched. Dutch technical agreements have been established between the Ministry of the Interior and the steel construction industry, and they are set to be launched in June (IMd).		The interesting thing is that almost all the parties have started doing something with it. We initially approached the demolition company, which couldn't find anything and became enthusiastic about it. They even started a circular demolition company. We asked Nebest to do this, and they also got excited about it. They are now taking steps to make more reused materials possible. It's quite unique to see that both companies are doing this because they see a business model in it (IMd).		That's one aspect, and ensuring regulations. So, I am also. This year, the first standard for the reuse of steel elements is being launched. Dutch technical agreements have been established between the Ministry of the Interior and the steel construction industry, and they are set to be launched in June (IMd).
Decline	Internal								
	External								

Very much

Many

Normal

Few

Very few

Hof van Cartesius

Characteristics Collaborations / Stages Life Cycle		Level of Specificity		Level of Uncertainty		Level of Trust & Commitment		Time Frame	
		Product	Process	Product	Process	Product	Process	Product	Process
Market Development	Internal	Because it requires a lot of work for them. It raised the price for a client like us. And if it's not dismounted professionally it requires a lot of work for the party how will reuse it because maybe it's a bit damaged. Maybe it's not clean and with clean I mean that maybe on a big facade like this or on a steel beam, you still have attached some parts you have to dismount it. Maybe it's really rusty, on the wooden beams you have screws on a windows like this PVC or aluminium. You still have a lot of kit, silicone you see a lot of material. At the end, if you count the hours that it is required to the professional demolisher or to the professional upcycler to reuse that material from the building it was used to a new building. It's. Yeah, the price is going really close to a new material. If we talk about the window we demolish it, we take apart this building we reuse the window. Once we dismount the window we make it clean, we sell it, we have to store it. We sell it to another client who still has to clean it because it's not new and to replace it the amount work and the hand work yes its a lot. That's what it makes mostly the cost. It's a lot work (Hof).	Yeah, for sure it requires the collaboration of different professionals, which it doesn't mean that all these professional there needs to be separate entities person some of them, they can, cover different of these roles or more of them they can cover also the same roles. So for example, if we go from the traditional actors and we talk about client, designer and builder for example, and I can go with the example of the hof. So here we have a client which is the cooperative then we have a building team and the design team, yes. Really small team, but still some of the players that are in this team, they are part of more than one team. And they cover different roles (Hof).		So we delivered a flexible temporary design saying we are going to have about this amount of windows. We don't know exactly which shape, we don't know the the finishing part and then later we update the permit. And say, OK, now that this part is built, we are going to buy this material and we are going to say what is it (Hof).		What is really interesting of this project is also this that is cooperative is a community. So for me that's also one attractive point and also why I came. It's because it's a bottom it's a bottom up project. So it's funded by the people, for the people, for themselves. It's an open space to the public. It's a space for the city, for the people of the city, is not how we create this always here. And we close it for for ourselves. It is owned by the renters themselves, there is a lot of community life. Participating already in the process of construction from the renters themselves, for example, finishing their facade. What is delivered to people is a casco unit (Hof).	So we delivered a flexible temporary design saying we are going to have about this amount of windows. We don't know exactly which shape, we don't know the the finishing part and then later we update the permit. And say, OK, now that this part is built, we are going to buy this material and we are going to say what is it. So with the structure, we will go a bit more fast because you have also less opportunity you have to buy it a bit more fast and it's also from where you start. So part of the structure material we will see here, the CLT or the steel or the rail columns. That's bit middle example. It is both before or it was already here after the first phase and from that is the material that influenced the design, because you have that material you have to use that material because it was a really good deal, so this construction, construction wood that it's come from massive CLT's cross laminated timber. It comes from a school in Rotterdam school that was built with three floors, totally made of wood, prefabricated piece. They did mistake. They had to demolish it. The the company failed the the constructor. They had to sell it. It is wood that is super expensive. They had to sell it for cheap material. From that wood we start the design of these three pavilions, and we already test it in the one I mentioned before the restaurant (Hof).	I don't know if you have a question more in the design, but. This thing of going back and forward, it's it's really fundamental we call this. Flexible dynamic design and there are a couple of other offices doing the same. And if you reuse this material, what I was saying when you first. The standard process requires you to apply permits to the municipality to have this permit to start your construction, but normally they would like to know exactly which kind of windows, which kind of materials, but we don't know because I cannot put all this effort in searching material that I cannot buy till I know for sure I'm going to build it. So we did, I think for the first time. We of course we designed the building with the volume, we changed some things then later, but the facade for example. Yeah, we couldn't really lose time in that or lose time in thinking about the material that maybe a few weeks, few months later was not available anymore (Hof).
	External		During the demolition, the Demolisher was not really educated from who to dismount it properly, so we start to cut the columns that we wanted to reuse, and when we went there with another architect saying what's going on here, it was too late to save part of them. So we got this for free. first they wanted to sell it to us. The municipality first made the proposal to sell it. Yeah, but it's not affordable for us. It's already just the transport of these materials. So we are going to pay the transport. We are going to go ourselves there to guide the demolition, but then it's a lot of work for it (Hof).		I don't know if you have a question more in the design, but. This thing of going back and forward, it's it's really fundamental we call this. Flexible dynamic design and there are a couple of other offices doing the same. And if you reuse this material, what I was saying when you first. The standard process requires you to apply permits to the municipality to have this permit to start your construction, but normally they would like to know exactly which kind of windows, which kind of materials, but we don't know because I cannot put all this effort in searching material that I cannot buy till I know for sure I'm going to build it. So we did, I think for the first time. We of course we designed the building with the volume, we changed some things then later, but the facade for example. Yeah, we couldn't really lose time in that or lose time in thinking about the material that maybe a few weeks, few months later was not available anymore (Hof).		But I I think as sooner the collaboration between all the parts the better. I mentioned before, I will put also the municipality, the government, so. If there is really interest in innovating in circular design, so I'm talking about a sector of the circular economy. Collaboration is fundamental so lets talking again about this dynamic, flexible design. It cannot be the design of a group of architect or of designer within it doesn't matter. You need really to combine all the actors to collaborate together. Take some decision, some steps that then they will guide the actors when they will work in their single jobs (Hof).		
Growth	Internal		So we already knew what it was possible to use that material and we started. So in this way, it's this flexible design, so sometimes it's the material that drive the design. So that's what you use the expression material driven design and other times than more you go in, the detail is the design that drive the research of the material. So the materials counting and this going back and forward we call it the flexible dynamic design (Hof).	There is yeah It is complicated. You know why? I don't know. I think we made a lot of mistakes. We also learned a lot, but we also draw a bit the path for others to do this. This kind of project, because yeah, it's really. With this kind of volumes of dimension of buildings and this amount of reuse material is I think it's a unique project (Hof).			The structure waterproof, windproof and with installation and and then. They finished the facade. They finished the interior. The garden there is almost no budget for the garden, of course. Then you can find some found there, but it's not in the the budget of the project. And the people collaborate to create this nice place. And it's also in the design. It's one of the pillars is it's called the Hof van cartesius so already from the first garden. And what we are maybe may seem more a green strip, but the idea is that they are hof, they are courts. Where the people meet. Going out from their private space, they meet in the garden, moving to the common space, for example the ground floor of the boomtorren and the kitchen. There are the toilets. It's not that everybody has a kitchen or toilet and also that I see this sustainable aspect that maybe it worked at the end a bit less in the balance of the reusing material, but it worked really good if you think. About the amount of space that there are here, if everybody will have a kitchen and will have a toilet. It means a lot of waste of space and then of materials and then of energy. So I think this sharing and co working space but not in a in a way of sitting at the table and have a rent a table, but in a way that yeah, part of this space they are they are shared like in a echo housing project (Hof).		
	External		So to build building warmus. It was a test case for a new team to develop this face. That is bigger than the other one, especially there are many buildings or two, three floors and a boom torren especially has 15 1/2 metres of four floors. So it was necessary this upgrade of the team a bit of growing in professionality, still with the small team of design and also of builders. So that building was a test case. It went pretty good and after that we designed this part so me together with Charlotte and together with another architect Peter De Bruin from Dynamo architect and he helped us with the with the permits and IMd they did its engineering office from Rotterdam. They did already the engineering of the first phase and they did this part too (Hof).	There is yeah It is complicated. You know why? I don't know. I think we made a lot of mistakes. We also learned a lot, but we also draw a bit the path for others to do this. This kind of project, because yeah, it's really. With this kind of volumes of dimension of buildings and this amount of reuse material is I think it's a unique project (Hof).	And there is no connexion in between the part, the political party who supported you and help and helps you to start this project, maybe also moving some money supports and the technician from the same municipality that come to cheque during the process and say yeah, but this is not OK (Hof).	I think that the main value of this project is to be a test case. To really be really sincere in what went good and what not. Accept also the mistake and show what we learn, show where we failed, show all these mistakes to the actors and the people who wants to go in that direction. Even for the innovation and standard developers. Here we can see in in which way? With creativity you can reuse also what was not meant to be reused. So we can help them to design something that can apply their needs but also future needs or who is going to reuse it? But I have the impression that is not what they want. Alright, that I think it's a problem of money. It will cost. They are not interested in designing that (Hof).			
Maturity	Internal		To try to be a bit short in my reply, I think what I mentioned before. Interested a differen balancing between the reuse of material, this new material that then anyway you will have to use to glue together, let's use this expression. This puzzle of 2nd hand material, so I think, I would choose to reduce the amount of secondary material and introduce. Some new material may be coming from real innovation materials that later can be reused, but then they can higher up a bit the level of the quality standard of the building, OK. And yeah, and. biobase material. Maybe also for whom? Later. He's gonna this dimount I would assign to do something else. Again, I don't know. I wouldn't like to use any polluting material and at the moment the second hend market for example of the insulation. It's the installation that they used in the past 10,20 years, so me I would like to have more biobased material. More so balancing between 2nd and really high quality second hand material and new as much as possible organic bio-based materials (Hof).						
	External								
Decline	Internal								
	External								

Very much
Many
Normal
Few
Very few