Stimulating circular building methods

A cross-case analysis to identify the role of the general contractor

By Lieke van der Wijk

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Preface

This thesis is written in order to complete my master program Construction Management and Engineering (CME) with an annotation for Technology in Sustainable Development at Delft University of Technology. When I started this journey, I knew that I wanted to do something with 'sustainable innovations in the building sector'. This was because I had the feeling that sustainable innovations in the buildings sector are developing very slowly. I am very pleased that I got the opportunity to research more about this urgent topic. Hopefully, this research helps to speed up all the amazing initiatives about circular building methods that are out there.

I would like to take this opportunity to thank some people that supported me during my research. First of all, I would like to thank all the participants of my interviews and focus group. All the people that I have approached and asked for help or contribution were always excited to do so. I would like to thank you for all the information that I received from you, but mostly for your openness, enthusiasm and inspiring conversations. It was amazing to see how much time, effort and energy all of you are putting in circular building methods because you really believe in it. Without your willingness to help, there would literally not have been a research at all.

I also want to thank my graduation committee for all their time and effort to give me feedback and suggestions. This made me look critically to my own work and why I did the thing I did. A special thanks goes to Jeanine, my supervisor from Dura Vermeer. Thank you for always making time for me and for our brainstorm sessions. But mostly thank you for trying to provide some structure in my sometimes chaotic mind.

Most importantly I would like to thank my friends, family, and housemates who supported me during this period. Writing this thesis was not always easy, but you were always there for me. You listened to my thesis talk, gave advice, allowed me to vent my heart at any possible time, and encouraged me to take enough time off from my thesis. Without you all to distract me from my thesis and enjoy some leisure time with, these last months would have been even harder.

Lastly, I would like to say thanks to my team members from Engineers Without Borders, who trusted me to be part of the team. Thank you for the fact that our project forced me to think of something else every now and then. But also thank you for dismissing me from our project when I had to work on my thesis.

The last thing I would like to say; enjoy reading this thesis.

Lieke van der Wijk
Delft, juni 2018

Abstract (Eng)

Research on circular economy in the construction industry is only recently gaining momentum. A circular economy does not produce any waste. The construction sector is the most polluting sector in the Netherlands and uses 50% of the used raw materials. Therefore, circular building methods might decrease the demand on raw materials in the Dutch construction sector. This research aims to identify what factors can stimulate the adoption of circular building methods by the general contractor.

In this research a cross-case analysis is conducted with two building projects that aimed to use circular building methods. During the interviews for these case studies, some barriers for the adoption of circular building methods were identified. The six barriers which are mentioned most often are the perception of high costs, limited regulation, lack of a circular business model, unattractive esthetics, negative attitude from actors involved, and lack of integrality within the building process.

To have a positive influence on the adoption of circular building methods, and resolve the identified barriers, the general contractor may take the role of an integral manager to manage the social network, supply chain, and building process and facilitate the learning process. When taking this role it is suggested that the general contractor works together with other actors to develop a new business model. This new business model should aim to take away the current barriers for circular building methods.

The main difference between any other innovation in the building sector and circular building methods is that circularity needs more integrality. Other innovations are often only on a specific part of the project, it suffices with only changing or managing on a small part of a building project. However, circularity affects every small part of a project and therefore needs an integral manager.

Abstract (NL)

Wetenschappelijk onderzoek naar circulaire economie in de bouwsector begint pas de laatste jaren vorm aan te nemen. De bouwsector is de meest vervuilende sector in Nederland en gebruikt 50% van de grondstoffen. Een circulaire economie is een economie zonder afval waardoor circulair bouwen de vraag naar grondstoffen af kan laten nemen. Dit onderzoek heeft daardoor als doel om te identificeren welke factoren de adoptie van circulair bouwen door de hoofdaannemer kan stimuleren.

In dit onderzoek is een cross-case analyse uitgevoerd met twee bouwprojecten die circulaire bouw methodes hebben toegepast. Tijdens de interviews voor deze case studies zijn barrières voor de adoptie van circulair bouwen geïdentificeerd. De zes meest genoemde barrières zijn; belemmerende wet en regelgeving, de perceptie van hoge kosten, gebrek aan circulair business model, onaantrekkelijke esthetiek, negatieve houding van betrokken actoren en gebrek aan integraliteit binnen het bouwproces. Dit betekent dat het oplossen van deze barrières een positieve stimulans zou kunnen zijn voor de adoptie van circulair bouwen.

Om een positieve invloed te hebben op de adoptie van circulair bouwen, en de huidige barrières op te lossen, zou de hoofdaannemer de rol aan kunnen nemen van een integrale manager. Deze integrale manager zal het sociale netwerk, de keten, en het bouwproces moeten managen en het leerproces faciliteren. Het wordt aangeraden dat alle actoren samen werken om een nieuw business model te ontwikkelen. Dit business model zou er naar moeten streven om de huidige barrières op te lossen.

Het grootste verschil tussen andere innovaties in de bouw en circulair bouwen is dat circulariteit meer integraliteit nodig heeft. Andere innovaties hebben vaak enkel betrekking op een specifiek deel van een project, het is dan vaak genoeg om enkel dat deel aan te passen of te managen. Circulair bouwen heeft echter effect op elk deel van een project, waardoor het belangrijk is om de integraliteit te optimaliseren.

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Glossary

Actor = A participant in the building process.

Advisor = The actor who gives advice on a particular field.

Bellevue = Case I: A sustainable renovation of the existing headquarter of regional energy grid operator Alliander at Arnhem.

Business model = The plan of a company on how to create revenues and profit.

Circular building methods = Building methods according to the principles of the circular economy.

Circular economy = Circular economy describes a model of closing material loops in an economically attractive way to decouple wealth from resource usage. It is an economy where waste does not exist (MacArthur, 2017).

It is important to realize that within this thesis the use of the term 'business model' is different from the regular use. Regularly 'Business model' refers to how an organization makes value. In this research it is talking about a 'business model' which should be created by different organizations together for the same goal.

Client = The actor who is paying for the project and who is often the one requesting the construction project.

Climate change = A change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods (UNFCCC, 2017).

Earth Overshoot Day = The day that we, all humans on earth, will have used more from nature in that year than our planet can renew in a one whole year. In 2017 this was on August 2 (Overshootday, 2017).

Fijn Wonen = Case II: Newly built houses which aim to be '70% circular'.

General contractor = The actor within the building project who is responsible for the completion of the project.

Innovation = The introduction and adoption of an idea which is new to the work team and which is a source of change and process of knowledge development.

Innovation system = a conceptual framework that reverses to a new understanding of innovation as an interactive process in which enterprises have interaction with each other to play a key role in bringing new products, processes and forms of organization into economic use. A network of organizations, people, and institutions within which the creation, diffusion and commercial exploitation of new technologies take place (Mytelka, 2010).

Inter-firm network = A network where primarily business-related goals are the basis for cooperation (Sprenger, 2001).

Knowledge management = Management of knowledge sharing within and between firms (Geels & Deuten, 2006).

Knowledge sharing = Arrangements that facilitates the sharing of knowledge and information that is needed to innovate between different players (Gann & Salter, 2000; Goverse et al., 2001; Kangari & Miyatake, 1997; Slaughter, 1993; Veshosky, 1998).

Material scarcity = The shortages in metal and mineral resources which are expected in the next decades (Wouters & Bol, 2009).

Multi-Level Perspective (MLP) = A transition which is seen as a non-linear process that results from the interplay of development at the analytical level: niches, socio-technical regimes, and socio-technical landscapes (Geels & Kemp, 2007).

Network = A number of actors who have a high sense of mutual interest, active participation by all parties and open communication, and who depend on each other for the realization of their goals (De Bruijn & Ten Heuvelhof, 2008).

Niche = Spaces in which innovations start to develop, test and learn, while they are sheltered from the mainstream competition (Schot & Geels, 2008).

Niche-innovations = The lowest level of the Multi-Level Perspective where innovations start to develop, test and learn. This is a rather flexible level where not many things are certain, and everything is easy to change and adapt (Geels, 2002).

Project management = Managing of a project focusing on initiating, planning, executing, monitoring and controlling, and closing (pmi, 2018).

Process management = Managing of a process of a project by focusing on the protection of core values, progress and momentum, quality of the result, and room for problems and solutions provided by the actors involved (De Bruijn, Ten Heuvelhof, & In 't Veld, 2010).

Relationship = A long-term commitment between two or more actors or firms to achieve the completion of a project. The relationship is based on trust, the dedication of common goals, and understanding of the expectations and core values of the other actors (Khalfan & McDermott, 2006).

Socio-technical landscape = The highest level of Multi-Level Perspective which consists of factors that cannot be influenced, like climate changes. As these factors are very hard to change, it is a stable level which will only change slowly (Geels & Kemp, 2007).

Socio-technical regime = The middle level of Multi-Level Perspective which consists of rules, traditions, systems, and markets. This level is dynamically stable, which means that it will only change under certain circumstances which are proven in the niche-innovations level (Geels & Kemp, 2007).

Socio-technical system = A system where technical and social change are interrelated. It consists of three levels; the niche-innovation, socio-technical regime, and socio-technical landscape (Geels, 2002).

Socio-technical transition = The shift from one socio-technical system to another or to other elements of the system. The system wants to link the technical, science, policy, socio-cultural, and user and market regime (Geels. 2004; Bidmon & Knab. 2014).

Strategic Niche Management (SNM) = Approach which focuses on niche management. There are three main niche processes: Shaping of expectations, building social networks and learning processes (Loorbach & Raak, 2006).

Sub-contractor = The actor who is responsible for a specific part of the completion of a building project.

Supply chain = The network of involved firms, through upstream and downstream linkage, in the different processes and activities that produce value, like products and services, for the customer (Christopher, 1999).

Supply Chain Partnering (SCP) = A long-term commitment between two or more firms as in an alliance for the purpose of achieving specific objectives by maximizing the effectiveness of each participant's resources (CII, 2018).

Sustainable innovation = The introduction and adoption of an idea, driven by social, environmental or sustainable issues, which is new to the work team and which is a source of change and process of knowledge development.

Sustainable transition = A transition which is different from regular transitions as it is goal-oriented but has less obvious advantages for the actors (Geels, 2004).

System innovation = Several independent innovations which have to work together to improve the whole system (Mlecnik, 2013b).

Transition = A complex and long-term process or a period of changing from one state or condition to another, that consist of multiple actors (Oxford, 2018).

Transition approach = Process to start dealing with the changes that occur due to the transition.

“The real challenge is not climate change but the change of mindset.” - T.M. Rau

1 Introduction

1.1 Need for circularity in the building sector

Sustainability

In September 2015, the countries of the United Nation (UN) adopted the sustainable development goals (UN, 2015c). These sustainable development goals are a set of goals to end poverty, protect the planet and ensure prosperity for all. There are specific targets to be achieved in the next 15 years for each goal. The goals can be seen in figure 1.

Figure 1: UN sustainable development goals (Source: UN, 2015b).

Goal 12 of the sustainable development goals of the UN is 'Ensure sustainable consumption and production patterns'. Globally, it is expected that more people will join the middle class in the next two decades. For individuals, this is a positive change. However, it will increase the demand on the natural resources which are already constrained. This might cause irreversible damage to the planet and environment. One of the targets for goal 12 is to reduce the waste generation (UN, 2015b).

Goal 13 is 'Take urgent action to combat climate change and its impact' (UN, 2015a). Climate change is one of the biggest problems nowadays which is cost by human activities. To deal with this problem, the United Nations Framework Convention on Climate Change (UNFCCC) addresses that action is needed (UNFCCC, 2015). The UNFCCC is a framework for international corporations to combat climate change. In December 2015, the Paris Agreement was adopted by 176 countries who joined UNFCCC. This agreement charts a new course in the global effort to combat climate change. The central aim of the Paris Agreement is to strengthen the global response to the threat of climate change. This will be done by keeping the global temperature rise this century below 2 degrees Celsius. The involved countries will even pursue efforts to limit the increase of the temperature further to 1.5 degrees Celsius (UNFCCC, 2015). However, in the latest Emissions Gap Report from the UN,

published in October 2017, they state that there is an urgent need for short-term action and longer-term national ambition if the goals of the Paris Agreement are to remain achievable (UN, 2017). Another growing and global issue is material scarcity (Wouters & Bol, 2009). Global Footprint Network is an international research organization which calculates Earth Overshoot Day every year (Overshootday, 2018). Earth Overshoot Day is the day that we, all humans on earth, will have used more from nature in that year than our planet can renew in a one whole year. In 2018 this was on August 1, which means that we use 1.5 times as many ecological resources as the planet can renew for us. For the Netherlands, this day is on the 14th of April which means that the Netherlands uses more than 3 times as many ecological resources as the planet can renew in one year (Overshootday, 2018).

To decrease a significant proportion of non-renewable resources and increase the use of natural resources, a circular economy is needed (McArthur, 2013). Besides, a circular economy could reduce the greenhouse-gas emissions by more than 70% (Wijkman & Skanberg, 2015). A circular economy is an economy where waste does not exist (McArthur, 2013). This is opposite from the linear economy we are using now as this linear economy is based on a 'take-make-consume and dispose' approach (Migliore, Lavagna, & Talamo, 2016). In a linear economy, raw materials get used and thrown away, where in a circular economy, raw materials will never be waste (Rijksoverheid, 2016). The difference between linear and circular economy is shown in figure 2.

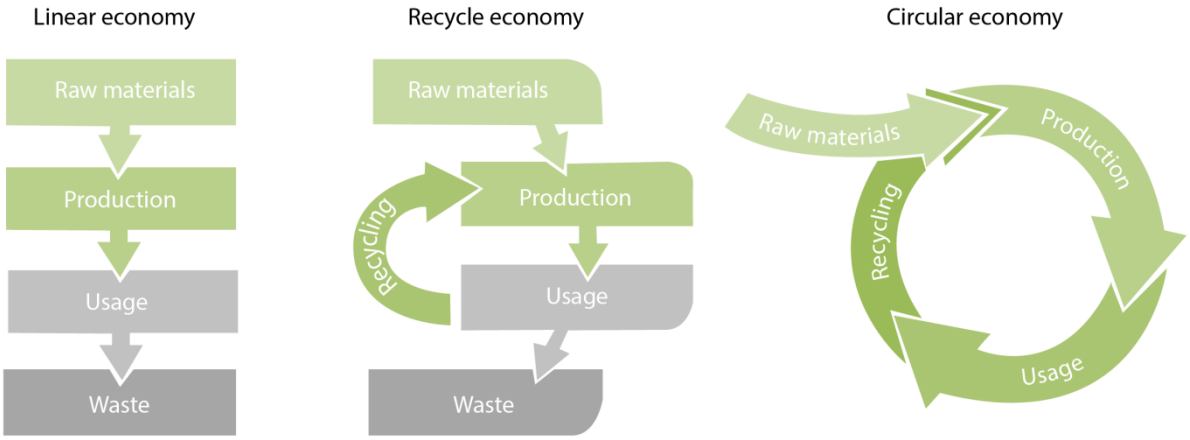


Figure 2: Linear to Circular economy (Source: own illustration based on Rijksoverheid, 2016).

In a linear economy, raw materials are used to produce a product. Whenever the product is not usable anymore, the waste will be thrown away. This is what often happens in the building industry as buildings get demolished and most waste is not usable anymore. In a recycle economy, some materials will be re-used. However, this is often in a less valuable way, which is called down-cycling. For example, bricks from buildings which are used as input for asphalt. In a circular economy, there will be no waste at all. This means that all the new materials, used for new products, need to be obtained in such a sustainable way that it does not do any harm to the natural and human environment. The re-use of materials should be with the same, or preferably higher, value. This is called up-cycling (Rijksoverheid, 2016). For the building industry, this means that new, circular building methods are needed to make sure that it is possible to re-use the materials again.

The Ellen MacArthur Foundation[1] developed an overview of the basic principles of the circular economy, shown in figure 3. This shows that products will be designed in such a way that materials

[1] The Ellen MacArthur Foundation was formed in 2010 to inspire a generation to rethink, redesign and build a positive future. The foundation believes that the circular economy provides a coherent framework for systems-level redesign and is such offers us an opportunity to harness innovation and creativity to enable a positive,

can be disassembled and re-used. This is different from disposal and recycling where a lot of energy and labor gets lost. Next to this, in the circular economy, there is a strict differentiation between durable and consumable parts. Consumable parts are made of non-toxic or even biological ingredients. Overall, the energy used to make this cycle should be renewable energy (McArthur, 2013).

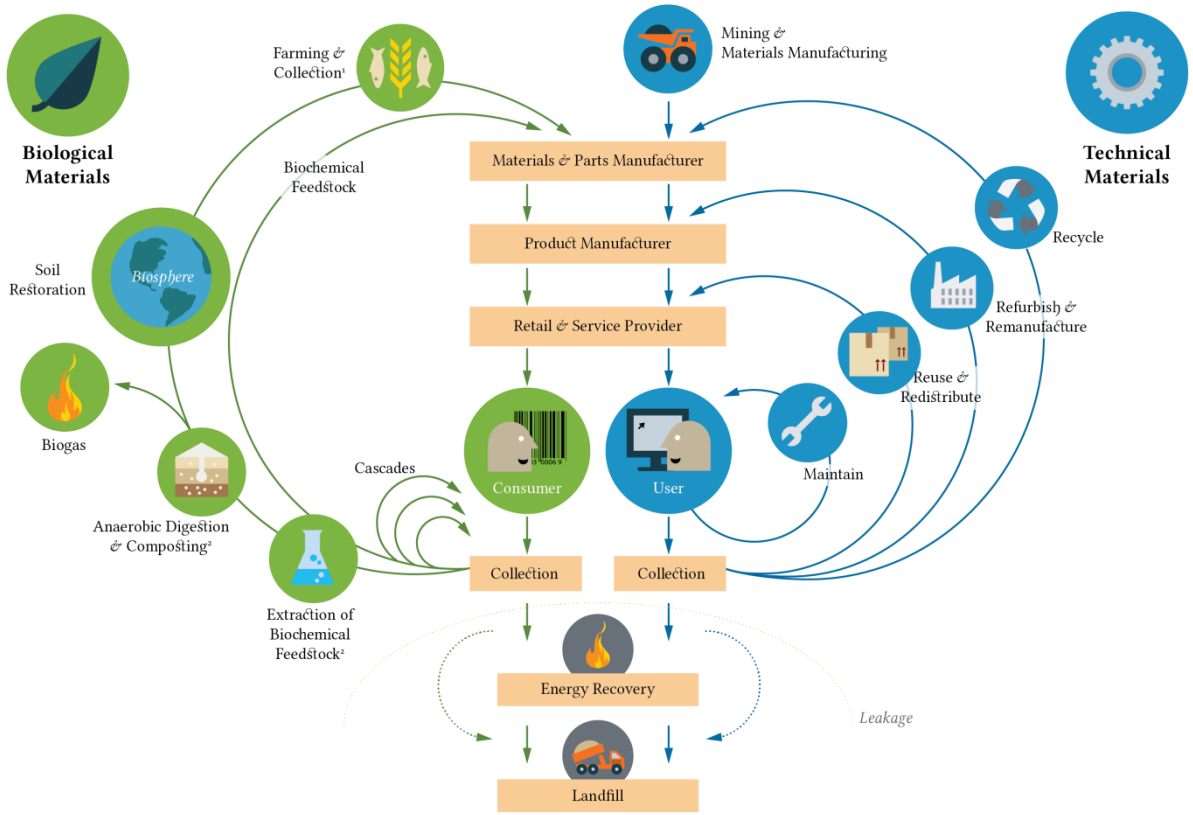


Figure 3: Circular economy overview by Ellen MacArthur Foundation (2013).

The European Union shows a shift from linear to circular systems (Commission, 2014). As does the Netherlands, the Dutch government has developed a nationwide program to stimulate circularity (Rijksoverheid, 2016). In 2050, they want to have an all circular economy and by 2030 they already want to be circular for 50% (Rijksoverheid, 2016). With this nationwide program for circularity, the Dutch government is contributing to the sustainable development goals of the UN which are described above (UN, 2015c).

Circularity in the Dutch construction sector

One of the priorities of the Dutch government in this nationwide program for circularity is the building sector. 50% of the used raw materials in the Netherlands are for the building sector, 40% of the energy consumption and 30% of the water consumption in the Netherlands is also used by the building industry (Rijksoverheid, 2016). This makes the building industry the biggest polluter in the Netherlands, with a share of 35% responsibility for the CO_2 emission (Ellemni, 2016). Govindan, Madan Shankar, and Kannan (2016) argue that sustainable constructions get more positive reviews as it impacts the environment, society, and economy. Sustainable construction materials may reduce the CO_2 emission up to 30% (Šaparauskas & Turskis, 2006).

However, even though the Dutch government calls it a program for circularity, it is more a vision than a program. This is because it consists of a perspective for the future but no specific steps that can or

restorative economy. The foundation has the aim of accelerating the transition to the circular economy. Since its creation, the charity had emerged as a global thought leader, government, and academia (McArthur, 2013).

need to be taken to achieve this circularity. There is a lack of consistent and challenging government policy (Arnoldussen, Groot, Halman, & van Zwet, 2017).

Research about circular economy in the construction industry is only recently gaining momentum (Pomponi & Moncaster, 2017). So far, most of these researches lack in the acknowledgment of the complexity of circular building methods (Luscuere, Geldermans, Tenpierik, & Jansen, 2016; Pomponi & Moncaster, 2017). This complexity is higher than regularly due to the different interconnection between the actors involved (Luscuere et al., 2016) and the high amount of materials involved (Pomponi & Moncaster, 2017). In the end, a building is an entity which is an assembly of standard products. These products make that buildings are complex and unique (Pomponi & Moncaster, 2017). This also makes that circular building methods need an integral approach. This is another aspect that is currently underexposed in research; an interdisciplinary approach is needed to understand and apply the circular economy in the construction sector (Pomponi & Moncaster, 2017).

1.2 Problem statement

The Dutch Economical Institute for the Building sector (In Dutch: Economische Instituut voor de Bouw, eib) identifies a lack of strong ambition in the policy and not very challenging and consistent government policy as two of the main barriers for innovation in the building sector (Arnoldussen et al., 2017). It is shown in a research by Geldermans and Jacobson (2015) that many circular innovations have passed the experiment phase, it is time to get market development to a bigger scale.

However, many innovations struggle to make it to the mainstream market. Written literature points out different reasons for this, like a possible lack of market demand (Mlecnik, 2013a), lack of management and coordination, tacit knowledge, regular informal communication (Milway & Saxton, 2011; Taylor & Levitt, 2004; Teece, 1984), and results that remain stuck in local projects because there is not enough learning between projects (Geels & Deuten, 2006).

The application of circular building methods is not just an innovation; it is a sustainable innovation in the building sector. This brings specific characteristics. The building sector is considered as a conservative and traditional sector (Davidson, 2013; Mlecnik, 2013a). Innovation breaks from the familiar circumstances and requires new skills and knowledge to replace the traditions in the building industry (Davidson, 2013). An important characteristic of the building sector is the fact that it has a project-based nature (Arnoldussen et al., 2017; Blayse & Manley, 2004; Geels & Deuten, 2006; Goverse, Hekkert, Groenewegen, Worrell, & Smits, 2001; Mlecnik, 2013a). The project-based nature gives a temporary multi-organization for every project (Davidson, 2013). This makes that project-based firms are often struggling to learn between projects (Blayse & Manley, 2004). Geels and Deuten (2006) also argue that it is important to pay attention to learning between and across projects. They acknowledge that knowledge and experience should be more widely than just the internal networks that are involved in a project (Geels & Deuten, 2006).

The role of social networks for sustainable innovations in the building industry is mentioned by more authors (Antikainen & Valkokari, 2016; Blayse & Manley, 2004; Caniëls & Romijn, 2008b; Geels, 2004; Goverse et al., 2001; Jain, Hoppe, & Bressers, 2017; Kemp, Schot, & Hoogma, 1998; Mlecnik, 2013b; Raven, van den Bosch, & Weterings, 2010). Relationships within industries have an extremely significant influence on construction innovation (Anderson & Manseau, 1999; Dubois & Gadde, 2002; Miozzo & Dewick, 2001). An active network is needed for actors in the project to be willing to collaborate (Mlecnik, 2013b; Raven et al., 2010) as well as to get knowledge flown between them (Geels and Deuten, 2006; Arnoldussen et al., 2017; Blayse & Manley, 2004). In a complex systems industry such as construction, firms must rely on the capabilities of other firms to produce innovations and this is facilitated to some degree by continuing cooperation between those concerned with the

development of products, processes, and designs (Miozzo & Dewick, 2001). Also, for circularity, the roles of the actors and networks are important (Antikainen &Valkokari, 2016). To facilitate and sustain a circular process, the adherence to multiple criteria and the input of multiple actors is required (Geldermans, 2016).

Another characteristic of the building industry is that many materials and companies are involved (Migliore et al., 2016). All these companies have different interests and views which gives complex dynamics (Geels & Kemp, 2007). Goverse et al. (2010) state that system innovation implies a large network change as there are explicit linkages between innovations and entail changes between players. Many authors like Geldermans (2016), Caniels & Romijn (2008) and Jain et al. (2016) agree with Goverse et al. (2010) about the importance of new networks for innovations. In figure 4 Blayse & Manley (2004) show a diagrammatic representation of the broad range of key participants in the construction industry and the need for an active network between them.

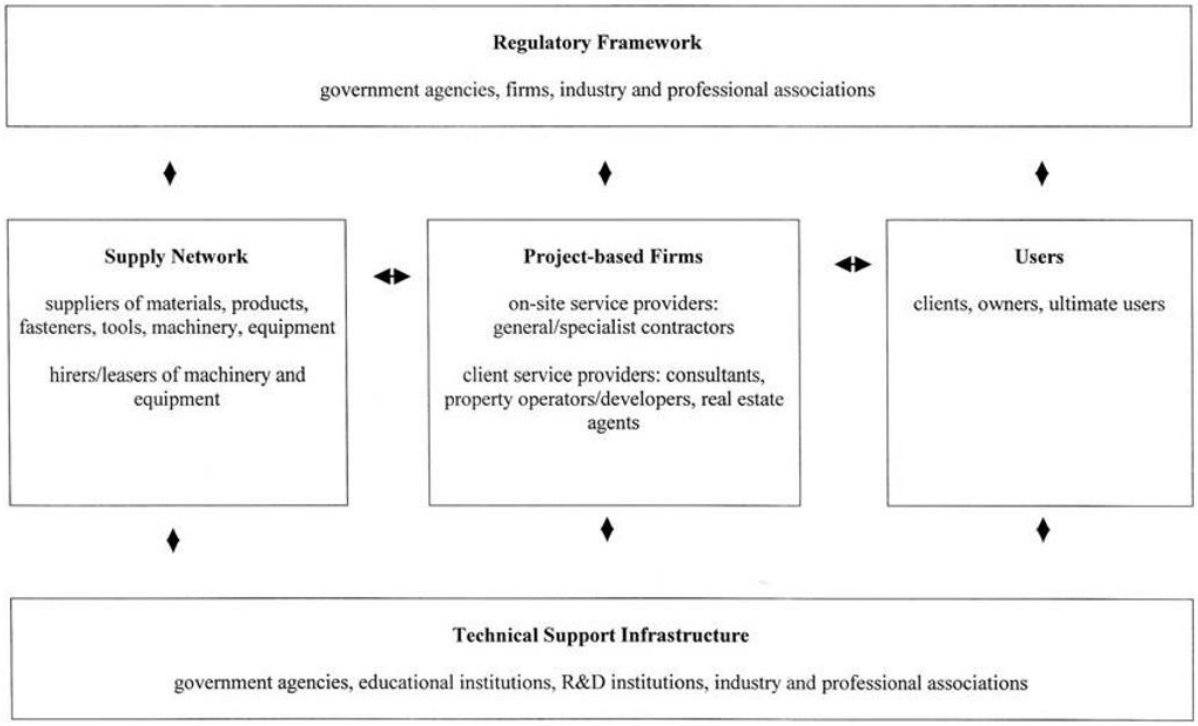


Figure 4: Diagrammatic representation of the broad range of key participants in the construction industry (Source: Blayse & Manley, 2004).

This figure also shows the key position of project-based firms like contractors (Blayse & Manley, 2004). Maintaining a relationship of high quality with sub-contractors is positively and strongly associated with the perceived performance of general contractors responding to the survey conducted by Kale and Arditi (2001). The relationship of a sub-contractor with a general contractor is close but also project-based (Hinze & Tracey, 1994) and therefore often temporary.

This introduction shows that circularity in the building sector struggles to make it to the mainstream market. This is mainly due to the fact that the building sector has a project-based nature. Therefore, the knowledge flow between different projects is not sufficient. It also shows that the different actors have a significant role in this knowledge flow and that an active network is required. A general contractor is a project-based firm who has a central role between all the actors involved. The problem statement is therefore that it is currently unclear what the role of the general contractor can be to have a positive influence on the adoption of circular building methods in building projects.

1.3 Research question

Following from this literature introduction, the main objective of this research is to contribute to the scientific knowledge of adoption of circular building methods. This research aims to identify what factors can stimulate the adoption of circular building methods by the general contractor. The goal is to give recommendations on how the role of the general contractor can have a stimulating influence on the adoption of circular methods, within its inter-firm network.

To get to this, the following research question will be central in this research:

> *Which actions can be executed by the general contractor to have a stimulating influence within its inter-firm network on the adoption of circular building methods in the Dutch housing industry?*

The main research question will be answered with the help of the following sub-questions:

1. *What role can the general contractor have within its inter-firm network regarding the adoption of circular building methods according to literature?*

This part will show what the literature says about the adoption of innovation and what the role is of the general contractor in the adoption of circular building methods. The emphasis will be on transition approaches and the management of knowledge in networks. This will provide the theoretical framework which will be used for the case studies.

2. *How did the different actors of circular building projects experience the adoption of circular building methods by the actors involved?*

In this chapter, the results from the case study-analysis will be presented. This will show what the experiences of the actors involved are with the adoption of circular building methods, which barriers they faced, and what aspects they think are important for a good collaboration. The theory development will be used to support the case studies.

3. *What can be learned from (mis-)matches between theoretical considerations and experiences?*

This will show which (mis-)matches there are between the theoretical considerations and the experiences from the actors concerning the role of the general contractor for the adoption of sustainable innovations. It will show what the causes are for these (mis-)matches.

4. *Which factors from these lessons can be applied by the general contractor for the circular building methods in the Dutch building sector?*

This part will show how the general contractor can apply the lessons, learned from the results of the case studies to the circular building methods in the building sector.

1.4 Research design and Method

To be able to answer this research and sub-questions, first a literature study will be done, followed by a multiple-case study.

Yin (1994) states that a case study is needed when there is a desire to understand complex social phenomena. This is the case in this research as the main objective is to analyze the role of the contractor in adopting circular building methods. Yin (1994) also defines three conditions for a case study. The first important condition is the type of research question. This should be an exploratory,

descriptive or explanatory question (Yin, 1994). In this thesis, the second sub-question will be central for the case studies. This sub-question is formulated as '*How did the different actors of building projects experience the adoption of sustainable innovations by the general contractor?*' This is an exploratory question. The second condition is that the question is asked about a contemporary event (Yin, 1994). As the research is focusing on innovations, which are a contemporary phenomenon, the question is contemporary, and the second condition is also met. The third condition states that the researcher has little or no control over the situation (Yin, 1994). For this research, this condition is met as well.

The literature study has an essential role in a research design (Yin, 1994). A good literature study will provide strong guidance in determining what data to collect and the strategies for analyzing the data (Yin, 1994). In this research, a literature study is conducted to provide definitions for the used concepts, like innovation and learning within the construction industry, and to provide the propositions that will be tested in the case studies. This literature study will also provide input for the interviews in the case study.

To be able to make the findings from the case study more reliable, the triangulation approach (Yin, 1994) will be used. In this research, interviews and a focus group with experts from the building industry will be used. The purpose of the focus group is to verify and deepen the findings by experts from the construction industry. This will be a diverse group where at least the three roles of the general contractor, sub-contractor and advisor will be represented. This focus group is needed to complement the findings and find underlying causes and problems. As some aspects are seen contrary by either the literature and the interviews or by different interviewees (Krueger, 2014). During a focus group, people can discuss their opinions and might shift or start agreeing with each other when they hear the other arguments. This is contrary to the interviews, where they will just tell their own opinion and do not have input to think critically about their own opinion. So, this way a distinction can be made between soft and strong opinions. Another aim is to explore workable solutions (Krueger, 2014).

According to Yin (1994), there are two types of case studies; the single and the multiple case study. The difference between these two is that a single case study is used when the case, that is being reviewed, is so rare and unique that it will not be repeated and it is not ethically justified to repeat the situation. Where the multiple case study is used when a replication logic is expected. For this research, even though the adoption of circular building methods is still unique, a single case study cannot be applied as the goal is to see how this can be repeated more often. Therefore a multiple case study will be done. Two projects with circular building methods will be reviewed.

To make sure that the case study has a solid design there are five important components; the research question, the proposition, the unit of analysis, the logic linking the data to the proposition and the criteria for interpreting the findings (Yin, 1994). The research question for the case study will be '*How did the different actors of building projects experience the adoption of sustainable innovations by the general contractor?*' The proposition is that this has a relation with different actors that are involved with the circular building materials and the building sector. Especially the learning and knowledge sharing between actors involved is a focus point. Therefore, the unit of analysis will be what the role of these actors, specifically the general contractor, is on the innovation adoption. For the last two components, the logic linking the data to the proposition and the criteria for interpreting the findings will look at pattern-matching between the cases and the literature findings.

To be able to keep track, analyze and interpret the data, Atlas.ti will be used (Atlas.ti, 2018). Atlas.ti is a Qualitative Data Analysis Software program. Atlas.ti is a tool to organize a great amount of data. The program does not do any analysis itself. But by coding the content of the document, the researcher is able to create relations and compare the different documents. This provides a better overview of the available data and the relations about certain topics for the researcher.

However, the use of the case study method has some limits as well. Yin (1994) states three common concerns. These are the concern whether case studies are rigorous enough, the generalization of case studies, the unmanageable level of effort and the comparative advantage. When a case study is not rigorous enough, this is often because the researcher has allowed equivocal evidence or biased views to influence the direction of the findings and conclusions. However, in this research different point of views are conducted and used. It is important to keep in mind that case studies are generalizable to theories, not to populations or universes. The unmanageable level of effort and the comparative advantage can be dealt with by rightly choosing the scope of the case study. Overall, these concerns have in common that they are highly related to the skills and work attitude of the researcher. It is therefore important to work precisely and systematic.

1.5 Data gathering and analysis

For this research, primary and secondary data will be conducted. The primary data will be obtained by doing interviews with actors involved in the cases and a focus group with experts from the construction industry. The secondary data will be obtained from the literature study. All the data which is needed for this research will be gathered mostly through existing literature and the connections within Dura Vermeer.

Dura Vermeer is a general contractor in the Netherlands. It consists of two divisions; 'construction and real estate' and 'infrastructure'. This research is conducted in collaboration with the 'construction and real estate' division. Dura Vermeer provided inside information and connections within the building industry.

For the development of the theory, the existing literature on the adoption of innovation and the role of the general contractor will be studied to get a clear overview of the current situation and literature. This will show what the barriers are for circular building methods in the building industry to make it to the mainstream market and what the role of the general contractor is in the current situation.

All this information will help to design the focus and questions for interviews of the case studies. Two case studies will be conducted; 'Bellevue' a renovation who aims to be circular by general contractor Dura Vermeer and 'Fijn Wonen', a project which aims to realize 70% circular houses by general contractor van Wijnen. More detailed information about the cases can be found in section 3.1. The interviews will be conducted with different actors who were involved with the realization of the cases. In both cases, there will be an interview with the general contractor, a sub-contractor, and an advisor. The list of interviewees and full interviews can be found in Appendix A. The interviews with these actors will show why the adoption of circular building methods did or did not work in these cases, what the causes were for the outcome and what role the general contractor had in these cases. It will help to identify how their inter-firm networks work and what is needed to improve the collaboration. Next to this, there will also be interviews conducted with a general group which, next to the same roles, also involves someone on a governmental level, a client, and directors from Dura Vermeer. There will be an elaborate description of this research design in chapter 3.

The method to analyze this data will be pattern-matching, where patterns between the two cases and the existing literature will be compared. This will give matches as well as differences, patterns, and barriers. These results will show what needs to change for the adoption of circular building methods in the building sector. These results will be discussed in a focus group with experts from the building sector. In the end, recommendations will be given for further research. And recommendations will be given to the general contractors about how they can change its role to have a positive influence on the adoption of circular building materials.

1.6 Thesis outline

The outline of this thesis is connected to the sub-questions and consists of six main parts: developing theory, data gathering, analysis, a discussion, and results, and giving recommendations to the general contractor. The first part consists of a scientific literature study. This will give input and guidance for the questions for the interviews of the case study because it will show more clearly what the important aspects are for innovations in the building sector. The next part is the data gathering that will obtain a clear overview of the barriers and possible solutions that are experienced by the interviewed actors. This will be done by conducting interviews with different actors who were involved in the case study and some that were not involved in the cases form the case studies. All the data and results will be verified by a focus group of experts from the construction industry. In the following part, conclusions will be made to get to an academic discussion and recommendations for the general contractor on how to adopt circular building methods in the building industry. An overview can be seen in figure 5.

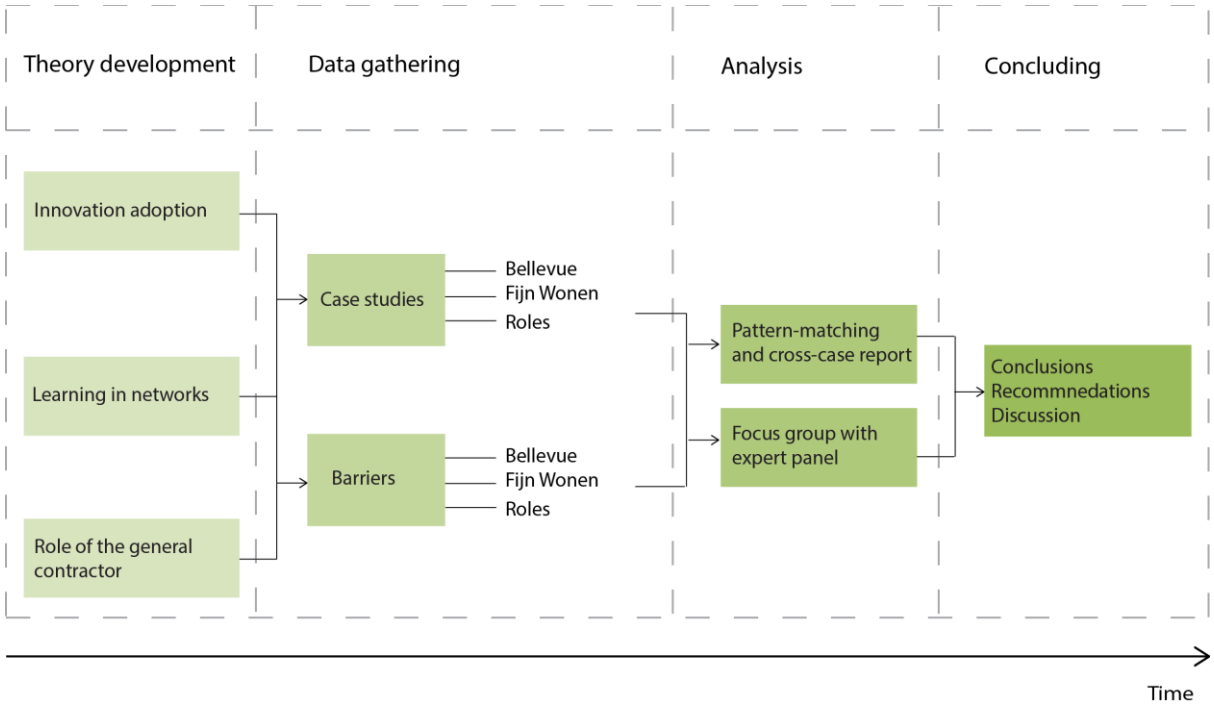


Figure 5: Thesis outline (Own illustration).

2. Theoretical framework

This part will show what the literature says about the adoption of innovation and what the role of the general contractor is in the adoption of circular building methods. The emphasis will be on transition approaches and the management of knowledge in networks. This will provide an answer to the first sub-question; '*What role can the general contractor have within its inter-firm network regarding the adoption of circular building methods according to literature?'* And this will contribute to the theoretical framework which will be used for the case studies.

First, there will be given a definition of innovation in the construction industry. As circular building methods are a sustainable innovation and the construction industry is a very specific sector, socio-technical systems will be described. A theoretical perspective that conceptualizes overall dynamic patterns in socio-technical transitions is the Multi-Level Perspective (MLP). This is also the theory where Strategic Niche Management (SNM) is developed from. SNM focuses on niche management, which is one of the levels in the socio-technical system and Multi-level approach (Loorbach & van Raak, 2006). In addition to these levels, there will be a look on the importance of social networks, how they contribute to knowledge sharing and how they can be managed. All of this will conclude in a few aspects that will be kept in mind while conducting and analyzing the case studies.

2.1 Innovation

A few central terms of this thesis are highlighted. As this thesis is about circular building methods, it is about a sustainable innovation. There are a lot of definitions for innovation; therefore, it is good to have a clear definition of innovation in this thesis. According to Ling (2003), innovation is defined as "an implementation of a new idea to a construction project with the intention of deriving additional benefits, although there might be some associated risks and uncertainties." This new idea can refer to technology, a new design, material component or, as circular building methods are, construction method used in a project (Asad, Fuller, Pan, & Dainty, 2005). West, Hirst, Richter, and Shipton (2004) state that innovation refers to the introduction and application of new and improved ways of doing things. Or to make it more complete West and Farr (1990) give the definition of innovation as;

"… the intentional introduction and application within a job, work team or organization of ideas, processes, products or procedures which are new to that job, work team or organization and which are designed to benefit the job, the work team of the organization" (West & Farr, 1990).

Circular building method is an idea which is new to most general contractors, which needs to be adopted by the construction industry and is a source of change and process of knowledge development. Therefore, it can be identified as an innovation. According to Mlecnik (2013b), some literature on innovation states that innovation journeys are social processes that involve organizational learning and collaboration. Mytelka and Smith (2002) claim that innovation is no longer a process of discovery but rather a non-linear process of learning. Besides, Mlecnik (2013b) states that innovation is more than just the development of knowledge, it is the knowledge that is developed to be implemented and the entire route from the development of the knowledge to the market launch. Innovation is also seen as an important source of change, each actor that is reacting to new economic possibilities (Geels & Kemp, 2007). This all leads to the definition of innovation in this thesis which is:

“The introduction and adoption of an idea which is new to the work team and which is a source of change and process of knowledge development”.

To see how circular building methods, as an innovation, can be adopted there will first be a look at the adoption of innovation in general. The adoption of innovation has been a topic of interest in the literature ever since the 1950s (Rogers, 2003). The hard times for new technologies are a common theme in the innovation literature. To develop a new idea a special kind of management is required, a management of attention and management of relationships (Kemp et al., 1998). This implies that for this thesis, the focus needs to be on the special kind of management. Since 1982, the development of innovation theory has gone through a reformulation as innovation is no longer primarily seen as a process of discovery but rather as a non-linear process of learning (Mytelka & Smith, 2002). In a period of dramatic change, innovation theories emerged, and continuous interaction and feedback had an important impact on the innovation theory (Mytelka & Smith, 2002). Compatibility, relative advantage, observability, trial-ability, and complexity are five innovation characteristics that consist of a significant relationship to innovation adoption (Rogers, 2003; Tornatzky & Klein, 1982). Commonly faced barriers for the implementation of new technologies are often not technical but institutional, economic and social barriers (Goverse et al., 2001).

In this thesis, the focus is on the adoption of circular building methods, which means that a transition towards sustainability is needed. Sustainable transitions have some special characteristics that make them different from regular transitions (Geels, 2004). First, sustainable transitions are goal-orientated as they address environmental problems. Sustainability can be seen as a collective good which gives private actors fewer incentives (Geels, 2004). Besides this, most sustainable solutions do not have direct advantages for users. It is therefore not likely that the sustainable innovation will replace the existing system without help from policies. Reasons for the failure of the introduction of sustainable technologies are linked to government policy and regulatory frameworks, infrastructure, demand and production, technology, and culture and society (Kemp et al., 1998). Transition to forms of circular economy represents a social and environmental need (Migliore et al., 2016). This sets challenges for established companies and might even destroy the usefulness of their existing capabilities, networks and business models (Antikainen & Valkokari, 2016). For circular building methods, this business model needs to change. Successful diffusion of green innovations within the built environment depends on adequate social embeddedness and on social-interactive processes in the life-cycle stages of design, implementation, and usage of buildings (Geldermans, 2016; Rohracher, 2001). Another important factor that might be a challenge for the introduction of sustainable technologies is the one-sided nature of most innovations, they are too technocratic and to static, not taking enough account of how environmental, social, technical, economic and temporal factors are integrated into practice (Boons & Baas, 2006; Vernay, 2013).

For successful implementation of innovation, a transition is needed. Transition, however, is a complex and long-term process that consists of multiple actors (Geels, 2004). As innovation is a complex social process, there does not exist a best strategy or a strategy that is suitable for managing innovations in every organization. It is therefore important that any innovation strategy sits naturally within the overall strategy of the organization (Egbu, 2004).

2.2 Transition approaches

To understand the interaction between different actors, the concept of an innovation system has been developed (Siva, Hoppe, & Jain, 2017). This interaction is also the scope of this thesis. Innovation systems is a conceptual framework that reverses to a new understanding of innovation as an interactive process in which enterprises have interaction with each other to play a key role in bringing new products, processes, and forms of organization into economic use (Mytelka, 2010). There is a

resurgence of interest in innovation and a reconceptualization of the firm, as the firm is now a learning organization embedded within a broader institutional context underlying the system of innovation (Mytelka, 2010). The approach draws attention to the behavior of local actors. Mostly to three key elements in the innovation process: learning, networking, and investment (Mytelka & Farinelli, 2000). Some literature on innovation systems advocates that the speeds and direction of innovation are strongly affected by the complex interaction between actors and the prevailing institutional infrastructure (Kieft, Harmsen, & Hekkert, 2017). So, innovation systems can be seen as a network of people, organizations, and institutions where the creation, diffusion and commercial exploitation of new technologies take place (Malerba, 2004). Innovation at building level suggests collaboration with other players and comes with high management and coordination costs (Mlecnik, 2013a). To bring about sustainable system innovation, an integration between technical and social development is needed (Hegger, Van Vliet, & Van Vliet, 2007).

When a technical innovation plays an important role for fulfilling societal functions and the functioning of technology depends on other elements within a socio-technical system, like in the construction industry, a socio-technical approach is used for transition (Bidmon & Knab, 2014). In socio-technical systems technical and social change are interrelated (Schot & Geels, 2008). A socio-technical transition is defined as the shift from one socio-technical system to another or to other elements of the system (Geels. 2004; Bidmon & Knab. 2014). Or in other words, the system wants to link the technical, science, policy, socio-cultural, and user and market regime (Witkamp, Raven, & Royakkers, 2011).

The socio-technical system consists of three levels which are shown on the next page in figure 6 (Geels, 2002). The lowest level is called the niche-innovations. This is the level where innovations start to develop, test and learn. This is a rather flexible level where not many things are certain, and everything is easy to change and adapt. The second level is the socio-technical regime. This consists of rules, traditions, systems, and markets. This level is dynamically stable, which means that it will only change under certain circumstances which are proven in the niche-innovations level. The highest level is the socio-technical landscape, which consists of factors that cannot be influenced, like climate changes. As these factors are very hard to change, it is a stable level which will only change slowly. Geels (2004) states that socio-technical systems are a special research topic as they are about relatively rare, long-term changes. Housing is a socio-technical system which is slow to change (Geels, 2004; Hughes, 1993; Rip & Kemp, 1998). Therefore, the adoption of circular building methods in building projects needs a specific research method.

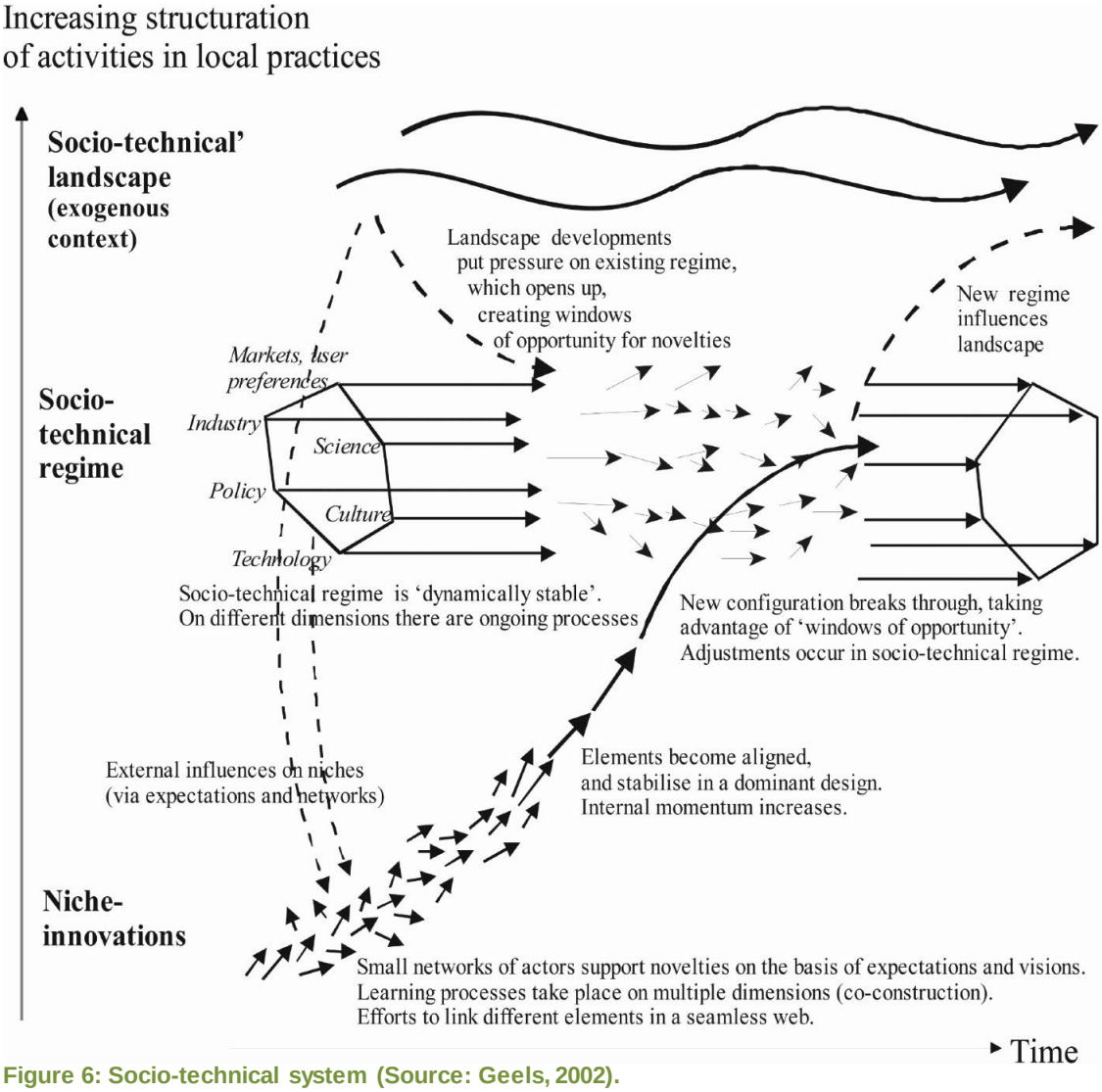


Figure 6: Socio-technical system (Source: Geels, 2002).

A research perspective that conceptualizes overall dynamic patterns in socio-technical transitions is the Multi-Level Perspective (MLP) (Geels, 2004). Originally, the MLP was developed to understand the transition and regime shifts (Geels, 2002; Kemp et al., 1998; Rip & Kemp, 1998; Schot, Hoogma, & Elzen, 1994). The idea behind the MLP stems from the sociology of technology. Here, the same three inter-related dimensions from the socio-technical system are important; the niche innovations which consists of social groups, the socio-technical regime which consists of the rules that are guiding for the social groups, and socio-technical landscape (Geels & Kemp, 2007). Figure 7 shows the MLP which is actually a simplified version of the socio-technical system.

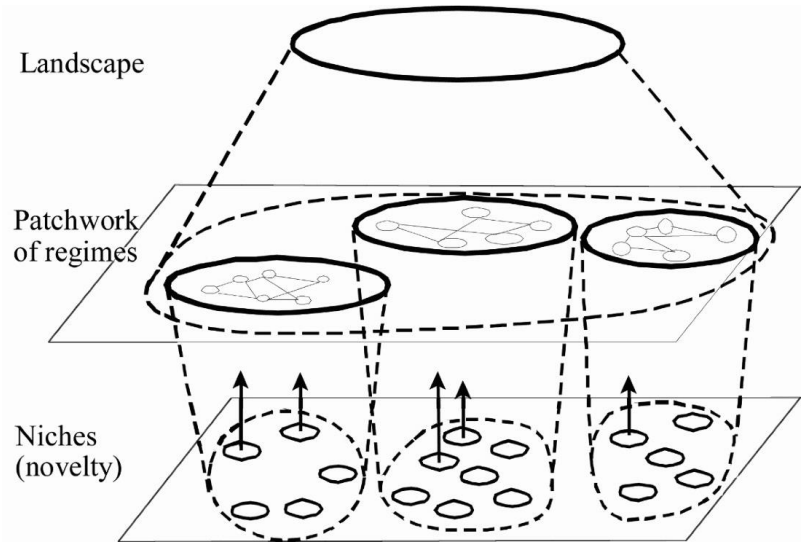


Figure 7: Multi-level perspective (Source: Geels, 2002).

The interplay between processes at different levels in different phases creates system innovations according to MLP (Geels & Kemp, 2007). So in the MLP, the transition is seen as a non-linear process that results from the interplay of development at the different levels, where each level refers to a heterogeneous configuration of elements where a higher level is more stable than a lower level (Geels & Deuten, 2006). This interaction is shown in figure 8 on the next page.

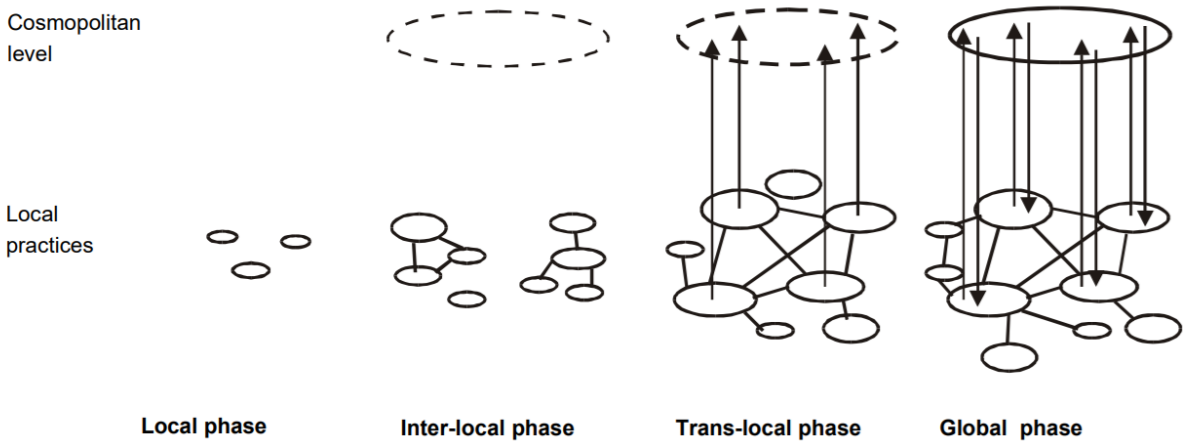


Figure 8: Interaction between levels in Multi-level perspective (Source: Geels & Deuten, 2006).

Strategic Niche Management (SNM) is based on the multi-level conceptualization of socio-technical regimes and they have the same conceptual base (Loorbach & van Raak, 2006). SNM is centered around the question which trajectories a technology or technological system could follow to fundamentally change an existing socio-technical regime (Loorbach & van Raak, 2006). It also consists of the same three socio-technical levels but focuses on the niche innovation level (Loorbach & Raak, 2006).

In the late 1990s, the SNM approach was introduced as a theoretical framework for the management of technological innovations and the facilitation of the market introduction of sustainable technologies (Schot & Geels, 2008). SNM aims to align the technical and the social dimensions (Loorbach & van Raak, 2006) which will ultimately contribute to a broad shift to more sustainable development (Caniëls & Romijn, 2008b). It is an instrument for analyzing the importance of networks of social actors for successful niche experimentation, which determines the successful development of sustainable technologies (Caniels & Romijn, 2008b). This approach suggests that sustainable innovation journeys can be facilitated by creating technological niches. These niches are protected spaces that make it easier to experiment with the co-evaluation of technology, user practices and regulatory structures (Schot & Geels, 2008).

There are three main niche processes: Shaping of expectations, building social networks and learning processes (Schot & Geels, 2008; Caniels & Romijn, 2008b; Mlecnik, 2014). The shaping of expectation is important as it will provide a shared vision which is socially embedded; it will clarify what the benefits of the niche will be. Building a social network is necessary as a new niche may require social networks to emerge and new actors to get together so that they provide and exchange the necessary resources. A network is a good network when it is broad and when there is regular interaction between the actors to align within the network (Schot & Geels, 2008). The learning process is important as it is likely that innovations will spur if there is a broad focus which addresses both techno-economic optimizations and the alignment between technical and social factors (Jain et al., 2017). However, there is some external learning and further research that needs to be done. SNM is not clear about the structure and functioning of the social network (Caniels & Romijn, 2008a).

2.3 Inter-firm learning

As learning, networking and investment are three important factors, this section will focus on inter-firm learning. The importance of learning at niche-innovation project level and between niches is acknowledged because of the structure of the housing industry (Femenias, 2004). Blayse and Manley (2004) state that organizational learning is hindered. Especially project-based firms, like construction firms, struggle to learn between projects (Blayse & Manley, 2004). To provide significant improvements in construction processes, construction firms make use of and combine knowledge that comes from different organizations (Miozzo & Dewick, 2004). The long-term relations between firms and collaboration with external sources of knowledge are two of the factors to develop strategic innovation (Miozzo & Dewick, 2001). Incremental innovation is based on current knowledge and experience and leads to small improvements in current practices and minimal impacts on other components and systems (Marquis, 1988). To achieve more than just incremental innovation, intensive knowledge transfer between different players in the construction chain is essential (Mlecnik, 2013b).

The development and sharing of knowledge and expertise in and between different players, that is needed to innovate, is represented by knowledge sharing (Bossink, 2004). Knowledge sharing consists of the arrangements that facilitate the sharing of knowledge and information that is needed to innovate between different players (Gann & Salter, 2000; Goverse et al., 2001; Kangari & Miyatake, 1997; Slaughter, 1993; Veshosky, 1998). Knowledge sharing can be used to innovate as it facilitates the development of new knowledge (Arnoldussen et al., 2017; Bossink, 2004). To ensure compatibility, it is in the interest of all the players to share knowledge, an 'open' network is most appropriate in such cases (Tidd, 2001). Repeated dealings, increasing trust and reducing transaction costs develop mutual knowledge and social bonds over time (Tidd, 2001). It is important to seek out and utilize strengths like actors' knowledge, skills, experiences, and network relations (Hinze & Tracey, 1994; Kale & Arditi, 2001; Weber, Hoogma, Lane, & Schot, 1999). To facilitate the exchange of knowledge and stimulate innovative solutions in the process, lateral communication in firms and construction projects is needed (Bossink 2004).

Knowledge sharing between projects is limited or even problematic when consecutive projects do not have a designed strategy for exchanging knowledge (Arnoldussen et al., 2017). For sparking ideas and allowing the development of innovation concepts, it is important to have information flows into and within the firm (Adams, Bessant, & Phelps, 2006). Knowledge needs to be contextualized to make it shareable between locations (Geels & Deuten, 2006). Results from many experimental projects with new technologies often remain stuck within local projects (Geels & Raven, 2006). It is needed to pay more attention to learning between and across projects, as shown in figure 9.

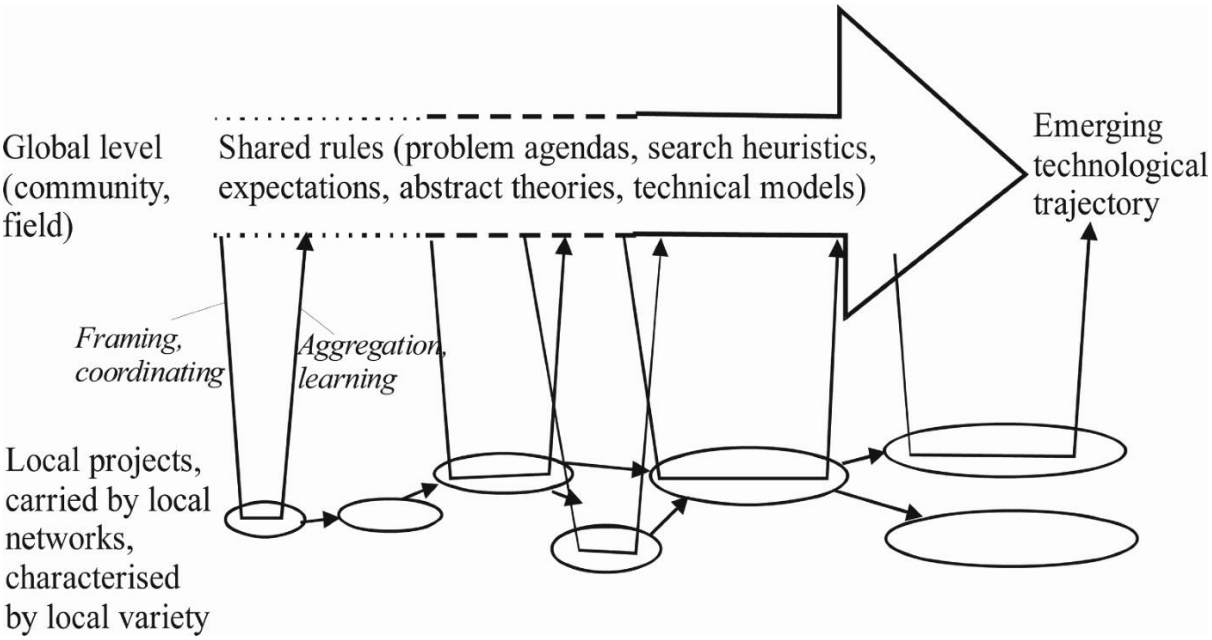


Figure 9: Local projects and emerging technical trajectories. The importance of paying more attention to learning between projects (Geels & Raven, 2006).

According to Buckler (1996), a learning process, in general, is effective when it consists of three main components. These are focus, environment, and techniques. The focus is needed to plan the course of the learning effort, the environment needs to facilitate the learning process and the techniques have to make sure that the learning process is efficient. In table 1 the indicators that are important for the learning process are shown.

Table 1: Indicators for facilitating the inter-firm learning.

Aspect	Indicators
Learning	Knowledge sharing
	Focus
	Environment
	Techniques

For leaders of construction projects and organizations, it is important that the process by which knowledge is created must be effectively managed (Egbu, 2004). Because of the dynamics and communication between the different levels, the socio-technical regime will be able to adjust to the innovation. New rules and traditions will occur and develop. By looking back at the socio-technical regime shown in figure 6 and combine it with knowledge exchange shown in figure 9, we see that this thesis will focus on the area between the local and global level which corresponds to the niche-innovation and the socio-technical regime level. This is shown in figure 10.

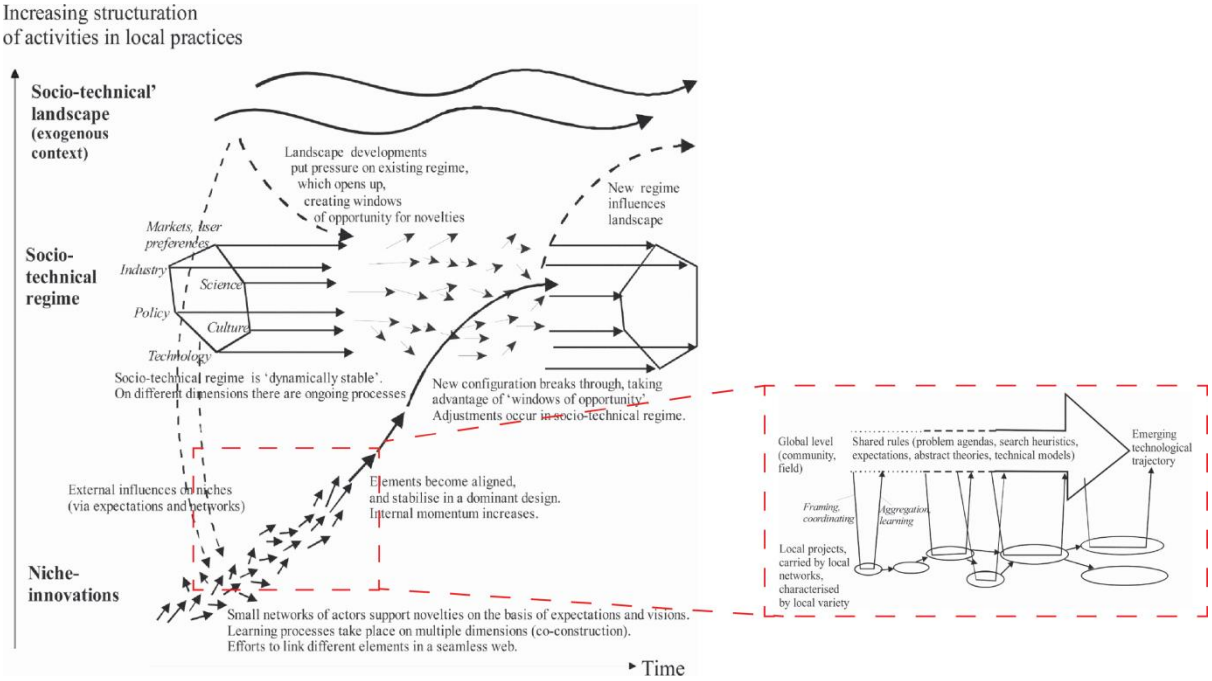


Figure 10: Knowledge management placed in MLP, focus of this thesis. (Adapted from Geels, 2002 and Geels & Deuten, 2006).

2.4 Important aspects of collaboration within a network

The importance of a social network to have a successful learning process

Caniels & Romijn (2008a), Blayse & Manley (2004) and Mlecnik (2014) point out how important a good network is for learning in between projects. A social network is considered good when it is a broad network with multiple kinds of actors and when it is deep which assures that there is regular interaction between the actors to assure alignment (Raven et al., 2010; Schot & Geels, 2008). Dewick & Miozzo (2004) say that it is important to understand the linkage between inter-firm networks and the ability of these networks to improve the adoption of innovation. The importance of social networks means that the different processes within SNM are strongly related to each other; to achieve a good learning process, a good network is necessary, and a good network will improve the learning process. The nature of the social network determines the depth and the breadth of the learning (Schot&Geels, 2008; Blayse & Manley, 2004). If learning is to be successful, it has to be an interactive process; networking is crucial for learning and innovation. It all highly depends on the successful functioning of the network (Caniëls & Romijn, 2008a). Different authors point out that especially long-term relations are a great external source of knowledge and are responsible for enhanced performance (Dewick & Miozzo, 2004; Blayse & Manley, 2004). Long-term relationships helped to overcome conservative tendencies, to encourage the adoption of new technologies and to increase trust between the parties (Dewick & Miozzo, 2004). But long-term relationships also increase stability and economies of learning and experience, which are important for the introduction of sustainable technologies (Dewick & Miozzo, 2004).

Table 2: Indicators which are important for managing the inter-firm network

Aspect	Indicators
Inter-firm network	Broad
	Interaction
	Nature of relationship

Intermediary actors in niche development have three key roles: aggregation of knowledge, the creation of institutional infrastructure, and reversal in the relationship and knowledge-flows (Geels & Deuten, 2006). Aggregation is the process where local knowledge is transformed into robust knowledge. This way the knowledge is sufficiently general, abstracted and packaged, so it is no longer tied to specific contexts (Geels & Deuten, 2006). The institutional infrastructure serves as a repository and forum for the storage, exchange, and circulation of the aggregated global knowledge. An infrastructure like that consists of forums that enable and introduce the gathering and interaction of actors, the exchange of experiences and the organization of collective action (Geels & Deuten, 2006). And when a reversal occurs, the collective knowledge repertoires at the global level become guiding for local-level activities (Geels & Deuten, 2006). Egbu (2004) states collaboration and long-term relationships enable construction organizations to learn from projects and transfer knowledge to the organizational base and along supply chains.

Process management

A good network, which is necessary for a good learning process, does not just function properly by itself. It needs a well-designed process management. First, a good definition of 'network' is needed. According to Snehota and Hakansson (1995), a network is defined as the actors' relationship with other actors. De Bruijn and Ten Heuvelhof (2008) elaborate this by saying that a network can be defined as a number of actors who have different goals, interests, and resources and who depend on each other for the realization of their goals. These different goals and interests of the different actors make that information in networks might be used and spread strategically. This is also because information is an important source of power as it might strengthen the position of an actor. On the other hand, the strategically use of information might harm the trust in the actor, which will give him a bad reputation. Therefore, in a network, there is more attention on the process of the interaction between the interdependent actors in a network than there is attention to the project approach (De Bruijn & Ten Heuvelhof, 2008).

A process is good when it is an open process, in which there is enough progress and momentum, protection of the core values of the actors, and in where the quality of the result is guaranteed (De Bruijn, Ten Heuvelhof, & In 't Veld, 2010). An open process is a process where the actors involved are certain that their interest will be addressed where possible. This also tempts parties to participate in the process. There has to be enough room to identify problems and find solutions together. It is important for the success of the process to be appealing to participate for each of the involved actors. This involvement also applies to the design of the process itself (De Bruijn et al., 2010). As actors most often do not come to a shared understanding of their strategic needs, it is important to pay attention to the social interaction between actors (Venselaar, Gruis, & Verhoeven, 2015). Strategic needs are influenced by social aspects like trust.

Table 3: Indicators which are important for managing the building process

Aspect	Indicators
Process management	Protection of core values
	Progress & momentum
	Quality of results
	Room for problems & solutions
	Appealing to participate

Collaboration within project networks

The collaboration with partners can improve the competition for learning. This collaboration and learning will develop through interaction (Holt, Love, & Li, 2000). Khalfan and McDermott (2006) define the relationship as a long-term commitment between two or more firms to achieve the completion of a project. The relationship is based on trust, the dedication of common goals, and understanding of the expectations and core values of the other actors. One of the collaboration types

that is more and more used in the construction industry at the moment is Supply Chain Partnering (SCP). SCP is a long-term commitment between two or more firms as in an alliance for the purpose of achieving specific objectives by maximizing the effectiveness of each participant's resources (CII, 2018). However, in this case, long-term only means for the duration of the project, and is therefore actually short-term (Briscoe & Dainty, 2005; CII, 2018). Mlecnik, Straub, and Haavik (2018) state that the development of a collaborative business model allows actors to define long-term incentives together. This enables and inspires members of a consortium to achieve a long-term goal, which will help to achieve short-term returns (Mlecnik et al., 2018). Traditionally, most long-term relationships were forms between the general contractor and client only. There was no full engagement with sub-contractors (Briscoe & Dainty, 2005). However, the different actors in the supply chain want trust and openness, an integrated supply chain, and the completion of a project within time, agreed cost and promised quality (Khalfan & McDermott, 2006). To achieve this, all the actors from the supply chain who have a close relationship and integrate activities collaborate in SCP (Koolwijk, van Oel, Vrijhoef, & Wamelink, 2015). The supply chain is defined as the network of involved firms, through upstream and downstream linkage, in the different processes and activities that produce value, like products and services, for the customer (Christopher, 1999). The most important indicators of SCP are close, long-term and intensive collaboration, shared objectives, and long-term success (Eriksson, 2015; Vrijhoef, Koolwijk, Van der Kuij, Van Oel, & Wamelink, 2014).

Long-term relations increase motivation for all the actors involved (Khalfan & McDermott, 2006). And when they are maintained well, these networks will improve mutual learning and trust (Holt, Love & Li, 2000). Trust is another important aspect of SCP. This is defined as the willingness of an actor to be vulnerable to the actions of another actor, based on the positive expectations (Mayer, Davis, & Schoorman, 1995). In the construction industry, the actors lack the time to engage in processes that are long enough to trust (Laan, Noorderhaven, Voordijk, & Dewulf, 2011). The development of trust in a network improves the communication about risks, and possible solutions will be more transparent. This makes that the management of these risks is more effective and the project outcomes will be more favorable. On the contrary, when the trust between actors stays weak, it is hard to realize these positive outcomes (Laan et al., 2011). Implementation should rely on social aspects, which will improve the collaboration over time (Ingirige & Sexton, 2006). Eriksson (2015) also states that the early involvement of the contractor is an important factor for the integration of the project-based supply chain.

Table 4: Indicators which are important for managing the supply chain

Aspect	Indicators
Supply chain	Trust
	Dedication to common goals
	Understanding & expectations of core values
	Equality and timing involvement

So, the importance of social network means that the different niches of SNM are strongly related to each other; to achieve a good learning process, a good network is necessary, and a good network will improve the learning process. In a network, all the actors involved have different goals and interests. Because of this, information within networks might be used and spread strategically. Therefore, in a network, there is more attention to the process of the interaction between the interdependent actors in a network than there is attention to the project approach. During this process, it is important to make sure there is a long-term collaboration with open communication, which will stimulate trust and have a positive influence on the attitude of the actors involved. However, SCP is only during one project, to improve the relationship between the different firms, a longer collaboration is needed.

The role of the general contractor regarding learning, networking, and investment

In the problem statement, the importance of social networks within the construction industry is addressed. Blayse & Manley (2004) showed the central role of the contractor within this network. Construction firms make use of different organizations to get their knowledge and technologies. Miozzo and Dewick (2001) also see the importance of the general contractor within this network. They state that the general contractor plays a mediator role; the general contractors are important sources and adopters of innovations, they integrate the different activities and innovations that are introduced by different actors (Miozzo & Dewick, 2001). Therefore, the general contractor might be a good actor to manage, integrate and secure the most important factors of process management.

The central and mediator role of the general contractor also implies that they might be a good actor to positively influence the inter-firm learning process. As the general contractor is so central in the construction network, they have the best access and opportunities to combine and share knowledge. This might have a positive influence on the contextualization of the knowledge so that the knowledge will be better shareable.

Transaction costs are all costs that are incurred when trading (Williamson, 1979). One of the costs of transaction costs is search and information costs. These costs are the costs that are made when identifying possibilities. The general contractor will need to invest in these costs. However, in the long run, these costs will decrease. So this will lead to an advantage compared to other actors who will start later.

2.5 Conclusion

This chapter aims to answer the sub-question; 'What role can the general contractor have within its inter-firm network regarding the adoption of circular building methods according to the written literature?' Therefore, this chapter has a closer look at the existing literature about the adoption of innovation in the construction industry. Besides this, the possible role of the general contractor within its network on the adoption of innovation is discussed.

There is shown that the key elements in the innovation process are learning, networking and investment. Some literature on innovation systems shows how important it is to understand the complex interaction between actors. Barriers for the adoption of innovation are often not technical but rather institutional, economic and social. The transition of sustainable innovations, like circular building methods, has some special characteristics that make it different from regular transitions. Sustainable transitions are more goal-orientated, do not have obvious advantages and they are mostly in empirical domains. The adoption of sustainable technology is facing extra challenges like one-sided nature, lack of information and depending on external factors. Again, the importance of the social embeddedness is mentioned. For sustainable innovations, integration between technical and social development is needed. In other words, a shift to a new socio-technical system is needed. In socio-technical systems technical and social change are interrelated. Housing is a socio-technical system which is slow to change. A research perspective that conceptualizes overall dynamic patterns in socio-technical transitions is the Multi-Level Perspective (MLP). In the MLP, the transition is seen as a non-linear process that results from the interplay of development at the analytical level: niches, socio-technical regimes, and socio-technical landscapes. To create socio-technical regime transition, niches are considered to be very important. Strategic Niche Management (SNM) is based on the multi-level conceptualization of socio-technical regimes and they have the same conceptual base. Besides this, it focuses on niche management. There are three main niche processes: Shaping of expectations, building social networks and learning processes. These niche processes are similar to two of the key elements of innovation: learning and networking.

To achieve more than just incremental innovation, intensive knowledge transfer between different players in the construction chain is essential. For knowledge sharing, it is important to have an open network, trust and utilize the strengths of the actors. A long-term relationship will increase the trust. Knowledge needs to be contextualized to make it shareable between locations. Therefore, the interaction between the niche-innovation and social-technical regime level is important. For leaders of construction projects and organizations, it is important that the process by which knowledge is created must be effectively managed.

The importance of social network means that the different niches of SNM are strongly related to each other; to achieve a good learning process, a good network is necessary, and a good network will improve the learning process. In a network, all the actors involved have different goals and interests. Because of this, information within networks might be used and spread strategically. Therefore, in a network; there is more attention to the process of the interaction between the interdependent actors in a network than there is attention to the project approach. During this process, it is important to make sure there is a long-term collaboration with open communication, which will stimulate trust and have a positive influence on the attitude of the actors involved. Also, the importance of networks within the construction industry is addressed. The general contractor plays a mediator role; the general contractors are important sources and adopters of innovations, they integrate the different activities and innovations that are introduced by different actors.

However, there is some external learning and further research that needs to be done. SNM is not clear about the structure and functioning of the social network. And it also lacks specifics about the networks within the building sector. It is important to understand the linkage between inter-organizational networks and the ability of these networks to improve the adoption of innovation. The nature of relationships between the actors that influence the innovation needs to be explored. So that in the end understanding of the interaction between the three SNM niche processes will increase.

2.6 Hypotheses

Altogether, there are four aspects identified that might be able to have a positive influence on the adoption of circular building methods in building projects. These aspects are the management of a network, the management of the supply chain, the management of the building process, and the facilitation of the learning process. A key person or actor with a mediator role should manage these aspects. All of this leads to the following hypotheses for this research;

- H1: A key actor, who manages his / her inter-firm network well, has a positive influence on the adoption of circular building methods in building projects.
- H2: A key actor, who manages the activities of the supply chain well, has a positive influence on the adoption of circular building methods in building projects.
- H3: A key actor, who manages the building process well, has a positive influence on the adoption of circular building methods in building projects.
- H4: A key actor, who facilitates the inter-firm learning process well, has a positive influence on the adoption of circular building methods in building projects.

Overall, the role of the general contractor needs to change. Its central role within the project network implies that the general contractor already is a key actor and therefore can be the integral manager in the process of using circular building methods in building projects. This leads to the fifth hypothesis:

- H5: The general contractor can be a good actor to take the role of an integral manager to have a positive influence on the adoption of circular building methods in building projects.

When combining the first four hypotheses, a theoretical framework can be developed. These factors will be measured in the case studies. This framework, shown in table 5 on the next page, will be used and for the analysis of this thesis. An elaborate description of how this will be used can be found in section 3.2.

Table 5: Theoretical framework which will be used in the analysis

Hypotheses	Indicators	Influence on circular building methods
Managing the inter-firm network	Broad	To be filled in by the case studies
	Interaction	
	Nature of relationship	
Managing the supply chain	Trust	
	Dedication to common goals	
	Understanding & expectations of core values	
	Equality and timing involvement	
Managing building process	Protection of core values	
	Progress & momentum	
	Quality of results	
	Room for problems & solutions	
	Appealing to participate	
Facilitating the learning processes	Knowledge sharing	
	Focus	
	Environment	
	Techniques	

3. Methodology and research approach

This chapter will describe the methodology and research approach of this research in more detail. First, the research approach will describe the selection criteria for the case studies and interviewees. After that, the research design of the case study will be described. This is based on the theoretical framework and hypothesis which are formed in chapter 2. This will give guidance for the analysis in chapter 4. Lastly, the research design of the barrier and solutions and of the focus group will be explained.

3.1 Research approach

Data gathering

Currently, there are not many projects realized in the Netherlands that use circular building methods. The pool of circular building project currently mainly consists of a few unique and leading projects in the utility sector. Some circular housing projects are developing but not realized yet. Therefore, not a lot of cases were applicable to the case studies conducted in this thesis. To be able to compare both cases, the cases are selected on a few criteria. These criteria are;

- The project uses a circular building method
- The project is a building project
- The project takes place in the Netherlands
- The accessibility of project data

The first case that is selected is 'Bellevue'. This is the new headquarter from Alliander at Arnhem. This building, realized in 2016, is presumed to be circular. And because it is built by Dura Vermeer, who collaborates on this research, it is possible to get good insight information. This is an interesting case study as it can show how Dura Vermeer and the other actors involved dealt with a circular request from a client. It can also be a good case to identify how the existing network from Dura Vermeer reacted on and worked with the circular request. This will help to see what the current role of Dura Vermeer, as general contractor, was within this project and where its role can improve to have a positive influence on the adoption of circular building methods. More details about the collaboration and process of this case will be described in section 4.1.

The second case is 'Fijn Wonen'. This is a project from general contractor Van Wijnen. Van Wijnen has the aim to realize a house which is '70% circular'. It will be very interesting to see how Van Wijnen got the idea to realize circular houses, how they realized it and what they did to involve other actors in its idea. Besides this, the actors in this process are very important. Lessons can be learned from the way the actors interacted and the role the general contractor played in this project; what went well and what went wrong? What barriers did they face? Where are possibilities for improvements? More details about the collaboration and process of this case will be described in section 4.2.

However, the two selected cases also have some differences from each other. The first difference is the fact that Bellevue is a renovation while 'Fijn Wonen' is newly built. However, as this requires different circular building methods, it is actually interesting to see what the differences are between those two kinds of circular building methods.

The next difference between the two cases is that 'Bellevue' is requested by the client and 'Fijn Wonen' is an initiative from the general contractor. This is related to the fact that Bellevue is a renovation and 'Fijn Wonen' a newly built project. This is not a problem for this research as it is interesting to see what the effect of this difference is on the adoption of circular building methods within the construction industry.

Another difference between the two cases is that 'Bellevue' is a utility project where 'Fijn Wonen' is a housing project. Ideally, in this research, both cases would have been housing projects. However, at the beginning of this research, 'Fijn Wonen' was the only project that was using circular building methods. Therefore, there was no other option than to use a utility project as well. This difference will be taken into account during this research.

For every case, a RACI model will be made. A RACI-model shows which role every actor has. These roles are divided into Responsible, Accountable, Consulted, and Informed (Jacka & Keller, 2009). By applying these roles to the actors is can be shown which actors were responsible for circular building methods in the different cases and what influences this has on the adoption of circular building methods.

The selection of the interviewees is made based on their occupation or role within the construction industry and their collaboration with one of the projects of the case studies. In the end, there were three groups; case I, case II and a general group. The general group consists of experts from the construction industry who were all working either with circular building methods or with innovations in the buildings industry. For each, there will be three roles interviewed; these are the general contractor, a sub-contractor, and an advisor. Next to this, two clients will be interviewed. One client is realizing her own sustainable and circular house at the moment. It will be interesting to see what barriers she faces and how the process evolves. The other client is from a municipality who realized a circular town hall. Again it will be interesting to see what barriers they faced and how the process evolved. But also to see what influences a governmental actor has in a circular building project. Lastly, two directors from Dura Vermeer will be interviewed. One is the general director and the other one is the director of finance. This is to see what their opinion is about circular building methods in the construction industry. All full interviews, in Dutch, can be found in Appendix A.

Data analysis

To be able to analyze the obtained data, Atlas.ti is used. Atlas.ti is a Qualitative Data Analysis Software program which enables to combine documents (Atlas.ti, 2018). This way, there is a better overview of the great amount of data and it is easier to compare the content of the different documents. To be able to get the needed data out of all the data, firstly, the documents were uploaded into the program. Each document is coded individually. When all this coding was done, families were created. A family enables to organize the documents. There are doc-families and code-families. A doc-family is a group of documents that are related to each other. A code family is a group of codes that are related to each other. For this research, especially the doc-family was useful. The different doc-families that were made are case I, case II, general, general contractor, sub-contractor, advisor and extra roles. This way it was easier to evaluate only the needed documents, per specific case or role, on the selected and interesting codes.

3.2 Research design case studies

Based on the hypotheses that are formulated in section 2.6, the analysis will take place. The aim of this research is to test these hypotheses, concluding in an exploratory research. In the literature study in chapter 2, some aspects of the first four hypotheses are mentioned.

For the management of a network, it is said that a good network depends on its broadness, interaction and nature of the relationship (Raven et al., 2010; Schot & Geels, 2008; Koolwijk et al., 2015). A network is broad when it has multiple kinds of actors (Raven et al., 2010; Schot & Geels, 2008). To be able to measure this in the case study, the number of new kinds of actors will be shown. The interaction within a network is good when it has regular interaction (Raven et al., 2010; Schot & Geels, 2008). Therefore, there will be a look at how often the actors involved were in contact with each other, what the actors did to maintain this interaction and how the interaction between different actors is experienced. The nature of the relationship will be based on the kind of contract between the actors.

The supply chain is managed well when there is trust, dedication to common goals, understanding & expectations of core values and equality between the actors involved. Trust is the willingness to be vulnerable with one another (Mayer et al., 1995). To be able to judge this, there will be a look at the opinions and experiences of the actors involved. Contracts between different actors might also show some extent of trust. The dedication of common goals depends on the time, cost and quality that is agreed on (Khalfan & McDermott, 2006). The experiences of the actors involved will show how the dedication to these common goals is experienced and complied. For the understanding & expectations of core values, there will be looked at the attitude of the actors involved. The equality of the actors involved will be evaluated by looking at the timing of the involvement of these actors within the project.

The management of the building process is done well when it is an open process (De Bruijn, van Heuvelhof & in T Veld, 2010). One aspect that is important here is that there is a protection for the individual core values (De Bruijn, van Heuvelhof & in T Veld, 2010). This will be judged by the opinion of the actors involved. Another aspect is the progress and momentum in a process (De Bruijn, van Heuvelhof & in T Veld, 2010). The timeline in each case will show how well this went. Next to this, the quality of the result is important for the process (De Bruijn, van Heuvelhof & in T Veld, 2010). This will be evaluated by looking at the measures that are taken by the actors involved to aim for the quality. Room for problems and solutions (De Bruijn, van Heuvelhof & in T Veld, 2010) will be judged by the experiences of the actors involved with barriers and how they are dealt with. Lastly, the process should be appealing to participate (De Bruijn, van Heuvelhof & in T Veld, 2010). For this, there will be a look at what measures were taken to involve other actors.

Facilitating the learning process depends on the aspects knowledge sharing, open network, trust, long-term relations and strengths from the actors who are involved. The amount of knowledge sharing depends on whether there were set arrangements (Slaughter 1993; Kangari and Miyatake 1997; Toole 1998; Veshosky 1998; Gann and Salter 2000; Goverse et al. 2001 in Bossink 2004). The focus of the learning process will be evaluated by looking at the course of the learning. The Environment will be judged by the available facilities, including resources and capacities, to learn. And the technique will be judged by how efficient the learning process was (Buckler, 1996).

This leads to table 6, seen on the next page, which will be used for the analysis of the case studies:

Table 6: overview aspects which will be tested in the case studies

Hypotheses	Indicators	How to measure
Managing the inter-firm network	Broad	Amount of (new kinds) of actors involved
	Interaction	How was interaction facilitated and experienced
	Nature of relationship	Type of contract
Managing the supply chain	Trust	Experiences actors involved Contracts between actors involved
	Dedication to common goals	Agreed time, cost and quality
	Understanding & expectations of core values	Experiences actors involved
	Equality and timing involvement	Evaluate when the different actors were included in the project
Managing building process	Protection of core values	Opinion of actors involved
	Progress & momentum	Evaluate the timeline
	Quality of results	Which measure were taken by actor involved to aim for quality
	Room for problems & solutions	Experiences of actors involved
	Appealing to participate	Which measures were taken to make it appealing to participate
Facilitating the learning processes	Knowledge sharing	Evaluate set arrangements for knowledge sharing
	Focus	What was the course for the learning effort
	Environment	Which facilities are there for the learning process
	Techniques	Was the learning process efficient

For every part of the framework shown in table 6, there will be stated whether there was a key actor for that part or not. And if so, there will be stated who this key actor was. Besides this, barriers that are faced during the project will be mentioned, together with lessons that can be learned from the individual cases. In the end, a cross-case analysis will be done where the similarities and differences between the cases will be described. From this cross-case analysis, conclusions will be made.

Although the conducted interviews where semi-structured and not following a strict list of questions, the framework, showed in table 6, was also the guidance for the interview questions. The interview questions were, therefore, focusing on the experiences of the actors involved with the management of the network, the supply chain, the process, the learning process, and the faced barriers and solutions for circular building methods. A full list of the guidance questions can be found in Appendix A.

Also for the coding in Atlas.ti this framework was guiding. When all the interviews were conducted, first a round of 'free-coding' was done. This means that all the interviews were scanned and segments that were possibly interesting for the research were highlighted and provided with one or a few keywords related to the content of that segment. When this was done for all the data, some of the codes were merged together to create uniformity. A quick analysis was done to observe re-occurring codes. In the end, different doc-families were used to discover what different actors said about a certain aspect. Sometimes the co-occurrence of codes was observed and some codes were useful for more than one aspect. An overview of the framework related to example questions and coding can be found in table 7 on the next page.

Table 7: Example questions and codes related to the theoretical framework

Hypotheses	indicators	Example interview question[2]	Example codes[3]
Managing the inter-firm network	Broad	Which actors are in your network?	Network
	Interaction	How often do you meet with different actors? How is this facilitated?	Timing Communication Collaboration
	Nature of relationship	What kind of contract did you have with this actor?	Collaboration Contract Relation
Managing the supply chain	Trust	How important is trust?	Trust
	Dedication to common goals	What actions are taken to achieve the goals?	Result
	Understanding & expectations of core values	How was the collaboration with this actor?	Collaboration Coordination Competition
	Timing involvement	When did other actors involve in the process?	Timing Long-term Short-term
Managing building process	Protection of core values	What actions are taken to protect the core values?	
	Progress & momentum	What did the process look like?	Timing Long-term Short-term Barrier
	Quality of results	What results did and did you not achieve in the end? Why was this?	Result
	Room for problems & solutions	How was the collaboration with this actor?	Problem Solution
	Appealing to participate	How did you decide to participate?	Collaboration Communication
Facilitating the learning processes	Knowledge sharing	How do you feel about knowledge sharing?	Knowledge sharing
Adoption of circular building methods	Barriers	What are the biggest barriers you experienced for circular building methods?	Barrier
	Possible solutions	How could this barrier be overcome?	Solution
	Future	How circular is the Netherlands in 20 years?	Future

For the fifth hypothesis, the different roles will be evaluated. The fifth hypothesis states:

- H5: The general contractor can be a good actor to take the role of an integral manager to have a positive influence on the adoption of circular building methods in building projects.

To be able to test this hypothesis, the same aspect of the first four hypotheses will be discussed per role. These aspects are managing the network, managing the supply chain, managing the building process and facilitating the learning process. The different roles are the general contractor, a sub-contractor, an advisor and a client. The cross-role analysis will be a comparison based on the roles and will show where the actors involved agree and disagree about the presence of an integral manager. Next to this, the barriers that are identified by each role will be evaluated. In the end, a cross-role analysis will be made. The conclusion following from this cross-role analysis will show which actor would be best to take the role of the integral manager, according to the interviewed actors.

[2] Question not necessarily asked and not list limited to these questions
[3] List not limited to these codes

Description of roles

In the Netherlands, traditionally, the collaboration between the different roles is hierarchal and consists of a clear distinction (Geraedts, 2009), shown in figure 11. Every role has its own responsibility for a specific part and there is not a lot of communication between the different actors. The client is often the actor who requests the project and the actor who pays for it. Therefore, the client has a lot of power. Within building projects, there is a broad range of areas where the clients can come from. This can be the municipality, a private investment or housing corporations. All these different kinds of clients have different incentives and therefore different strategies and involvement. The client stars with a collaboration with an architect. The architect will be responsible for the design of the project. When this design is finished, the general contractor will be involved. The general contractor is responsible for the completion of the project. To do so, the general contractor hires several sub-contractors. The sub-contractors are all responsible for a small part of the project. All of this is a divided and closed process. An elaborate description of the roles can be found in Appendix C.

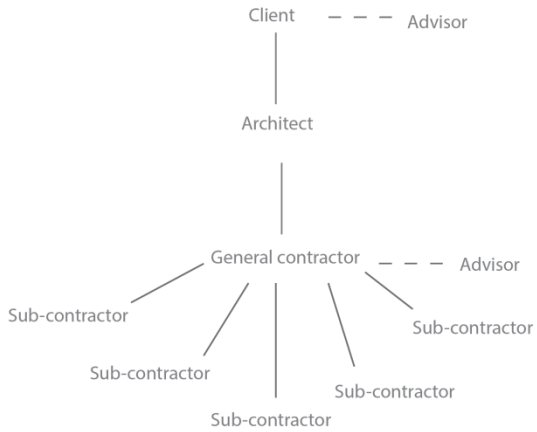


Figure 11: Traditional collaboration (Source: own illustration based on Geraerdts, 2009).

3.3 Research design barriers and possible solutions

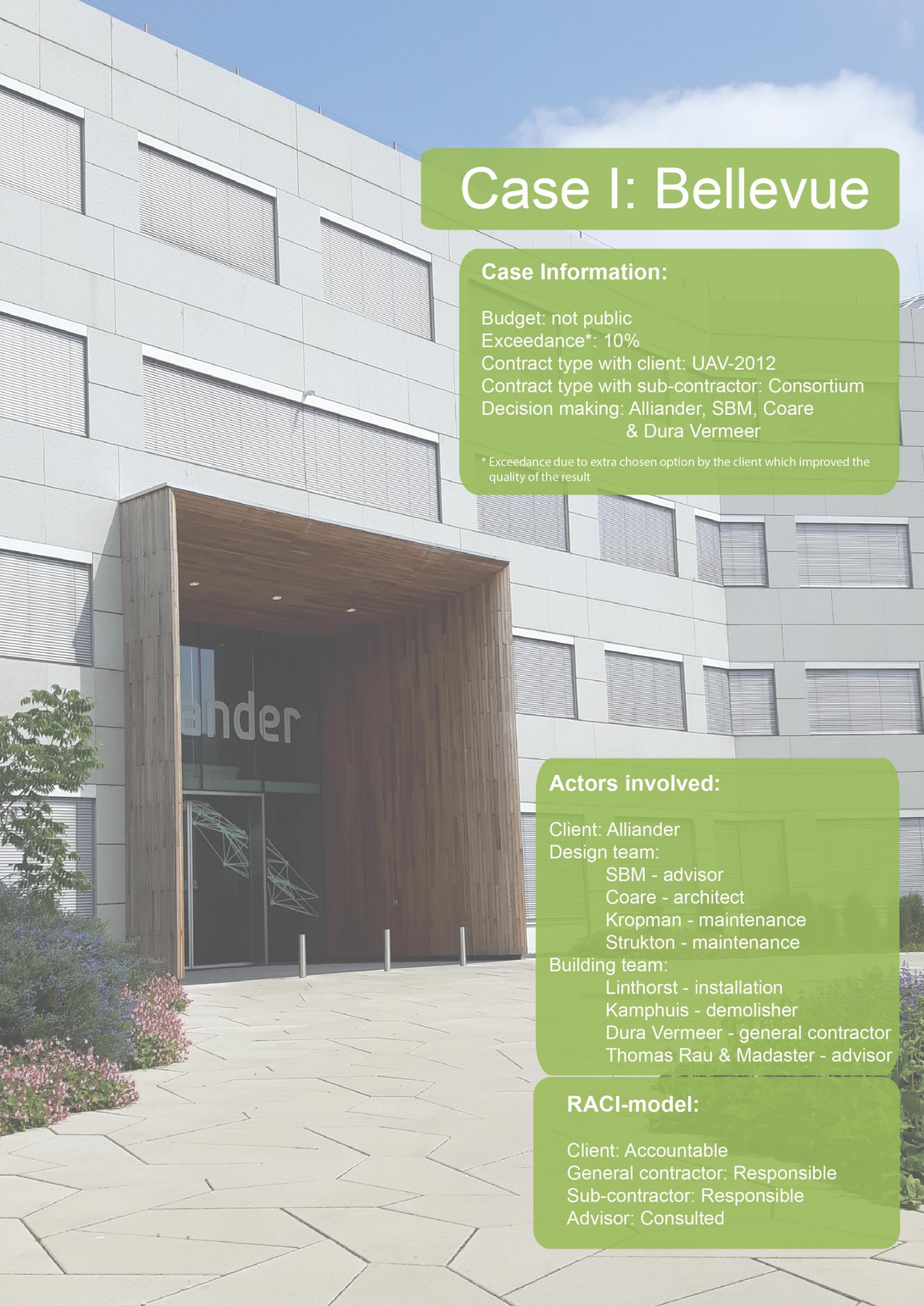
Next to the actors involved, a general group has been interviewed as well. This general group consists of a general contractor, a sub-contractor, one governmental client, one private client, and two directors from a general contractor firm.

All the interviewed actors have identified several barriers and possible solutions for the adoption of circular building methods. To be able to compare the identified barriers and possible solutions, first, all the barriers that are mentioned are identified per case and role. After that, a relation is made between barriers that are identified by more than one different role. The barriers that are mentioned by at least three different roles are described more detailed. After this, for each of these barriers, there has been a look at the interviews to seek possible solutions. Some of the barriers might actually be able to help each other to be resolved or might have the same solution. After this, there is a comparing with the literature. To do this there is a look at where in the transition approaches the barriers are mentioned and what the literature says about possible solutions. So this part will not be focused specifically on the case studies but on the identified barriers for the adoption of circular building methods overall. To verify these findings, a focus group with experts from the construction industry will be held. A detailed description of the research design of the focus group can be found in Appendix D.

4. Case study and role analysis

This chapter aims to answer the sub-question '*How did the different actors of circular building projects experience the adoption of circular building methods by the actors involved?* 'And will analyze the two case studies which are conducted for this research. The first part will contribute to evaluate the first four hypotheses which are stated in section 2.6. The analysis is guided by the theoretical framework and hypothesis showed in section 3.2. Table 6 will be used as guidance for the analysis. The completed tables which will give an overview of the aspect specifically for case I and case II can be found in table 8 and 10 respectively. After the cross-case analysis, conclusions will be made.

This is followed by the second part which is a cross-role analysis. The cross-role analysis describes the experiences of different roles on the aspects of the theoretical framework and hypothesis. Also, actors who were not involved in one of the two cases are included to expend the input. This will evaluate the fifth hypotheses. In the end, a conclusion will provide an answer to the sub-question.



Case I: Bellevue

Case Information:

Budget: not public
Exceedance*: 10%
Contract type with client: UAV-2012
Contract type with sub-contractor: Consortium
Decision making: Alliander, SBM, Coare & Dura Vermeer

* Exceedance due to extra chosen option by the client which improved the quality of the result

Actors involved:

Client: Alliander
Design team:
- SBM - advisor
- Coare - architect
- Kropman - maintenance
- Strukton - maintenance

Building team:
- Linthorst - installation
- Kamphuis - demolisher
- Dura Vermeer - general contractor
- Thomas Rau & Madaster - advisor

RACI-model:

Client: Accountable
General contractor: Responsible
Sub-contractor: Responsible
Advisor: Consulted

4.1 Case I: Bellevue

General information case

The 'Bellevue' building is the headquarter of regional energy grid operator Alliander at Arnhem. Alliander is responsible for the distribution of energy in the east of the Netherlands. In March 2017 they had 5.6 million clients (Alliander, 2017). For 'Bellevue', Alliander requested a sustainable renovation of the existing building. Alliander gave the project to an architect and two actors who already have a long-term contract to do the maintenance of this building. The design team made the first design. When the sketch design was finished, the client started the tender process for the building team. This was a rather traditional way of tendering; first, the sketch design was finished and only later in the process, the building actors were involved. For the sketch design, there were four central ambitions requested by the client. These were that the building should be energy circular, neutral, should have a stimulating work environment and should be sustainable locally. Alliander also set two criteria for circularity; 95% of all the materials that came from the existing building had to be used in a responsible way. And from all the materials that would be brought in new, 80% needed to be from a sustainable and responsible source. When this sketch design was finished, the client challenged the market to criticize this design and improve it where possible.

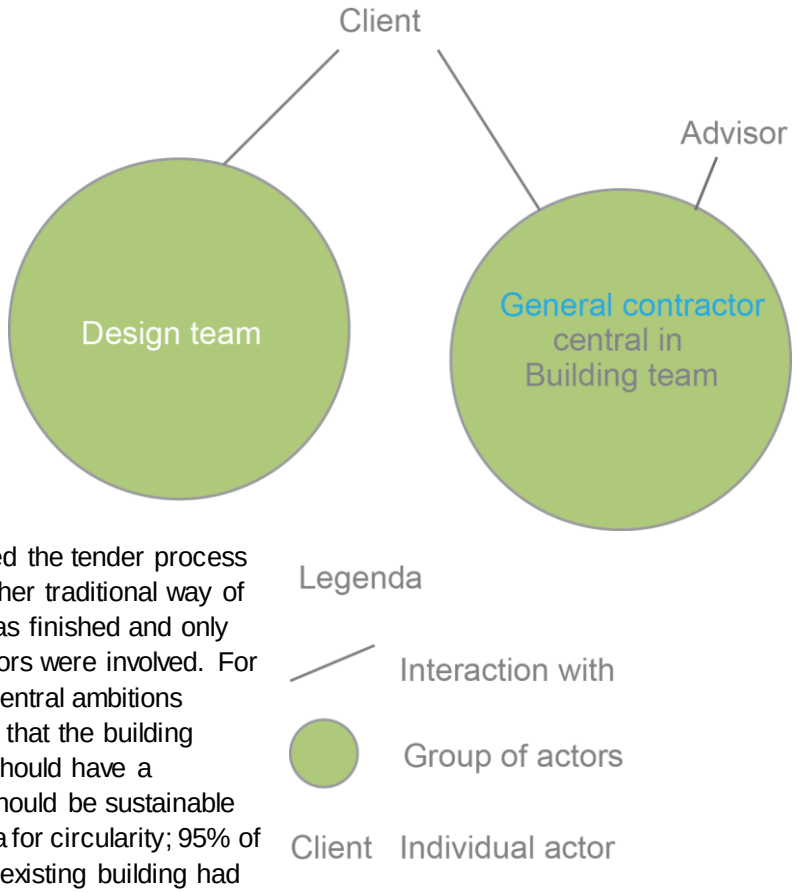


Figure 12: Place of general contractor within network for the project; central in building team (Own illustration).

First, there was a pre-selection. Dura Vermeer asked architect and circular building expert Thomas Rau from RAU architects to join the team and advise them on circularity. Thomas Rau was asked to join the team because he is an expert on designing in a circular way, but also because he just finished the project for Alliander in Duiven, so he knew the client. Dura Vermeer made it through the pre-selection and when the tender phase started, all the general contractors that made it through the pre-selection were invited for a presentation about the further expectations of the client. After this presentation, Dura Vermeer, Thomas Rau, and the demolisher visited the building to have a closer look at what materials were already in the building and what options there were to reuse in the building.

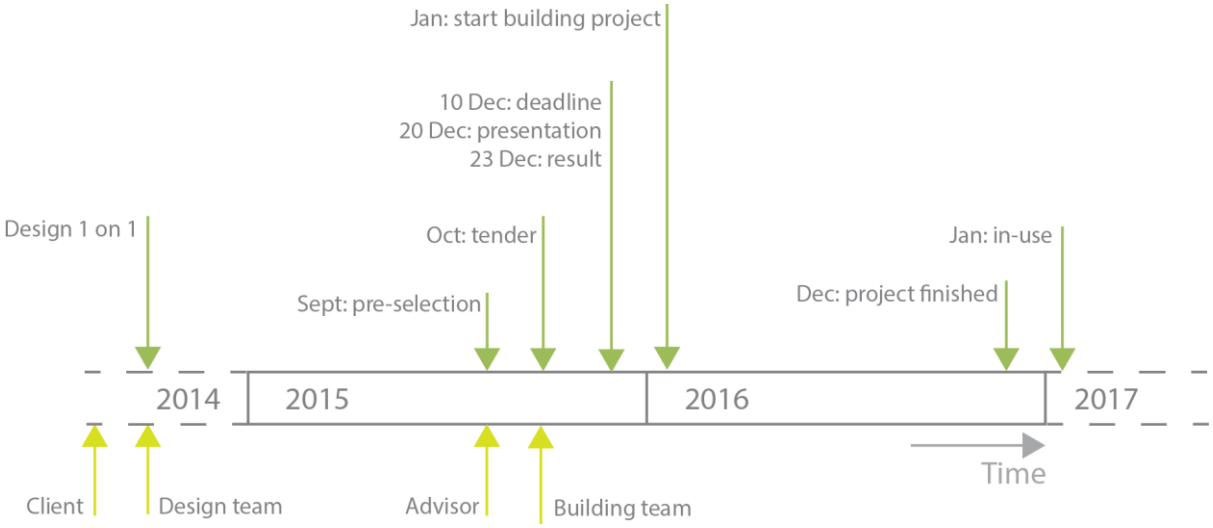


Figure 13: Timeline 'Bellevue' and timing involvement actors (Own illustration).

Contrary to the overall traditional process, the client asked specifically for a consortium of the building team. So, Dura Vermeer worked together with installation actor Linthorst, Dura Vermeer infrastructure, and demolisher Kamphuis. The collaboration between these actors already started before Dura Vermeer knew whether it would get this project or not. Dura Vermeer signed a letter of intent with all these actors. This letter of intent stated that all these actors were involved early in the process and that, if it would win the tender, Dura Vermeer would work together with them for the rest of the project and make legal contracts after the tender phase. This made that these actors were involved from the beginning of the tender part of the process. This way, all the actors in the consortium were equal to each other instead of the more traditional and hierarchy way of collaboration. Besides that, the general contractor did not have the chance to search for the sub-contractor with the lowest price after the tendering phase. For the client, the price was not the priority during the tender phase in this case. The client had as one of the criteria; 70% was quality, 30% price. The place of the general contractor within the network of the project is shown in figure 12.

The experiences of the actors involved will be analyzed in the next part according to the identified criteria shown in table 6 in section 3.2.

Specific for case I on the theoretical framework

Managing the inter-firm network

- There was no key actor who managed the overall network.

General
For this case, the network can be divided into two sub-networks, the network from the client and the network for the building team. This separation is made because the building team joined the project later in the process. The network of the general contractor was only needed for the building part of the project. This was because the design team was already arranged by the client and the building team was only asked into the process when this design was already roughly finished. The general contractor really needed its own network here as the client asked for a consortium for the building team. This meant that the general contractor could not tender alone but needed other actors to tender with them. The actors that ended up tendering together with the general contractor were firms from the network of the general contractor. The general contractor worked with these actors before. This shows that the actors have positive experiences and trust each other as otherwise, they would not want to collaborate again.

The interaction between actors within this network was good. An example of that is the fact that the general contractor and the building team walked through the building to see everything that was in the building already. Together they came up with ideas on how they could use everything. Another thing was that all actors involved just developed new and spontaneous ideas and felt free to communicate these ideas. There were regular meetings, but for the interaction in this case, it was more important that ideas occurred spontaneous, outside of meetings.

The openness of the network was judged to be very good by all interviewed actors. This was due to the attitude of the project manager. Overall, this was a tough and intense process for all the actors involved. However, the project manager was open and accessible to the other actors. And because of this, the other actors felt more equal and came up with creative, new and circular ideas themselves. The client also states that this positive attitude is one of the reasons why he picked Dura Vermeer to build 'Bellevue'; "We asked all the pre-selected building teams to do a presentation with the people who were actually going to build 'Bellevue'. During this presentation, Dura Vermeer really presented itself as a team. They were full of energy, enthusiasm and involved in the project altogether. This was definitely not the case for some of the other presentations".

Due to the UAV-2012[4] contract, the nature of the relationship between the general contractor and the client was rather traditional. However, both the general contractor and the client had a positive and informal experience for their relationship. The nature of the relationship between the general contractor and the sub-contractor was less traditional as they had a consortium which implied that the actors were more equal to each other.

Overall, the general contractor functioned as the central manager for all the actors involved in the building team. The biggest downside in this project network was the fact that the whole building team only joined the project team rather late in the process, when the design was already finished. Therefore, some boundaries were already set and decisions made. These decisions could not be discussed or changed anymore. There was some flexibility to adjust the design, but this was very limited. It is not possible to identify a positive or negative influence of the management of the network on circular building methods.

Influence of managed inter-firm network on the adoption of circular building methods
Overall the management of the network of the building team showed to have a positive influence on the adoption of circular building methods. This is because in the consortium the parties who were ambitious about circular building methods could join and share their ideas. However, the management of the overall network was more traditional. Even though it was tried to make this as flexible as possible, it still had boundaries for the adoption of circular building methods. It is hard to say if a key actor who managed the overall network would have a positive influence on the adoption of circular building methods.

Managing the supply chain

- The general contractor acted as a key person to manage the supply chain.

General
The client asked for a consortium of the building team. Therefore, the actors involved worked together as a supply chain. This was positively judged by these actors. The aspect that was judged most positively was the fact that the sub-contractor was already involved early in the process, where normally the sub-contractor is involved after the tendering phase. Therefore, the sub-contractor felt

[4] In Dutch: Uniforme administratieve voorwaarden voor de uitvoering van werken en van technische installatiewerken 2012 (UAV 2012). Free translation; uniform administrative conditions for the execution of works and technical installation works.

equal to the other actors. This is different from a regular form of collaboration between the general contractor and the sub-contractor as regularly the sub-contractor does not really participate in the conversation about how to implement the project. However, as this was new for most actors, they had to get used to this way of collaboration. Besides this, the interviewed actors state that there was a lot of trust between the actors involved. As one of the interviewees said; “Trust is very important. I have experienced that a lot of things just happened on intuition. And together we made some estimates that were used for decision making. You really need to trust each other to be able to do that”. Overall, the management of the supply chain was positively experienced.

Influence of managed supply chain on the adoption of circular building methods
The management of the supply chain had a positive influence on the adoption of circular building methods. This is mostly due to the fact that the sub-contractor was involved early in the process. This way they were able to create ideas and eliminate possible barriers for the use of circular building methods together.

Managing the building process

- There was no key person who managed the building process

General
The process for this project was basically very traditional. The client requested a design team for the design and when this was roughly finished they started the tendering phase for the building team. For this reason, the involvement of the building team was rather late in the process. This made that the building team had barely any influence on the design at all, which lead to their knowledge hardly being used. However, for the building team, the client specifically asked for a consortium. This made that all the actors were involved in this part of the process from the beginning. This also influenced that the actors were more equal to each other. This process also made that the client was in the end responsible for the circularity as he had to approve the decisions and end result.

The general contractor and sub-contractor worked with each other before, but it was always in a more traditional general contractor – sub-contractor relationship. One thing that was mentioned by several actors was the fact that this way of collaboration was new for most of them. Therefore it had to get used to it. For example, one of the problems that occurred during the project was that there was some discussion about the additional work. However, several interviewed actors state that this problem was solved due to the open communication and process between the actors.

After the delivery of the building, the general contractor and client mostly have positive experiences together. The client also encourages the general contractor to be open about the building process and show it to other actors. Overall the management of the building process was experienced positively by all interviewed actors.

Influence of managed building process on the adoption of circular building methods
Even though the actors involved all did experience a positive building process, the influence of this process on the adoption of circular building methods was not ideal. The process was rather traditional. Some boundaries were already set in the design phase. This caused that the circular building methods could not be developed to the fullest. Therefore, there was a negative influence on the adoption of circular building methods.

Facilitating the learning processes

- There was no key person who facilitated the learning process

General
All the interviewed actors for this case agreed about the positive amount of knowledge sharing. This was mainly due to fact that the client asked for a consortium in the tendering phase. Because of this, the different actors were all involved in this project from the beginning of the tender phase. Therefore, the actors already talked about some aspects even before there were any contracts. This took away some insecurity and risks and made that all actors – especially the sub-contractor – felt equal to each other. Due to this, the communication was very open, and every actor felt like having the ability to come up with good and new ideas. This is also what happened and brought nice spontaneous ideas. For example, the team working on site that came up with the idea to design the shack inside the building and with all materials that were obtained from the reconstruction. However, all of this learning just occurred spontaneously and there was no facilitation for the learning process.

The communication was experienced good by all actors. This was not only due to the consortium, but also to the people who were working on the project, their way of working and attitude made that they felt like they could be open in the communication. The client itself wanted to be an example regarding sustainable business. Therefore, the client believed that he should be very open and share what he experienced. The client stated; “We want to be an example. And we think that; to be an example, we need to be open about our experiences, we need to tell other actors if we want projects like this to be repeated. So we are also encouraging the actors from the building sector to share their knowledge”.

The trust aspect was increased because of the consortium that was established in the supply chain. This was because the communication between the actors was so good. However, there were some hiccups. This was mainly related to the additional work. As this form of collaboration was new for most actors, they had to get used to it. So, when additional work occurred, there were some struggles to see who and how to solve this. This did not necessarily mean that it was harmful to the trust. But it was definitely an aspect that needed some attention. This was partly because there is a lot of distrust in the construction sector, to begin with. Therefore, trust is not a given and actors struggle to let go of this easily.

Overall, the course of the learning, in this case, was on how to use circular building methods. However, there were no facilities to provide the learning. Most ideas happened spontaneously and are case specific. Therefore, the learning process was not efficient either. This concludes that the facilitation of the learning was not experienced positively.

Influence of the facilitation of the learning process on the adoption of circular building methods
All actors involved state that there were a lot of spontaneous ideas and organically learning about circular building methods during this project. However, this learning was not facilitated or structured. This makes that it is case specific and not easy to repeat or generalize. Therefore there was a negative influence on circular building methods.

Table 8: Overview influence on circular building methods on aspects of Case I

Hypotheses	Indicators	Influence on circular building methods	
Managing the inter-firm network	Broad		Actors focused on circularity joined
	Interaction		Easy to spark ideas
	Nature of relationship		Mixed: general contractor - client – traditional – tried to be as flexible as possible to get more circularity in design Positive: general contractor – sub-contractor – consortium – equal, easier to share ideas about circular building methods
Managing the supply chain	Trust		Easy to share ideas about circular building methods
	Dedication to common goals		Same goals for circular building methods due to the consortium
	Understanding & expectations of core values		Same core values for circular building methods due to consortium
	Equality and timing involvement		Sub-contractor early involved which eliminated possible barriers in early stage
Managing building process	Protection of core values		No specifics found
	Progress & momentum		Short timeline gave some set decisions and needed quick decisions about faced circular building methods barriers
	Quality of results		Set decisions design
	Room for problems & solutions		Quick decision making and additional work
	Appealing to participate		Sub-contractor could show circular building methods
Facilitating the learning processes	Knowledge sharing		Positive – spontaneous ideas Negative – no arrangements
	Focus		Circular building methods
	Environment		No facilities
	Techniques		Not efficient

Table 9: Relation presence key actor, overall experience, and influence of circular building methods case I

Case I	Presence key actor	Overall experience	Influence on CBM
Managing the inter-firm network			
Managing the supply chain			
Managing the building process			
Facilitating learning			

Positive	Negative	Undefined

CBM = Circular Building Methods

Lessons (to be) learned

Positive:
What the interviewed actors experienced as positive during their collaboration for this project was the fact that the client asked for a consortium of the building team. This way, all the actors felt equal to each other and had developed the circular content of their idea together. Especially the timing that the actors in the building team were involved was positively experienced for the same reasons. This consortium, together with the attitude of the involved people, made that there was very open and intense communication. All of this together has led to ideas that spontaneously were developed by, sometimes unexpected and unusual, actors.

Negative:
There were also some negative experiences during this process. One of them was the timing, as the building team was only involved in the project when the design was almost finished. This made that some boundaries were already set and some decisions made, this reduced the possible input from the building team. Next to this, the consortium for the building team was a new way of collaboration for them. There were some struggles with how to deal with this new way of collaboration, especially when additional work occurred. All actors needed to get used to this way of collaboration. However, this is even more for the sub-contractor as its role was changing the most.

Case II: Fijn Wonen

Case information:

Budget: not public
Exceedance: -
Contract type with client: Turn-key
Contract type with sub-contractor: Performance*
Decision-making: Van Wijnen

* In Dutch: prestatiecontract

Actors involved:

Client: Elkien
General contractor: Van Wijnen
Sub-contractor: De Groot Vroomshoop
Advisor: Alba concepts

RACI-model

Client: Informed
General contractor: Responsible & accountable
Sub-contractor: Responsible
Advisor: Consulted

4.2 Case II: Fijn Wonen

General information case

'Fijn Wonen' is a project which is initiated by general contractor Van Wijnen. This project, in general, has the aim to develop standardized houses which will contribute to a cheaper and more efficient building process. The specific case, which will be used for this research, is the variant which claims to be 70% circular. What is important in this project is that it is an initiative from the general contractor and not a request from a client. Another specific for this case is the fact that Van Wijnen has a product development department.

The general contractor started this project as it believes that the traditional building methods are not sustainable for the future. Therefore, it started looking at new business models. The general contractor believes that if it wants to be different from others, it should find another way to be selected for projects than just the lowest price. And to achieve the circular houses, the general contractor seeks for a collaboration combination of doing some parts itself and doing it in collaboration with actors from the supply chain. So, the general contractor made a pre-selection from supply chain actors that might or might not be interested in collaborating. For some partners in the network, the general contractor decided from the beginning that collaboration for circular building method was not a good idea. To the other partners in the network, it asked who was interested to join. Most of the actors that are working on the circular houses, were already involved in the regular 'Fijn Wonen' project as well.

The network for this project is divided into three sides with the general contractor as a central point of contact. The first side consists of the advisory companies. This can be advisors for circularity, but also more traditional ones like an architect, physical and construction advisor. Special here was that the general contractor included an industrial design firm to advise them on the industrial aspects. On the other side, there is the client, which not necessarily asked for circular houses.

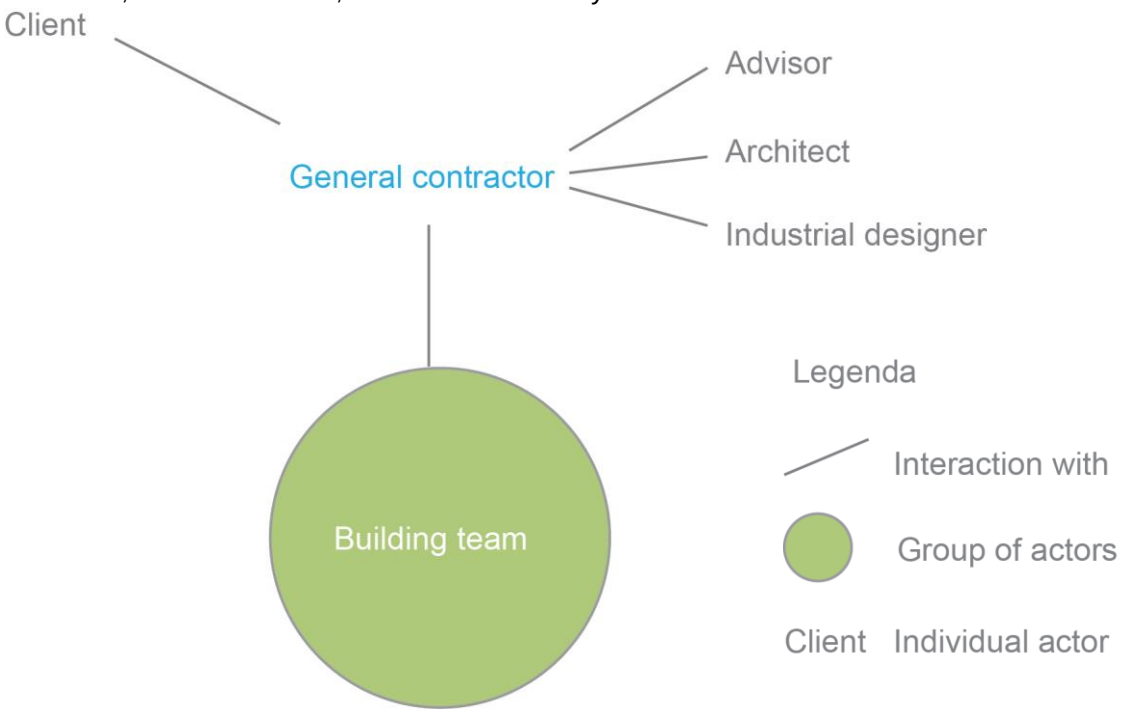


Figure 14: Place of general contractor within network for the project; central in overall network (Own illustration).

However, the general contractor started this project by talking to the client about the business model that the general contractor developed. And the third side is the supply chain, with all the actors that physically built the house. In this case, the general contractor decided to do the hull, kitchen and bathroom, itself. They have the same contracts as with the regular 'Fijn Wonen' project. Between the general contractor and the sub-contractor, this was a performance contract where they made long-term agreements. This collaboration gives obligations both ways. Besides this, the general contractor asked all actors involved to sign a confidentiality statement. An overview of the timing of the actors involved and the place of the general contractor within the network of the project can be seen in figure 14 and 15.

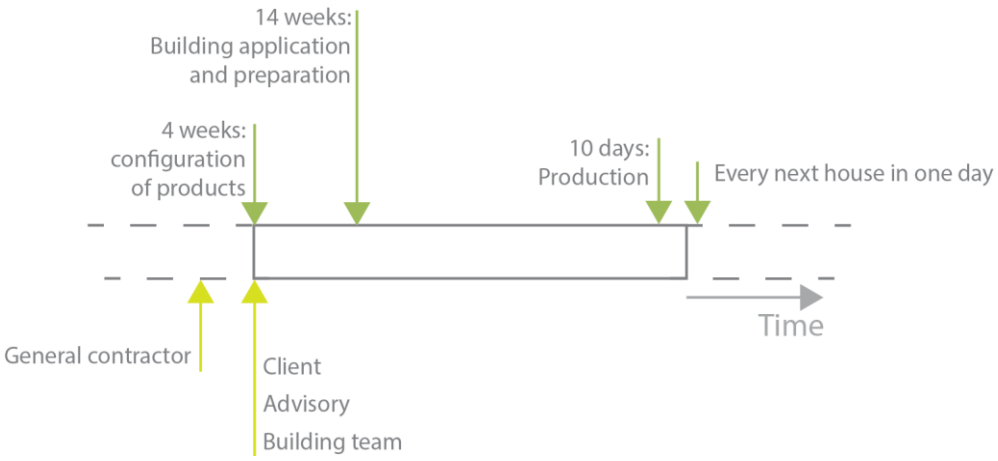


Figure 15: Timeline 'Fijn Wonen' and timing involvement actors (Own illustration).

Specific for case II on the theoretical framework

Managing the inter-firm network

- The general contractor was the key person who managed the network.

General
As the general contractor initiated this project, it really needed its network to find the right partners to collaborate with. The general contractor already did a preselection itself about who it thought would be suitable for this project. This makes that the general contractor closed off its network without knowing whether some sub-contractors really did not want to or could not join this project. When the general contractor established the project team for this project, it had different collaborations with different sides of the network. It started with conversations with the client; this was to see whether the business model it developed was interesting for the client. For the advisory for this project, the general contractor started a new collaboration with a circular advisory company and an industrial design firm. As a collaboration between a general contractor and an industrial design firm is not very common, this shows that the network was open to new actors as well. However, with the advisors and industrial design firm, the general contractor had very traditional contracts and collaboration.

Together with the partners from its network, the general contractor started conversations about the collaboration. For the supply chain, they ended up having supply chain collaboration. But the different sides of the whole project team did barely have contact with each other. Overall the nature of the

relationship between the actors depended on the actors. The general contractor and sub-contractor both state that they had an informal relationship. The performance contract also implies an equal relationship. However, the nature of the relationship between the general contractor and advisor was contractual and more formal. Overall, the management of the network was positively experienced.

Influence of managed network on the adoption of circular building methods
The management of the network had a positive influence on the adoption of circular building methods as from the beginning of the process the general contractor extended the network with actors that had extra knowledge or skills about circular building methods.

Managing the supply chain

- The general contractor was the key person who managed the supply chain.

General
Contrary to the traditional construction industry, where actors are seen as closed, the actors in the 'Fijn Wonen' case did not experience this closeness. The interviewed actors state that they had very open and good communication. This is due to the people who were involved in the project rather than a specific firm. The fact that they were doing business with each other for a longer time already, was very helpful for this. This makes that they felt free to talk with each other, also when they did not agree with each other. One of the interviewed actors states: "We already did some collaborations with them, as did some competitors of us. However, I have a very good relationship with the people who are involved in the 'Fijn Wonen' project. We trust each other, and that is why they asked us and why we decided to join this project". The general contractor and sub-contractor have built a relationship of trust. When there is trust between the actors, they have better communication. This is partly a feeling, but it helps when the contracts show trust. For example, the contract between the general contractor and a sub-contractor had a shorter payment term. Normally, the general contractor sends a receipt to the subcontractor after, for example, 20 days. When the sub-contractor has received the receipt, it is allowed to send an invoice to the general contractor with a payment term of 60. In total, this makes 80 days. Sometimes it is hard for a sub-contractor to disburse this much money. While in this contract, there is no receipt anymore and a payment term of 45 days. This shows that the general contractor trusts the fact that the sub-contractor will deliver according to plan. And, as the sub-contractor receives the money earlier, this gives the sub-contractor more freedom.

The general contractor and sub-contractor had a performance contract which made that they stimulated the dedication to the common goals. As the general contractor mentions: "I think it is part of a performance contract to start the dialogue with the other actors. Because I do not mind changing my plans, but they will have to convince me first based on content". Overall the management of the supply chain was positively experienced by the interviewed actors.

Influence of managed supply chain on the adoption of circular building methods
The management of the supply chain had a positive influence on the adoption of circular building methods as it stimulated the whole supply chain to adopt circular building methods. Due to the different contract and open communication, the sub-contractor was able to have conversations with the general contractor about the best way to do so.

Managing the building process

- The general contractor was the key person who managed the building process.

General
What was important for the timing during this process is that the general contractor started talking with the client. Even though the client did not ask for this project, this way the general contractor wanted to make sure that it had a good business model.

Due to the long-term collaboration and open communication, the actors felt free to discuss any problems. They knew how to find each other when something was wrong.

For the protection of the core values and quality of results, the general contractor made quite some decisions itself within its own product development department. As the general contractor took the lead in this process, he was also the actor who was responsible for the circularity of the end result. The general contractor experienced that it is most efficient to work with smaller teams. As the interviewed general contractor stated; "Within our product development department, we try to make teams as small as possible. And then find a binding factor to keep it integral. But this is very complex." However, the general contractor did nothing to make it appealing for sub-contractors to participate. The general contractor feels like actors should only join the project if they really want to. The management of the building process was positively experienced.

Influence of managed building process on the adoption of circular building methods
As this process involved most actors at an early stage, all the actors were able to add their knowledge about circular building methods at an early stage. This caused that the management of the building process had a positive influence on the adoption of circular building methods.

Facilitating the learning processes

- There was no key person who facilitated the learning process

General
In this project, the general contractor was the key actor who came up with some new and innovative ideas. However, the general contractor did most of these itself in its product development department. It was very closed about its ideas and made sure all other actors signed a confidentiality statement. "In the industry, we know 'copyright', but in the construction industry, we say 'right to copy'" as the general contractor stated to underpin the importance of confidentiality statements. Even though the sub-contractor does not necessarily agree with the importance of the confidentiality statement, he does understand it; "When you are ahead of your competitors, you have a financial benefit. When you share your knowledge, you will lose your head start and with that your financial benefit".

None of the actors acknowledged that there was knowledge sharing or learning during this process. However, the general contractor was very willing to provide learning for other actors; "We always start with finding out if other actors want it. Because if they are not able to do it; we are willing to teach them. But if they do not really want to, we cannot help them".

The attitude from the general contractor was determinative in this case. It came up with the idea which was supposed to be adopted by the other actors. However, it was open to having a dialogue with other actors. If these actors were able to convince the general contractor, the general contractor would change his plans. The general contractor had to be convinced based on content, not by the ones who were making the most noise. Overall, the general contractor really appreciated it when

other actors would brainstorm with them and come up with new ideas. A downside was that the different sides of the network did not have much communication with each other. The general contractor acted as a key actor but did not facilitate, for example, the architect and sub-contractor to talk with each other.

Even though this process was open, all the actors had to sign strict confidentiality statements. This can be a barrier for learning between the projects as the knowledge that is gained during this project cannot, or only partly, be used in other projects. Some actors had more difficulties with this confidentiality statement than others. Which is due to whether they are used to it or not. However, within the supply chain, the trust was increased due to the fact that they had some aspects of their contract that showed trust. For example, the payment term that was shorter. This was possible because the actors knew each other and have positive experiences in the past.

This entire project was developed to learn about circular building methods. The general contractor was willing to facilitate the learning process and created opportunities to teach and learn about circular building methods. However, due to the strict confidentiality statement, there is no positive experience about the facilitation of the learning process.

Influence of facilitated learning process on the adoption of circular building methods
The aim of this project was to learn how to adopt circular building methods. The general contractor also stated that it was willing to teach the sub-contractors who needed it and wanted it about circular building methods. However, due to the confidentiality statement that had to be signed, the gained knowledge is hard to share and contextualize. Therefore, it is not possible to judge the facilitation of the learning process either positive or negative.

Table 10: Overview influence on circular building methods on aspects of Case II

Hypotheses	Indicators	Influence on circular building methods	
Managing the inter-firm network	Broad		Including new actors specifically for circular building methods
	Interaction		Started conversation with the client to see if business model for circular building methods was possible
	Nature of relationship		Some traditional some more equal, not defined what influence was on circular building methods
Managing the supply chain	Trust		Different contract which gives more freedom
	Dedication to common goals		General contractor decided about circular building methods
	Understanding & expectations of core values		Willingness to think in chain collaboration
	Equality and timing involvement		Early conversation
Managing building process	Protection of core values		Small teams to prevent doing concessions on circular building methods
	Progress & momentum		No specifics found
	Quality of results		Own product development department for circular building methods
	Room for problems & solutions		Long-term collaboration made it easy to discuss any circular building methods related problems
	Appealing to participate		Other actors really had to want to join
Facilitating the learning processes	Knowledge sharing		Confidentiality statement
	Focus		Circular building methods
	Environment		General contractor willing to teach sub-contractor
	Techniques		Creates to learn

Positive | Negative | Undefined

Table 11: Relation presence key actor, overall experience, and influence of circular building methods case II

Case II	Presence key actor	Overall experience	Influence on CBM
Managing the inter-firm network			
Managing the supply chain			
Managing the building process			
Facilitating learning			

Positive	Negative	Undefined

CBM = Circular Building Methods

Lessons (to be) learned

Positive:
One thing which was experienced positively by the interviewed actors is mostly the long-term collaboration between the actors. The long-term collaboration had a positive influence on the open communication and trust between the actors involved. However, this was also due to the attitude and relation between some of the people who were involved rather than the firm. Another positive experience was the fact that the general contractor initiated this circular project. They also introduced a new external actor within the network of the general contractor.

Negative:
The confidentiality statements that had to be signed by the actors involved were experienced negative mostly. Even though the actors involved did understand why this was asked of them, the confidentiality statement is a barrier when other projects would like to learn from this circular project. Next to this, there was not a lot of integrality between de different actors. This made that these actors did not take each other into account or learn from each other directly.

4.3 Cross-case analysis

This part will compare the two case studies. It will evaluate the differences and similarities between the two cases. This will evaluate each of the first four hypotheses which are stated in section 2.6.

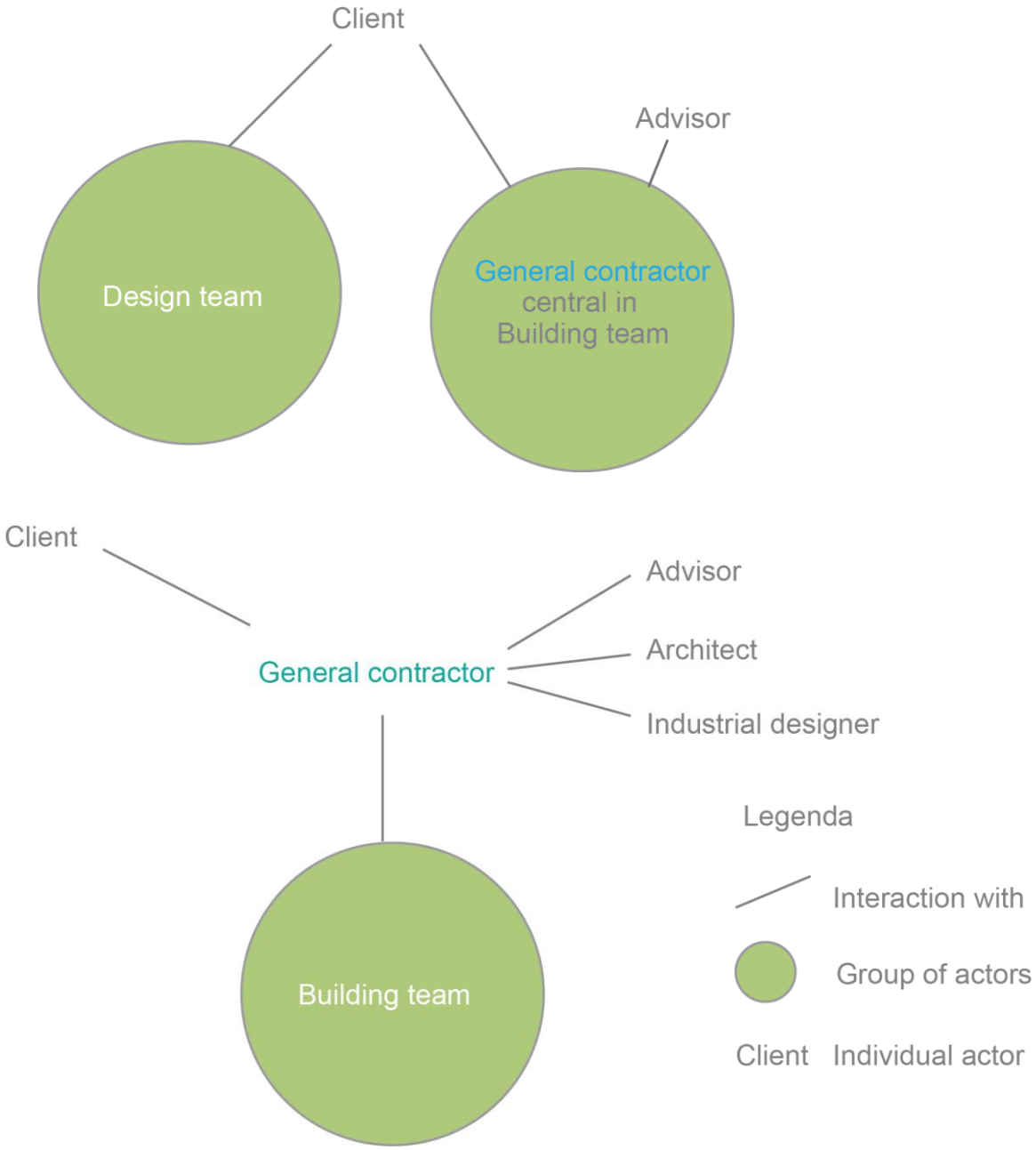


Figure 16: Differences in collaboration between Case I and Case I (Own illustration).

Managing the inter-firm network

To start with; case I did not have a key actor who managed the network, where in case II the general contractor was the key actor who managed the network. This difference was due to the fact that case I was initiated by the client, where case II was initiated by the general contractor. In both cases, there were some positive and negative aspects. Due to the traditional collaboration in case I, especially the timing was judged negatively. The general contractor and the building team joined the project later in the process. And because of this, some boundaries were already set. This limited the flexibility and openness of the project. This also had a limited effect on the adoption of circular building methods. In case II the management of the network was judged more positively. The general contractor was central here and it initiated this project with circular building methods. On one hand, the general contractor was very open to new actors, also from outside the construction industry, whenever these actors could have a positive influence on the adoption of circular building methods. On the other hand, it took the lead in the negotiations and excluded some actors without even asking them. Also, the different sides did not have contact with each other. But the central position of the general contractor was positively judged as the general contractor could secure the use of circular building methods.

The difference with circular building methods and any other innovation in the building sector is that for many other innovations, it is enough the only manage a part of the network. Often these innovations are regarded to a small part of the building and with that only need a small part of the network. Circularity, however, is more complex and integral and not related to only a small part. It, therefore, needs the whole network and even actors from outside the construction industry. A broader network which is managed will, therefore, have a positive influence on the adoption of circular building methods in the building sector. When a network is managed well and includes a diverse range of actors, more actors may be involved in a project with circular building methods. This could possibly elaborate the input for circular building methods.

Managing the supply chain

In both cases, the supply chain had the general contractor as a key actor who managed the supply chain. In both cases, the management of the supply chain is discussed as good. Factors that were judged positively are due to the fact that every actor joined the project from the beginning, which made that they could discuss and agree on things at an early stage. Especially while working with circular building methods, this was judged positively. This was because the actors could discuss their knowledge and possible barriers at an early stage. This made the adoption of circular building methods easier. This timing also led to more equality between the different actors, which made that all the actors felt like other actors would listen to them and their knowledge about circular building methods was appreciated. However, as this way of collaboration was new for the actors, they had to get used to it.

Managing the building process

The process was quite different in both cases. Case I had a more traditional process where there was no key actor to manage the building process. The client first made a design and the building team was included later. Because of this, some boundaries were already set, which was constricting for the adoption of circular building methods. The consortium for the supply chain was experienced positively as together they could come up with new ideas on how to use circular building methods. However, as this consortium was new to the actors, they had some conflicts about the additional work that occurred during the project. They handled this well due to the open communication. In case II the process was led by the general contractor, who can be seen as the integral manager. This gave very different interaction than in case I. In case II, the general contractor made quite some decisions about the use of circular building methods himself. Overall the communication was experienced as very open and all actors involved were willing to listen to each other. However, during this process, the different sides of the network did not communicate with each other.

This is different from any other innovation as the actors together can develop core values about circular building methods instead of core values individually. This results in a more coherent attitude and quality of results. As circularity need integrality, it is even more important to develop these core values with all actors together in an early stage.

Facilitating the learning processes
In both cases, there was no active learning process and no key actor to facilitate the learning process. This does not mean that there was no learning about circular building methods at all. In case I the attitude and communication were indicated as a positive aspect of the learning and developing new ideas about circular building methods. Also, in case II the open communication was positive. However, as the general contractor made all the actors involved sign a confidentiality statement, it limited the knowledge sharing and learning for the use of circular building methods.

Lessons learned
In both cases, there are positive and negative lessons to be learned. These can be seen in table 12. the lessons to be learned are different for both cases. However, all of them correspond with the literature as the positive lessons are all also mentioned as stimulating factors and the negative lessons are mentioned as limiting factors.

Table 12: Lessons learned

Positive/negative	Case	Lessons	GC	SC	Adv	Cli
Positive	Case I	Consortium building team				
		Timing involvement				
		Attitude actors involved				
	Case II	Long-term collaboration				
		Initiative general contractor				
Negative	Case I	Timing involvement				
		Getting used to new form of collaboration				
	Case II	Confidentiality statement				
		Integrality				

GC = general contractor SC = Sub-contractor Adv = advisor Cli = Client

When looking at both RACI-models for the responsibility of circular building methods in table 13 it can be seen that the role of the general contractor and the role of the client were different in both cases. Compared to a regular project, case I is the most similar one. However, due to the building team, the sub-contractor was also responsible here. Case II has very different roles for the general contractor and client. The general contractor was not only responsible but also accountable, where the client was only informed. This difference has a positive influence on the adoption of circular building methods as the accountability and responsibility are at the same actor.

Table 13: RACI model for the responsibility of circular building methods for both cases

Roles / Task	General contractor	Sub-contractor	Advisor	Client
Regular	R	I	C	A
CBM case I	R	R	C	A
CBM case II	RA	R	C	I

R = Responsible A= Accountable C = Consulted I = Informed CBM = Circular Building Methods

Conclusion cases

This part aims to evaluate the first four hypotheses which are stated in section 2.6. The two case studies are compared to the theoretical framework and will be concluded here.

As seen in table 14, both cases were different in terms of the presence of a key actor. There is shown how the different aspects of the theoretical framework are experienced by the interviewed actors who were involved in the project. It can be noticed that the presence of a key actor aligns with a positive experience for that aspect. This part will explain the connection between the presence and absence of a key actor and a positive or negative experience.

Table 14: Relation presence key actor, overall experience, and influence of circular building methods case I and case II

Case I	Presence key actor	Overall experience	Influence on CBM
Managing the inter-firm network			
Managing the supply chain			
Managing the building process			
Facilitating learning			

Case II	Presence key actor	Overall experience	Influence on CBM
Managing the inter-firm network			
Managing the supply chain			
Managing the building process			
Facilitating learning			

Positive | Negative | Undefined

CBM = Circular Building Methods

The *managing of the inter-firm network* in Case I is hard to judge as the collaboration was traditional. So the general contractor only needed and used its network to form the consortium. The management of the network from the general contractor was judged well. However, as the network of the general contractor was only for a small part of the whole process, it is hard to give a conclusion on whether this had a positive influence on the adoption of circular building methods. In case II the management of the network was led by the general contractor who acted as a key actor. Even though there are some downsides and lessons to be learned about this way of collaboration, overall it was judged positively due to the nature of the relationships.

In both cases, the general contractor acted as a key actor for the *management of the supply chain*. The supply chain is often still managed very traditional. But in these two cases, there was both more equality and open communication between the actors involved. It was especially the trust between the actors involved that increased due to this supply chain management. Because of this trust, there was more openness to explore the options for circular building methods together. This was judged positively in both cases.

The *managing of the building process* in case I was done without a key actor who managed the building process. Even though the overall process went well, for the adoption of circular building methods the process was judged negatively overall as it was very traditional. This made that some boundaries were already set and decisions were made before the building team joined the process. The late involvement of the building team limited their influence on the circularity in this project. In case II the building process was led by the general contractor. There were some downsides to the

process, but overall it was judged positively by the interviewed actors. Again because they were able to explore the different option for circular building method together and every actor had the ability to speak up and give input.

The *learning process* was in both cases not facilitated. The learning that did occur was due to the open communication between the actors involved. This learning happened more organically. This resulted in new ideas on how to adopt circular building methods. For case II the aim of the project was to learn about circular building methods. But due to the confidentiality statement, it is hard to judge what the influence of the learning process was on the adoption of circular building methods. However, in both cases, the interviewed actors acknowledge that there was limited learning. When the learning is facilitated it might be more structured and with that generate more knowledge about the use of circular building methods which is shareable. An integral manager might be able to facilitate this.

Overall, there is shown in this part that almost every time, the presence of an integral manager corresponds to a positive influence on the adoption of circular building methods. And the absence of an integral manager corresponds to a negative influence on the adoption of circular building methods. This does not always correspondent with the overall experience. This shows that, even though the actors involved had a very positive experience during the process, this is not necessarily enough to have a positive influence on the adoption of circular building methods.

4.4 Cross-role analysis

This part aims to evaluate the fifth hypothesis *'The general contractor can be a good actor to take the role of an integral manager to have a positive influence on the adoption of circular building methods in building projects.'* It will do so by describing how different roles experience the aspects of the theoretical framework, showed in table 6 in section 3.2, and which actor they see as a possible integral manager. First, a short description of every role will be given. This will be followed by the experiences of the different roles on the different aspects. This will verify the first four hypothesis or not. In the conclusion, it will show which actor could best take the role of the integral manager according to the different roles. The case studies have shown that the presence of a key actor has a positive influence on the adoption of circular building methods. When comparing the different roles, this part will have a look at the opinion of the different actors on the adoption of circular building methods. This will lead to a conclusion on which actor could take the role of an integral manager. Next to the actors involved in the two cases, other actors from outside these cases but with similar roles are interviewed. This will extend the input for the cross-role analysis.

Even though all the actors acknowledge the importance of a broad *network*, it are mostly the general contractor and advisors that show to have a broad network as they include all different kinds of actors within a project. These new actors might be unexpected and unusual actors. For the adoption of circular building methods, the inclusion of new, unexpected or unusual actors is important as they might bring in new and missing knowledge about circularity. An outstanding observation is the fact that all actors state that the nature of the relationship between different actors is most of the time still traditional. This means that the actors are not equal to each other. However, every actor sees the importance and is open for new forms of collaboration. As the general contractor and advisors have the broadest network, one of them would be best to manage the network for a project.

The *management of the supply* chain is currently already experienced positively as this improves open communication and trust. Due to this open communication and trust, it is easier to deal with barriers that occur when working with circular building methods and to find solutions together. Currently, the general contractor is the actor that is leading the management of the process. As this is

positively judged by the actors involved, there is no need to change this. So the general contractor would be a good option to take the role of an integral manager within the supply chain.

It is important for the *building process* that all the actors involved have the same incentives and core values. Especially when working with circular building methods. As circular building methods are integral methods, there is a shift needed from personal incentives and core values to integral incentives and core values. All the actors acknowledge the importance of a well-managed process; however, they are still figuring out how to do this. An integral process should have a positive influence on the process, especially when it involves circular building methods. This way, all the actors will have the same incentives and core values. It will stimulate the actors to work together better and create more room for problems and solutions. This is because, with an integral process, the goal of the project will be reached easier. It is also stated that it is important that such an integral process is led by an integral manager. As all actors are struggling with how to accomplish an integral process, there is not one actor that is clearly applicable to the role of an integral manager. However, the actors that did mention a possible actor who could take the role of integral manager, they proposed the general contractor to take this integral role. So judged by the opinion of the interviewed actors, the general contractor could take the role of the general contractor.

Every interviewed actor agrees on the fact that there is currently not enough knowledge sharing within the construction industry. The *learning* between projects is barely facilitated. Therefore, a lot of gained knowledge about working with circular building methods is not shared. A huge barrier for the knowledge sharing is the matter of trust, which is not a given in the construction industry. Through experiences, it are mostly the general contractors who struggle to trust other actors and who are the least open of all actors. This is experienced by the other actors as well as acknowledged by the general contractors themselves. All actors agree on the fact that long-term collaborations will stimulate the knowledge sharing, which will increase the learning about circular building methods. When this learning process will be facilitated, there will be more structured learning which will contribute to the contextualization of the gained knowledge. Overall, most of the interviewees agree that the best way to learn is to “Just do it”.

Table 15: Possible actors who could take the role of integral manager

	General contractor	Sub-contractor	Advisor	Client	Unclear
Managing the inter-firm network					
Managing the supply chain					
Managing the building process					
Facilitating the learning process					

4.5 Conclusion

This conclusion aims to answer the sub-question '*How did the different actors of circular building projects experience the adoption of circular building methods by the actors involved?'* By combining the conclusion from the case studies and the conclusion from the roles, some patterns will be shown, and a tentative conclusion can be made. This will later be verified by a focus group with experts from the building sector.

Overall there is shown to be a positive relationship between the presence of a key actor and a positive influence on the adoption of circular building methods in building projects.

For the *management of the inter-firm network*, this is actually not that clear. In case II, the presence of a key actor who manages the network was judged positively and had a positive influence on the adoption of circular building methods. This is because the general contractor was in charge of the amount of circularity in this project. In case I, there was no key actor who managed the overall network. However, the general contractor acted as an integral manager for the building team. The management of the building team was experienced very positive. It is hard to say for case I what a possible effect on circular building methods, a possible overall integral manager would have. According to the cross-role analysis, the general contractor or the advisor would be a good option to be this integral manager. This is different from other innovations because circular building methods are affecting every part of a project and therefore need the whole network instead of only a small part. Even actors from outside the construction industry might be a good addition to the network.

For the *management of the supply chain*, a very clear relation between the presence of a key actor in combination with a positive experience and influence on the adoption of circular building methods is shown in both cases. Therefore, this implies that an integral manager for the supply chain would have a positive influence on the adoption of circular building methods for building projects. In both cases, the general contractor took the role of the integral manager. All the actors involved state that the general contractor should keep the role of an integral manager for the supply chain.

As seen in the cross-case analysis, did case I not have a key actor who *managed the building process*, case II did have the general contractor as a key actor. The process in case II was judged more positive than the process in case I. Due to the difference in the process, in case II there was more positive influence on circular building methods than in case I. Therefore, this implies that an integral manager for the management of the building process will have a positive influence on the adoption of circular building methods in building projects. According to the cross-role analysis, most interviewed actors state that the general contractor is in the right position to take the role of integral manager for the process.

In both cases, there was no key actor who *facilitated the learning process*. The learning about circular building methods that did occur happened organically. The absence of a key actor is related to a bad experience of the facilitation of the learning process. The presence of a key actor, who facilitates the learning process, might be able to structure the learning about the usage of circular building methods. All the learning about circular building methods that happened organically now, would be managed and therefore be contextualized and shareable. Therefore, the presence of a key actor who facilitates the learning process might have a positive influence on the adoption of circular building methods in building projects. However, as seen in the cross-role analysis, it is not clear yet which actor would be best suitable to take this role of integral manager.

As shown in table 15 on the previous page, the general contractor is the actor that is mentioned most by the interviewed actors to potentially take the role of an integral manager to have a positive influence on the adoption of circular building methods in building projects. The management of the supply chain by the general contractor is already experienced positively. And only for the facilitation of

the learning process, the general contractor is not mentioned. However, there is also no argument to not let the facilitation of the learning process be managed by the general contractor. Therefore, when start looking for the right actor to take the role of an integral manager; it makes sense to start with testing to see if the general contractor can take this role.

In conclusion, the case studies show a positive relationship between the presence of an integral manager and the adoption of circular building methods. Taken this into account, the cross-role analysis shows that the general contractor is most likely the best actor to take this role of integral manager. This conclusion will be verified by the focus group with an expert panel, which is described in section 5.4.

5. Results

This chapter aims to answer the third and fourth sub-question. The first part will focus on the third sub-question; '*What can be learned from (mis-)matches between theoretical considerations and experiences?'* This will identify barriers according to the interviewed actors. It will also show where these barriers are in the literature and what possible solutions are for these barriers. The second part will focus on the fourth sub-question: '*Which factors from these lessons can be applied by the general contractor for the circular building methods in the Dutch building sector?'* This part will provide findings from the focus group with experts of the construction industry and a conclusion.

5.1 Barriers and possible solutions identified in the case studies

Barriers for circular building methods case I

The interviewed actors who were involved in this project all stated some barriers for circularity.

Costs - It is said that circular building projects do not have to be more expensive. However, the experience of the actors involved is that it does cost more money. However, they state that it is important to identify how much circularity is worth in terms other than just money. Currently, the general contractor is often too much focused on short-term money making. While the power of circular building methods might be in the fact that the value of the building will not change too much. It is therefore important that the actors start thinking about the future and long-term impact and influence.

Standardization – Another problem which is identified by the actors involved is the fact that there is no standard yet. Most of the circular building projects that are currently realized are individual projects. These projects all have their own way of working with and give their own meaning to circular building methods. This makes that there is no standard yet and projects will stay individuals as they will be approached in a way which cannot be repeated.

Insecurity – Insecurity is a huge barrier as this makes that different actors are afraid. They are not sure what the end result will be and therefore need a lot of trust in the other actors. This insecurity also influences the risks and how the actors deal with these risks. As, because of the insecurity, the risks are higher and the actors involved actively need to be willing to take this extra risks.

Esthetics – The esthetics of circular building projects are still limited as there is not a lot of choices. The question is whether people are really willing to pay for such a specific look.

Regulations – Another barrier for circular building projects are regulations. Currently, the regulations often are not applicable for circular building methods. A general contractor sketches an example about regulations regarded to fire safety:

"All the products we usually buy are tested on fire safety. However, when we re-use materials in a circular way, they are not tested again on fire safety. So we were in a gray area where it was not always clear what was acceptable and what was not. In the end, we worked very closely together with the firefighters to solve this problem, but it would have been easier if this was arranged by regulations."

Attitude – The attitude from the actors involved is very important for the use of circular building methods. If the actors involved do not have the right mindset, it is impossible to apply new methods. And even when the actors involved do have a positive mindset and attitude, some of the actors might need to get used to different ways of working.

Barriers for circular building methods case II

Some barriers for circular building methods were mentioned by the interviewed actors.

Regulations - The actors involved have experienced that the regulations are not applicable to the circular building materials yet. This is a serious problem as every project has to deal with the regulations; otherwise, they will not be able to get a building permit. The regulations also assure the safety in the construction industry. Besides this, there is barely any room within the regulations to be creative with new materials.

No tool to measure – Currently there is no universal tool to measure to what extent a design is circular. So, therefore, the actors struggled to define the circularity for this project. They needed to do some good research and collaborate with other actors to develop their definition of circularity.

Warranty – The general contractor is traditionally the actor who has the most risks in a building project. It is therefore not surprising that the general contractor is the actor who is worried about the warranties that need to be given to the clients. However, the general contractor often experiences that circular building materials are not able to provide long-term guarantees. As a general contractor mentions: "Sometimes the only warranties that can be given is that there are no warranties. When this is the case, we really need a client who wants circularity so badly that they are willing to take this risk".

Costs – Surprisingly, in this case, the costs are not mentioned as a barrier that often. What is mentioned is the fact that it is important to find out what acceptable costs for circularity are. Together with what the value of circular buildings is. There should be a long-term vision instead of short-term money making.

Opportunities for the adoption of circular building methods identified by both cases

Both cases identified different barriers for circular building projects, shown in table 16 on the next page. There are two barriers that are identified in both cases; costs and regulations. To deal with the costs, a new business model must be developed. For this business model, all actors need to be involved. The regulations are a more long-term barrier.

For the costs, it is mostly mentioned that it is important to identify what the value of circularity is. This also implies that actors should start looking at long-term vision instead of the more traditional short-term money making. The price of a project should not be the most important criteria.

The regulations are mostly a barrier as it is a limiting factor. When a project does not fit the regulations, it will not be able to obtain a building permit. Also the safety, which is guaranteed by regulations, is very important. However, the current regulations are not up to

It is important to realize that within this thesis the use of the term 'business model' is different from the regular use. Regularly 'Business model' refers to how an organization makes value. In this research it is talking about a 'business model' which should be created by different organizations together for the same goal.

date with circular building methods and might need a revision. One of the actors involved also states that regulations could have a positive influence on the adoption of circular building methods. With regulations, it is possible to force actors to start using circular building methods.

Table 16: Overview barriers case I and case II

Barrier	Case I	Case II
Costs		
Standardization		
Insecurity		
Esthetic		
Regulations		
Attitude		
No tool to measure		
Warranty		

5.2 Barriers and possible solutions identified by the different roles

Barriers for the adoption of circular building methods identified by the different roles

More intensive – Projects that are different from regular projects, like projects with circular building methods, are way more intense for the actors involved than regular projects.

Costs – "The general contractor is still focusing on short-time money making". This is a statement from one of the interviewee, but costs are a barrier for circularity that is mentioned by almost every interviewee. One of the sub-contractors stated: "For 80 to 90% of the requests, they still chose for the lowest price. Only the general contractors and clients that are very aware of sustainability and have a positive attitude, think about the economically most valuable option instead of the cheapest". For the interviewed general contractors, it applies that all of them mentioned the importance of the costs. On one hand, the fact that circular building projects are not at a point yet where it is cheaper than regular building projects is mentioned. "When the money tap is open, everything is possible, but this is not repeatable. How can we make circularity affordable?" is what one of the interviewed actors stated. On the other hand, most of the general contractors understand that this short-term way of looking at costs is outdated. The general contractor, however, blames this on the client; at this moment, most of the time the general contractor still gets selected for a project based on the lowest price. One of the general contractors is asking "what is the added value of circularity?" The clients also wonder how much more circular building projects are allowed to cost. Next to this, they see that it is important to look at the value in a different way than just money. They all state that it is important to keep the long-term in mind while dealing with value. One of the interviewees, who is building her own sustainable, circular house explains "circularity does not have to be more expensive. You just need to look at the added value and the value retention".

Business models - One of the main barriers for circularity that is identified by the interviewees, is the need for a new business model. The traditional business model is seen as outdated as it is mainly focused on short-term money making. There is no long-term vision and there is no value for other things than money. So, an important aspect to take into account is what the added value of circularity is. A new business model is important to all actors involved, but mostly for the general contractor. This is because the general contractor is now de actor who oversees most costs and contracts. But they are not transparent about its business model. As one of the interviewees stated: "The division within the business model of the general contractor needs to disappear, it needs to be done more integral."

Another interviewee agrees and adds: “The general contractor needs to be more transparent about how they and the actors involved earn their money.” Several interviewed actors state that a new business model should make sure that all the actors involved in a project gain together and lose together. That way the project interest will come before the individual interest. ” Even though the interviewed sub-contractors acknowledge that the business models have to change, other interviewed actors feel like the sub-contractor is not on the level of seeing the urge for the change of business models yet. The advisors also see this new business model will be the hardest for the sub-contractor because they do not see the importance yet. One of the most important factors for this new business model will be the fact that all the actors need to be very transparent about how they earn their money. The advisors specifically state that the general contractors are currently too closed about its business model.

Warranties – One identified barrier for circularity for the general contractor, is the fact that the general contractor traditionally is responsible for the warranties on the building and has the most risks. Currently, the general contractor has the liability to deliver a finished and good working building. However, when realizing a circular building, it is hard to give warranties for some parts. Therefore, the risks for the general contractor are even higher than regular. “We should leave the risks at the actor who is best able to deal with it, which is the actor that has the most knowledge about it” is the statement of one of the interviewee. Also the sub-contractors identified this barrier. One of them states: “It is a shame that the current regulations are so stiff and not able to play with them, this is a real constraint for circularity. I hate saying it, but it would really work if the municipality would stimulate this a bit”. The clients agree and say that there is nobody thinking about the adoption of circular building methods at a strategic level.

Regulations – Related to the risks aspect is the aspect of regulations. The general contractor experiences quiet some barriers for circularity related to the regulations and the required certificates. For example, the fact that all new materials have a fire safety certificate. But for re-used materials, it is not possible to get such a certificate. This results in a grey area where it is unclear what is allowed and what is not allowed. Safety is a very important aspect in the built environment, and everybody understands that it is necessary to have strict regulations for safety. However, some actors are wondering if the regulations are still up to date and whether it is possible for the government to have a closer look at this.

Esthetics- Another barrier for circularity that is identified by an advisor is the esthetics. One advisor wonders “do people really want to have second-hand objects in their building when it does not look good?” However, he also states that this is something that is already changing. He sees that the younger generation is easier with this than the older generation. Therefore, he is optimistic about the change to more and other esthetics. Mostly because people are currently not used to what circular projects look like. Whenever the look of circularity gets more normal, when there are a lot of example projects and when people are getting used to this, they also will not mind spending money on it. As one of the clients states: “We just really feel like this is more beautiful, so we do not mind spending more money on it. But I can imagine that other people might not feel this way”.

Getting used to it – While the sub-contractors feel like they are all ready to start new forms of collaboration, the other interviewed actors state that the sub-contractors need to get used to more equal forms of collaboration. The sub-contractors need more experience to really know how to deal with the extra responsibilities that are given to them. Both a general contractor and an advisor acknowledge that there is still a way to go for most sub-contractors. They also both state that the general contractor should take the lead in this and make sure that the sub-contractors are able to learn. As one of the general contractors mentions: “If the sub-contractors are willing to join and change, we are willing to take them along and put energy in them to learn. But if they do not want to learn, we cannot do anything for and with them”.

Attitude - The advisors that are interviewed are all very clear about the biggest barrier for circularity. They all state that the mindset and attitude of the actors involved are critical when circular building methods are to be adopted in the construction industry. To positively increase this mindset, a lot of good examples and PR is needed. However, the advisors see that a lot of actors are afraid. These actors are afraid of failing and losing money. Most sub-contractors feel like currently, most circular projects are more window-dressing and a PR trick. It is only done by clients who are aware of sustainability. And to really change it, the whole building sector has to join and change its attitude. One of the interviewed clients experienced that every mistake that was made, was blamed on circularity. He states: "Most of the times the mistakes were not related to circularity at all. However, other actors always wanted to blame it on the circularity. But I am actually really sure that we would have more problems if we did not have circular building methods". This negative mindset does not have a positive influence on working with circular building methods.

Equality - Related to this is the fact that most sub-contractors feel like there is not enough collaboration within the construction industry most of the time. This is retaining for the circularity as this is hindering the communication. Next to this, most of the time, the sub-contractors do not feel like an equal actor. Whenever the sub-contractor is involved within the project in an early stage, the sub-contractor sees an improvement in the equality between the different actors. One of the interviewed sub-contractors states "It is good to be involved in an early stage as we can show that this really adds value to the project".

Integrality - Connected to the new business model is the way the general contractor and sub-contractor interact with each other. It is important that the whole chain is willing to collaborate for circularity. Most advisors state that the relation between the general contractor and the sub-contractor has a big influence on the implementation of circular building methods. The general contractor has the power to negotiate with the sub-contractor about what the role of the sub-contractor could be. And as the general contractor is the connection between the client and the sub-contractor, it is important that the general contractor and sub-contractor have very clear agreements. Overall, the collaboration between all actors needs to be more integral. The advisors agree on the fact that the general contractor could possibly be the actor who secures the integral project, as the general contractor already has a central place within the project. What the sub-contractors do not like at the moment, and see as a barrier for circularity as well, is the fact that the general contractors are very good in cutting the whole project in 1000 pieces and very secretly try to solve every little piece. The interviewed sub-contractors feel a need for more transparency, openness and an integral manager. They suggest that the general contractor should take the lead.

Trust - The construction industry, in general, is seen as a distrustful sector. Some of the sub-contractors see this as well. All of the interviewed sub-contractors state that they are trustworthy and had a positive experience with the other actors during the circular projects. However, they also have experienced that other actors called them not trustworthy. This does not give a positive attitude to the project.

Effect of circularity - The interviewed advisors also identified some barriers they are expecting for the future. These are problems with the validation and verification of circular building materials. "How is it possible to know whether the claimed circular building materials are really circular or not?" And another barrier might be that at this moment, the effects of circular building methods cannot be foreseen yet. As one of the advisors states "Of course, wood is a circular building material. But it is impossible to harvest enough wood to accommodate the whole world, at some point the natural boundary of wood will be reached. It is too early now to put all your cards on circularity because we do not know enough about the effects".

Technical unknown- One client also acknowledges that some mistakes are due to the circularity. Most often this is because of technical ignorance. Sometimes the circular building material is new to all actors when they are not used to work with it; they might not adjust their regular way of working to the circular building material. Therefore, mistakes might occur.

Circularity is luxury- What is also seen as a barrier for circular building methods by the clients is that circular building methods are – still – a luxury. It is something that is not for regular people and it has the image of being only for the rich and special ones. This is causing an invisible barrier and symbolic boundary for circular building methods.

Lack of standardization - Another barrier for circular building methods, faced by the client, is the fact that there is no standard for circular building methods yet. Because of this, most projects that are built with circular building methods now are incidental. There is no strategy yet on how to get the knowledge which is gained during these incidental circular projects to get to a higher scale. Regulations might help to give some guidance.

Possible solutions for the adoption of circular building methods identified by the different roles

When all the barriers for circular building methods are listed together, it is quite a list. It is interesting to see how every different actor has different priorities and therefore experiences different barriers. However, there are a few barriers that are mentioned and acknowledged by several actors. These are the business model, regulations, costs, esthetics, attitude, and integrality. This can be seen in table 17 on the next page.

Lack of *integrality* is perceived as a barrier due to the fact that in the Dutch construction industry, projects are often cut into a lot of small pieces which are all executed by actors of their own. As such, there are different actor configurations in the different stages of construction projects. Moreover, there is no clear communication between these stages, and hence the actors involved. As a circular project requires often not one approach for every small part of the project, but rather an overall approach, it is important that all the small parts integrate. To improve the integrality between the actors involved in a building process, a new form of collaboration is needed. This should be a collaboration where all actors are equal to each other and have a common incentive.

Costs for circular building methods is another barrier which is often mentioned. Even though circular building projects do not necessarily have to cost more money, actors often assume that it will. For this, it is very important to look at the value in another way than just short-term money making. And therefore, a new business model is needed. It needs to be said that a new business model is not a barrier but rather the solution. The old business model is the barrier. This new business model needs to keep the long-term money making in mind. Like a business model where gains and losses are shared with all actors involved.

The *attitude* of the actors involved has a high influence on the success of circular building methods. As this is still new to most actors, a positive attitude is needed. However, very often, different actors are afraid. They mostly see high risks and insecurities which makes that they have a negative incentive. Some of the interviewed actors state that the attitude will probably change when the material scarcity increases. This is, however, a negative incentive. It would be better to create awareness about the need for circular building methods. This can be done by the right PR. But it might also increase when the actors involved get something positive out of it, which could be caused by a new business model.

Meeting *regulatory standards* is often not feasible for circular building projects. Regulatory norms are frequently too stiff and do not have room for flexibility. Partly, the circular building methods might need to adjust to the regulation. But it would also be good to have a look at the regulations and see if they

are not outdated. New regulations might also stimulate the use of circular building methods as this way actors will be forced by regulations to start using circular building methods. It is, however, a long-term barrier which needs more circular projects to be able to change.

Currently, the *esthetics* for circular building projects are still different from regular building projects. The choices for the materials are not as broad as for regular building projects and therefore the choices for the esthetics are limited as well. Whenever people like the esthetics, or have more choice about it, they are more likely to pay more for it. This barrier also needs more time and more circular projects to resolve. When more projects are made with circular building methods, potential clients will get used to esthetics. Besides that, over time more options with different esthetics will be developed and possible clients will have more choice.

Overall, the general contractor is mainly focused on the costs, where the sub-contractor mentions the equality between the different actors as important. The advisors are mainly focused on the attitude and mindset of the actors involved. They state that the negative incentive is the most important barrier for circularity. For the clients, the most important aspect is the communication.

The six barriers that are identified by most interviewed actors are the business model, regulations, costs, esthetics, attitude, and integrality. The business model, costs, attitude, and integrality are related to each other. The solutions for these barriers could work together to resolve each other. This will be explored in the focus group. Regulations and esthetics are both long-term barriers, which can be overcome by doing more circular projects.

The conclusions that are made from this analysis, together with the identified barriers will be the input for the focus group. This focus group is held with experts from the construction industry.

Table 17: Overview of overlap of barriers represented per actor

Barrier	General contractor	Sub-contractor	Advisor	Client
More intensive				
Business model				
Warranties				
Regulations				
Costs				
Esthetics				
Getting used to it				
Attitude				
Equality				
Integrality				
Trust				
Long-term influence				
Technical unknown				
Circularity is luxury				
Lack of standardization				

5.3 Linking the identified barriers and possible solutions with literature

Within the cases, the costs and regulations are mostly identified as barriers during a project with circular building methods. These two barriers are also identified by the different roles. The different roles extend this list with the business model, esthetics, attitude, and integrality. The costs, business model, attitude, and integrality are barriers that might be influenced when an integral manager is present. The esthetics and regulations are barriers that will need more time to be overcome. Table 18 shows the most identified barriers by cases and roles.

Table 18: Barriers identified by cases and roles

Barrier	Case I	Case II	GC	SC	Advisor	Client
Costs						
Regulations						
Business model						
Esthetics						
Attitude						
Integrality						

GC = general contractor SC = Sub-contractor Adv = advisor Cli = Client

In figure17 on the next page, the identified barriers are placed in the MLP. It can be seen that most identified barriers fall between the niche-innovation level and the socio-technical regime. The barrier of regulation is the only one that is entirely in the socio-technical regime. This is because regulations are dynamically stable and will only change under certain circumstances. More circular projects need to be realized to be able to give enough input to change the regulations. The barriers of costs and esthetics are in the niche-innovations level as they need to be developed more and change easily. The other three; business model, integrality, and attitude are between the two levels of niche-innovations and socio-technical regime. This is because these are barriers which prevent the different projects and knowledge to align and give enough input for the socio-technical regime. However, whenever these three barriers – business model, integrality, and attitude – are resolved, they will have a positive influence on the change in the socio-technical level.

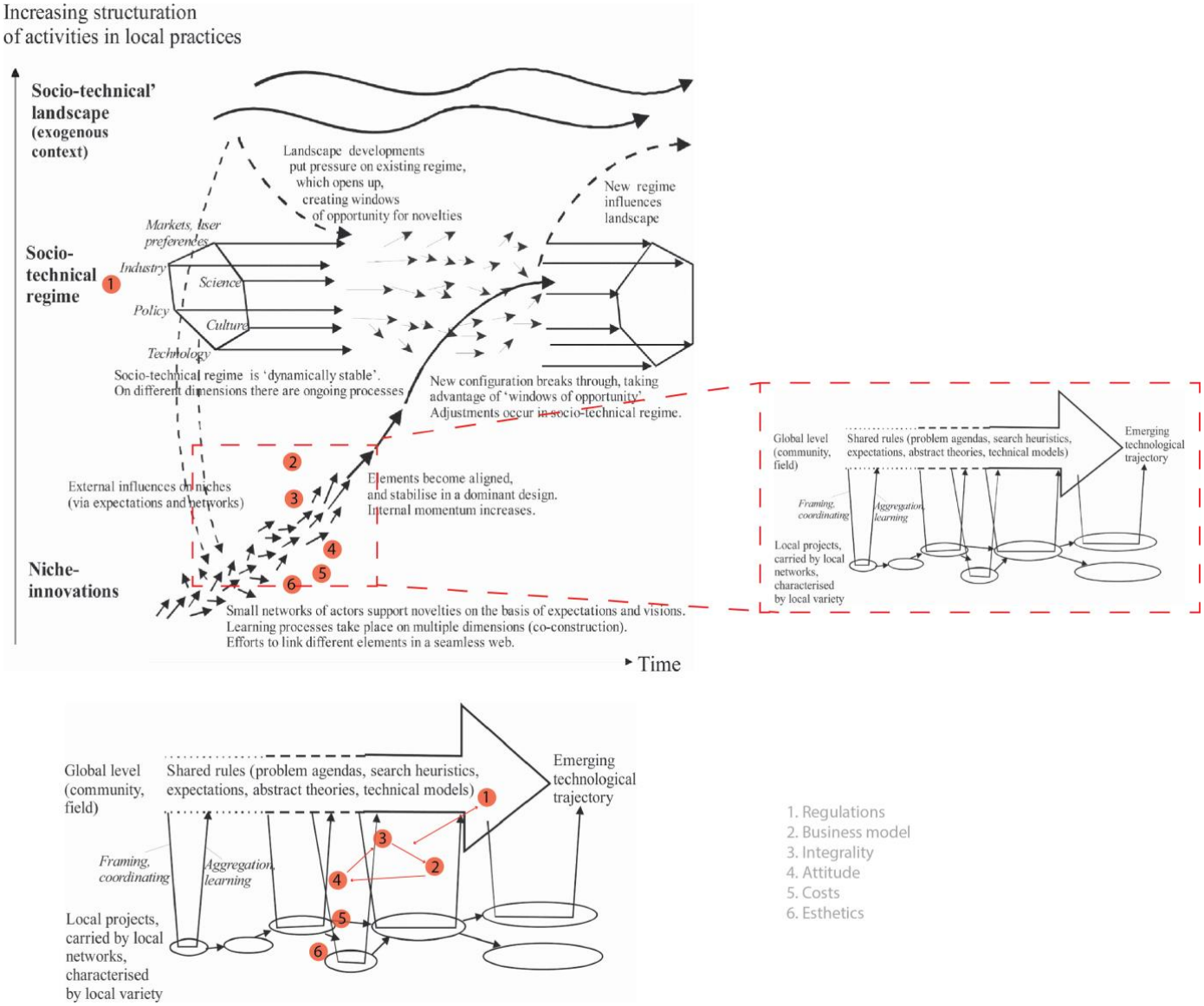


Figure 17: Barriers in MLP and knowledge management (adapted from Geels, 2002 and Geels & Deuten, 2006).

The interaction between the different levels in the socio-technical system may positively influence the barriers. This way, business model, integrality, and attitude will not be barriers anymore but may be opportunities to overcome the barriers and take the niche of circular building methods to the socio-technical regime level. This may also positively stimulate the regulations which are now experienced as a barrier. The other way around, when the regulations adapt, this might have a stimulating influence to overcome the other barriers easier. This suggests that for the transition path of circular building methods, interaction between the niche-innovation level and socio-technical regime level is needed. This should not be limited to only information shared from niche-innovation level to socio-technical regime level, but also the other way around and even within the area between the different levels.

The conclusions that are made from this barrier analysis, together with the conclusion of the case study analysis will be the input for the focus group. This focus group is held with experts from the construction industry.

5.4 Focus group

This focus group is conducted for two reasons. The first aim is to verify the findings from the cross-case and cross-role analysis. The second aim is to create the ideal collaboration for the actors involved in a circular building project. As there are two aims, the focus group has two parts. In the first part, statements will be judged. These statements are obtained from the interviews and related to the theory, see table 19. The second part contains a fictional case and a framework to get to the ideal collaboration. An elaborate description of the research design can be found in Appendix D.

Table 19: Statements used in focus group with related theory aspect

Statement	Related theory
If you want to be an example for other actors in the area of circular building methods, you have to be very open yourself.	Attitude Learning
Project gain should be more important than personal gains	Integrality Costs Process
Due to an open communication, there will be less anxiety and conflicts	Interaction Trust Process Supply chain
Due to an open process, everybody feels and is equal	Attitude Process Supply chain

Statement	Statement	Related theory
In 10 years the general contractor will not exist anymore. The role of the general contractor has to change	In 10 years the general contractor will not exist anymore, but it does not matter when the general contractor goes bankrupt	Business model
If you have a head start, you will always have a head-start, so knowledge sharing is not a bad thing	Knowledge sharing gives you a head-start on your competitors and with that a financial advantage, when you share your knowledge you will give away you head-start; sharing is stealing	Attitude Learning
The client will only start asking for circular building methods when the general contractor is able to use circular building methods	The general contractor will only start using circular building methods when the client asks for it	Network Core values Process
There is no sufficient regulations regard to circular building methods because there are not enough circular projects	Circular building methods are not used enough because there are no sufficient regulations	Regulations
Actors in the construction industry cannot be trusted and therefore it is not possible to be open	Actors in the construction industry are too distrustful to be open	Trust Supply chain Learning
Circular building methods will only be successful when the client gives more time and money	Circular building methods will only be successful when the actors really have a circular heart.	Costs Attitude Network Process

Results

For the first part, with the statements, the overall observation is that the group is overall not very divided. Also, the participants of a specific role mostly agree with each other. Some statements are discussed during the focus group.

The first statement that was discussed is the statement 'open communication makes sure that actors are less afraid of conflicts', where most participants agreed. What was mainly said here is that, even though there might be open communication, there will always be conflicts. However, the actors do not have to be afraid for it anymore as the open communication will make it easier to deal with these conflicts. It is therefore important to define the rules before the process starts.

The second statement is ‘actors in the construction industry cannot be trusted and therefore it is not possible to be open’ versus ‘actors in the construction industry are too distrustful to be open’. The majority voted for ‘actors in the construction industry are too distrustful to be open’. The main comment was that expert from the construction industry would not say that actors from the construction industry cannot be trusted because they would imply that they are not trustful themselves. Besides this, they stated that their experiences from the past, where things went wrong, made them distrustful. This caused a discussion about whether the actors can be trusted or not. As some state that, when your experiences make you distrustful this proves that actors cannot be trusted. The conclusion was that, when you distrust an actor because of experiences in the past, this does not necessarily mean that all actors cannot be trusted.

The next statement that was discussed is ‘in 10 years the general contractor does not exist anymore, therefore the current role of the general contractor needs to change’ versus ‘in 10 years the general contractor will not exist anymore, but it is not a big deal when all Dutch general contractors go bankrupt’. There was only one general contractor who voted for the ‘in 10 years the general contractor will not exist anymore, but it is not a big deal when all Dutch general contractors go bankrupt’. The discussion that occurred was about whether the future role of the general contractor needs to be a new role or a role adapted from its current role. And what the difference is between those two options. In the end, they agreed that this is a matter of interpretation. Besides this, one of the participants stated: “The bankruptcy of the general contractor could be a good catalyzer for this changing role.”

The last statement that was discussed was ‘if you have a head start, you will always have a head-start, so knowledge sharing is not a bad thing’ versus ‘knowledge sharing give you a head-start on your competitors and with that a financial advantage, when you share your knowledge you will give away you head-start; sharing is stealing’. What was mainly concluded was that it is not a bad thing to share your knowledge. However, you will not automatically keep your head-start. You will always have to work on it.

After this everybody started with filling in their own personal form which was the starting point for the joint version. The group was divided into two groups where each role was represented. This means that group 1 consisted of a general contractor, a sub-contractor and an advisor. Group 2 consisted of two general contractors, a sub-contractor and an advisor. Both groups came up with very similar designs for the ideal collaboration.

Figure 18: Participants occupied with answering statements during the focus group (Own photograph).

Both stated groups the importance of an open, equal, joint and integral process. The importance of gain and risk sharing is addressed. The first group specifically states that this should also involve actors from the municipality. The second group, however, includes a financial expert, legal advisor

and the support of its internal organization. The first group also addresses the importance of the timing so that every actor is involved, as the group members believe that all the actors should be involved in the process from an early stage. The second group merged the expectations and promises together as they stated that one can only expect what one promises to others. And that one should only promise what one expects from others. An overview of the differences and commonalities between the two groups can be seen in Table 20.

Table 20: differences and commonalities between the two groups

Assignment	Group 1	Group 2
Personal core values	- Materials from existing building will be the basis for new buildings	- Formulate rules and boundaries together
Other actors	- Include the municipality in the network	- include financial expert, legal advisor and support from internal organizations
Expectations other actors	- Include all actors from early stage	- and promises should be the same
Promises to other actors	- Collective agenda more important than individual agenda - Change distrust to trust	- Expatiations and promises should be the same
Ideal collaboration	The product is the outcome of the process	- In need of a director to lead the process

When both ideas were pitched and discussed, some questions were asked. When asked which of their personal core values did not make it to the final design, they all said that none of their core values were lost. However, there was addressed that this was all on a higher scale. Some of the participants were afraid that if one would dive deeper into it, one would probably want other ways to achieve those higher goals and conflicts will occur. The next question was which actor they would have liked to join while designing this. The answer was: the one who pays. And to deal with the project-based nature it is important to make sure that these collaborations will be long-term.

Some final remarks that were made by the participants: All the pieces to start building with circular building methods are already there, someone only needs to give the first push. This could be anyone; the government with regulations, the client with a circular request, and the general contractor with a circular approach or any other actor from the building industry. However, at this moment the start of a process is already demotivating as everybody starts with their own core values. They should start the process even more open and formulate these core values together with the other actors. Moreover, the participants from the focus group stated that the sector is currently dominated by engineers. However, the building process is not something technical; it, therefore, needs more 'soft skilled' people. One of the downsides of a long-term collaboration is that you need to find a way to still be open for actors and parties that are new to the sector.

5.5 Conclusion

This conclusion aims the answer the third and fourth sub-question, respectively: '*What can be learned from (mis-)matches between theoretical considerations and experiences?'* and '*Which factors from these lessons can be applied by the general contractor for the circular building methods in the Dutch building sector?'* Therefore, this section will show how the general contractor can apply the lessons, learned from the results of the case studies, to the circular building methods in the construction industry.

As shown in section 5.3 most identified barriers can be placed between the niche-innovation level and the socio-technical regime of the MLP. This is the level where the knowledge about circular building methods will be contextualized in such a way that is it shareable. When it is shareable the socio-technical regime will adopt the circular building methods more easily. This shows that, when the barriers between these levels – namely business model, integrality, and attitude - will be resolved, this will have a positive influence on the adoption of circular building methods in building projects.

So the answer to the third sub-question is as follows: the lesson that can be learned from the (mis-)matches between theoretical considerations and the experiences, is that a solution for the barriers business model, integrality and attitude will have a positive influence on the adoption of circular building methods.

From the focus group, a few conclusions can be made. First of all, everybody agrees on the fact that the role of the general contractor needs to change. Besides, an open attitude is important to improve trust and learning about circular building methods. Next to that, the barriers of costs, business model, attitude, and integrality, which are experienced at the moment, could be solved by developing a new business model. A business model, where the overall gains are more important than the personal gains, could have a positive influence on the attitude and costs. Lastly, both groups developed a new form of collaboration with a key actor. As circular building methods are integral methods, this key person should be an integral manager who secures the integrality of circular building methods.

The findings from the focus group, with experts from the construction industry, verify the tentative conclusions made in section 4.5. Most importantly the focus group showed that an integral manager is desired to take a lead in the process when circular building methods are involved. They also agree on the fact that the general contractor might be the right actor to take this role. This shows that the answer to the fourth sub-question is that the general contractor should take the role of an integral manager to manage the network, supply chain, and building process and facilitate the learning process to have a positive influence on the adoption of circular building methods. When taking this role they should work together with other actors to develop a new business model. This new business model should aim to take away the current barriers for circular building methods. This is different from regular innovations as the involvement of all the actors is even more important. Next to this, the focus group with experts shows the importance of actors from outside the construction sector.

6 Conclusions, recommendations and discussion

This chapter provides the conclusions of this research, recommendations for the general contractor, a discussion on the relevance of this research, the limitations, and suggestions for further research.

6.1 Conclusions

In this section, the conclusion of this research will be shown. This will be done by answering the sub-questions which will lead to the answer to the research question:

> *Which actions can be executed by the general contractor to have a stimulating influence within its inter-firm network on the adoption of circular building methods in the Dutch housing industry?*

As stated in the introduction in chapter 1, research about circular economy in the construction industry is only recently developing. Most of these researches lack the acknowledgment of the complexity and integrality that is needed for circular building methods. Circular building methods in building projects are facing barriers to be adopted in the construction industry. This is partly due to the fact that the construction industry is project-based. The general contractor, as a project-based firm, is currently struggling on how to develop its role to have a positive influence on circular building methods in the building industry.

> *Sub-question 1: What role can the general contractor have within its inter-firm network regarding the adoption of circular building methods according to literature?*

Written literature shows that learning, networking, and investment are three key elements in the innovation process. For sustainable innovations, like circular building methods, a different transition approach is needed. A shift to a socio-technical system will provide integration between technical and social development. A research perspective that conceptualizes overall dynamic patterns in socio-technical transitions is the Multi-Level Perspective (MLP). In the MLP, the transition is seen as a non-linear process that results from the interplay of development at the analytical level: niche-innovation, socio-technical regimes, and socio-technical landscapes. To create socio-technical regime transition, niches are considered to be very important. Strategic Niche Management (SNM) is based on the multi-level conceptualization of socio-technical regimes and they have the same conceptual base. Besides this, it focuses on niche management. There are three main niche processes: Shaping of expectations, building social networks and learning processes. These niche processes are similar to two of the key elements of innovation: learning and networking.

To achieve more than just incremental innovation, intensive knowledge transfer between different actors in the construction chain is essential. For knowledge sharing, it is important to have an open network, trust, and utilization of the strengths of the actors. A long-term relationship will increase the trust. Knowledge needs to be contextualized to make it shareable between locations. Therefore, the interaction between the niche-innovation and social-technical regime level is important.

The importance of social networks means that the niche processes learning and networking of SNM are strongly related to each other. In a network; there is more attention to the process of the interaction between the interdependent actors in a network than there is attention to the project approach. The importance of networks within the construction industry is addressed. The general contractor plays a mediator role; general contractors are important sources and adopters of innovations, they integrate the different activities and innovations that are introduced by different parties.

The answer to the first sub-question is that literature implies that a key person is needed. This key person may manage the network, supply chain, and building process and facilitate the learning process to have a stimulating influence on the adoption of circular building methods in building projects. This key person may be an integral manager who takes care of the integrality of the process. The general contractor can be a good actor to take the role of an integral manager. That way the general contractor might have a positive influence on the adoption of circular building methods in building projects

This resulted in four hypotheses that were used to provide an answer to the following sub-questions. These hypotheses are:

- H1: A key actor, who manages his / her inter-firm network well, has a positive influence on the adoption of circular building methods in building projects.
- H2: A key actor, who manages the activities of the supply chain well, has a positive influence on the adoption of circular building methods in building projects.
- H3: A key actor, who manages the building process well, has a positive influence on the adoption of circular building methods in building projects.
- H4: A key actor, who facilitates the inter-firm learning process well, has a positive influence on the adoption of circular building methods in building projects.
- H5: The general contractor can be a good actor to take the role of an integral manager to have a positive influence on the adoption of circular building methods in building projects.

Sub-question 2: How did the different actors of circular building projects experience the adoption of circular building methods by the actors involved?

The answer to this sub-question will be provided by testing the hypotheses within two case studies.

H1: A key actor, who manages his / her inter-firm network well, has a positive influence on the adoption of circular building methods in building projects.

The managing of the network was very different in both cases. In case I there was no key actor who managed the overall network. However, the building team was managed by the general contractor who had a key role here. The key role of the general contractor was experienced positively by the actors involved as it was easier to create circular ideas together. It is hard to say though if the adoption of circular building methods would have been better when a key actor had managed the overall network. In case II the general contractor was the key actor who managed the network. This was experienced positively for the adoption of circular building methods as the general contractor was in charge of the amount of circularity in this project and could link the right actors to this project. The cross-role analysis shows that the general contractor or advisor may be a good option to take the role of an integral manager.

H2: A key actor, who manages the activities of the supply chain well, has a positive influence on the adoption of circular building methods in building projects.

In both cases, a relation can be seen between the presence of a key actor and a positive experience on the adoption of circular building methods. This is because in both cases the actors involved had the same incentives and core values regarding circular building methods. The general contractor is usually the key actor for the managing of the supply chain, and this is experienced positively for the adoption of circular building methods, this suggests that there is no reason to change this.

> *H3: A key actor, who manages the building process well, has a positive influence on the adoption of circular building methods in building projects.*

Case I did not have a key actor who managed the building process, case II did have the general contractor as a key actor. The process in case II was judged more positive than the process in case I. Due to the difference in the process, in case II there was more positive influence on circular building methods than in case I. This was partly due to the fact that in case II there was room to talk about conflicts regarding circular building methods due to the long-term collaboration. In case I it was harder to solve conflicts. Therefore, this implies that an integral manager for the management of the building process will have a positive influence on the adoption of circular building methods in building projects. According to the cross-role analysis, most interviewed actors stated that the general contractor is in the right position to take the role of integral manager for the process.

> *H4: A key actor, who facilitates the inter-firm learning process well, has a positive influence on the adoption of circular building methods in building projects.*

The learning process for circular building methods was not facilitated in both cases. The learning about circular building methods that did occur happened organically. The absence of a key actor is related to a bad experience of the facilitation of the learning process. The presence of a key actor, who facilitates the learning process, may be able to structure the learning about the usage of circular building methods. All the learning about circular building methods that happened organically now, may be managed and therefore be contextualized and shareable. Therefore, the presence of a key actor who facilitates the learning process may have a positive influence on the adoption of circular building methods in building projects. However, it is not clear yet which actor would be best suitable to take this role of integral manager.

> *H5: The general contractor can be a good actor to take the role of an integral manager to have a positive influence on the adoption of circular building methods in building projects.*

The general contractor is the actor that is mentioned most by the interviewed actors to potentially take the role of an integral manager to have a positive influence on the adoption of circular building methods in building projects. The management of the supply chain by the general contractor is already experienced positively. Only for the facilitation of the learning process, the general contractor is not mentioned. However, there is also no argument to not let the facilitation of the learning process be managed by the general contractor. Therefore, when starting to look for the right actor to take the role of an integral manager, it is suggested to start with testing if the general contractor can take this role.

This concludes with the answer for the second sub-question which is;
Overall, the adoption of circular building methods was experienced more positive when a key person was present. The general contractor is the actor who is most likely to take the role of an integral manager.

The difference between any other innovation in the building sector and circular building methods is that circularity needs more integrality. For other innovations are often affecting only a certain part of

the project, it therefore needs a smaller amount of actors involved. Circular building methods are not only concerning a certain part of the project but are influencing a building project on many levels. Therefore the integrality is more important.

Sub-question 3: What can be learned from (mis-)matches between theoretical considerations and experiences?

In the two cases and the different roles, some barriers for the adoption of circular building methods are identified. The six barriers which are mentioned most often are costs, regulation, business model, esthetics, attitude, and integrality. When these barriers are placed in MLP, it can be seen that most of these barriers fall in the area between the niche-innovation level and the socio-technical regime. This shows that, when the barriers between these levels – namely business model, integrality, and attitude - will be resolved, this will have a positive influence on the adoption of circular building methods in building projects.

When looking at the transition path of circular building methods, it can be seen that the barriers business model, integrality, and attitude may become an opportunity to work together to be able to resolve the barriers. The interaction between the different levels in the socio-technical system may positively influence the barriers. This way, business model, integrality, and attitude will not be barriers anymore but may be opportunities to overcome the barriers and take the niche of circular building methods to the socio-technical regime level. This may also positively stimulate the regulations which are now experienced as a barrier. The other way around, when the regulations adapt, this might have a stimulating influence to overcome the other barriers easier. This suggests that for the transition path of circular building methods, interaction between the niche-innovation level and socio-technical regime level is needed. This should not be limited to only information shared from niche-innovation level to socio-technical regime level, but also the other way around and even within the area between the different levels.

So the answer to the third sub-question is as follows: the lesson that can be learned from the (mis-)matches between theoretical considerations and the experiences, is that a solution for the barriers business model, integrality and attitude will have a positive influence on the adoption of circular building methods. Interaction within the area between the niche-innovation level and socio-technical regime might eliminate the barriers that are currently identified for circular building methods.

Sub-question 4: Which factors from these lessons can be applied by the general contractor for the circular building methods in the Dutch building sector?

The answer to this sub-question is that the lessons learned suggest that the general contractor takes the role of an integral manager to manage the network, supply chain, and building process and facilitate the learning process to have a positive influence on the adoption of circular building methods. When taking this role, it is suggested that they work together with other actors to develop a new business model. This new business model should aim to take away the current barriers for circular building methods.

This is different from regular innovations as the involvement of all the actors is even more important. Next to this, the focus group with experts shows the importance of actors from outside the construction sector.

This all leads to the answer of the main research question;

> *Which actions can be executed by the general contractor to have a stimulating influence within its inter-firm network on the adoption of circular building methods in the Dutch housing industry?*

The overall conclusion of this research is that the general contractor is preferred to take actions to start a new form of collaboration with its inter-firm network. Within this new collaboration, the general contractor may take the role of an integral manager within its inter-firm network, the supply chain, the building process and the facilitation of the learning process to have a positive influence on the adoption of circular building methods in building projects. This integral manager may facilitate and secure the integrality between the actors involved in such a way that all the actors involved are able to share their knowledge and ideas for circular building methods in an early stage in the process. This way the collaboration between the actors involved will improve. This is especially important for circular building methods as it improves the much-needed integrality. Suggestions on how to do this will be given in section 6.2.

Another action is to develop a new business model together with a diverse range of actors. This business model may tackle the barriers that are currently experienced, especially the barrier of attitude, business model, and integrality. This will have a positive influence on the adoption of circular building methods in building projects as it will help overcome these barriers and therefore make it easier to contextualize the gained knowledge from the niche-innovation level. This contextualized knowledge may have a positive influence on the regulations that are currently experienced as a barrier for circular building methods. Suggestions on how to do this will be given in section 6.2.

6.2 Recommendations for the future role of the general contractor

This section will give recommendations for the future role of the general contractor to have a positive influence on the adoption of circular building methods in building projects. These recommendations are based on the findings of this research.

Recommendation I: Take the role of integral manager

Findings from the research show that the traditional way of collaboration does often not have a positive influence on the adoption of circular building methods in building projects. Traditionally the client has a request for a project. First, a design is made, and when the design is almost finished, the tender phase will start. The general contractor that wins the tender will start dividing the project into small pieces and tell the sub-contractors what they expect from them. This all happens without openness.

The interviewed actors all mentioned that this traditional way of collaboration is a barrier for the adoption of circular building methods. This is a barrier for a few reasons. Firstly, as the design is already finished before the building team joins the project, some boundaries are already set and decisions are made before the building team is involved. This way, it is not possible for the building team to join the conversation about options to improve the design. And yet the building team has on-ground knowledge and ideas which may improve the design of the project. Besides this, the early involvement of the building team may improve the building process as possible problems can be discussed and solved early in the process. Next to this, the traditional way of collaboration is very close. This does not have a positive influence on the trust between the actors involved. The traditional way of collaboration is hierarchical which does not invite all actors involved to join the conversation about how to improve the design.

A new way of collaboration should make sure that all actors involved trust each other and are open to each other. It should be an integral process where all actors involved feel equal to each other. To get such collaboration the first recommendation for the general contractor is:

> The general contractor should take the initiative to start a new form of collaboration with the actors involved where the general contractor takes the role of integral manager.

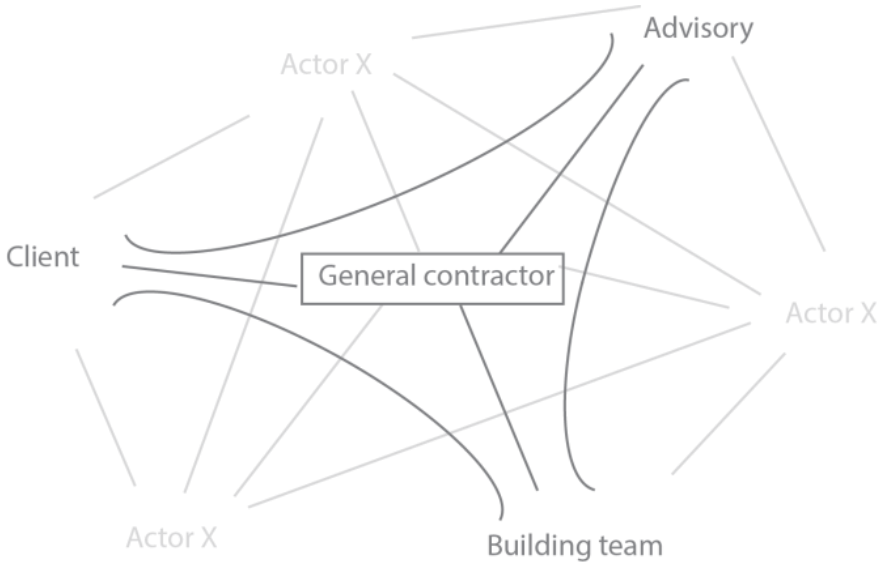


Figure 19: A new form of collaboration with an integral role for the general contractor (Own illustration).

As seen in the findings of this research, an integral manager who manages the network, supply chain, and building process, and facilitates the learning process could have a positive influence on the adoption of circular building methods in building projects. The interviewed actors identified that the general contractor may be right the right actor to take the role of an integral manager. The results from the focus group also identify the need for an integral manager. The participants also mentioned that all the puzzle pieces to make circular building methods are already there, somebody just needs to start.

As circular building methods need integrality, this also means that it is not just the future role of the contractor that may need to change. All the other actors involved are important as well, as they all have to work together. In this research, the emphasis is on the role of the general. It shows that it makes sense to start by investigating whether the general contractor could be the integral manager. This does not mean that the other actors could not take this role; it only implies that the general contractor would be the best option when starting to explore. When looking at other actors, they may have limitations which makes that they are a less obvious choice to take the role of an integral manager.

For the client, this is because, often, the client does not want to be involved within the project too much. A pro-argument could be that the client is often the actor who pays, therefore has a lot of power which could have a positive influence on circular building methods, especially when the client sees circular building methods in the building project as an important aspect.

For the advisors, this is because they are often specialized in a specific part. On the other hand, most advisors have a broad network which could bring together new actors and advisors are more independent than the other actors. Moreover, they are usually also only involved in a specific part of the project.

For the role of the sub-contractor, it is acknowledged by different interviewees that the sub-contractor is currently changing its role to become a more equal actor. This, however, already is a big step for them, changing all the way to an integral manager might be a step too far at this moment.

Where for the actors that are mentioned above the role would be similar to what is suggested for the general contractor now, policymakers could have another important role. Policymakers would probably have a critical look at the current regulations and see where some flexibility and adjustment is possible. It would probably work best when policymakers would team up with actors from the building sector to discover together where adjustment of the regulations is needed and possible.

Recommendation II: Joint gain and loss business model

Some barriers that are repeatedly mentioned in this research are, among others; costs, current business model, attitude, and integrality. These barriers could be resolved altogether by developing a new business model. The most important characteristic of a new business model should be a strong incentive for the actors to participate in a project with circular building methods. Some of the interviewed actors already had some ideas about such a possible business model. They state that a joint gain and lose business model is important. This way all the actors involved win together and lose together. During the focus group, the participants agreed with this statement. Some of the interviewed actors also stated that the general contractor should be more open about its business model. Therefore the second recommendation for the general contractor is:

> The general contractor should work with joint gain and loss business models to have a positive influence on circular building methods in building projects.

Such a business model should show how the collaborative actors can create value together in projects that use circular building methods. For this, it is important that the actors decide in the beginning for what percentage every actor is responsible. As soon as the whole project creates more value, every actor will receive its share. However, when the whole project will cost more money, all actors have to pay their percentage. When the general contractor takes the initiative for a business model with joint gains and losses, they start opening up to the actors involved. And as all the actors involved will gain together and lose together, their positive attitude towards the project will increase. Also, the risks and costs will be reduced for all the actors. The right term for such a business model needs to be developed the share the right message.

Recommendation III: Act now

The timing is now. Almost every interviewed actor stated that the best way to learn and to stimulate circular building methods is to “just do it”. At this moment the whole building sector is in a transition, caused by the energy transition and the fact that all new buildings have to be without gas. As the building sector is forced to change its regular way of thinking and designing, this could be an opportunity to include circularity as well. Therefore the third recommendation is:

> The general contractor should take the opportunity now, caused by the fact that the building sector is forced to change its regular projects, to start using circular building methods.

Because most actors know that within a few years they will have to change everything again to a circular design, so why not include circularity in the design right now to save time in the future.

6.3 Discussion

The problem statement defined in section 1.2 states that it is unclear what the role of the general contractor can be to have a positive influence on the adoption of circular building methods in building projects. Research about circularity in the construction sector is only recently gaining momentum. Therefore, this research aims to extend the knowledge about circular building methods in de Dutch building sector.

The research shows that mainly the business model, costs, regulations, integrality, attitude, and esthetics are identified as barriers for circular building methods. By placing these barriers in the socio-technical system developed by Geels (2002), it can be seen that the barrier of esthetics is in the niche-innovation level as it needs more research and development. The barrier of regulation is in the socio-technical regime level as it is a stable aspect which will need the input from the niche-innovation level to change. The other four aspects – business model, attitude, and integrality – can be placed in the area between the niche-innovation level and the socio-technical regime level. This shows that the niche for circular building methods is already growing into the socio-technical regime. This might also positively stimulate the regulations which are now experienced as a barrier. The other way around, when the regulations adapt, it could stimulate to overcome the other barriers easier. This suggests that for the transition path of circular building methods, interaction between the niche-innovation level and socio-technical regime level is needed. This should not be limited to information sharing from niche-innovation level to socio-technical regime level only, as is suggested by Geels and Deuten (2006), but also the other way around. Even interaction within the area between the different levels is important.

To overcome the barriers for circular building methods, identified in this research, a new form of collaboration is needed. This new form of collaboration should be an integral collaboration. Current literature about the management of networks, supply chain management, and building process already suggests that these managements focusses will have a stimulating influence on the collaboration and goals for a project. However, this research shows that these factors are even more important when dealing with circular building methods.

For the management of networks, literature states the importance of a broad network, interaction and the nature of the relationship. This research adds to the existing literature, that for circular building methods, the broadness of the network is even more important than in regular projects or with any other innovation. This is due to the fact that circular building methods are affecting every small part of a project. This is contrary to other innovations as in those cases it is only affecting a small part of the project and therefore only needs a small part of the network.

The management of the supply chain, according to literature, is important for the trust, dedication to common goals, understanding, and expectation of core values and equality. In this research, it is shown that these factors also have a positive influence on circular building methods. This is because the sub-contractors are involved in the project early which provides the opportunity to use their knowledge in an early stage and prevent possible obstacles in an early stage that might show up later in the building process.

The building process is managed well when the protection of core values, progress & momentum, quality of results are kept in mind and when there is room for problems and solutions and when it is appealing for actors to participate. In addition to the current literature, this research shows that a well-managed building process has a positive influence for circular building methods as the actors together can develop common core values about circular building methods instead of individual core values.

This results in a more coherent attitude and quality of results. As circularity need integrality, it is even more important to develop these common core values with all actors together in an early stage.

Current literature states that for the facilitation of the learning process, knowledge sharing, focus, environment, and techniques are important factors. This research adds that it is not only important to have these factors within a project, but even so between projects, as that way the socio-technical regime can be reached. Next to that, this research identified that currently most learning about circular building methods is occurring spontaneously, while more structured and focused learning may provide better shareable knowledge about circular building methods.

The project-based nature and high amount of actors involved, are two of the characteristics of the building sector (Davidson, 2013; Migliore et al., 2016). Even though these characteristics are generally seen as barriers for innovation in the building sector, for the adoption of circular building methods these characteristics are desired. The project-based nature makes that actors are already used to working on different projects every time. This also applies to building projects with circular building methods, they are never the same. The amount of actors involved is an opportunity for building projects with circular building methods, as the new form of collaboration implies that all the different actors can insert their own knowledge. This way the integrality will be developed. Besides this, the fact that the building industry usually has a lot of actors involved also means that most actors probably have built a broad social network which can be useful when adding new actors to a project network.

As research about circular economy in the construction sector is only recently starting to develop (Pomponi & Moncaster, 2017), this research contributes to the existing literature. This research elaborates on the work about Multi-Level Perspective and Strategic Niche Management and shows how this connects to circular building methods. Especially the niche processes of learning and networking are considered for circular building methods. Most researches so far were lacking to take into account the complexity, integrality and inter-disciplinary of circularity. This research elaborates on these aspects specifically in the building sector.

6.4 Limitations

As every research, also this thesis has some limitations. It is important to realize some of these limitations.

The first limitation is due to the fact that this research is a case study. Only two cases are considered. More case studies would give a more reliable outcome which would be easier to generalize. However, it should be kept in mind that cases are generalizable to theories, not to populations or universes (Yin, 1994).

This research focusses on the Dutch building sector only. When extracting these findings to other sectors or regions, it is important to be aware of the similarities and differences between the Dutch building sector and the one of interest.

Next to this, external factors from the cases might have an influence on the experiences of the actors. For example, both cases take place in areas outside of the Randstad. This research does not focus on the fact whether this might influence the process or not.

In the theoretical framework, three main focusses of SNM are identified; learning, networking, and investment. However, the investment part is underexposed in this research.

There is also a limitation in the way 'trust' is operationalized. In literature, there are different ways to operationalize 'trust'. Wong, Cheung, Yiu, and Pang (2008) even developed a framework for trust in the construction contracting. Due to the scope of this thesis and the available data, the 'trust' aspect lacks a deeper operationalization.

Another limitation is that for case II the client is not included. However, a total of three clients – not from case II - have been interviewed. These three were different in terms of background and incentives. There are a lot of different kinds of clients and it is therefore barely possible to generalize all of them.

All the interviews that are conducted for this research were with actors who were either working with circular building methods or were very excited about it. A limitation for this research is that no conservative actors are involved. This makes that the conservative point of view is not exposed enough.

6.5 Recommendations for further research

This research contributes to the scientific knowledge of circular building methods as it identifies barriers for the adoption of circular building methods in building projects. In addition, this thesis elaborates on possible solutions to eliminate these barriers.

Based on the findings and limitations of this study, some recommendations for further research are given below:

1. More in-depth research

This research has been an exploratory research. Therefore more in-depth research will provide more knowledge about the adoption of circular building methods. This in-depth research could be focused on specific parts that are addressed in this research. For example; the improvement of trust within a network while working with circular building methods. Or how the learning in such a complex project can be better facilitated. However, the integrality between all the different aspects of a circular building project should always be kept in mind.

2. Test the role of integral manager for the general contractor

This research concludes that the general contractor could be a good option to take the role of integral manager. It is recommended to test and verify this in real life cases.

3. Design a new business model

A possible solution to eliminate the barriers is the use of a new business model. It is therefore recommended to design such a new business model. Some first suggestions for this business model are given in recommendation II in section 6.2. But more research needs to be done to shape this business model.

4. Include investment

The three main focusses for SNM identified in chapter 2 are learning, networking and investment. Investment was not part of the scope of this research. Including investment in the research results in a better understanding of the influence of the different niche focusses of SNM.

5. Just do it

Circular building methods are a very interesting topic to study, and there are still some knowledge gaps. However, to really obtain new knowledge it is time to just start using circular building methods. This way more knowledge will be gained and the transition can really start taking off.

7 Personal reflection

Writing this thesis has not always been easy for me. But looking back at this journey I can only admit that I learned a lot. Some of these lessons are very cliché like; when you have a writer's block, keep writing and read while looking for what you want to find. But other lessons were very valuable for me personally.

First of all, I have learned that writing a thesis is not easy. During my study, I have written several reports, which were never a problem for me. However, I struggled a lot while writing this thesis. It was hard for me to get my thoughts clearly on paper. Sometimes when I was reading back, I did not even understand what I had written myself. I missed a clear structure which resulted in insecurity from my side.

Another lesson that I learned is that conducting interviews is not as easy as it seems. Although I enjoyed the conversations a lot, sometimes I was not sure whether I really got all the information I wanted. This was mainly due to the fact that I needed to decide on the spot where to ask more questions and where not. Sometimes, while making the transcripts of the interviews, I realized that more subjects were addressed that might have been interesting to know more about. Same was for the focus group results.

Also when using the data from the literature I experienced barriers. I conducted my interviews in Dutch. This was on purpose to eliminate any language barriers and get the fullest of information from the interviewees. However, when I started using the data from the interviews it was sometimes hard the get a good translation for the quote. Sometimes the translation did not cover the message in the quote. In such a case I had to adapt the quote a bit to align it with its original content.

Probably the most important lesson that I have learned is about independence. I have always been proud that my parents have raised me to be very independent. However, during the last months, I have experienced a downside of being independent. As whenever I was struggling with something during this process, I would rather solve it myself instead of asking for help. Looking back now it would probably have been better if I asked for help sometimes. In my opinion, this is the most valuable lesson I have learned in the past month as it will be very useful for the rest of my career.

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9 Appendices

A. Overview interviews
B. Guiding interview questions and Atlas.ti codes related to hypotheses
C. Elaborate description roles
D. Design and full results focus group


SAMENWERKEN
KAN JIJ DAT OOK
ZO GOED ALLEEN
Loesje