Transition Experiments for Circular Construction: Learning-by-doing, *but how*?

A typology for transition learning in circular building experiments

Sietse Gronheid
MSc Industrial Ecology
Thesis Research Project

v

Transition Experiments for Circular Construction: Learning-by-doing, *but how*?

A typology for transition learning in circular building experiments in the Netherlands

Thesis Research Project
MSc Industrial Ecology
TU Delft & Leiden University

STUDENT

Sietse Gronheid	TU Delft: 5187109 Leiden University: s2623277
Date of submission:	October 18th, 2021

SUPERVISORS

First supervisor:	Prof.dr. Ellen van Bueren – Architecture and the Built Environment, TU Delft
Second supervisor:	Dr.ir. Jaco Quist – Technology, Policy and Management, TU Delft
Daily supervisor:	Ir. Mart van Uden – Architecture and the Built Environment, TU Delft
External supervisor:	MSc Malu Hilverink – Over Morgen

Executive summary

Context

The construction sector is a major contributor to global greenhouse gas emissions and resource depletion. To lower its environmental impact, a circular construction economy (CE) has been pushed forward by the sector and academia. Currently, the Dutch construction sector resides in the first phase of a transition, which consists of experimentation. Circular building experiments should trigger radical new ways of thinking and new ways of doing, called transition learning. 'Learning-by-doing' is the device, however, clear conceptual knowledge on how to achieve this is still understudied.

Purpose

The main goal of this research is to understand how circular building experiments could be designed in order to stimulate transition learning. The research focuses on stakeholders involved in the design and construction process of a circular building experiment. The main research question is divided in four sub-themes: *who learned* (the subjects), *learned how* (the process)*, learned what* (the objects) and *to what effect* (the outcome). The results should provide a conceptual understanding of learning in experiments for academia and provide practical insights to support practitioners in setting up future experiments. This research is conducted in collaboration with consultancy firm Over Morgen.

Theory

From transition literature three mechanisms – deepening, broadening and scaling up – are used to understand how experiments contribute to a wider transition. These are operationalized from an organizational perspective. *Deepening* relates to learning in the context of the experiment. Here, stakeholders should learn about new practices, cultures and structures. To assess whether this triggered radical change, three learning loops of organizational learning literature are used. These include single-loop (improvement without reflection), double-loop (improvement with organizational reflection) and triple-loop learning (learning how and what an organization should learn). These latter two are deemed necessary for transitions. The *effect* of these lessons learned is assessed through *broadening*, as the process of reproducing (elements of) the experiment in follow-up projects, and *scaling up*, referring to the institutionalization process of lessons learned.

Method

A multiple-case study approach is used in which four circular building experiments are researched via semi-structured interviews. Based on a longlist of circular building experiments (Appendix D) four cases were selected: Assinklanden (Enschede), SUPERLOCAL (Kerkrade), the Green House (Utrecht) and Vondeltuin (Amsterdam). In each case all stakeholders involved in the design and construction process are interviewed, resulting in 29 interviews. The interviews are transcribed, coded in Atlas.ti and analysed following a coding scheme based on a literature review.

Results

The case studies prove that double-loop learning is achieved in each experiment. These are obtained by builders and initiators who learned about three themes: *technical* (construction for disassembly), *economic* (new business models) and *process* (procuring for a CE). Individual- , group- and system reflection supports double-loop learning and could be achieved through essential activities of collaborative visioning, monitoring and evaluation. For this learning process, several conditions were found important: (1) collaborative approach, (2) diverse group of expertise (including cost-controllers and supply chain partners), (3) a clear vision, (4) commitment, (5) transparency, (6) trust, (7) time and budget (in line with ambition) and (8) agreement on risks and approach.

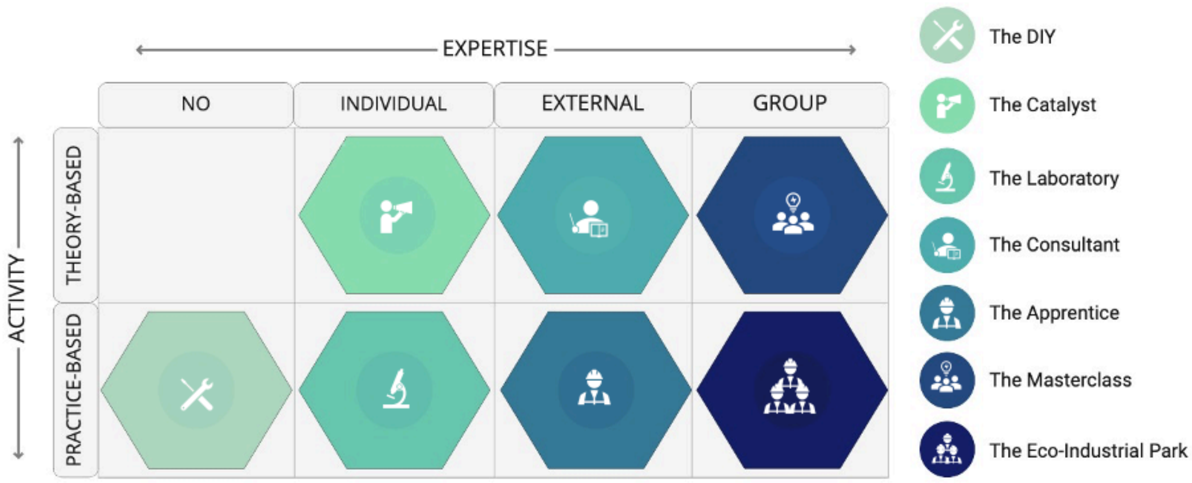
In addition, this research highlights barriers for the scaling up process of lessons learned. Technical learnings are hindered by (1) lacking broadening possibilities (no follow-up projects), (2**)** context

specificness of the lessons learned and (3) an overheated construction market. Economic lessons learned regarding new circular business models are obstructed by (4) regulations, (5) negative perceptions of other colleagues and (6) lacking internal competences to model with circular business models. Ultimately, (7) a missing learning structure to connect lessons learned to was a main barrier for four large organizations. These limited the effect of transition learning.

Furthermore, the emphasis of how to achieve double-loop learning differs in each experiment. These could be exemplified by four transition learning *flavours*: *The Masterclass* (group learning based on theory) represented in Assinklanden, *the Laboratory* (technical, practice-based learning) characterizes SUPERLOCAL; *the Catalyst* (internal individual expertise) reflects the learning process in the Green House; and *the Consultant* (external expertise) resembles learning in the Vondeltuin.

Discussion

These transition learning *flavours* were further discussed. It is argued that transition learning in an experiment comes from two axes, as shown in the figure below. The first is based on activities, which were either theory-based (designing) or practice-based (testing). The second relates to expertise, consisting of individual, external or group expertise. Based on theoretical reasoning, 'no expertise' has also been added. From this, seven learning *flavours* are introduced of which the above-mentioned four have been proved empirically. Each of these *flavours* trigger double-loop learning, where it has been shown in the cases that combinations of flavours can be made (as shown in Figure 6.1, p. 119). Depending on the context, these *flavours* yield different outcomes. A group approach results in a variety of double-loop learning, and can be recommended. Available time influences the depth and number of combinations possible. As well as the previously introduced transition learning conditions. These *flavours* provide a toolbox on how to design circular building experiments. The hexagons can be connected, where the emphasis (size of the hexagon) and the combinations of hexagons can differ per phase of the development.



Conclusion

This research provides evidence that circular building experiments are an effective means to create change for a transition. However, this research also shows that careful attention should be paid to the learning structure in these experiments *and* in the organizations involved. The transition learning *flavours* provide a typology for learning in experiments and allow researchers to understand, set-up and evaluate transition learning experiments. Here, combinations of *flavours* can yield different outcomes. The following conclusions are found:

- Circular building experiments trigger double-loop learning for different stakeholders in different experiments. These are generated by individual, group and system reflection.
- A collaborative approach and group visioning stimulates double-loop learning. Ensuring these in experiments is highly recommended.

- Monitoring positively impacts transition learning. As this was only properly addressed in one case, it is recommended to dedicate time for reflection and evaluation. This should include both quantitative (circularity) and qualitative (learning process) monitoring.
- Setting up an experiment as a series (broadening) supports the scaling up potential of innovations. Here, focusing on 'small wins' instead of solving the entire system and ensuring follow-up experimentation projects is recommended.
- Broadening is essential for circular construction, therefore before starting an experiment, lessons learned of other experiments should be collected and internal lessons aggregated. Intermediary actors (CE platforms) are important in this process and should be involved.
- Clients and principal contractors are influential regime actors and should learn in circular building experiments.
- Circular buildings often include a different business model. Including cost-controllers in the experimentation process is important for scaling up economic lessons learned.
- Circular construction is often hindered by regulations. Public controllers should be involved to gain insight in systemic failures and can stimulate the possibilities of the experiment.
- Not all organizations follow-up on the lessons learned. Time should be dedicated before the start of the collaboration and after each decisive phase on how lessons learned are integrated in the organization.

Recommendations and implications
For academia, the transition learning *flavours* should be further explored on their completeness and applicability. For practitioners: continue the experimentation process. To do so, a roadmap with checklist questions (see Chapter 7.3, p. 131) has been developed to maximize the transition learning potential. Ultimately, the scope of this research did not allow for an in-depth understanding of triple-loop learning in organizations. More research on the post-experimentation process of organizations involved in circular building experiments is recommended.

Acknowledgements

Today, October 18th, 2021, marks the end of a challenging, yet rewarding process. Looking back on the entire process, I am very happy that I have managed to combine two fields of interest in my final product: spatial planning and a transition towards a CE. For me personally, the greatest added value of this research, and something I initially hoped for, is the confirmation that I want to pursue a career in this domain. With all those double-loop learnings gained from this research, I have a solid foundation to build on and I am curious what the future has in store. All of this, was never possible without the great support I have experienced during the past 8 months.

First of all, I want to thanks my academic supervisors, where I was the lucky one of not having *two*, but *three* supervisors. My first word of thanks goes out to Ellen van Bueren. I still remember the day I sent you a request for thesis supervision. It felt like a long-shot, where Erwin Heurkens said I could try, but given your busy schedule, he did not expect the odds to be on my side. The combination of circular construction and ULL proved to work well and I felt honoured to have you involved. The monthly progress meetings were always accompanied with laughter and I want to thank you for all your sharp and pragmatic advice. Especially the latter was important for me, because if I had not, I would still be wandering in the depths of Web of Science somewhere.

Secondly, I want to thank Jaco Quist for your thoughtful feedback. Even though I was well trained in transition literature through SUISCY (where I think no IE'er will ever forget the MLP), you still surprised me with critical points of attention and introduced me to learning literature. Furthermore, the Zoom-calls always brought a smile to my face whenever you would pop in with a Hawaiian background. I appreciate the time you made available for me.

Thirdly, I want to thank my academic pillar of strength: Mart van Uden. As my "weekly supervisor" you have supported me a lot throughout this process. I want to thank you for all your advice, brain teasers and availability. Even up until the last week, where in my mind I was already preparing for the "dots on the I", but you kept challenging me to raise the academic bar. A big thanks to you.

Next to my academic supervisors, I want to give thanks to Over Morgen and with that to Malu Hilverink and Thijs Aarden (and of course the rest of the team) for giving me the opportunity to combine academic work in a professional environment and your support throughout the process. I have always felt part of the team, which is not a common feature for graduate researchers. You are doing amazing work and I just want to say keep up the good work!

Finally, last but definitely not least, I want to thank my partner Guusje, who had to endure my highs and lows throughout the process and who could not wait for me to hand it in. Let the good times begin. And of course a big thank you to my parents for their support and giving me the opportunity to study. Something I do not want to take for granted.

And to whoever is going to read the entire piece: Best of luck and enjoy!

Sietse Gronheid

Amsterdam, October 2021

Table of Contents

v

Chapter 1. Introduction

1.1 Context and problem

Urban areas play an important role in the environmental pressures' planet earth is experiencing. It is estimated that urban areas consume 60-80% of all extracted natural resources on earth, contributing to over 70% of worldwide greenhouse gas emissions and producing 50% of global waste streams (Williams, 2019). More specifically, the construction sector is the largest consumer of raw materials and contributes to 25-40% of all global CO_2 emissions (WEF, 2016). This contribution is likely to become even larger as the percentage of people living in urban areas is expected to grow from 55% in 2018 to 70% in 2050 (UN, 2019). Furthermore, urban land cover is expected to triple in 2030, leading to a loss of habitats, biomass and carbon storage (Seto et al., 2012). These facts emphasize the need to rethink society's current linear economy in which resources are consumed according to the 'take, make and waste' principles. A circular economy (CE) has been advocated as a favourable alternative offering environmental, social and economic advantages (Kirchherr et al., 2017). In a CE, biological cycles are *regenerated* and technical cycles are *restored* following multiple feedback loops (Ellen MacArthur Foundation, 2019)

In the Netherlands, the value of a CE has been acknowledged, where in 2016 a government-wide program was launched to realize a CE by 2050 (Rijksoverheid, 2016). The goal of the program is to develop an economy which meets societal needs without causing unacceptable environmental pressures and preventing the depletion of natural resources. In the program, the construction sector is one of the five strategic priorities which cause large environmental pressures. The Dutch construction sector faces a major challenge in the coming decades, where, for example in the housing sector it is expected that 80,000 houses need to be built annually until 2030 to meet demand, while simultaneously CO_2 emissions need to drop to 49% of 1999 levels (Circle Economy, 2020). To transition the construction sector into a less carbon-intensive industry, changes are necessary, which according to the program demand technological, social and systemic innovations.

1.2 Experiments for a CE and research motive

One form to trigger these innovations is through experiments. Experiments have been widely cited in literature to support transitions by creating space for innovative solutions to develop (Kemp et al., 1998; Loorbach & Rotmans, 2006; Schot & Geels, 2008) and are considered the starting point for transforming a system (Fuenfschilling et al., 2019). Experiments come in different forms and various scholars have developed a typology of the diverse set of experiments (Ansell & Bartenberger, 2016; Kivimaa et al., 2017; Sengers et al., 2019). For this research the definition of Sengers et al. (2019, p. 153) is adapted where 'experiments' are referred to as "*practice-based and challenge-led initiatives, which are designed to promote system innovation through learning under conditions of uncertainty and ambiguity."*. Here, experiments are conducted in society to introduce new technologies or practices that can shift societal needs, as opposed to experiments in the natural sciences which are often performed in a controlled environment, such as a laboratory (Sengers et al., 2019). Furthermore, the term 'experiment' differs from the term (pilot or demonstration) 'project' as in experiments *learning* takes a more central role (Hoogma et al., 2005).

This learning component is essential to transform a system and trigger a new (socio-technical) configuration (Sengers et al., 2019). The extent to which organizations learn, highly influences the transformational potential of an experiment (Van den Bosch & Rotmans, 2008). To assess this, in literature a distinction is made between single-loop (improvement without reflection), double-loop (improvement with organizational reflection) and triple-loop learning (learning how and what an organization should learn) (Argyris & Schon, 1974; Bartunek & Moch, 1987). These latter two, are considered *higher order learning*, which are deemed necessary for transitions as these influence the frame of reference of actors and provide insights on how to tackle a problem, such as reducing the environmental impact of the construction sector (Hoogma et al., 2005; Kemp & van den Bosch, 2006). However, research has shown that higher order learning is not always subject to experiments (e.g. the Rügen case in Hoogma et al., 2002) and the lacking involvement of important actors in experiments can hamper niche innovations from breaking through (Schot & Geels, 2008).

Furthermore, experimentation and 'learning-by-doing is pushed forward as the means to transform the construction sector into a circular one, as shown in the roadmap towards a circular construction economy (Figure 1.1) by Platform CB'23 (2020) – a sector-led platform to support circular construction in the Netherlands. Via experimentation (2018-2023), acceleration (2023-2030) and emergence and institutionalization (2030-2050) the circular construction sector should take shape. This research zooms in on this first phase, where experiments should trigger *"radical new ways of thinking and radical new ways of doing"* (Platform CB'23, 2020). Whether and how this occurs, in combination with the fact that clear conceptual knowledge of learning processes in sustainability transitions is still lacking (van Mierlo & Beers, 2020), fuelled the need for this research.

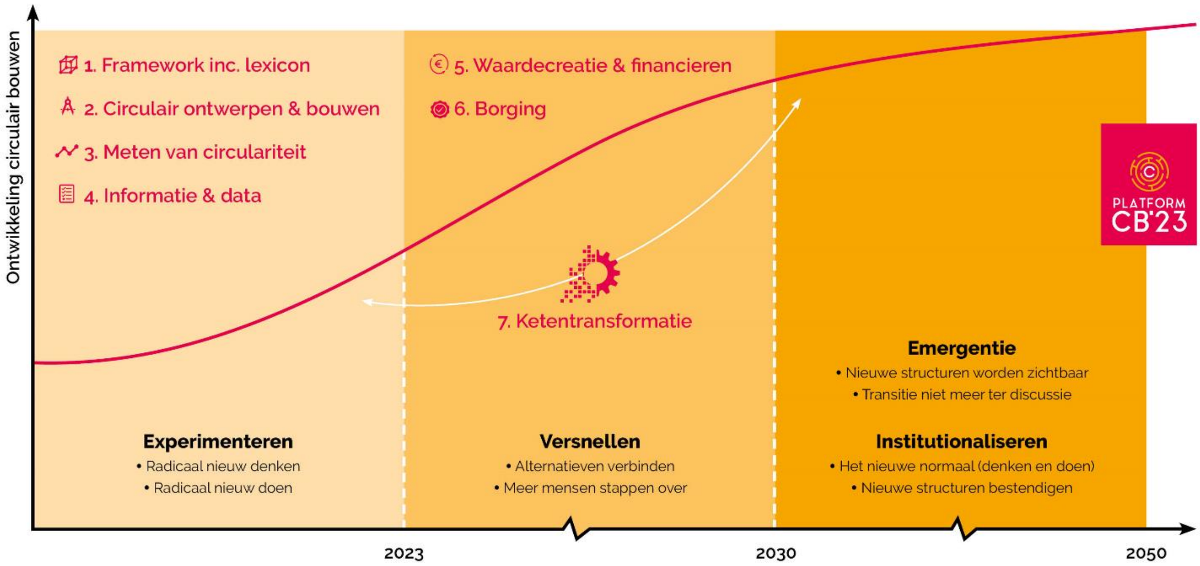


Figure 1.1. Overview of the transition pathway for circular construction according to Platform CB'23 (2020).

1.3 Aim and research questions

Taking this as a starting point, this research aims to assess the learning dynamics of transition experiments for circular construction; to ultimately understand how such an experiment should be approached and designed in order to stimulate transition learning among the involved stakeholders. By adapting the transition learning framework of Van de Kerkhof & Wieczorek (2005), who have analysed policy learning processes in transition projects, and applying these on circular building experiments, clearer insights will be given on learning processes in these experiments. Their transition learning framework is based on (1) the subjects (*who learns*), (2) the objects *(learns what*), (3) the process *(learns how*) and (4) the effect of the learnings (*to what effect*). Furthermore, by supporting this with transition literature, guiding principles will be clarified that are necessary to support learning in and from experiments to accelerate a wider CE transition in the construction sector. To do so, a multiple-case study approach will be used to answer the following central research question:

How could transition experiments for circular buildings in the Netherlands be designed in order to stimulate transition learning among stakeholders involved in the design and construction process?

v

To address this main research question, the following sub research questions will be answered:

1. Which stakeholders involved in the design and construction process need to learn from circular building experiments?
2. How do stakeholders learn in circular building experiments?
3. What do stakeholders learn and to what extent can higher order learning be identified among stakeholders involved in the circular building experiment?
4. How are learnings from circular building experiments embedded and diffused by involved stakeholders in order to support a transition in the construction sector?

1.4 Relevance for Industrial Ecology

This research is exemplary for the Industrial Ecology (IE) programme, as the concept of CE is rooted in the origins of IE. Essentially, IE stems from the idea that industrial systems should be viewed and approached in the same way as biological ecosystems, therefore integrating activities and the cycling of resources, as happens in biological systems (Graedel, 1996). This is also the basis of the concept of CE, which seeks to increase more efficient use of resources by adopting economic models of closed material loops to improve the balance between economy, environment and society (Ghisellini et al., 2016; Kirchherr et al., 2017). In this research, the industrial activities will be targeted to the construction sector (*Industrial*), to explore ways to implement more circular and environmentally-sound solutions (*Ecology*). This solution-oriented focus for sustainability challenges is also one of the core characteristics and foundations of the IE-programme. Furthermore, IE takes an integrated perspective from environmental, technical and social sciences. However, it is argued that IE rests on a technological bias, where the field can still benefit from a social science perspective (Boons & Howard-Grenville, 2009). Therefore, this research adds a social perspective towards a technology-oriented field. This perspective can be seen as an important element to the transition towards a circular construction economy in the Netherlands, which it is not “simply” a technological fix. As Brown & Vergragt (2008, p.110) put it:

> “Sustainability will not be reached by technology alone, but by deep learning by individuals, groups, professional societies and other institutions.”

1.5 Thesis outline

This research will be of explorative nature and is divided in seven chapters. After this introduction, Chapter 2 embeds this research topic in a state-of-the-art literature review, which ultimately introduces a guiding conceptual model. Chapter 3 explains the motive for multiple-case study research, the research design and how the cases have been found. The four selected cases are then extensively elaborated in the Chapter 4. After these separate case-studies, Chapter 5 will compare the four cases to understand any differences and similarities. In Chapter 6 these empirical findings will be discussed and embedded in broader academic debates. Furthermore, the main academic contributions will be exemplified and a reflection on the methods and limitations will be given. Ultimately, in Chapter 7, the central research question will be answered in the conclusion and key directions for future scientific research and practical recommendations, as well as implications, will be proposed.

Chapter 2. Literature review

This chapter dives into the literature of central themes of this research by explaining definitions, defining trends and identifying a literature gap. It follows a funnel approach where at first the topic of the CE is explained, in which a leading definition is proposed. Afterwards, CE will be linked to the built environment to understand the status quo. Following this, transition theory will be introduced, the role of experiments for transitions will be explained and a conceptualization of how learning processes can be assessed in experiments will be developed.

2.1 Introducing a CE

The CE is a theme which has gained momentum by practitioners and scientists, and even dubbed by some as the new sustainability paradigm (Geissdoerfer et al., 2017). This is because CE could go beyond the concept of 'sustainable development' or 'green development', which was labelled vague and unimplementable (Engelman, 2013), and could be operationalized by businesses and organizations (Ghisellini et al., 2016). However, as the body of literature is growing year after year, clear consensus about what a CE entails conceptually was lacking. To create transparency and prevent 'blurriness' of the concept, Kirchherr et al. (2017) analysed 114 different CE definitions and came to a comprehensive definition. Their definition of a CE is used in this research, which entails:

> "CE is an economic system that replaces the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes (…), with the aim to accomplish sustainable development, thus simultaneously creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations." (Kirchherr et al., 2017, p. 229)

Hereby, the importance of the *waste hierarchy* and the *systems perspective* should be emphasized (Kirchherr et al., 2017). The waste hierarchy is described as a priority order of favoured to unfavoured waste management options based on their environmental impacts. Here, the 9 R's as proposed by Potting et al. (2017) are often cited (e.g. Kirchherr et al., 2017). The 9 R's are depicted in Figure 2.1 and show the preferred circular strategies (refuse) over the less preferred, more linear, strategies (recover). The basic assumption is that in the higher circular segments fewer natural resources are necessary, which correlates with less environmental pressures. Another often used visualization is the *butterfly diagram* by the Ellen MacArthur Foundation (2019), which includes a biological cycle and a technical cycle, which are characterized by feedback loops indicating retaining the flow of materials, energy and information in the system. For the technical cycle this includes retaining the highest utility value (R-ladder) of materials and products at all times (*restorative*). For the biological cycle (the other wing of the butterfly) this encompasses biological materials (e.g. food or cotton) that can return to a natural system (*regenerative*) (Ellen MacArthur Foundation, 2019).

Next to the waste hierarchy, it is important to include systemic change in the definition, which necessitates the fundamental shift CE needs over incremental shifts. Here, Termeer et al. (2017) add to this discussion stating that thinking in this divide, *transformational/fundamental change* (revolutionary, systemic and quickly achieved) vs. *incremental change* (shallow, partial and slow), is not fruitful as revolutionary, systemic and quick changes are hard to achieve because of their trade-offs. Rather, they propose *continuous transformational change*, which focuses on a series of *small wins*, which are in-depth (innovative and fundamental) and quick, but are not aimed at solving the entire system, but a part of it. This perspective offers nuance to the systemic change discussion. These changes can then be targeted to different levels: from micro- (products, businesses, consumers), to meso- (eco-industrial parks or regional levels), to, ultimately, macro-level (city, region, country etc.). The systemic and resource focus are furthermore essential elements of the industrial ecology perspective (Hertwich, 2005).

v

Smarter product use and manufacture	**R0: Refuse**	Make product redundant by abandoning its function or by offering the same function with a radically different product
	R1: Rethink (*slowing*)	Make product use more intensive (e.g. through sharing products)
	R2: Reduce (*narrowing*)	Increase efficiency in product manufacture or use by consuming fewer natural resources and materials
Extend lifespan of products and its parts	**R3: Re-use** (*slowing*)	Re-use by another consumer of discarded product which is still in good condition and fulfils its original function
	R4: Repair (*slowing*)	Repair and maintenance of defective product so it can be used with its original function
	R5: Refurbish (*slowing*)	Restore an old product and bring it up to date
	R6: Remanufacture (*closing*)	Use parts of discarded product in a new product with the same function
	R7: Repurpose (*closing*)	Use discarded product or its parts in a new product with a different function
Useful application of materials	**R8: Recycle** (*closing*)	Process materials to obtain the same (high grade) or lower (low-grade) quality
	R9: Recover (*closing*)	Incineration of materials with energy recovery

Figure 2.1 The 9 R's: Strategies for a CE. Follows a priority order of favoured to least favoured options (Potting et al., 2017). Behind the R-strategy is the circular business model strategy (*slowing*, *closing* or *narrowing*) as proposed by Bocken et al. (2016) which will be further elaborated on in Chapter 2.2.3.

2.2. CE in the built environment

Since the 1990s different efforts have been proposed to reduce the environmental pressure of the building sector. Pomponi & Moncaster (2017) identified two paradigms and introduced a new one. In making buildings more environmentally-sound, the first paradigm was aimed around 'green buildings'. However, with a sole focus on the use-phase and technological improvements of the building, it did not deliver the necessary systemic changes to reduce its environmental impacts. The subsequent sustainability-paradigm addressed these shortcomings by expanding the scope to include environmental impacts over the building's life-cycle. However, as Pomponi & Moncaster (2016) mentioned, it was mainly centred around the reduction of energy consumption and CO_2-emissions, where day-to-day practices in the building sector did not change, nor did It spark systemic changes. In aiming to achieve this, a CE-paradigm is pushed forward by practitioners and academics based on the foundations of a sound management of resources to reduce the demand of finite resources and accompanying environmental impacts (e.g. Pomponi & Moncaster, 2017; Hart et al., 2019; Regina Munaro et al., 2020). In this research the definition of *circular construction* of Platform CB'23 (2019) will be used:

> "(…) developing, using and reusing buildings, areas and infrastructure without unnecessarily depleting natural resources, polluting the living environment and affecting ecosystems. Building in a way that is economically and ecologically responsible and that contributes to the well-being of humans and animals, for current and future generations" (Platform CB'23, 2019, p.12)

v

2.2.1 Characteristics

CE in the built environment can be analysed on different levels, each with different characteristics. Pomponi & Moncaster (2017) developed a framework for CE research in the built environment and stress the differences in the scope of analysis. They identify three levels: the micro-level (building components), the meso-level (buildings) and macro-level (neighbourhood, city, region), as depicted in Figure 2.2. Furthermore, they state that most research has focused on the component level (micro-scale) or on city/neighbourhood level (macro-scale) and specific focus on the building-level of CE research is lacking. For this research the focus will be drawn to the building level, which consists of all structural components that perform one function. The following definition of a *circular building* will be used for this research:

> "A circular building is designed and constructed conform the circular design principles[1] and realized with circular products, elements and materials." (Platform CB'23, 2019, p.12)

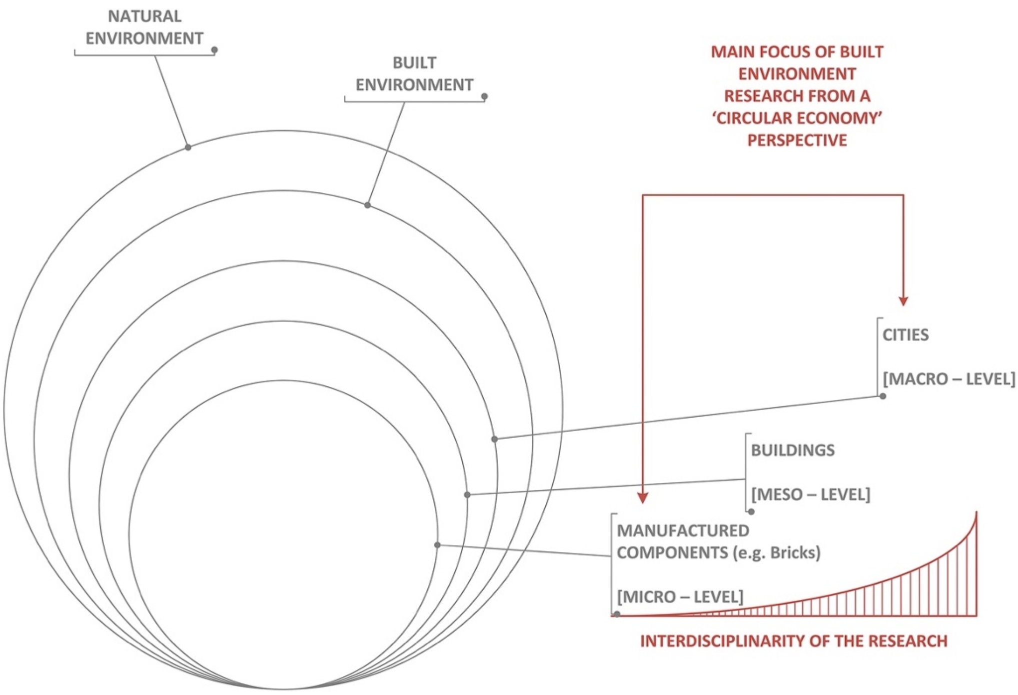


Figure 2.2 Different scopes of analysis for CE research in the built environment. The inner circle represents the micro-level (building materials), and it subsequently zooms out to the meso-level (buildings) and macro-level (cities). Derived from Pomponi & Moncaster (2017).

For CE-practices on the building level there are different distinct features which need to be taken into account: (1) buildings tend to have a long-life span (60-90 years), so solutions for a short-life span are less likely to be used for buildings and (2) buildings are comprised of separate manufactured products (e.g. bricks, insulation material etc.), but when assembled they form a unique, complex "entity", which does not follow any standard manufacturing process anymore (Pomponi & Moncaster, 2017). This was already visualized by Brand (1995) in his shearing layers model, which indicates the different lifespans of each layer of a building, depicted in Figure 2.3. Hart et al. (2019) also stress these characteristics and add to this that the built environment is characterized by a wide array of stakeholders, hundreds of components and corresponding materials, that all interact. From a systems perspective it is important to keep these characteristics

[1] Circular design principles are listed in Appendix A.

in mind when developing, refurbishing or deconstructing a building, so that components can be harvested at their end-of-life state (Kirchherr et al., 2017).

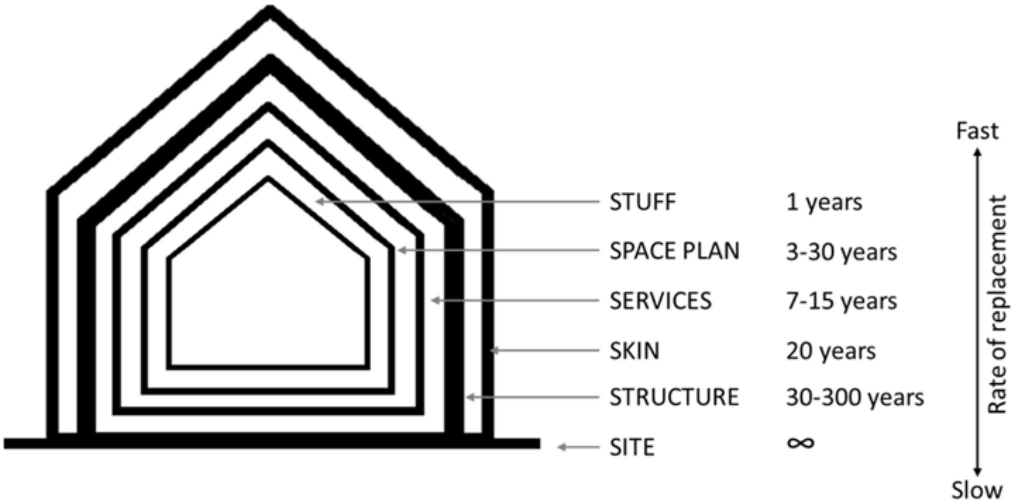


Figure 2.3. The shearing layers model of Brand (1995) indicating the different lifespan of each layer of a building. Derived from (Eberhardt et al., 2019)

2.2.2 The construction process

To understand how the development of circular buildings takes place, it is first of all valuable to understand how the conventional, linear construction process of a building occurs. Even though construction projects are single-production products and therefore often unique (Arditi et al., 2004), four distinct phases of the development of a building can be identified as proposed by Wamelink et al. (2010). It starts with the *initiation phase*, in which the program requirements are developed, followed by the *preparation and design phase*, in which the program requirements are translated in an architectural design. Subsequently the development starts in the *construction phase*, where a detailed implementation plan is used which includes defining the tasks and activities, selecting and contracting subcontractors, defining the budgeted resources and planning and realizing the activities. Finally, in the *use-phase* the building is used and maintained. In conventional development processes, the end of life (EoL) of a building is not included. This is included in the development of a circular building, which focuses on its entire lifecycle, including the end of its first-use cycle. According Platform CB'23 (2021) the development of a circular building consists of five phases: (1) initiative, (2) design, (3) construction, (3) use and maintenance and (5) repurposing and deconstruction, as depicted on the right side of Figure 2.4.

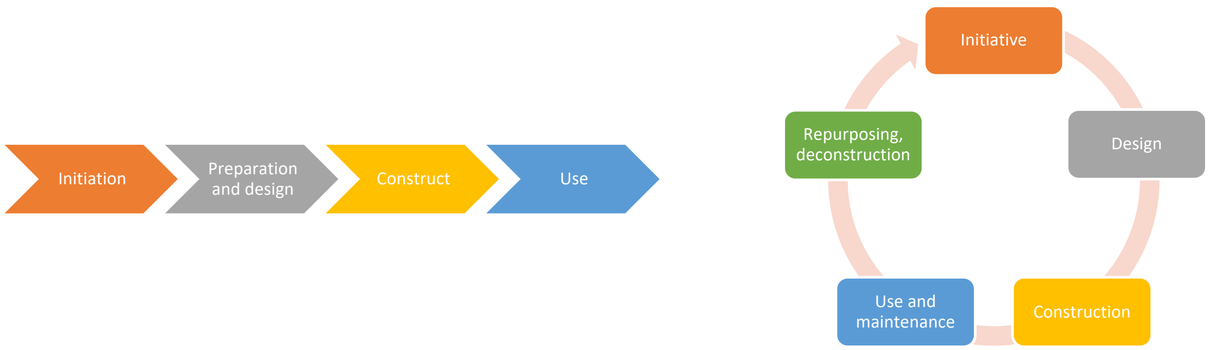


Figure 2.4. The difference between a traditional linear building process (on the left) (Wamelink et al., 2010) and a circular building process on the right (Platform CB'23, 2021).

v

2.2.3 Enablers, barriers and a research framework

In aiming to understand what can be learned in and from circular building experiments, this paragraph will zoom in on different research themes which are of interest when analysing a CE in the construction sector, to ultimately integrate these in a research framework. As different scholars classified CE barriers, enablers and research themes under different categories (e.g. Hart et al., 2019; Kirchherr et al., 2018; Pomponi & Moncaster, 2017), overlap between the categories occurred. Therefore, for this research an integration of categories was made, in which the six research pillars of Pomponi & Moncaster (2017) are merged into five research categories, where the pillars 'behavioural' and 'societal' will be combined into a new category named 'cultural', following a conceptualization of Hart et al. (2019) and Kirchherr et al. (2018). The five research categories and associated research elements are listed and defined in Table 2.1. Important to note, the content of this table is derived following a literature review and aimed to be comprehensive, however it could be the case that other topics are found empirically.

Table 2.1 Integrated research framework indicating different research for circular construction.

1 Economic	2 Governmental	3 Environmental	4 Cultural	5 Technical
• Business model innovation • Business model experimentation • Investment costs • Funding	• Laws and regulations • Incentives • Consistent regulatory framework	• Impact assessment • Impact categories	Organizational: • Silo mentality • Knowledge/skills • Perception Sectoral: • Collaboration • CE interest • Acting in a linear economy • Sector characteristics	• Design practices • Construction practices

Economic

Pomponi & Moncaster (2017) refer to the economic pillar mainly from a business model perspective. From this perspective, business model innovation is seen as a necessary element to cope with increased pressures on finite resources and to transition towards a CE (Bocken et al., 2018). Business models for circular buildings require new ownership models and earning strategies (Pomponi & Moncaster, 2017). Bocken et al. (2016) looked at *circular business model strategies* for which three main strategies need to be kept in mind: (1) slowing, (2) closing and (3) narrowing resource loops, as linked to the 9 R's in Figure 2.1. *Slowing* refers to extending and/or intensifying the use of a product, for example through repair or remanufacturing services. *Closing* refers to connecting the post-use phase with the production phase through reuse or recycling, which stimulates a circular resource flow. *Narrowing*, also called resource efficiency, relates to using less resources per product. As resource efficiency has already been successful in linear business models and can be included in both *slowing* and *closing* resource loops this was not further elaborated on by the scholars. When linking this to experiments, Bocken et al. (2018) looked into *circular business model experimentation*, which can help companies to make the first steps from a business as usual model towards a circular business model, which supports slowing, closing or narrowing resource loops. Circular business model experimentation supports organisational learning on how to shift towards a circular transition (Bocken et al., 2016) and will therefore be analysed in this research.

In literature, different barriers have been found relating to the economic aspect of CE. Both Kirchherr et al. (2018), who assessed European CE-barriers, and Hart et al. (2019), who assessed CE-barriers in the built environment, found that (1) low prices of virgin materials, (2) high upfront investment costs and (3) limited funding hamper successful CE development from a business perspective. High upfront investment costs relate to the first mover advantage, where companies that move first are often confronted with high research and development costs (Kirchherr et al., 2018). For the built environment this means the development of new infrastructures, such as reverse logistics, R&D and new certification and compliance processes for CE-activities (Hart et al., 2019). Limited funding and access to finance is seen as a major barrier in different sectors, as well as for the built environment (Hart et al., 2019), which can be assessed for circular building experiments. Contrarily, low prices of virgin materials are important to tackle in order to support a CE transition, however, exceed the scope of this research and are therefore not included. To conclude, in assessing the economic perspective of circular building experiments focus will be drawn to the business perspective, focussing on business model innovation and experimentation and the role of investment costs and funding, as described in Table 2.2.

Table 2.2. The four research themes for the economic category, including their description.

Economic pillar	Description
Business model innovation	In circular building experiments business model innovation might be applied through three strategies: slowing, closing or narrowing resource loops (Bocken et al., 2016).
Business model experimentation	Circular business model experimentation can help initiate a sustainability transition in businesses (Bocken et al., 2018)
Investment costs	High upfront investment costs can hamper the development of a CE in the construction sector (Hart et al., 2019; Kirchherr et al., 2018) .
Funding	Limited funding and access to finance can occur as a barrier. For leasing models often long-term finance is necessary (Hart et al., 2019)

Governmental

The governmental pillar is referred to by Pomponi & Moncaster (2017) as governmental- and policy-support, such as municipalities envisioning a circular city or national or European-level tax breaks. In literature, policy and regulations are often mentioned as barriers or enablers. Kirchherr et al. (2018) indicate that (1) obstructing laws and regulations, (2) limited circular procurement and (3) lacking global consensus were found as main regulatory barriers. Hart et al. (2019) also found obstructing laws and regulations and a lack of a consistent regulatory framework (including a lack of global consensus and public targets) as main barriers. Next to these, they further add a lack of incentives, which can be understood as public procurement and tax incentives. Contrarily, (1) policy support through public procurement, (2) regulatory reform (to reduce obstructing regulations) and (3) incentives (e.g. VAT reduction in CE construction projects) are seen as enablers. Adams et al. (2017) state that legislation and policy did not occur as the most pressing challenges for CE in the construction sector, however ambiguous regulations for end-of-waste handling were found to be the most important barrier in this category, especially indicated by demolition contractors.

To conclude, the governmental pillar can be understood as all activities that public authorities perform to support or hamper CE-activities. The associated activities are listed in Table 2.3. Given the Dutch government's focus on achieving a CE, as mentioned in Chapter 1.1, a lack of consensus is not expected to be a main barrier for developing circular buildings. However, a lack of public targets should be taken into account in the category 'regulatory framework'.

Table 2.3 An overview of the different research themes considering the governmental research pillar.

Governmental pillar	Description
Laws and regulations	Laws and regulation can obstruct or enable CE-activities, such as the categorization of waste for the reuse of materials and components.
Incentives	Public procurement and tax incentives/breaks
Consistent regulatory framework	Refers to public authorities' targets to achieve a CE

Environmental

The environmental perspective is referred to by Pomponi & Moncaster (2017) as the expected lower environmental impacts that CE-practices can have over the use of new products. This can be seen from both a resource slowing and from a resource closing loop. From a resource closing perspective, Ghisellini et al. (2018) looked at environmental and economic cost and benefits of CE practices in the construction and demolition sector. Based on a literature review of Life Cycle Assessment (LCA) studies, they found that most cases in which construction or demolition waste was reused or recycled, both environmental as economic benefits were achieved. However, stressing the need to keep site-specific conditions and factors in mind, such as material type, building elements, transport distance and the economic and political context as key elements influencing these potential benefits. Therefore, emphasizing that the sustainability benefits of CE-practices via *reduce, reuse, recycle* are site-specific outcomes and cannot be defined beforehand, which stresses the need to measure the environmental impacts of novel CE-practices.

From a resource slowing perspective, new business models that are aimed at extending the lifetime of a product should be critically reviewed to what extent environmental and social benefits are obtained. Bocken et al. (2018), for example, stress the fact that new business models, through for example Product Service Systems (PSS), do not automatically lead to environmental benefits. Therefore, in applying new models, the environmental impact should be checked through soft checks, referring to whether new models still include elements of resource slowing or closing, and hard checks through environmental assessments like LCA (Bocken et al., 2018). This emphasizes the need to measure the environmental impacts of new circular practices applied in circular building experiments.

Table 2.4. An overview of the environmental research pillar.

Environmental pillar	Description
Environmental impact measurement	New CE practices can have mixed environmental results (Bocken et al., 2018; Ghisellini et al., 2016). For circular building experiments it is interesting to see to what extent environmental impact assessments are applied (e.g. LCA/LCC)

Cultural

In literature, cultural barriers and enablers for a CE have been grouped differently by various scholars. For this research, the *cultural* category includes aspects related to (1) an organization, such as behaviour, managerial skills and company culture and (2) the sector, such as collaboration, willingness and sectoral characteristics. An overview of these aspects is given in Table 2.5.

From an organizational perspective, different topics can be identified. Hart et al. (2019) refer to a lack of collaboration between business functions within an organization, also called *silo approach*, as a barrier to move towards a common goal, and a *lack of knowledge and skills* within the organization. An information/knowledge related barrier was also found by Ghisellini et al. (2018), who state that a lack of information on the quality of recycled products, uncertainty about their durability and assumed higher costs, hampered the implementation of CE-practices in construction projects. Furthermore, they refer to *managerial skills* as a barrier, which can be understood as a focus on the lower ladders of the 9 R's model (Figure 2.1) instead of preventive solutions (Ghisellini et al., 2018). Contrary, leadership and systems thinking, as managerial skills, are seen as key enablers for realizing a CE (Hart et al., 2019). A third organizational aspect has to do with *perception*, where Pomponi & Moncaster (2017) refer to the 'behavioural pillar'. This has to do with the perception on why people or organizations embrace CE principles. Ghisellini et al. (2018) found a negative perception of clients about the capacity of reused/recycled products a barrier for adopting CE principles in construction and demolition.

From a sectoral perspective, different aspects need to be taken into account. Hart et al. (2019) refer to a *lack of interest in the value chain* of the construction sector for CE, which resonates with 'hesitant company culture' and 'lack of consumer interest' found by Kirchherr et al. (2018) indicating that CE is a niche discussion. Here should be noted that the 'lack of CE interest' can also refer to the organizational level, where employees experience a lack of interest or hesitant culture within their

v

company. A second sectoral element relates to *'acting in a linear economy'* (Hart et al., 2019; Kirchherr et al., 2018), where CE infrastructures are not in place which poses practical issues. Thirdly, *collaboration and partnerships* between businesses is widely cited as an important aspect for CE in the built environment (Debacker et al., 2017; Hart et al., 2019; Pomponi & Moncaster, 2017). This can be vertical collaboration (in the supply chain) or horizontal collaboration (such as the willingness to share supply chain assets) (Hart et al., 2019). Fourthly, and finally, there are some *characteristics of the construction sector* that need to be taken into account: the competitive nature (Adams et al., 2017), its conservativeness (Debacker et al., 2017) and the complexity of buildings (long product lifecycles, multiplicity of actors and technical challenges) (Hart et al., 2019).

Table 2.5 Overview of the different cultural CE aspects relating to the organization and the sector.

	Cultural	Description
Organizational	Silo mentality (internal)	An organization's internal structure and collaboration can influence the move towards a CE (Hart et al., 2019)
	Knowledge/skills	Internal skills, availability of information and knowledge and managerial skills can enable or block the implementation of CE practices (Ghisellini et al., 2018; Hart et al., 2019).
	Perception	The perception of individuals and organizations towards embracing CE principles (Ghisellini et al., 2018; Pomponi & Moncaster, 2017)
Sectoral	Collaboration	Collaboration and partnerships are seen as essential in moving towards a CE
	CE interest in value chain	The interest in the value chain of the construction sector (from producer to consumer) in CE can influence the transition (Hart et al., 2019; Kirchherr et al., 2017).
	Acting in a linear economy	Sector is organized as a linear economy, infrastructures for CE-practices are not in place.
	Construction sector characteristics	Competitive (Adams et al., 2017), conservative (Debacker et al., 2017) and complexity might hamper CE developments.

Technical

The technical category refers to innovations regarding design and construction principles (Pomponi & Moncaster, 2017). Adams et al. (2017) performed a literature review on circular design and construction practices and listed the key aspects, such as Design for Disassembly (DfD), design for adaptability, reverse logistics, selective demolition and closed-loop recycling. This list, including the business model strategy linked to it (Bocken et al., 2016) are listed in Appendix A. Challenges regarding the technical pillar as found in literature are (1) limited circular design, (2) too few demonstration projects and (3) lack of data (e.g. on impacts) (Kirchherr et al., 2018). Regina Munaro et al. (2020) state that opportunities for CE transitions in the construction sector are based on (1) adopting flexible and modular design concepts, (2) more efficient use of resources including the reduction of waste and (3) through the development of innovative practices to create more value. In the technical category focus will be drawn to both design and construction related CE-practices, as listed in Table 2.6.

Table 2.6 Overview of the technological research theme.

Technological pillar	Description
Design practices	CE calls for modular and flexible designs, e.g. DfD, design for adaptability and flexibility, design for standardization (as shown in Appendix A).
Construction practices	CE needs new innovative construction practices on how close resource loops, e.g. using secondary materials, selective demolition, reuse of products and components and closed-loop or open-loop recycling (Adams et al., 2017).

Conclusion

To conclude, CE in the built environment is a relative new field of research (Regina Munaro et al., 2020). The building level, as the scope of this research, appeared to be less studied for analysing CE compared to the micro- and the macro-level (Pomponi & Moncaster, 2017). To further expand on this scope, this chapter explained some of its characteristics, such as the different layers of a building, the difference in construction process when including CE-practices and the various research topics that are distinctive for implementing a CE. Finally, these topics are merged into a research framework focusing on the following themes for CE in the built environment: (1) economic, (2) governmental, (3) environmental, (4) cultural and (5) technological. These themes will be used to analyse the lessons learned of stakeholders involved in circular building experiments.

2.3. Understanding transitions: A niche-transition perspective

As stated in Chapter 1.1, the large amounts of natural resources consumed by the construction sector and the accompanying energy consumption and waste production underline the important role of the construction sector in transitioning towards a CE (Eberhardt et al., 2019). However, CE aspects are not widely adopted by the sector and are in construction projects often applied in isolation (Adams et al., 2017). To understand how the sector can transition and how these transitions occur, this subchapter introduces transition literature. At first, the two major theoretical streams in literature, strategic niche management (SNM) and the multi-level perspective (MLP), will be placed next to each other to understand their dynamics. Finally, an introduction will be given on transition management (TM) as a governing tool to support transitions. This chapter explains the context of experimenting to move towards a CE transition within the built environment.

SNM has its origins in the 1990s and rests on the idea that new, more sustainable technologies can replace dominant (polluting) technologies through a process of niche development (Kemp et al., 1998). Here, technological niches can be seen as protected spaces in which experimentation of technology, user practices and accompanying regulations are facilitated. Ultimately, if these niches are developed in the right way, it can lead to societal changes and a new configuration of the incumbent regime (Schot & Geels, 2008). To successfully develop a technological niche, three internal processes are proposed: (1) articulation of expectations and visions, (2) building of social networks and (3) learning processes (Schot & Geels, 2008). Later SNM work focused on how protective space can be conceptualized. Here, Smith & Raven (2012) mention three processes which are essential: shielding, nurturing and empowering. SNM proved to be a useful framework for evaluating transitions (Schot & Geels, 2008).

Contrary, to the perspective of SNM, which argues that transitions come about through bottom-up expansion of niches, the MLP (Geels, 2002) argues that transitions come about through an alignment of processes at multiple levels: niche, regime and landscape (Schot & Geels, 2008). Niche development is still essential, but here the importance of co-evolving processes at the other levels (landscape and regime) are included (Schot & Geels, 2008). In short, the three levels differ in activities; in niches, rules, relationships and interdependencies are not set in stone, and therefore there is more room to deviate from the norm and try out new things. The regime consists of the dominant set of rules, is path-dependent (locked-in) and activities are structured. The landscape is the exogenous environment which cannot be changed by actors' will (such as shared cultural beliefs, or shocks such as wars or pandemics). Transitions come about through an alignment at all three levels. If the regime is stable then no transitions are expected. However, the landscape can put pressures on the regime if these are misaligned and if tensions arise, which creates a window of opportunity. If landscape pressures result in an unstable regime, and simultaneously the niche is co-evolved and substantially developed, niches can take advantage of the window of opportunity and a new configuration of the socio-technical regime emerges. This is, as explained and shown in Figure 2.5, in short, how transitions occur according to the MLP (Geels, 2019)

To limit the level of abstraction between the levels of the MLP and to understand how stakeholders involved in the experiments relate to the MLP, the following three levels will be differentiated based on their activities. *Landscape-activities* can be seen as pressures that can influence regime- and niche-activities, which can be slow-changing developments (e.g. aging population, societal concerns or geopolitics) or fast-changing external shocks (e.g. economic crises, oil prices, wars etc.) (Geels, 2019). *Regime-activities* can be seen as the dominant, unsustainable, traditional construction activities, characterized by shared rules, efficiency and are being incrementally improved by regime actors (Geels, 2019). *Niche-activities* can be understood as circular construction activities, which are radically different than regime construction activities. It consists of multiple different niche innovations, such as timber construction, DfD, secondary construction materials or design for adaptability (modularity) (as listed in Appendix A), which can reduce the high environmental impact of regime routines. In between the niche and the regime is the niche-regime as further explained in Chapter 2.5.2 (Van den Bosch & Rotmans, 2008). *Niche-regime activities*, can be seen as circular construction innovations that are maturing, have been repeated and become more stable. They can be seen as circular construction practices that are not yet replacing regime activities, but are building momentum to do so. As circular building experiments involve stakeholders from different (MLP-) levels this distinction can support understanding *who* should learn in these experiments.

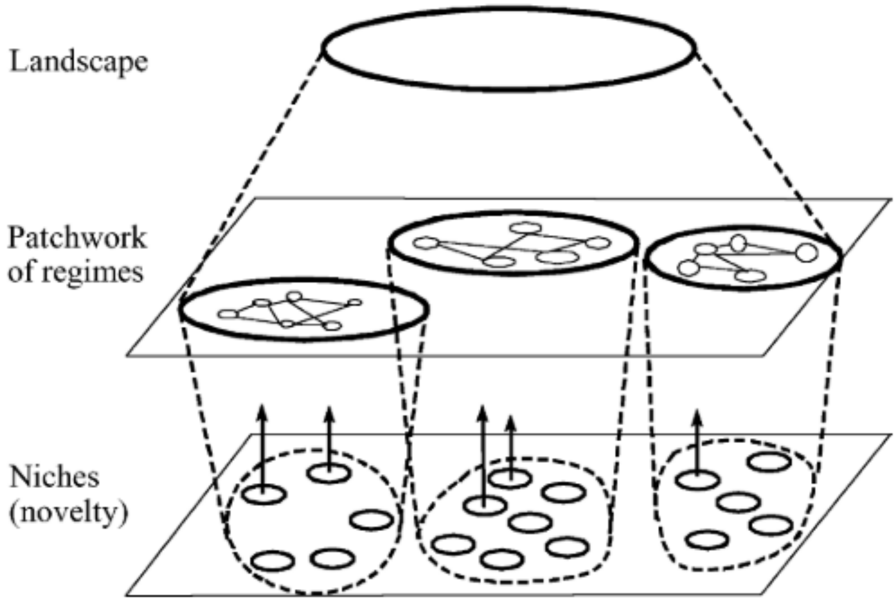


Figure 2.5. Static depiction of the multi-level perspective (MLP), distinguishes the niche (including experiments), the regime (socio-technical system) and the landscape. Derived from Geels (2002).

Transition management (TM) is another strand of transition literature and supports governing transitions. It offers a practical management framework to assess how actors deal with societal issues (Loorbach et al., 2015). The central idea is that certain regime- and niche-actors are brought together in transition arenas or experiments, where a shared ambition and agenda is set which empowers the actors and aims to translate the lessons in their own practices. The framework is set around four phases, as shown in Figure 2.6, which in practice do not necessarily follow a subsequent order and can occur bottom-up (from the experiments) or top-down (from the transition arena). The first phase consists of (1) problem structuring and establishment of a transition arena. Here, space is created for frontrunners in transition arenas, which are networks of innovators and visionaries that develop long-term visions which form the basis of agendas and experiments (Loorbach & Rotmans, 2006). The second phase consists of (2) developing visions, pathways and transition-agendas. Problem structuring and visioning are essential processes of TM. The third phase (the operational level) is about applying the ideas by (3) initiating and executing transition experiments. Finally, (4) continuous monitoring is essential for the search and learning process of transitions. Transition experiments need to be monitored based on the development and transfer of new knowledge and insights, as well as social and institutional knowledge (Rotmans & Loorbach, 2009).

v

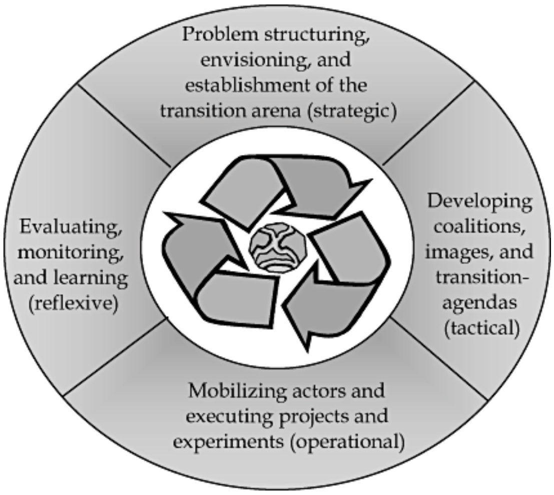


Figure 2.6. The transition management cycle, derived from Rotmans & Loorbach (2009).

To conclude, this subchapter gave an overview of the different streams in transition literature. For this research, the niche-perspective is important to understand how transitions come about. For this the MLP proves to be useful in understanding the broader picture of how experiments can contribute to a wider transition, as well as distinguishing which actors (characterized on their activities) should learn in circular building experiments. Furthermore, this research will look into circular building experiments, which can be understood as transition experiments at the operational level of the TM-cycle (Rotmans & Loorbach, 2009). The characteristics of transition experiments and other types of experiments will be explained in the next subchapter.

2.4 Experiments: forms and definition

In all the theories mentioned in Chapter 2.3, experiments play an important role in realizing a sustainability transition, however the nature of the experiment is different in each of these forms. From a SNM-perspective, niches are developed to conduct experiments in, which are often focused on introducing a new technology (Van den Bosch, 2010). These technological innovations deviate from the regime and are more sustainable, such as the introduction of electric vehicles (Hoogma et al., 2002) or renewable energy technologies (Raven et al., 2008). Transition experiments, as an instrument of the TM-cycle, do not take the sustainable technology as a starting point, but the societal challenge (Van den Bosch, 2010), such as how to meet the housing needs while lowering the carbon footprint. Sengers et al. (2019) analysed different experiments in transitions literature and found five forms of experiments, each with their own theoretical background, as listed in Table 2.7.

Table 2.7 Different experiments for sustainability transitions with their corresponding theoretical background as analysed by Sengers et al. (2019).

EXPERIMENT FORM	KEY CHARACTERISTICS
NICHE EXPERIMENTS	Originates from strategic niche management (SNM), which rests on the idea that experiments are facilitated in protective spaces, where radical innovations can develop.
BOUNDED SOCIO-TECHNICAL EXPERIMENTS (BSTE)	Stems from social learning literature and introduces a technology or service as an experiment in a geographically bounded area, including the local community, involves small number of users and takes approximately 5 years.
TRANSITION EXPERIMENTS	Stem from transition management (TM) literature, aimed at solving societal problems (not limited to technological or environmental change). Used as a tool of TM and focusses analytically on three processes: (1) deepening, (2) broadening and (3) scaling up.
GRASSROOTS EXPERIMENTS	Bottom-up, ideological solutions for sustainability, focused on the local area and involves the local community.
SUSTAINABILITY EXPERIMENTS	Planned, goal-oriented experimental tests for novel sustainability transition ideas.

v

Sengers et al. (2019) also found that the term ‘experiment’ in the context of sustainability transitions has been unclearly addressed. Different studies have defined the characteristics of experiments, such as iconic projects, high-risk, can potentially make a large innovative contribution to a transition (Loorbach, 2010), stimulate and develop new forms of collaboration and social learning (Rotmans & Loorbach, 2009), but clear consensus of a definition was lacking (Sengers et al., 2019). Van den Bosch (2010, p.58) defined transition experiments as “*innovation projects with a societal challenge as a starting point for learning aimed at contributing to a transition*”. Learning here refers to organizational learning as coined by Argyris & Schon (1974), which will be further explained in Chapter 2.5.1. Sengers et al. (2019, p. 153) propose an integrated definition of experiments for sustainability transitions and define them as an “*inclusive, practice-based and challenge-led initiative, which is designed to promote system innovation through social learning under conditions of uncertainty and ambiguity.”*. This definition fits the scope of this study, however, given the fact that social learning in this context refers to learning of all actors involved in the transition arena (Rotmans & Loorbach, 2009) and that this research focuses on organizational learning in circular building experiments, the ‘learning’-component will refer to organizational learning just as Van den Bosch (2010) intended. Therefore the definition of Sengers et al. (2019, p. 153) is adapted and ‘experiments’ are referred to in this research as:

“*Practice-based and challenge-led initiatives, which are designed to promote system innovation through learning under conditions of uncertainty and ambiguity.”*

The terms in this definition have been explained by Sengers et al. (2019), where the experiment is ‘practice-based’ as it is tested in a real-life context and ‘challenge-led’ given its highly novel and innovative nature. ‘System innovation’ refers to the goal of experiments where structural change is aimed for by (1) initiating change on a small scale and (2) gain insight about structures that might constrain wider diffusion. The conditions of ‘uncertainty’ and ‘ambiguity’ refer to the highly novel and unpredictable nature of experiments which can generate different views on developments in the experiment (uncertainty) and contest the norms and values by (re-)framing problems and solutions (ambiguity). In the original definition also the term ‘inclusive’ has been used, which referred to the social learning aspect of including all stakeholders in the transition arena. This has been left out as transition experiments can also occur bottom-up in the transition management cycle (instead of top-down) (Van den Bosch, 2010), and in that case the transition arena is not defined yet and social learning, as the learning process of the transition arena, is not apparent (yet).

The difference between an experiment and a project is also worth mentioning here. Reasoning from the MLP, experiments are conducted outside of the regime, where experiments and innovations can lead to niches, which can ultimately grow into the regime (Schot & Geels, 2008). Here, it is important to note that experiments do not have to meet the requirements of the regime to be adopted, therefore room is provided to deviate from the regime (Schot & Geels, 2008). Projects, however, as clearly conceptualized by Van Bueren & Broekhans (2014), can be placed between the niche-level and the regime-level, where niche innovations are used according to the rules and practices of regime actors. In this regime setting, projects provide the space for interactions between niche innovations and the regime, and can be regarded as the *portals* through which niche innovations can transfer into the regime (van Bueren & Broekhans, 2014). *Experiments* can fail and are developed to learn from (Sengers et al., 2019), whereas *projects* can be understood as a testbed of already proven successful niche innovations in a regime context, to understand if and how they can be adopted and adapted by the regime (van Bueren & Broekhans, 2014).

To conclude, this subchapter introduced different forms of experiments and proposed a leading definition to which experiments will refer to, including its characteristics, such as practice-based, challenge-led, and system-innovation through learning under uncertain and ambiguous conditions. The difference between *transition experiments*, as the scope of this research, and *construction* *projects* should also be taken into account. *Transition experiments* take place in the niche-level, as shown in Figure 2.5, where there is more room to try out new things and *projects* operate in a regime context, where proven niche innovations can be tested for regime adoption. The next subchapter will further zoom-in on the central theme of experiments: learning.

2.5 Transition learning

Learning of actors involved in the experiment is an important condition for transformative change (Brown & Vergragt, 2008; Leising et al., 2017) and transitions (Loorbach & Rotmans, 2006; Raven et al., 2008). 'Learning-by-doing' is the device by gaining theoretical knowledge from practice. However, deep learning is not a given per se (Hoogma et al., 2002, 2005) and a lack of involvement of regime actors can lead to failed niche developments (Schot & Geels, 2008). Furthermore, there remains a gap on how these learning processes occur and how they are conceptualised (van de Kerkhof & Wieczorek, 2005; van Mierlo & Beers, 2020). This chapter, first of all, dives in the learning literature to understand how learning occurs to operationalize the assessment of stakeholder learnings in transition experiments. Secondly, an in-depth analysis will be given of transition literature to understand how lessons learned can contribute to a sustainability transition.

2.5.1 Organizational learning theory

There are different strands of learning literature which can be useful to understand learning processes in sustainability transitions, such as collaborative learning (educational sciences), organisational learning (management studies), social learning (complex system thinking) and interactive learning (institutional economics) (van Mierlo & Beers, 2020). These strands and their potential added value for this research have been explained and are listed in Appendix B. The scope of this research is on transition learning of actors involved in circular building experiments, therefore the focus for this research will be sought in organizational learning theories.

From an organizational learning perspective, a differentiation is made between single-loop, double-loop (Argyris & Schon, 1974) and triple-loop (or 'deutero-') learning (Bartunek & Moch, 1987). These conceptualizations will be used in this research to assess how stakeholders learn in circular building experiments. *Single loop learning* occurs when new insights are developed about options for a given problem in a given context, but it does not alter an organization's current policies, objectives or point of view (Argyris & Schon, 1974). This can be seen as corrective learning, where actions are corrected, but not reflected, as shown in Figure 2.7. It is the simplest form of learning, in which the results of the experiment are related to an earlier understanding of the problem to detect errors in current ways of working (Aminoff & Pihlajamaa, 2020). An example of single-loop learning, also called 'technical'- or 'instrumental'-learning, given by Brown et al. (2003) is improved technological design or marketing and pricing strategies after the introduction of electrical vehicles.

Double-loop learning takes it a step higher, and occurs if an error is detected and corrected which changes the organization's underlying norms, policies and objectives (Argyris & Schon, 1974). Reflection - about goals, problem framing and about how goals can be achieved - plays a central role here (Ersoy & Van Bueren, 2020). Double-loop learning changes the knowledge and competency base of an organization by reframing problems and leads to new insights about problem definitions, norms, values, goals and approaches on how to solve the problem (Quist, 2007). It can develop through ongoing reflection and dialogue of key actors involved in the organization (Romme & Van Witteloostuijn, 1999). Here, organizations reconsider their capabilities and environment, which offers new opportunities and can lead to radical innovations (Aminoff & Pihlajamaa, 2020). An example of double-loop learning given by Brown et al. (2003) is the discovery of finding new ways of organizing mobility after introducing electric vehicles. Double-loop learning is seen as a condition for the acceptation and subsequently implementation of sustainable solutions and change processes (Quist, 2007).

v

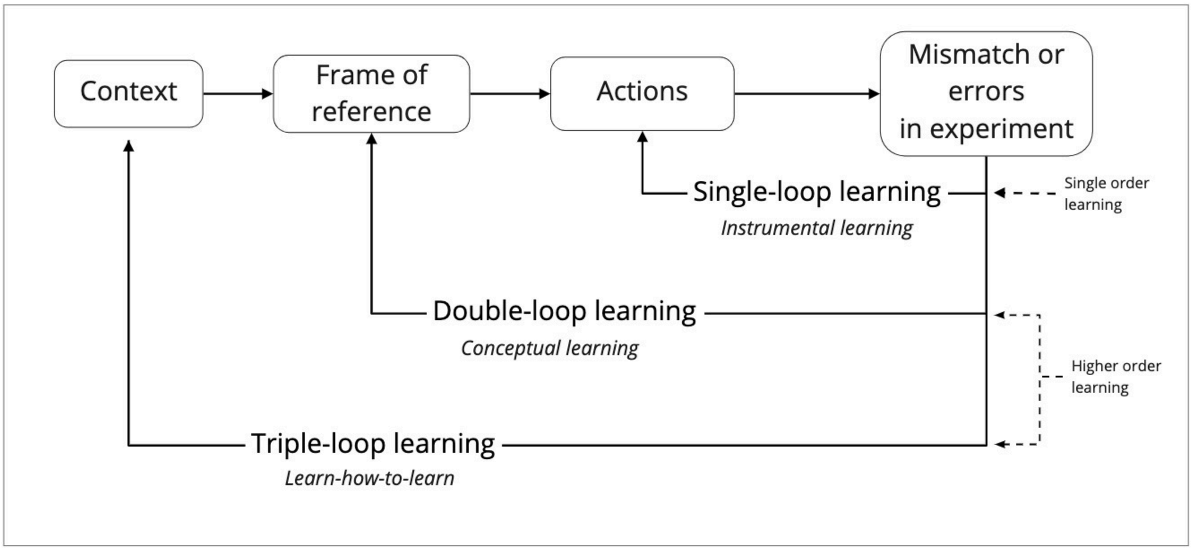


Figure 2.7 Conceptualisation of the different learning loops and the potential results of the learning. Based on (Argyris & Schon, 1974; Ersoy & Van Bueren, 2020; Kemp & van den Bosch, 2006)

Triple-loop learning was first coined by Bartunek & Moch (1987) and occurs when the capacity of people to reflect on the system of which they are part of is developed. Ersoy & Van Bueren (2020) state that triple-loop learning changes the structural context and factors that determine the frame of reference (double-loop), as shown in Figure 2.7. It is often referred to as 'societal' learning which indicates the meta-level, such as regime change, socio-cultural change or a paradigm change (Kemp & van den Bosch, 2006; Termeer et al., 2017). Given the fact that the results of these learnings rest on wider societal diffusion and adoption, which is an important but difficult process to assess (Quist, 2007), triple-loop learning will be operationalized in this study on an organizational level. Argyris & Schon (1974) refer to 'deutero-learning' which means 'learning to learn'. Seeing it from this perspective, third-loop learning relates to the ability to learn and often results in the production of new structures and strategies for learning (Romme & Van Witteloostuijn, 1999). Aminoff & Pihlajamaa (2020) state that *triple loop learning* is reflective of nature and can support the institutionalisation process of innovations in an organization by drawing on the learning context from successful and unsuccessful experiments. Table 2.8 gives an overview of how the three learning loops are operationalized for this research.

Table 2.8 Overview of the operationalization of the three learning loops for this research.

LEARNING LOOP	**DESCRIPTION**
SINGLE LOOP	Detecting and solving errors without further reflecting on the goals, policies or assumptions of the organization (Argyris & Schon, 1974). *Do you do things right?*
DOUBLE LOOP	Improvement and adaptation based on reflection. Challenges current company policy, goals and approaches on how to solve the problem (Argyris & Schon, 1974). *Do you do the right things?*
TRIPLE LOOP	'Learning how to learn', shift in the organizational learning ability. Results in new learning methods, strategies or ability to utilize single- and double-loop learnings (Bartunek & Moch, 1987; Romme & Van Witteloostuijn, 1999). *Do we learn the right things?*

To further understand organizational learning, Crossan et al. (1999) found that organizational learning can occur on three levels, as shown in Table 2.9. They state learning occurs on the (1) *individual level*, where learning occurs via processes of intuiting and interpreting, (2) the *group level*, where learning occurs through interpreting and integrating processes and (3) the *organizational level*, where learning occurs via institutionalization. To further elaborate on these processes, *intuiting* occurs when an individual recognizes a possibility, through for example experiences.

Interpreting then builds on these intuitions and further refines these through conversation or dialogue, these are often on the group levels and not on an organizational level. Following the interpretation process, the group can obtain a shared understanding which can result in coordinated actions, this occurs in the *integrating* process. Finally, the actions, if deemed successful can result in formal rules and procedures, this process of embedding is called *institutionalizing* which occurs on the organizational level. For circular building experiments, in which often agents (individuals) of an organization are involved, this can be an interesting perspective of how lessons learned extend the individual level. As for transitions, it can be assumed that in the end, organizations involved in unsustainable regime activities should learn on the organizational level.

Table 2.9. Four processes on three different levels through which learning in organizations occurs. Adapted from Crossan et al. (1999).

LEVEL	PROCESS	INPUTS OR OUTCOMES
INDIVIDUAL	Intuiting	Experiences, images and metaphors
	Interpreting	Conversation or dialogue Cognitive map Language
GROUP	Integrating	Shared understandings Mutual adjustment Coordinated actions
ORGANIZATION	Institutionalizing	Formal rules and procedures Routines

2.5.2 Learning in and from transition experiments

Now that it is clear how organizations can learn, the bridge will be made between stakeholder learning in experiments and transitions. For this, transition literature will be used, where different scholars have operationalized mechanisms on how experiments can contribute to transitions; transition management through *deepening, broadening* and *scaling up* (Van den Bosch & Rotmans, 2008; Van den Bosch & Taanman, 2006), Urban Living Labs through *embedding*, *translating* and *scaling* (von Wirth et al., 2019) and transformational change through *sensemaking*, *coupling* and *integrating* (Termeer et al., 2017). Given the focus on circular building experiments from the scope of the TM-cycle, for this research, the three mechanisms of transition experiments (*deepening, broadening* and *scaling up*) are used which can explain how (1) stakeholders learn in experiments and (2) how experiments can contribute to a wider transition (Kemp & van den Bosch, 2006; Van den Bosch & Rotmans, 2008; van den Bosch & Taanman, 2006). This chapter will introduce each of these mechanisms, as depicted in Figure 2.8, and adapt these to be operationalized for the scope of this research.

Deepening

The first, *deepening,* refers to direct context of the experiment, where actors learn about new practices (shift in doing things, habits and routines), cultures (soft: shift in way of thinking and perspectives) and structures (hard: shift in organizing the physical, institutional or economic context) that differ significantly from regime activities (Van den Bosch & Rotmans, 2008). Transition experiments, can provide room to deviate from the regime, including its structures, ways of thinking and activities, and therefore be regarded as a testbed for different practices (Van den Bosch & Rotmans, 2008). Here, the link is made with *single- and double-loop learning*, where Kemp & van den Bosch (2006) refer to *instrumental learning* as single-loop (e.g. new innovative solutions) and *conceptual learning* as double-loop (e.g. the emergence of new concepts or perspectives on how to fulfil a societal need). Reasoning from the MLP, they state in order to break from unsustainable regime activities, which are path-dependent and locked-in, transition experiments can act as a catalyst for both *instrumental* and *conceptual learnings.*

Deepening includes learning about the innovative activities and practices as well as learning about the possibilities and constraints of the context of the transition experiment. Here, Kemp & van den Bosch (2006) emphasize that successful deepening rests on the quality of the internal learning processes, such as scale, competences, diversity, formulating learning goals and commitment of involved actors. Van den Bosch & Rotmans (2008) clearly state that the outcome of *deepening* should be an understanding of how to fulfil a societal need in a fundamentally different way. For the scope of this research, that is delivering the need for buildings (societal need) following circular principles (fundamentally different way). Ultimately, deepening will be operationalized in this research as the mechanism which focuses on learning, through obtaining knowledge in the experiment as well as sharing it beyond the scope of the experiment, to also include other agents/organizations in the learning process.

Broadening

A saturated deepening process of a transition experiment in a local context is characterized by low influence, dominance and instability when comparing it to the regime (Van den Bosch & Rotmans, 2008). Therefore, in order to increase its stability, successful experiments should be replicated in different contexts. This occurs via the mechanism of *broadening,* which is a horizontal process aimed around repeating the learnings of the transition experiment in another context or by relating it to different experiments, functions or domains (Van den Bosch & Rotmans, 2008). Here, it is important that the outcomes of the experiment are tested in a variety of contexts so that it builds influence and can increase its stability (Van den Bosch & Rotmans, 2008). Horizontal diffusion is also mentioned by Von Wirth et al. (2019) who refer to *translation* as the process of replicating and reproducing elements of the experiment in a new context. In this research, *broadening* will be researched as the replication or reproduction of elements of the experiment in another context.

Scaling up

The third, *scaling up,* can be referred to from two perspectives: from experiments to niche, as explained by Geels & Deuten (2006) or from sustainable niche activities to mainstream regime activities (Van den Bosch & Rotmans, 2008). *Scaling up* from the second perspective, focuses on how dominant culture, practices and structure of transition experiments are embedded on the societal system level (regime). This step leads to a fundamental change or transition, but takes a longer time to come to fruition (5-10 years) (Loorbach, 2010). Within this research, where the focus is on stakeholders involved in transition experiments, *scaling up* will be operationalized as how the lessons learned in the context of the transition experiment are institutionalized within the participating organizations. Therefore, scaling up is referred to from the lessons obtained by the agent of the organization and how these are institutionalized to the level of the organization. This learning process of institutionalization refers to setting up formal rules and procedures on the organizational level, as mentioned by Crossan et al. (1999) in Table 2.9. The operationalization of these three diffusion mechanisms is listed in Table 2.10.

Table 2.10. Operationalization of the diffusion mechanisms (the effect) for this research. Based on (Termeer et al., 2017; Van den Bosch & Rotmans, 2008; von Wirth et al., 2019)

DIFFUSION MECHANISM	*OPERATIONALIZATION*
DEEPENING	Deepening relates to learning on the level of the experiment and how these are shared. These are combined with, and assessed through, single-, double- or triple-loop learning.
BROADENING	Broadening focuses on replicating or reproducing (elements of) the experiment in another context.
SCALING UP	Scaling refers to how knowledge from the experiment, obtained by the agent of the organization, is scaled up to a higher scale of the organization.

v

2.5.3 Relation between the different diffusion mechanisms

The three diffusion mechanisms are related to each other, which will be further explained with the help of Figure 2.8 (Van den Bosch & Rotmans, 2008). *Deepening* can help break away from regime activities and is therefore visualized with an opposite arrow from the regime. *Broadening* can link the transition experiment to other niches and is important to prevent isolation, which limits the learning potential. The links made between niches can result in niche-clusters and eventually if it becomes more stable and gains more influence can become a niche-regime, which can challenge the incumbent regime. *Scaling-up* in this sense refers to how changes of transition experiments can influence niches and eventually scaled up in the dominant regime. Here, Van den Bosch & Rotmans (2008) state there is a paradox between the context of the niche and the context of the regime. According to them the context of experiments works well to test sustainable innovations in, but is too specific for the context of the regime (scaling up). Therefore, they state that, at first, *broadening* should be performed to test the innovations in different contexts, create more learning processes (*deepening*), which can eventually be scaled into a niche-regime (*scaling up*).

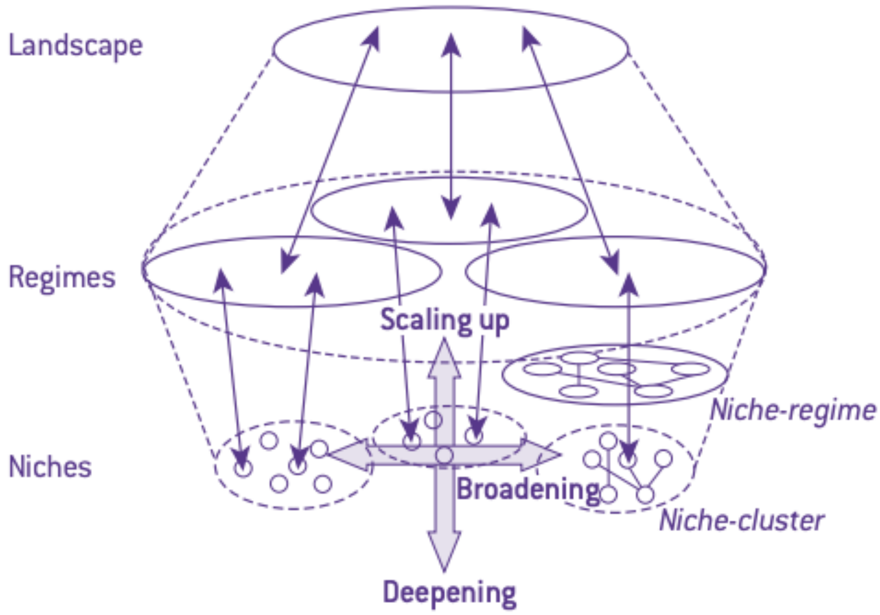


Figure 2.8 The three mechanisms of transition experiments related to the MLP. Derived from Van den Bosch & Rotmans (2008).

Conclusion

To conclude, this chapter explained, from organizational learning literature, how stakeholders can learn following single-, double- and triple-loop learnings (see Figure 2.7). Furthermore, there are different levels in an organization through which these learning loops can be obtained, on an individual, group or organizational level (Crossan et al., 1999). Experiments can contribute to transitions following three mechanisms, (1) *deepening*, (2) *broadening* and (2) *scaling up*. The first, deep learning (double- or triple-loop) is deemed crucial to break from locked-in and path-dependent, often unsustainable, regime activities (van Mierlo & Beers, 2020). To acquire deep learning, and break away from regime activities, transition experiments are conducted (Van den Bosch & Rotmans, 2008). Not a single experiment can trigger a transition, therefore the importance of *broadening* is emphasized in which a diverse set of experiments are conducted in varying contexts. Finally, *scaling up* then refers to how knowledge and innovation obtained in the experiment is scaled up within the organization. This refers to the organizational level of Crossan et al. (1999) via a process of institutionalization.

v

2.6 Research focus: learning processes of transition experiments

The previous subchapters explained how transitions occur, the role of experiments and how learning can contribute to this process. This chapter will further build on this work to operationalize learning processes in circular building experiments. Ultimately, integrating all these elements in a conceptual model. In doing so, this chapter is structured following research by Van de Kerkhof & Wieczorek (2005). They state that learning has a positive connotation and is a key element of transition management, but that it is unclear how to organize learning in transition experiments. Based on Bennett & Howlett (1992), they conceptualized the assessment of learning processes through four components: (1) the subjects of learning (*who learns?*), (2) the process of learning *(learns how?*), (3) the objects of learning (*learns what?*) and (4) the result of learning (*to what effect?*).

This framework, which was applied to a transition project and focused on policy learning, will be adapted and used to understand the learning processes of circular building experiments. First of all, by coupling the subject (*who learns*) to the construction sector, a closer look will be given on the stakeholders involved in this process. Secondly, this will be followed up by *process features* to understand which activities can support the learning process in experiments and how stakeholders can learn from the process. Thirdly, by focusing on the substance, *learns what*, a link will be made to the circular building research themes developed in Chapter 2.2. Finally, in aiming to achieve a broader change, insight will be given on the effect of learnings (*to what* effect) and how this can be operationalized.

2.6.1 The subjects - Who learns?

Who learns refers to the actors involved in the experiment. Van de Kerkhof & Wieczorek (2005) refer to the subjects of learning as the participants of the transition management process. In their case-study, this includes who is and who is not involved in the *transition arena*, which are networks of innovators and visionaries that develop the basis of agendas and experiments (Loorbach & Rotmans, 2006). However, as the focus of this research will be on circular building experiments, a closer look will be given on the involved stakeholders on the micro-level (the experiment), instead of the meso-level (the transition arena). An overview of the stakeholders involved in the development of a building according to their life-cycle stage is given in Appendix C. This gives an overview of which stakeholders might be involved per stage.

However, given the fact that a key characteristic of the development of circular buildings is that stakeholders are involved in new non-traditional collaboration forms (Pomponi & Moncaster, 2017), a closer look will be given on who is involved in each stage, what their role is and which resources they provide. Here, the stakeholder network of the experiment will be assessed and stakeholders analysed based on their interest, resources (e.g. funds, technology, authority, knowledge or reputation) and relations (De Bruijn & Ten Heuvelhof, 2008). As Bulkeley et al. (2016) state it is not only about the inherent capabilities and resources that organizations bring, but also about assessing how the experiment reconfigures these capabilities and resources (e.g. application of certain technologies, knowledge, roles). Which is also backed by Peng et al. (2019) who state that re-alignments of actors, resources and institutional arrangements are important internal processes for embedding innovations in experiments.

Transitions can potentially change traditional division of roles, as operationalized by Wittmayer et al. (2017) for transition research. They state that *roles* are a social construct and consist of a set of recognizable activities and attitudes of an actor, which are shared by a group of people (community), which can be created, broken down or existing ones can be altered. Platform CB'23 (2021) analysed new actor roles in circular construction processes. They state that in traditional construction, the design and construction chain is sequentially organised, from initiation to, low-grade, deconstruction. Here, traditional actors' roles in the construction process can be understood as *suppliers* and *buyers*. For a circular process, the focus is on storing value during one cycle, with the focus on using it for multiple cycles. This urges stakeholders to extend their scope from a single phase in the construction process and deliver a service that transcends the single building, to ensure use for multiple cycles. Here, roles change from suppliers and buyers to *applicators* and *users*, who are in contact after every successive cycle.

They furthermore find that roles of individual actors change, as their responsibility shifts from a sole focus on delivery, or warranty in use-phase, to a responsibility over the entire cycle of the product ensuring the focus on performance. This makes collaboration more important, but also complex as the timeline of collaborations extends, more stakeholders enter the design process with potentially diverging goals. They find four types of stakeholder roles in this complex web of collaboration, as shown in Table 2.11. As circular buildings and experiments rest on new collaboration forms, it will be interesting to assess who is, and who is not, involved in each stage, who brings which resources and performs what role. For this analysis, the different role groups from Table 2.11 will be used.

Table 2.11. An overview of four different role groups that potentially can obtain changing roles as found by Platform CB'23 (2021).

Role group	Description	Examples
Initiators	initiators who or are responsible for the construction need and are characterised through their direct involvement and/or benefit of the completed building.	- National or local government - Investor or broker - Developer - Private or professional client - Resident or user
Advisors	The second role group consists of *advisors*, which are parties who, based on the wishes of the initiator, develop a process and design to achieve the intended result.	- Technical advisor (e.g. engineer, architect, installation) - Financial advisor - Process advisor (e.g. project- or process manager) - Circularity manager - Purchasing advisor - Environmental advisor (e.g. biologists, toxicologist) - Societal advisor (anthropologist, sociologist) - Management advisor (e.g. legal, financial, insurance)
Builders	*Builders* are responsible for the physical execution and maintenance of the building. This can be via materials, labour or installations. They are rewarded for developing, maintaining or deconstructing (parts of) the building.	- Contractors (builders and wreckers) - Suppliers - Producers - Maintenance - Material trader - Lease companies - Insurance companies
Controllers	*Controllers* are independent private or public organizations who check buildings or the design of a building on laws and regulations	- Regulator - Regulation controller - Certifying authority - Performance controller

2.6.2 The process – Learns how?

The processes which occur in an experiment can influence the learning process of the involved stakeholders. Van de Kerkhof & Wieczorek (2005) refer to the *process of learning* from a process management perspective for transitions. Processes can be regarded as a sequence of actions which occur in transition experiments, which are important for producing certain learning outcomes (Luederitz et al., 2017). In this subchapter, an analysis is given of key components of the process of an experiment found in literature which can support the learning outcomes.

Visioning

The process of visioning gets an explicit mention as it has been deemed important both from SNM (Schot & Geels, 2008) as TM (Loorbach & Rotmans, 2006) literature, and also has been proved empirically for circular building pilots (Leising et al., 2017). Shared visions can have the potential to guide actor behaviour, provide coordination among actors from different professional backgrounds and support collective action if it is generated in a collective process (Quist, 2007). It can identify different frames of reference and support the learning process. Furthermore, Leising et al. (2017) conceptualized the functions of visions based on Quist (2007) and Van der Helm (2009) and state that visions need to *guide* (through clear collective goals, presence of alternative rule sets and leadership), provide *images* (through the inclusion of potential metaphors, words and images) and support *orientation* (through motivational, inspirational and directional characteristics).

Reflexivity and monitoring
Next to this, it is found that reflection and self-evaluation enhances the potential of higher order learning (Brown & Vergragt, 2008). Reflexivity is the iterative analysis of all components of the experiment, which includes processes, actors and the broader institutional context (Luederitz et al., 2017). Reflection should occur during as well as after the experiment. Indicators for reflexivity can be found through the presence of a shared learning agenda or dedicated reflection points, such as meetings to reflect on the experiment, review processes or changes to the experimentation process (Luederitz et al., 2017). Monitoring has been found important for reframing problems and solutions and support social learning (Porter et al., 2015; Rotmans & Loorbach, 2009).

Transparency
Transparency is found to support the learning process (Luederitz et al., 2017; van de Kerkhof & Wieczorek, 2005). It includes open and honest reporting of the intentions and activities of the experiment through documents and reports about the process, data, decision-making process and conclusions. It ensures that all actors have access to relevant information (Luederitz et al., 2017). Transparency can increase opportunities for learning as stakeholders can focus on the discussion and will not be disturbed by issues regarding planning or procedure, as those have been made transparent. Furthermore, it supports commitment, as stakeholders know about the costs and benefits before they engage in the process (van de Kerkhof & Wieczorek, 2005). Indicators for transparency can be: openly published results, reports and documentation of decision-making process (Luederitz et al., 2017).

Process features
Brown & Vergragt (2008) who refer to lower (first-loop) and higher order (double- and triple-loop) learning researched the development of an energy neutral residential building as a bounded socio-technical experiment (BSTE) and monitored and assessed under which conditions and through which mechanisms learnings occur and under which not. They state that interactions on the problem, frame of reference (double-loop) and context are most intense, as this is where differences in problem definition, motivations, private interests, organizational missions and perspectives on technologies take place. The degree of second order learning depends on the confrontation and how these are managed by the stakeholders. They furthermore, found that several factors facilitated the interaction, problem solving capacity, reflection on individual interpretive frameworks and changes to individual problem definitions among participants. These factors were: (1) clear focus and boundaries of the project, (2) intense interactions among professionals who commit to the process and its goals, (3) sense of urgency (through time and financial pressures), (4) agreement about vision, social mission and process, (5) overlap among interpretive frameworks of participants and (6) availability of time and funding.

Furthermore, Van Mierlo & Beers (2020) found that (1) deliberation and reflection, (2) systems thinking, (3) sense of urgency, (4) atmosphere of trust, (5) stakeholder commitment and (6) a feeling of mutual interdependence are regarded as conditions supporting learning in innovation projects. Relating this to transition experiments, Kemp & van den Bosch (2006) stated that several elements can support the *deepening* process: (1) scale and diversity of the experiment (diverse group of actors), (2) competences and commitment of involved stakeholders and (3) formulating learning goals, (4) open learning system with dedicated reflection moments, (5) determine follow-up actions (*learning for action*) and (6) connect with other experiments to build on learning experiences. All in all, all these process features, as well as the importance of visioning, reflexivity and monitoring and transparency will be used to assess how stakeholders learned and which process factors were of influence in this process. Next to these found in literature, it might also be the case that other learning factors supported transition learning of stakeholders involved in circular building experiments, which will be empirically assessed.

2.6.3 The objects – Learns what?

The *objects* refer, in this research, to the lessons learned by stakeholders involved in the experiment. According to Van de Kerkhof & Wieczorek (2005) one can speak of learning when individuals acquire new information and use it in further actions. Next to the individual level, learning can also occur on the team level, as shown by Brown & Vergragt (2008). To understand learnings, and a change in actions of individuals and organizations, use will be made of the single-, double- and triple-loop learning as operationalized and explained in Chapter 2.5.1. These learning loops will be coupled to the CE research themes as identified in Chapter 2.2 and explained in Table 2.1. By identifying the main barriers, enablers and research themes a theoretical foundation is given to understand potential learnings of implementing CE practices in construction experiments, but are not used as a comprehensive set. This leaves the possibility open to identify other learnings acquired in the experiment.

2.6.4 The result – To what effect?

Finally, the *result*, will be operationalized as the effect of learnings, which will be understood in this research as how the knowledge and innovation of the experiment is used and diffused. This can be approached in different ways, but for this research the effect of the learnings will be analysed via the three mechanisms explained in Chapter 2.6 and Table 2.10: *deepening*, *broadening* and *scaling up*. These will be analysed on the organizational level through stakeholders' experiences. How these four elements: *subjects, process*, *objects* and *result* will be assessed, will be explained in the conceptual model introduced in the next, and final, subchapter.

2.7 Towards a conceptual model

To conclude, this chapter gave an overview of how the learning dynamics of circular building experiments will be assessed. By adapting the theoretical framework of learning by Van de Kerkhof & Wieczorek (2005) and including these in transition literature, this research aims to understand how circular building experiments are approached, who learns and who should learn, what the results are (learnings) and how these learnings contribute to a transition through *deepening, broadening,* and *scaling up*. The research is composed of four parts, which all interlink. The first part aims to understand who should learn in circular building experiments, after which the learning process will be researched, thirdly the actual lessons learned will be assessed based on the five CE research themes and the three learning loops; finally, the fourth part assesses the effect of the learnings and how these learnings are shared (external deepening), broadened (repeated) or institutionalized in the organization (scaled up). To embed this in transition learning literature, Figure 2.9, illustrates how these research objectives relate.

To elaborate on the conceptual model, use is made of the MLP to understand the wider sectoral dynamics (Geels, 2002). Reasoning from the top, landscape developments can influence both the regime- as the niche-level and can be seen as a constant, unchangeable factor. The regime-level then consists of the traditional, linear, construction sector, which is path dependent, improves only incrementally and can be assumed unsustainable. To change this, circular construction, as a niche development, aims to break this unsustainable regime. In doing so, double- and triple-loop learning is necessary to change the frame of reference and the context of regime actors (Kemp & van den

Bosch, 2006). To learn about radically different ways of doing construction, circular building experiments are being conducted, where niche- and regime actors come together, which are defined as: "*Practice-based and challenge-led initiatives, which are designed to promote system innovation through learning under conditions of uncertainty and ambiguity.*", based on Sengers et al. (2019). This *deepening* process, will be analysed through the three learning loops, as depicted by the three circles surrounding 'deepening' in Figure 2.9, and the five CE research themes derived from the literature review. Subsequently, these lessons learned are potentially *broadened* after the experiment in other experiments or niche-regime contexts, or *scaled up*, indicating the institutionalization process of including CE innovations in the routines of the regime actors.

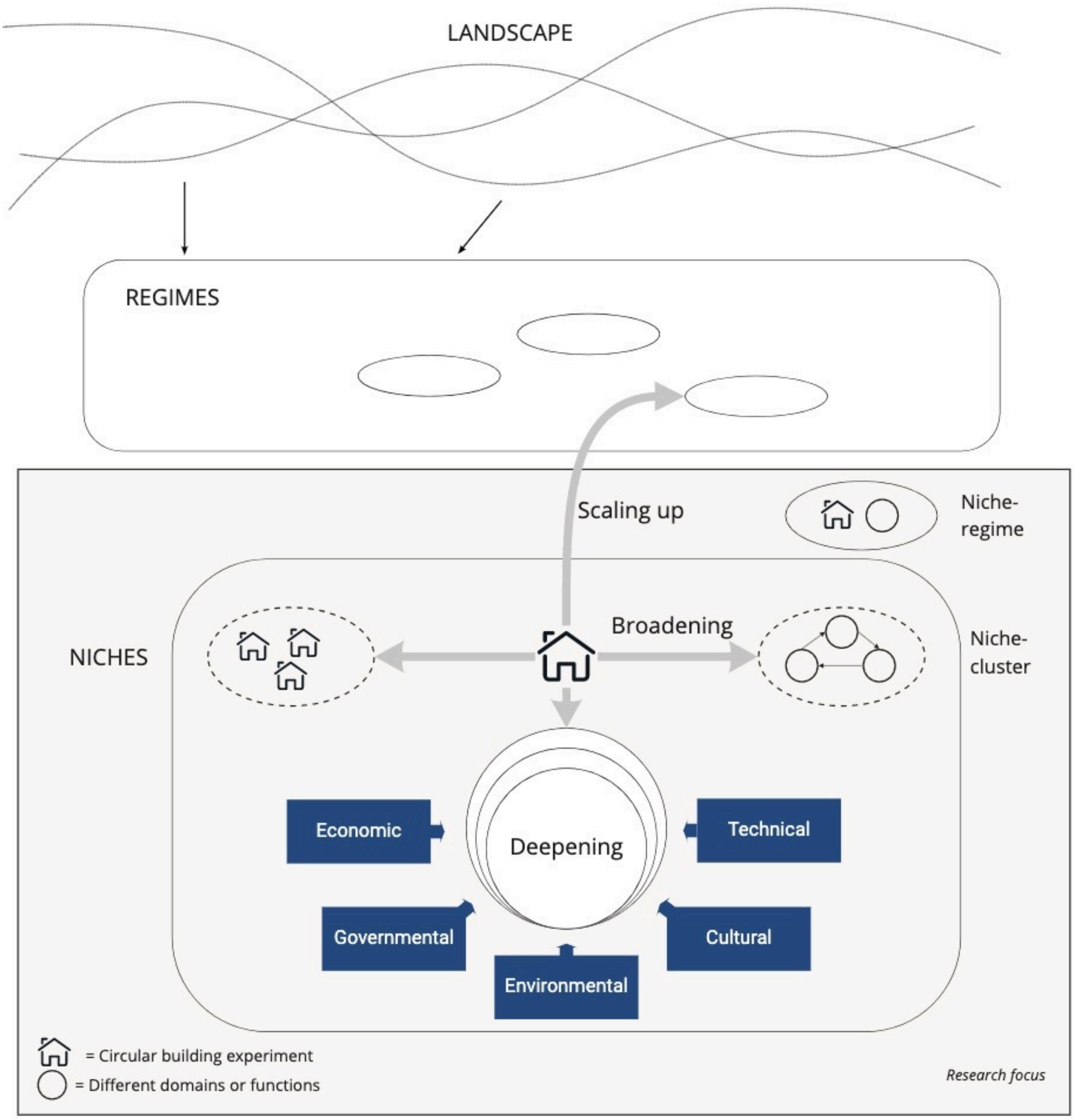


Figure 2.9. Conceptual model of this research. Where the circular building experiment is placed in the MLP, where three mechanisms will be research which can support a CE transition in the construction sector: *deepening* (including three learning loops indicated by three circles), *broadening* and *scaling up.*

v

Chapter 3. Methods

Following the literature review and the proposed conceptual model, the aim of this chapter is to explain through which methods this theoretical model will be assessed. The first subchapter explains the chosen methodology (3.1.1), its theoretical underpinning (3.1.2) and its limitations and how these will be addressed (3.1.3). In the second part, the research design (3.2) will be introduced, which explains how the chosen method will be applied in this research, including a research flow diagram and a careful explanation of how each stage in the research is operationalized, including the selected cases.

3.1 Methodology

3.1.1 Case-study research

This research assesses transition learning in circular building experiments in the Netherlands. A theme which has not been widely studied before as it is a relative recent phenomenon, which gained increasing attention after the introduction of the government-wide program 'The Netherlands circular in 2050' (Rijksoverheid, 2016). Therefore, it is explorative of nature and aims to understand how these experiments should be approached to support transition learning. In doing so, a case-study research approach will be used as it allows to research a contemporary phenomenon within its real-life context (Yin, 1994). Furthermore, case-study research is favoured if the main research question is explorative (follows a 'how' or 'why' question), if the research questions seek to understand an in-depth understanding of a social phenomenon and if the behaviour of actors in the phenomenon cannot be manipulated (Yin, 2009). Furthermore, to improve the reliability of the empirical evidence (Baxter & Jack, 2008) multiple cases will be assessed to understand similarities and differences between various circular building experiments. For this, various paradigms exist, which will be briefly discussed in the next subchapter.

3.1.2 Different multiple case-study paradigms

A multiple case-study research can be approached via different methodologies (Steenhuis & De Bruijn, 2004). In literature, the work of Yin (2009), *grounded theory* by Glaser & Strauss (1968) and the work of Eisenhardt (1989) is often cited. The research design of these three methodologies differ from each other, where the work of Yin (2009) and Glaser & Strauss (1968) can be seen as opposing approaches. Yin (2009) takes a *deductive approach* in which the testing of theory is important, here literature forms the basis which is then empirically validated. The grounded theory of Glaser & Strauss (1968) takes, in contrast to Yin (2009), an *inductive approach* in which theory is developed based on the empirical data of the cases. Here, literature is only used after an empirical framework (theory) is developed. The work of Eisenhardt (1989), *theory building from case study research*, falls in between the two previous mentioned approaches (Steenhuis & De Bruijn, 2004). This approach can be labelled inductive, but it allows for the use of literature before conducting the case studies. This method is used for this research as it is deemed useful for assessing new topics (Eisenhardt, 1989), such as circular building experiments, and offers the possibility to combine a theoretical framework (deductive), but leaves room for empirically building theory (inducive), which suits the explorative nature of this research. However, various limitations should be addressed when conducting case-study research, which are introduced in the next subchapter.

3.1.3 Limitations: Validity and generalization

An important point of attention for case-study analysis are its potential drawbacks. Yin (2009) names two traditional concerns regarding case studies. The first one is about *validity*, which refers to the quality of the data and to what extent this resembles a valid portrayal of the phenomenon in practice (Yin, 2013). Case-studies are often criticized for being conducted in a sloppy manner, where systematic procedures are lacking and therefore prone to biased views which can influence the results (Yin, 2009). Secondly, the concern of scientific *generalization* is addressed, where results of

v

the case-study can support theoretical propositions, but cannot be generalized to populations. Yin (2013) explains several ways to deal with the two concerns of validity and generalization. Regarding the prior different methods can be used to strengthen the validity of the cases studied: (1) checking for rival explanations, (2) triangulating data/methods and (3) using logic models. This is addressed in this research by using multiple sources (reports, interviews and literature) and by performing a cross- case analysis using the replication logic. Secondly, to prevent false generalizations from happening, this research (1) makes use of analytic or conceptual generalizations, which explains how the evaluated case produced its results and (2) the findings are connected to existing literature. A third strategy (3) is to replicate the findings of the original case study to strengthen the theory. All in all, a sound research design is necessary to improve the validity of the research and to ensure false generalizations from happening, which will be elaborated on in the next subchapters.

3.2 Research design

According to Eisenhardt (1989) theory building from case study research should follow several phases, which are merged for this research in five stages. At first, (1) *define research questions*, for which literature can be included. Secondly, (2) *select cases*, for which theoretical sampling can be used as a case-selection method, where cases are categorized based on different theoretical criteria (Eisenhardt, 1989). Thirdly, (3) *define methods and collect data,* where multiple data collection methods should be used to substantiate the theory. Fourthly, (4) *analyse data*, at first within the individual cases and afterwards across the cases to build theory. A verification process (replication logic) by replicating hypotheses in each case strengthens the internal validity of the research (Eisenhardt, 1989). Finally, (5) *embed in literature,* which should be coupled to compare the findings to existing literature. These phases, as depicted in the research flow diagram (Figure 3.1) below, will be further operationalized in the following subchapters.

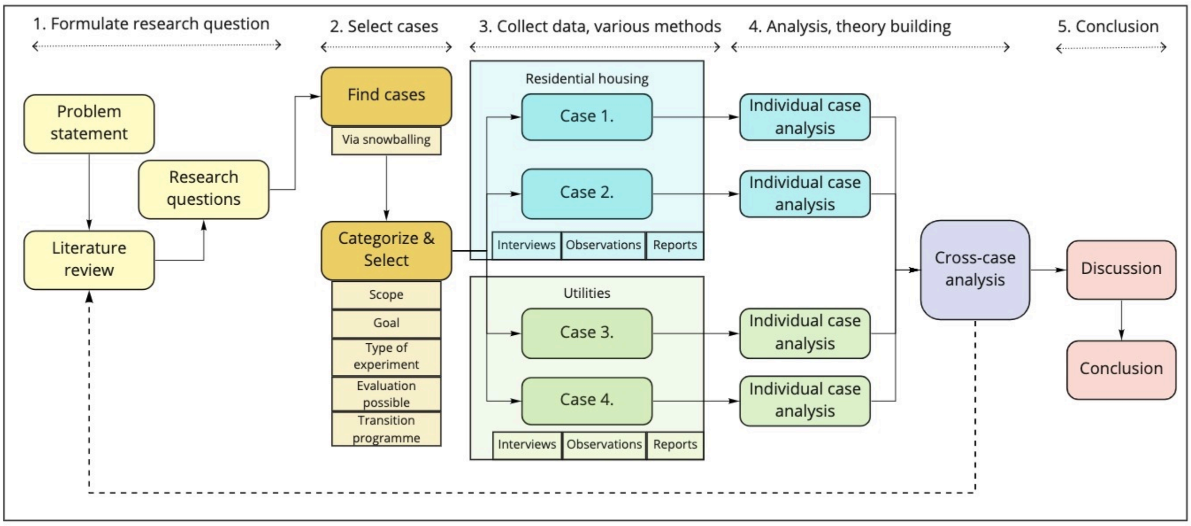


Figure 3.1 Research flow diagram, based on 'building theory from case studies' from Eisenhardt (1989).

3.2.1 Research questions and literature review

The motive for this research started from a practical problem experienced by a consultancy firm who were looking into ways how circular building experiments should be approached and designed. To support them and to approach this academically, this emerging phenomenon was placed in the state-of-the-art literature. From this literature review, the topic was embedded in transition and learning literature and eventually shaped in a transition learning perspective. For this literature review a snowball method was applied and scientific articles were found via Google Scholar and Web of Science. Search terms used in this process were: '*circular economy*', '*circular economy in the built environment*', '*circular buildings*', '*organizational learning*', '*transition literature*', '*transition* *experiments'*, '*CE barriers and drivers'* and '*learning in transition experiments*'. These search terms have been combined and selected based on their relevance and citations.

From the theoretical basis a central research question emerged, for which four sub-questions have been formulated around *who learns, learns how, learns what* and *to what effect,* as introduced in Chapter 1.3. The scope of these research questions was drawn to stakeholders involved in the design and construction process, as in these phases, it is expected that the interplay between niche and regime actors takes place. Furthermore, given the topicality of circular building experiments, as further explained in the next subchapter, the geographical scope was drawn to the national level, instead of a regional or municipal level.

3.2.2 Case-study selection

For the case-study selection method theoretical sampling was used (Eisenhardt, 1989). For this, a long-list was created, where Dutch circular building experiments are categorized based on several general and theoretical criteria, as shown in Appendix D. For replicability purposes, the following search terms were used in Google and further snowballed: *"Proeftuinen circulair bouwen", "Bouwprojecten circulair bouwen", "Circulaire proefwoningen", "Circulair bouwen leren door te doen", "Circulair (bouw)experiment"* and *"Circulair bouwproject experiment"*. From these, two circular construction platforms were found which listed practical examples of circular buildings that proved to be helpful (Circulaire Bouweconomie, 2021; Platform31, 2019). Through this snowballing method 29 potential cases were identified which were further selected based on three key criteria.

The first criterium encompasses the research scope of this research. As a CE in the built environment can take different scopes of analysis, from material- to a regional level, this research will focus on the building-level. This is also an understudied theme for researching CE in the built environment according to Pomponi & Moncaster (2017). Here, the building-level refers to all structural elements that form a whole with one specific function, such as a residential dwelling or office, and excludes area characteristics such as public green or infrastructure (Platform CB'23, 2019). The second criterium involves the type of experiment, as this research takes the perspective of transition literature, the focus of this research is on transition experiments. These are identified for this research as circular building experiments which are part of a transition programme, which according to Taanman (2014, p.16): are: *"(…) temporary institutions that purposively group together and coordinate different change actions and change agents to stimulate a sustainability transition through a process of searching, experimenting and learning.".* In the longlist, the potential cases are categorized based on the five types of experiments as found by Sengers et al. (2019). The third criterium is that evaluation should be possible, therefore the experiments need to be completed to evaluate the learning processes, and effects, adequately.

Based on these criteria, the 29 cases were further deducted, which led to different findings in the process. A remarkable finding in this process was that nearly half of the experiments are still in development (1, 3, 5, 7, 13, 16, 20, 23, 26, 27, 28), emphasizing the topicality of experimenting with circular construction, or were not able to continue (2, 17). Ultimately, ten transition experiments have been identified of which five could be evaluated and focused on the building level. Of these five cases, four experiments could be grouped for comparability purposes, where there were two cases initiated by a housing corporation focused on social housing and involved the same activities of circular deconstruction and newbuild. The other two cases were both circular pavilions (including a bar/restaurant) initiated by the public sector. For comparability, these four experiments are then chosen, which are listed in Table 3.1.

v

Table 3.1. Different characteristics of the four cases, based on their scope, starting date and transition program

CASE	SCOPE	FUNCTION	YEAR	TRANSITION PROGRAMME
De Woonplaats Assinklanden	Block of seven dwellings	Social housing	2017-2019	Regional Transition Agenda Circular Building Overijssel (province, Saxion, Pioneering and RBON). Focuses on 12 experiments/pilot projects.
SUPERLOCAL: Feniks-3	Three dwellings	Social housing	2016-2019	IBA Parkstad, focuses on innovative projects with the aim to transform the seven municipalities of Parkstad and the province of Limburg into a desired economic, social and environmental direction .
The Green House	Building	Café/restaurant	2014-2018	City Deal Circular City 2016-2018: transition programme including best practices in 9 municipalities. It includes 18 experimental projects supporting a CE in the built environment
Vondeltuin	Building	Café/restaurant	2019-2020	Municipal transition programme: 'Circulair: Leren door te doen', with the aim to adopt principles for circular real estate development

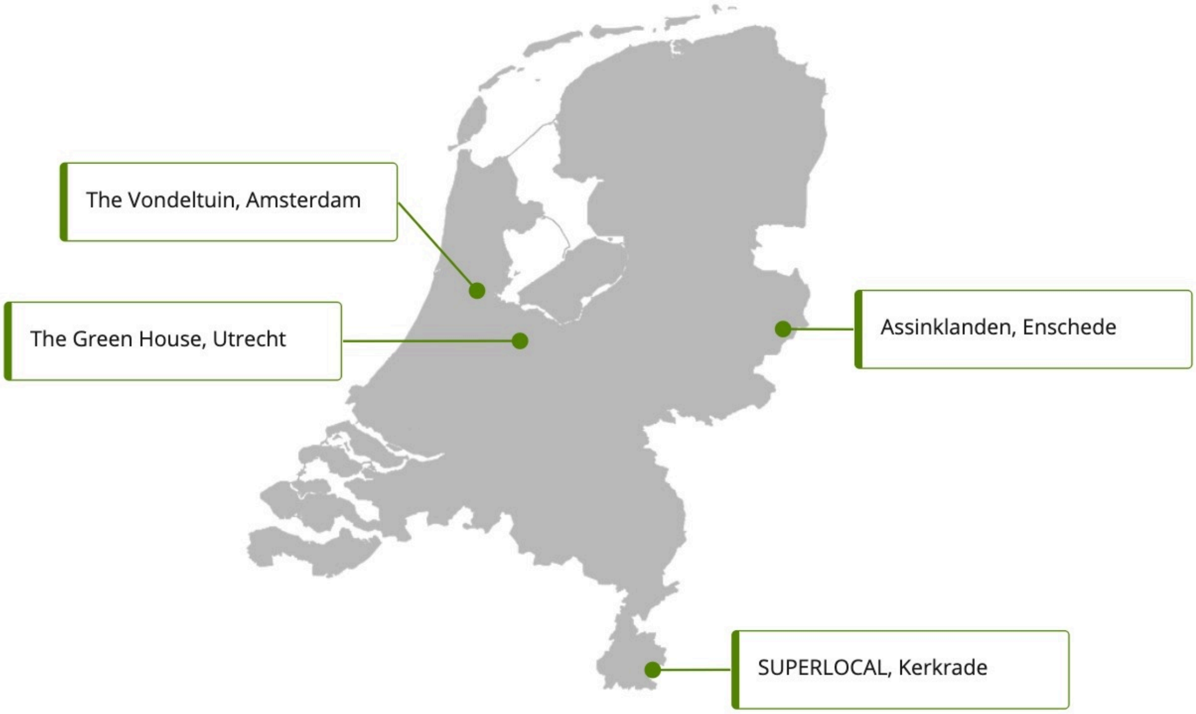


Figure 3.2. Geographical distribution of the four selected circular building experiments.

3.2.3 Data collection

The main source of empirical data that will be collected is through expert interviews. Per case, the stakeholders involved in both the design and construction will be interviewed. The advantages of in-depth interviews is that they allow to identify personal experiences, sensitive issues and the context of the experiment (Hennink et al., 2020). For assessing lessons learned this is deemed essential. Disadvantages are, however, that there is no interaction or feedback with others, it only highlights individual perceptions and multiple interviews are needed to identify all issues at stake (Hennink et al., 2020). Therefore, to improve the validity of the research, data triangulation is ensured via existing reports and other online articles. Next to this, to increase the trustworthiness of the research, the interviews will be recorded and the data collection process will be documented carefully for replication purposes (Baarda et al., 2013).

v

Eventually 29 respondents were interviewed via semi-structured interviews, as shown in Table 3.2. Before starting the interview, all respondents have been asked for consent to record the interview, to process the results anonymously (only company name and function) and to have the end result reviewed by the respondents for accuracy. After consent, the interviews were conducted which were supported with a topic-list based on the five CE research themes as derived from literature, as shown in Appendix E. Due to the COVID-19 pandemic, all interviews have been conducted online in Zoom. This made the act of interviewing more challenging as there was less room for informal trust-building and technical issues interrupted the process. Next to the online interviews all cases have been visited, however, due to the pandemic not all field visits could be accompanied with a guided tour. Luckily two project leaders were willing to give one (the client of Assinklanden and the operator of the Vondeltuin). Finally, all interviews were conducted in Dutch, which was also the language of the transcripts, and translated by the researcher for the quotes used in the analyses.

Table 3.2 Overview of the interviewees per case; their company, function, date and length of interview

Case	Company type	Company name	Function	Date	Length
Assinklanden	Housing corporation	De Woonplaats	Project manager	25/05/21	55:31
	Architect	LKSVDD	Architect	21/05/21	1:02:49
	Construction company	Oude Wolbers	Director	25/05/21	45:25
	Installation company	Loohuis Installatiegroep	Branch manager	03/06/21	51:10
	Structural engineering company	Lucassen Bouwconstructies	Director	25/06/21	24:45
	Construction company	Ter Steege Advies	Director	21/05/21	01:24:02
	Innovation platform	Pioneering	Consultant	02/06/21	42:38
	Maintenance company	Gebr. Van der Geest	Commercial director	18/06/21	41:05
	Lawyer	Kienhuis Hoving	Lawyer	09/06/21	40:11
SUPERLOCAL	Municipality	Municipality of Kerkrade	Sr. Project leader Jr. Project leader	17/06/21	59:12
	Architect	SeC Architecten	Architect	06/07/21	46:32
	Construction company	Bouwbedrijf Jongen	Innovation Manager	23/06/21	1:09:44
	Demolition company	Dusseldorp	Planning engineer	07/06/21	01:07:26
The Green House	Central government real estate agency	Central Government Real Estate Agency	Consultant	13/07/21	42:24
	Developer	Strukton	Project leader	15/06/21	52:54
	Structural engineering company	Pieters Bouwtechniek	Structural engineer	14/06/21	26:35
	Property operator	Albron	Marketing director	09/06/21	59:45
	Architect	Cepezed	Architect	28/05/21	01:03:05
	Consultancy	Alba Concepts	Consultant	27/05/21	42:17
	Interior supplier	Maasdam	Commercial director	09/06/21	31:44
Vondeltuin	Municipality	Municipality of Amsterdam	Project leader	03/06/21	01:18:04
	Architect	DOOR Architecten	Architect	04/06/21	51:45
	Construction company	De Nijs	Director	04/06/21	43:42
	Construction company	De Nijs	Project manager	08/06/21	
	Digital engineering company	OMRT	CTO	22/06/21	38:45
	Building physics consultancy company	Cauberg Huygen	Consultant	17/06/21	36:55
	Environmental consultancy company	Copper8	Consultant	17/06/21	53:13
	Structural engineering company	Van Rossum	Structural engineer	04/06/21	40:28
	Property operator	Vondeltuin	Catering manager	29/06/21	45:05

3.2.4 Data analysis

The data analysis phase, consisted of several steps which are introduced here. At first, to improve the analysis of the interviews, use is made of computer-assisted qualitative data analysis software (CAQDAS). For this, a software to support the process of transcribing (Amberscript) and a software to code the transcripts (Atlas.ti) are used. Amberscript is a software to automatically transcribe an audio file, for which the recordings were transcribed verbatim, meaning that every word of the respondent is transcribed. Even though this resulted in an efficient process, it proved that the software was not as accurate as a person, as for example names, companies or unclearly articulated words or sentences due to technical issues were falsely transcribed. Therefore, after transcribing, each transcript was manually reviewed and where unclarities or errors occurred, the audio file was checked and the transcript corrected. This mixed method further increased the reliability of the analysis. Secondly, Atlas.ti is a software that supports the coding process and can improve the reflexivity of a researcher (Woods et al., 2016). Before using this software, a coding scheme was made, as shown in Figure 3.3. This scheme was based on theoretical findings from the literature review and notes of the interviews. The coding scheme is structured according to four main colours, which reflect the related sub research question, which are briefly introduced here.

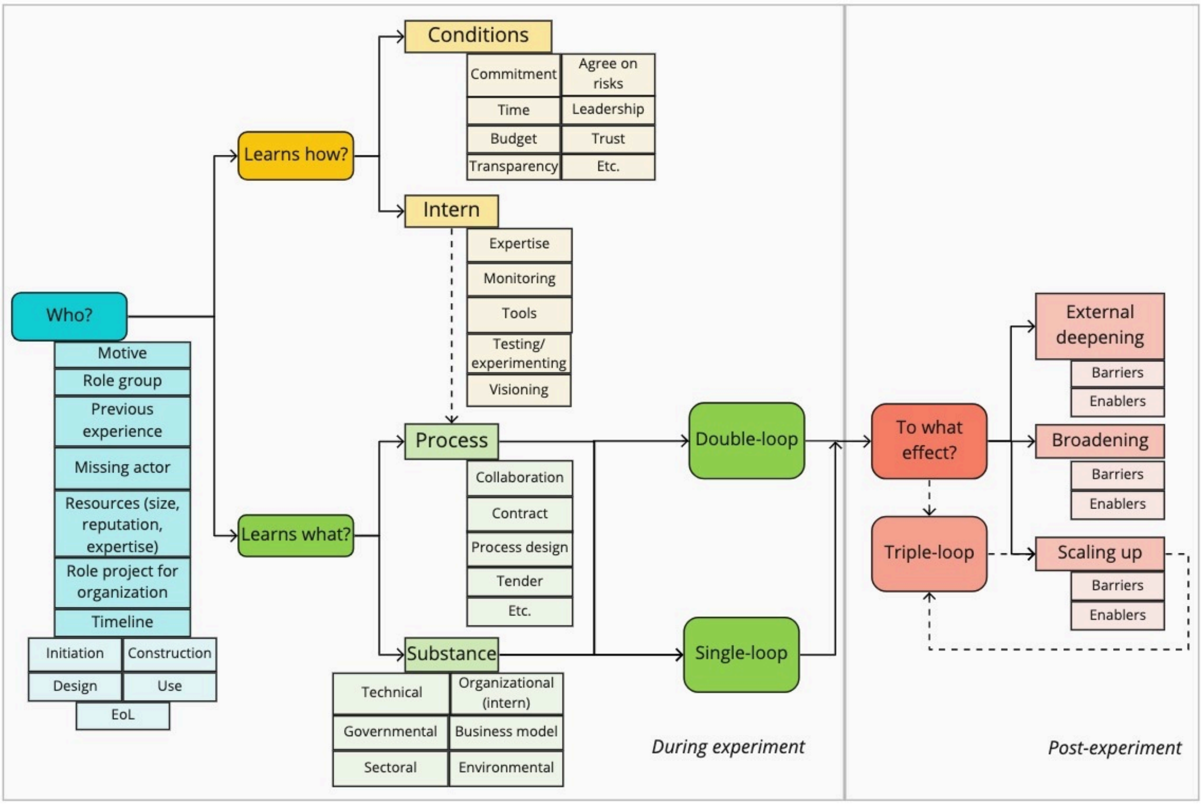


Figure 3.3. Coding scheme used in the data analysis process. The arrows indicate an expected link and the dashed arrows indicate a possible link.

At first, the blue colour represents the first sub research question: *who learns*. For this, a stakeholder analysis is conducted to shine light on the key characteristics of the interviewed stakeholders. This category contains several coding labels, such as motive for participating, role group (according to the roles of Table 2.11 (Platform CB'23, 2021)), previous CE experience, whether there were any missing actors, the company's resources and role of the project for the organization. Furthermore, timeline labels have been included to understand the development process and key activities of each case. This timeline will be introduced in each case analysis and the blue label category should provide the data for the case introduction and the stakeholder analysis.

v

Secondly, the yellow colour reflects the learning process in the experiment (*learns how)*, which is subdivided in two main categories (1) *the internal learning processes*, including subcodes such as involving expertise (derived from first notes), monitoring (Luederitz et al., 2017; Rotmans & Loorbach, 2009), visioning (Leising et al., 2017), tools and testing (both from notes); and (2) *the conditions necessary for a learning environment*, such as commitment (Brown & Vergragt, 2008; Kemp & van den Bosch, 2006), transparency (Luederitz et al., 2017; van de Kerkhof & Wieczorek, 2005), budget, time and leadership (last three from notes).

Thirdly, the green colour resembles the learning themes (*learns what*). This is divided into process-learning and substance-learning. Lessons learned regarding the process can reflect the collaboration form, contract, process design or tender procedure (all from notes). In Figure 3.3., these are indicated with a dashed line from *internal learning processes* as *how* has been learned could also result in a lesson learned regarding the process (*what*). Furthermore, *substance* learning relates to the five central research themes derived from the literature review (economic, governmental, cultural, environmental and technical). Based on this first coding round, these lessons learned are subsequently assessed whether the lesson learned can be seen as a single- or double-loop learning. As indicated in Chapter 2.5.1 and operationalized in Table 2.8, single-loop learnings will be identified as those learnings that supported solving errors in the experiment, but without further reflection on their own organization, their practices or company goals. Double-loop learning is then identified in those lessons learned which actually triggered organizational reflection of the agent involved and challenges the practices, goals and policy of the organization (Argyris & Schon, 1974).

Fourthly, in red, a post-experiment perspective will be applied. Here, the focus will be drawn to how lessons learned, albeit single- or double-loop, will be shared beyond the scope of the experiment (external deepening) and integrated in the organization (broadening and scaling up). In this process, third-loop learnings can occur. Third-loop learning takes an organizational learning perspective, ‘learning how to learn’, where an experiment can trigger a change in the learning direction of an organization, resulting in for example new learning methods or strategies to implement, or create more, single- and/or double-loop learnings. (Bartunek & Moch, 1987; Romme & Van Witteloostuijn, 1999). These third-loop learnings can occur before the process of integrating the lessons learned in the organization or during or after the process, e.g. if any lessons learned occurred in the post-experiment institutionalization process which reflected the organizational learning process. Therefore, there is a dashed arrow included before and after scaling up.

Ultimately, this coding scheme formed the basis of the case-study analysis. In the next chapter the results will be presented. Each of the four cases is structured in similar fashion. At first, an introduction will be given on the case, including a timeline and key characteristics of the development process. Secondly, a stakeholder analysis will give insight in the *subjects* (*who learns*) of the experiment by shining light on their general background, interest in the projects, role and resources. Thirdly, the learning process (*learns how*) will be discussed by elaborating on the core learning activities and the key conditions necessary for it. Fourthly, the associated lessons learned, the *objects* (*learns what*), will be introduced. These will be linked to five CE research themes as derived from literature: *governmental, economic, environmental, sectoral* and *technical* and whether these can be regarded as single- or double-loop learnings. Finally, a post-experiment perspective will be used by discussing how the lessons learned have been shared beyond the borders of the experiment (external deepening) and how the integration process in the organization (broadening and scaling up) occurred), called the *results* (*to what effect*).

v

Chapter 4. Results: Individual case analysis

This chapter zooms in on the results of the four selected cases by individually assessing each case. As stated in the final paragraph of Chapter 3.2.4, each case analysis consists of six separate sections: (1) case introduction and development process, (2) the subjects (*who learns*), (3) the process (*learns how*), (4) the objects (*learns what*) and (5) the effect and (6) an overall case conclusion. The analysis starts with two experiments focused on social housing, at first Assinklanden and subsequently SUPERLOCAL, after which the development of the two utility experiments, the Green House and the Vondeltuin, will be discussed. Ultimately, the results of these individual cases will be compared in a cross-case analysis in Chapter 5.

Table 4.1. Overview of the interviewees, their company and function. In the text, respondents are referred to their interview number (e.g. interviewee 1; 2 etc.).

INTERVIEWEE	COMPANY TYPE	COMPANY NAME	FUNCTION
1	Housing corporation (client)	De Woonplaats	Project manager
2	Architectural firm	LKSVDD	Architect
3	Construction company (operational)	Oude Wolbers	Director
4	Installation company	Loohuis Installatiegroep	Branch manager
5	Structural engineering company	Lucassen Bouwconstructies	Director
6	Construction company (consulting)	Ter Steege Advies	Director
7	Innovation platform	Pioneering	Consultant
8	Maintenance company	Gebr. Van der Geest	Commercial director
9	Law firm	Kienhuis Hoving	Lawyer

4.1 Case 1. Assinklanden, Enschede – Circular deconstruction/newbuild dwellings

Figure 4.1. Top two pictures show the seven social housing dwellings (Own source, 2021). Bottom picture indicates a replica of the seven dwellings that had to be deconstructed (Google Maps, n.d.).

v

4.1.1 Case introduction and development process

In Enschede, in a neighbourhood called 'Stroïnkslanden', seven social housing dwellings were designed following the 9 R's and delivered in January 2021. The seven dwellings are located on the Assinklanden, where prior to the experiment seven single-floor dwellings needed to be deconstructed as these did not meet the client's standards anymore, as shown in Figure 4.1 (interviewee 1). This subchapter explains its development process according to the five development phases of a circular construction project: initiation, design, construction, use and deconstruction and afterwards the circular strategies applied in the experiment, as depicted in Figure 4.3 following the shearing layers concept of Brand (1995). A timeline of the events per phase is indicated in Figure 4.2.

Figure 4.2. Timeline of the events and the start of every phase.

Initiation phase

The idea to redevelop these dwellings following circular principles did not originate from the client. They were approached by Pioneering, a platform for innovation in the construction sector oriented in the Eastern part of the Netherlands. After inquiring their members early 2017, Pioneering decided to develop a series of masterclasses based on six different circular construction themes. The masterclasses consisted of field visits, lectures and a case study. Instead of a fictive case-study, the goal was to work with a practical case, where participants can apply the learnings in a real-life setting (interviewee 7). To do so, Pioneering contacted the client who were keen to cooperate and offered the seven dwellings on the Assinklanden as a real-life case. For the tendering process, the client, under consultation of Pioneering, allowed all companies to participate (also those not connected to Pioneering) under the condition that they would follow the masterclasses, and provide a financial contribution for it.

In the end, 20 companies participated, including 6-7 construction companies. After the final workshop was conducted, the participants were asked to participate in the experiment. Five stakeholders showed their willingness, where only a structural engineer and an installation engineer were missing. These were added to the group based on the network of the architect who previously worked with them. The ambition of the client was explained in the requirement specifications, stating that for the pilot project the 7 dwellings had to be demolished and 5 or 6 new dwellings had to be constructed. Under the header 'sustainability' it said the focus should be on the *trias energetica* and CE, which they understood as: a closed material cycle from cradle to cradle (interviewee 1). To achieve this, solutions had to focus on the following starting points: (1) closed cycles, (2) stimulate high-value reuse of materials, (3) deliberate choice of materials and (4) sustainable design of the buildings (interviewee 1). This ambition, together with a budget which was predetermined in 2014, formed the preconditions after which the group could start the design stage.

Design phase

After the core team was created, which will be discussed in Figure 4.2.1, the team agreed on a collaborative collaboration form in which they as a *consortium* participate from the design-phase onwards. This collaboration rested *consent*, where decision-making was based on the principle 'who knows, decides'. Objection for certain decisions was allowed, but the argument should be collectively agreed upon (interviewee 2; 3; 6). Near the end of the design phase, this collaboration form was formalized, so it could be applied in the construction phase. Through the involvement of an external lawyer an innovative collaboration contract based on (1) open communication, (2) early warning management system and (3) stepped dispute resolution was developed (interviewee 9). However, to cope with legally-binding responsibilities, a traditional formal contract still had to be applied, where the client signed an agreement with the construction companies, who have signed a contract with the advisors (architect and structural engineer) and other builders (prefab supplier, maintenance company and installations company). So, the experiment involved an innovative collaboration contract and a traditional contract regarding responsibilities (interviewee 9).

The design was structured around a DfD-strategy together with the 9 R's, where eventually the skin and services are separated from the structure, as shown in Figure 4.2 (Stichting Pioneering, 2020). The team met every 14 days to discuss the various options. In this process, the first step on the ladder is refuse and the question was raised why the client needed five/six dwellings. Instead, the team tried to go for seven dwellings and reuse the entire structure and add a topping to it. However, the load bearing structure could not carry the weight of the topping and they decided to reuse the foundation and build a two-floor, light-weight, timber construction on top (interviewee 3; 6). Eventually the design process took two years instead of the expected six months and after the first year, meetings occurred once a month instead of every 14 days (interviewee 7). This was mainly due to pricing difficulties in the materialisation stage, where extra funding pools and subsidies had to be found. After the final design was agreed upon, the contract was signed in March 2020.

(De-)Construction phase
In May 2020, the team started the deconstruction, removing asbestos and constructing the new buildings. In the construction phase, the team met and discussed every 14 days again. In these sessions a system of early warnings was monitored by the lawyer, that obliged a duty to report if members of the team observed anything that could influence the planning, costs, quality or sustainability of the building (interviewee 9). Apart from minor incidents with the prefab timber supplier, who delivered mirrored construction elements, everything went according to plan (interviewee 3; 6). The *use phase* started in January 2021, during this time the client set out an interview procedure to find users who 'fit the mindset', as gardens and surroundings are designed as shared space (interviewee 1). They try to incentivize communal maintenance by for example giving householders different maintenance tools, such as a rake, a shovel and a broom (interviewee 6).

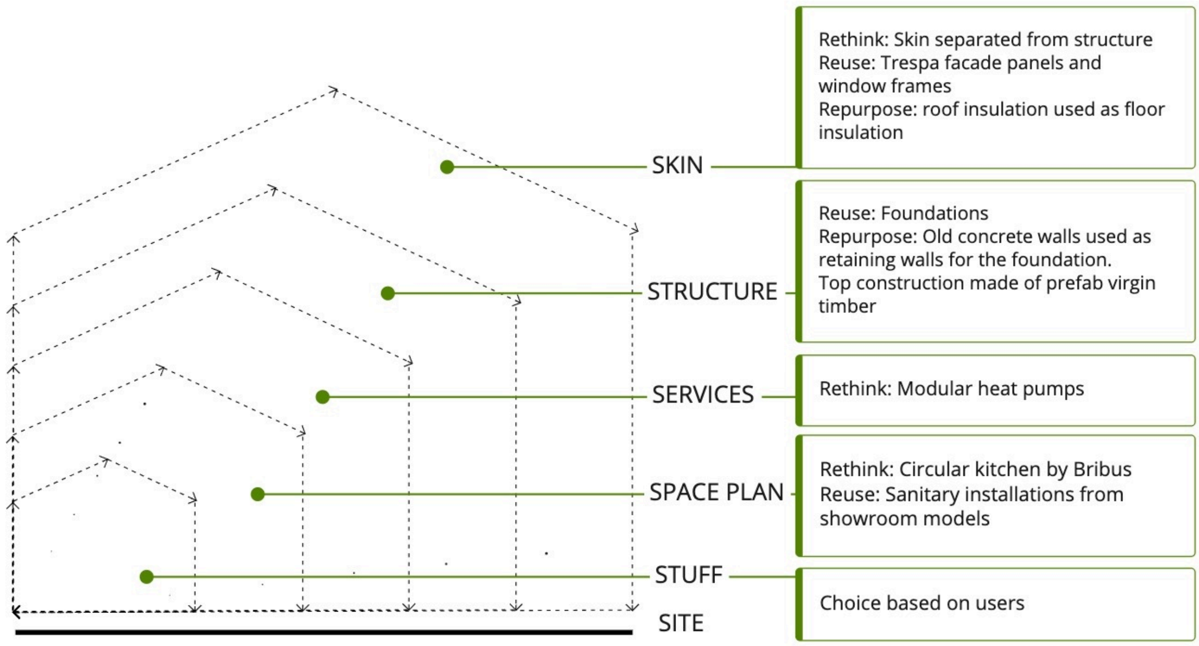


Figure 4.3. The circular strategies applied in the seven dwellings on the Assinklanden based on the 9 R's (Potting et al., 2017) and determined per shearing layer of the building (Brand, 1995)

4.1.2 The subjects: Who learns?

The experiment included a variety of different actors. To understand their roles, their interests and resources, this subchapter starts with a stakeholder analysis to get a grasp of the stakeholder dynamics. Secondly, next to those who *were* involved, it is also valuable to assess which actors, or role groups, *were not* involved. Therefore, the second part of this subchapter zooms in on actors, or actor roles, that were not included or deemed missing by the respondents in the experiment. Table 4.2 provides a descriptive stakeholder analysis based on the conducted interviews. Figure 4.4 plots these actors in a map, based on the four role groups as described by Platform CB'23 (2021): Initiators (green), advisors (orange), builders (blue) and controllers (pink) and their level of involvement, subdivided in: core team, involved and informed. The *core team* exists of the 'consortium' who are involved in the design and construction phases, *involved* are those who have been involved in a single phase to provide input or help the project move forward and *informed* are those not directly involved, but want to stay informed and can provide input when necessary.

Table 4.2. Stakeholder analysis of Assinklanden. Overview of key actors, their interests, role and resources. The colour indicates their role group: green = initiators; orange = advisors; blue = builders.

STAKEHOLDER	BACKGROUND (GENERAL)	INTEREST (PROJECT)	ROLE (PROJECT)	RESOURCES
Housing corporation *(De Woonplaats)*	Deliver social housing in a cost-efficient way in Enschede and Achterhoek. Medium-sized: 197 FTE.	Experiment with circular construction. Part of an internal working group on CE.	Financial responsibility, material scout for sanitary installations	Financial resources, decision-making
Architectural firm *(LKSVDD Architecten)*	Regionally operating architectural firm with a focus on societal impact, design buildings for reuse, repurpose and flexibility. Small-sized: 23 fte.	Involved in innovation platform Pioneering, asked to lead the group as supervisor and architect.	CE-lead in design phase, supervisor, material scout	Circular design knowledge; reputation
Structural engineering company *(Lucassen Bouw-constructies)*	Ambition to support developing smart and inventive building structures. Small-sized regionally operating company: 22 fte (eastern part of NL).	Worked together with the architect, asked to consult on structural construction	Construction controller/expert	Construction knowledge
Innovation platform (*Pioneering*)	Platform to stimulate innovation in regional construction sector via initiatives and workshops.	Showcase project	Knowledge development and dissemination	CE theoretical knowledge, network
Law firm *(Kienhuis Hoving)*	Try to pioneer within conservative law sector, CE not main focus. Medium-sized: 122 fte.	Test circular contracting model	Conflict management and monitoring construction phase	Legal knowledge
Construction company *(Oude Wolbers)*	Regionally operating construction company, family-owned, existing for 90 years. Medium-sized: 75 fte.	Saw that initiators (clients) started to focus on circular construction, wanted to explore.	Operational contractor and secondary material scout	Construction knowledge, network of suppliers
Construction company *(Ter Steege Advies & Innovatie)*	R&D department of Ter Steege Group focus on energy transition, circular construction and sustainable innovations. Large-sized, 331 fte, 42nd largest construction company of NL (Cobouw, 2020)	Worked on elements of circular construction before, first project to fully experiment with circular construction	Control and consulting contractor	Operational knowledge, CE vision and reputation (member of CB'23)
Installations company *(Loohuis Energie & Installatie Advies)*	R&D department (5 fte) of Loohuis Installation Group (large-sized, 500 fte). Focus on installation technology. Operate regionally.	Explore and gain knowledge about circular construction	Expert on installations and CE knowledge	Installation knowledge, CE reputation (partner of modular Finch Buildings)
Maintenance company *(Gebr. van der Geest)*	Painting and property maintenance. Operate regionally, Medium-sized: 75-80 fte.	See it as a learning experience, an expensive course	Biobased painting and maintenance expert	Innovations for the building's skin
Material supplier *(Prefab NL*)*	Producing and delivering timber construction elements. Went out of business after the project	Were enthusiastic in the masterclass, but apathetically present in the design stage (interviewee 1; 3; 6)	Material supplier	Manufacturing knowledge

Company size: Micro-sized: < 10 fte; small-sized: < 50 fte; medium-sized: <250 fte; large-sized: >250 fte (RVO, n.d.-b).
*Bankrupt

v

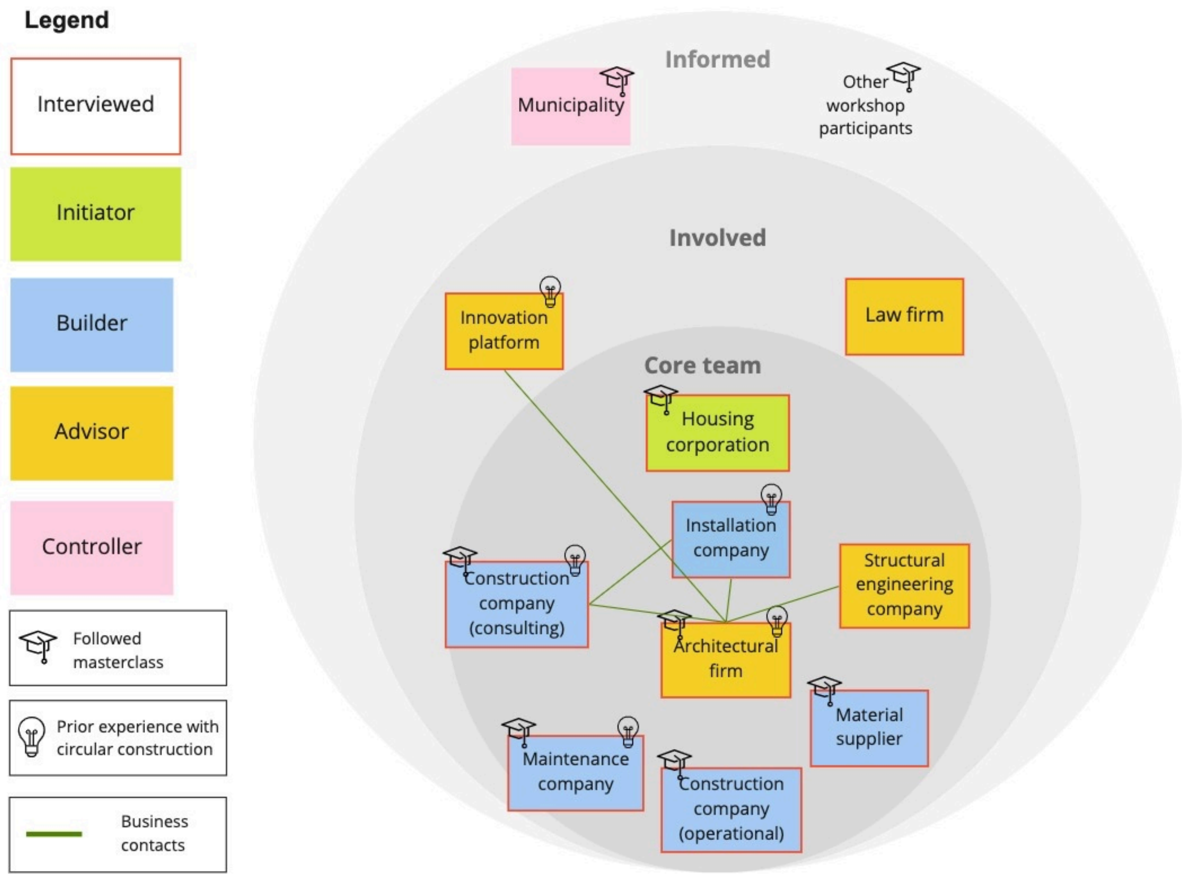


Figure 4.4. Stakeholder map of Assinklanden. Stakeholders mapped according to their involvement and role group.

Subjects' analysis

A first interesting insight is that the collaboration form insisted that different role groups are involved from the design phase onwards. Where traditionally the design team consists of only *advisors*; namely an architect/engineer, a structural engineer and an installation advisor (Platform CB'23, 2019), in this experiment also the *builders* (material supplier, construction companies and maintenance company) and the *initiator* (client) were involved. Next to this, the architect (LKSVDD) has a more important role, because of a) his knowledge about circular construction and reputation via previous circular projects, such as the Upcycle Centre in Almere, and b) his network and business contacts (depicted with the green arrow in Figure 4.4) (interviewee 1; 3; 6; 8). He acted as the spider in the web and can be seen as the system integrator in the design stage. Moreover, the triangle between the installation engineer, the consulting construction company and the architect in Figure 4.4 is worth mentioning, as they met each other previously in networking events (interviewee 4) and share a common vision about the future of the construction sector (interviewee 2; 4; 6). All in all, it is valuable to emphasize that all involved stakeholders are regionally operating, SME's[2].

Missing actors

From the interviews it became clear that various actors connected to different role groups were not involved in the experiment. The first group who were not involved, where large, nationally operating, actors, even though they were involved in the masterclass (e.g. Van Wijnen). A limiting factor for them was the relatively small size of the project, which made it not financially interesting

[2]Except for the consulting construction company and the installations company who are part of a larger concern (Ter Steege Groep and Loohuis Groep, respectively), even though their independent companies are medium-sized (interviewee 4; 6).

for them (interviewee 7). Next to this, it appeared that the representatives of the *builders'* group who were involved in the experiment, with the exception of the material supplier, were part of the innovation department of their company (Loohuis Energie Advies and Ter Steege Innovatie & Advies) or their companies were already focusing on innovation (Oude Wolbers and Van der Geest). Traditionally operating actors in the *builder's* role group were not involved or dropped out, as these do not allow to invest extra time for these experiments or focus less on R&D (interviewee 2; 4; 8), as exemplary stated by the installation's expert: "They want to build, deliver, cash in and move to the next project. (…) Developing concepts does not fit in that cycle. (…) Initially there was another, more traditional, installation company involved. In the end, they do not receive the time and budget from their boss, that is also why they dropped out and we entered." (interviewee 4).

Furthermore, it is not only the willingness of traditional companies in the *builders'* group, it is also the collaboration with their subcontractors which should be revised. Traditional contractors are locked-in due to long-term collaboration contracts. For example, the architect stated: "The construction sector has focused on *efficiency* for decades. We deliver good products, but we do not do the right thing as we keep harming the plant. Rather, to do the right thing we have to focus on *effectiveness*. In doing so, we have to break traditional processes, especially for contractors. We are in that phase right now, and you need these experiments to break these patterns." (interviewee 2). Meaning that in order to stimulate a CE in the construction sector it is necessary to break from locked-in processes and start new forms of collaboration. Involving suppliers, or subcontractors in these experiments could be key to onboard them in this transition, as emphasized by the installation engineer: "I tried to involve our suppliers to think with us. For example, the ventilation boxes or radiators have been the same for decades, can you think of a refurbished model? But there was no response. That was an eye-opener for me, the market is not ready yet." (interviewee 4).

Finally, three different actors mentioned the absence of the *control* group as a missed opportunity, meaning those actors who check buildings or the design of a building on laws and regulations (interviewee 2; 6; 8). Even though there was a structural engineer of the municipality involved who supported the team to find old construction plans, they could not be involved in the experiment as they did not have the capacity for it (interviewee 2). A missed opportunity, according to the architect, maintenance company and consulting construction company, who emphasized the necessity for them to see systemic failures in norms and regulations and the value of collaboratively exploring the possibilities to work within current regulations. As indicated by the architect: "More freedom to comply to norms would have helped. (…) Plus experiencing it yourself works better than explaining it. It takes a lot of time, and therefore money, to show a civil servant that there are different ways to comply to a norm." (interviewee 2).

Conclusion

Regarding *who should learn*, from this stakeholder analysis it becomes clear that, compared to traditional developments, more expertise is integrated in the design stage, where different *builders* and the client are involved from the start. It also becomes clear that these are the stakeholders with no prior CE expertise (as indicated in Figure 4.4) and could therefore be regarded as stakeholders who should learn in the experiment. Furthermore, from this analysis it becomes clear that the involved stakeholders are all small- or medium-sized companies operating regionally. Apparently, the small scope of the experiment was not of interest to large *regime actors*, who were involved in the masterclass. Furthermore, various actors were not involved, or withdrew, who were regarded as stakeholders who should learn about circularity, these were: (1) both *traditional builders* and their (2) *subcontractors and/or material suppliers* and, from the control group, (3) *governmental controllers* to experience how current norms and regulations hinder CE activities.

v

4.1.3 The process: Learns how?

Building on the involved actors, this subchapter zooms-in on the learning process. From the interviews it became evident that the learning process resulted in both individual and group learning outcomes and that most learning occurred in the design stage (interviewee 1; 2; 3; 6), as emphasized by the operational construction company: "In the design and initiation phase I mostly learned, because in the construction phase you do not have to research things anymore (…) and by doing research and through group deliberation I learned how things are related" (interviewee 3). Furthermore, to use the full potential of these learning activities, there were certain (pre)conditions necessary. This subchapter explains the learning process by discussing (1) learning activities (blue boxes in Figure 4.5), (2) (pre)conditions for the learning activities (yellow boxes) and (3) missing process features that could have supported the learning process (light-coloured boxes).

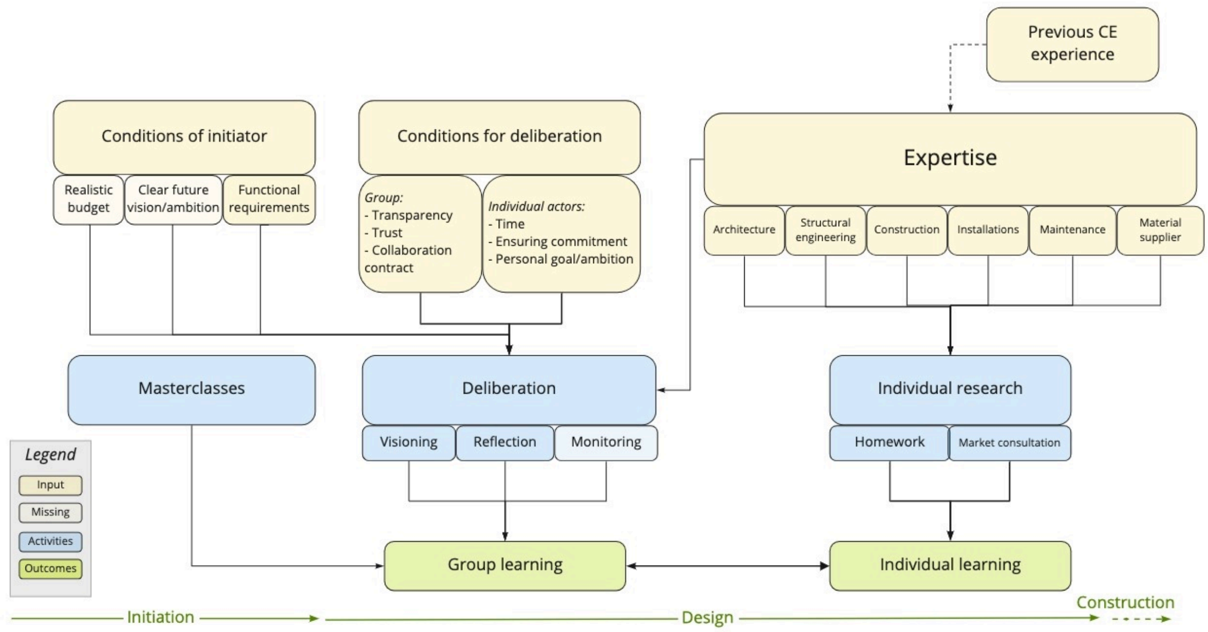


Figure 4.5. Overview of the learning process in Assinklanden. To produce learning outcomes (green), different activities were necessary (blue), which rested on certain (pre)conditions (yellow).

Learning activities

In the experiment there were three main types of learning activities, (1) the plenary workshops, (2) individual research, related to individual learning, and (3) deliberation relating to group learning. First of all, the experiment is characterized by a learning process via six different masterclasses, including field visits, regarding six different research themes. These ensured a reflection on the current system and a circular system and involved themes such as circular business models, the 10 R's, the relationship between energy and materials (embodied energy in PV versus reduced energy demand during use), new value models (e.g. Total Cost of Ownership), circular construction techniques and new collaboration forms and contracting (e.g. *rapid circular contracting*) (interviewee 7). This ensured that all stakeholders, except those that joined in a later stage, had the same knowledge regarding circular construction from the start (interviewee 2; 3; 8). For the operational construction company this for example stimulated deep learning regarding the possibilities of a CE: "The masterclasses made me realize how much is possible. From ESCo's[3] to circular business models to high-tech materials. All of which I had never heard of before." (interviewee 3).

[3] ESCo = Energy Service Company, realizes, through different measures, energy reduction for a building owner based on a performance contract. (RVO, n.d.-a)

v

Secondly, individual learning occurred within the expertise of an actor, albeit structural engineering, construction, installations or maintenance. In the design phase, actors were asked to research various possibilities within their own expertise. For example, the operational construction company stated that he learned most in the moments the group got together, but also when he went home with ‘homework’ or assigned an employee to consult the market for secondary materials for the entire week (interviewee 3). Also, the maintenance company stated individual research prohibited the group to fall back on old routines. For example, in the detailing process they did not find a solution for disassembly: “Then it was easy to fall back on old routines, especially for builders. The architect then said: that is the easiest way, but it does not fit in the long-term mindset of the masterclass. Go home and think about it, next week we will discuss it again.” (interviewee 8).

Thirdly, group learning occurred when actors brought their own expertise to the table and deliberated about each other’s circular design vision. This visioning process was led by the architect, who deliberately chose for an integral approach in the design stage: “Through integrally approaching the design of the building, the plan reaches a higher level. But you need to make sure that you constantly challenge each expertise: Are we doing the right thing together?” (interviewee 2). By collaboratively discussing the possibilities of each expertise, organically a design developed (interviewee 2). For example, the architect stated that at first the structural possibilities should be discussed, which then influences the role of the prefab timber supplier, which subsequently influences the total energy demand and the choice for installations, and so on. Next to this, it offered the possibility to reflect on each other’s expertise to reach a better understanding. All in all, group learning occurred by reflecting on each other’s expertise and the entire system. In achieving this several conditions where necessary as highlighted in the next section.

Group conditions

Several conditions impact the extent to which learning is facilitated in the experiment. These can be divided into (1) group conditions, (2) initiators conditions and (3) individual conditions. From the interviews it became apparent that in order to deliberate about each expertise, an environment of **trust** and **transparency** is necessary in the group. Next to the fact that some actors in the design team already trusted each other as they worked on previous projects (Figure 4.4), trust and transparency was formally agreed upon via a **collaboration contract** based on consent. This approach invited group participation and led to unexpected contributions, as stated by consulting construction company: “Because you work with the principle of consent, the traditional divide between contractor vs. subcontractor disappears. Instead, you become partners in a consortium. (…) Through this, the painter (maintenance company) also dared to introduce a new innovation of theirs, namely vacuum glass. That was an eye-opener for me.” (interviewee 6). The principle of consent demanded reflection, and prevented arguments such as *“we always do it this way”*, which urged the stakeholders to find new solutions (interviewee 2). Furthermore, transparency meant that all communication should be open, including budgeting and planning.

Conditions of the initiator

Next to the relational conditions, the conditions set out by the client determined the extent to which transition learning was possible. At first, the project wishes should follow (1) **a clear future vision**. As the consulting contractor stated: “With today’s knowledge, I would have set down with the initiator, and ask: “What are your plans for the future?”, because that determines the circular approach. Start with the end of life.” (interviewee 6). This resonates with a back-casting visioning approach (Quist, 2007). Secondly, the vision should correspond with (2**) a realistic budget**, where all participants indicated that limited budget was a constraining factor for the experiment. Using secondary materials takes more time, is therefore more labour-intensive and more expensive. However, this was not reflected in the available budget, which was predetermined based on a plan from 2014 (interviewee 2). Furthermore, this led to choices in the construction phase which affected the ambition, such as virgin prefab timber elements, which should have been secondary elements (interviewee 5; 6). Next to a clear vision and a realistic budget, (3) **functional project requirements** was seen as a precondition by the team. Traditionally, design teams receive an extensive list of project requirements, but for circular construction a list of project wishes instead of requirements works better. This means that some aspects cannot be determined in the initiation phase, as it could hinder and exclude possible solutions. This approach demands flexible attitude of the initiator (interviewee 7).

Individual conditions

Finally, individual conditions were mentioned as investing sufficient **time** for the process and set out a **personal goal or ambition** for the project. This way, the team knows what every stakeholder at the table wants to get out of the project (interviewee 4). This relates to the final point **commitment***,* which can be understood as being committed to achieve the project's goals through the entire length of the experiment. For example, one of the project partners, the supplier of prefab timber elements, was in the masterclass very ambitious and enthusiastic, but in the design phase passively present. A lack of commitment trickled down to the construction phase in which mirrored elements were delivered and fault connection points applied. This led to disappointment of both the architect and the two contractors (interviewee 2; 3; 6). Commitment is also present in **ensuring continuity** in decision-making, for example a lot of choices are made in the design phase, but the operational project leaders do not know why certain choices were made. They receive a limited budget in the construction phase and need to invest extra time to use secondary materials, for them it is tempting to fall back into old routines, as was the case according to the installation engineer (interviewee 4).

Missing process features

From the interviews it became also clear that some features of the process were missing or could be improved. As stated before, the **clear future vision** of the initiator could be improved. Next to this, a downside to the process of deliberation was that it took two years instead of six months, which was time- and energy-intensive as indicated by the operational contractor and constructor. This could have been improved with a **clear project leader**. The architect took the role of circular leader, which was an important aspect as mentioned by the maintenance company, the constructor and both contractors, however according to him he was not the leader or chairman. This resulted in unclear task division, especially regarding documentation, which was absent (interviewee 2). This relates to the final point and that is **monitoring**. Environmental monitoring was performed via three MPG calculations and monitoring in the construction phase was performed via the system of early warnings in the building meetings. However, no monitoring process was applied in the design phase to document how the process, including the learnings, developed, as well as in the use-phase to understand how the building performs. According to the architect and installation engineer, a valuable lesson and something to include in a next experiment (interviewee 2; 4).

Conclusion

The learning process was characterized by theory, via the masterclasses about CE in the built environment, and group deliberation in the design phase as reflected in the amount of time invested in it (two years). *Deep learning* in the experiment was acquired by integrating the different role groups (initiator, builders and advisors) in the design stage, collaboratively envisioning circularity from each expertise and reflect and deliberate about this. Through the integrating role of the architect, system reflection was ensured to look at the broader picture, who also prevented the team to fall back in old routines, *regime activities*, by inserting moments of individual reflection (individual research) to afterwards discuss this plenary in the next session again. Furthermore, the masterclasses in the initiation phase ensured that all stakeholders had the same basic CE knowledge from the start of the design phase. Next to this, it is interesting to see that monitoring was included in the construction stage, but was absent in the design phase. Monitoring, through clear

v

documentation, reflection/evaluation moments and making a stakeholder responsible for this process seems to be important in ensuring continuity from a project management perspective and instigate process reflection which stimulates stakeholder learning. Furthermore, a clear vision regarding circularity from the initiator can support choices regarding circularity, which can provide focus for the learning process.

4.1.4. The objects: Learns what?

Now that the learning process is clarified, the question remains what stakeholders actually learned in the experiment. To do so, the lessons learned will be categorized based on the five circular construction research themes as introduced in Chapter 2.2.3; (1) economic, (2) governmental, (3) environmental, (4) cultural (organizational or sectoral) and (5) technical. These lessons learned will be linked to single-, double- and triple-loop learning. Table 4.3 recalls the definition of each learning loop. As triple-loop learning takes a post-experiment perspective of how lessons learned result in any changes in the organization, this learning loop will be discussed in Chapter 4.1.5 (*to what effect*). This chapter further introduces the lessons learned of each stakeholder, which will be discussed in order of role group, at first the initiator, then the advisors and ultimately the builders.

Table 4.3 A recall of the definition of the three learning loops for this research.

LEARNING LOOP	**DESCRIPTION**
SINGLE LOOP	Detecting and solving errors without further reflecting on the goals, policies or assumptions of the organization. *Do you do things right?*
DOUBLE LOOP	Improvement and adaptation based on reflection. Challenges current company policy, goals and approaches on how to solve the problem. *Do you do the right thing?*
TRIPLE LOOP	'Learning how to learn', shift in the organizational learning ability. Results in new learning methods, strategies or ability to utilize single- and double-loop learnings. *Do we learn the right things?*

Initiator

The initiator learned from (1) the tendering and design process, (2) business model innovation and (3) law and regulations. From the tendering process he stated: "I have learned so much from being part of the design process. Normally I send out a tender and receive something back. Now I could hear how actors think about certain requirements, which decisions are being made and why. (…) Would I do this again? No, I think there is a line for a client and we became too involved. It was unique in its sort." (interviewee 1). Given the fact that the development process did not proceed as he expected (mismatch or error), he became part of the design team, but in the end did not affect his way of working (interviewee 1). Therefore, it can be regarded as single-loop learning. Next to this, there were more practical learnings regarding the *Building Decree*, which hinders the reuse of window frames and doors, or the high price of reusing gypsum board due to extra labour and transport. Interesting, however, is the lesson learned about their own role regarding new business models: "I think we have to take a different perspective on our own property. Currently we only focus on price, but if we include a Total Cost of Ownership (TCO)-perspective, we have resale value at the end of a cycle. (…) We have looked into lease constructions, but our organization is not that far yet.". This second-loop learning (reflection of company's role) is acquired by the agent of the organization, but not obtained by the organization (yet). This will be further elaborated in 4.1.5.

Advisors

For the **architect** the most important lessons regarded the process design: including all stakeholders upfront in the design phase and collaboration based on consent (conflict management), where he encountered some first-loop learnings*:* Include documentation, a monitoring process on how the building 'behaves' and a clear project leader. It is important to mention that he had prior experience with circular design (DfD, design for adaptability/flexibility). For the **constructor**, the experiment entailed how to constructively deal with using secondary materials and how to assess which quality

v

these products have. In doing so, he learned two things: (1) it is a hard to transform a single-floor building into a two-floor building (single-loop), and (2) the importance of having constructive information available, both from the previous building as from secondary materials from other buildings. The latter is something he encounters in a lot of renovation projects. For this experiment, constructive information was missing, so they made a comparison calculation and decided to go for a light-weight timber construction. This lack of information about quality, is emphasized by the **lawyer**, who states that for circular construction, especially in this early stage, more risks are involved. According to him, traditional contracts do not suit this process as these are built on constantly transferring risks to someone else, therefore limiting trust. He learned about contracting, where a new contract based on trust, open communication and easy dispute resolution proved to work well. Finally, the agent of the **innovation platform** learned that collaboration (instead of competition) and transparency are key for this stage of the transition towards a circular built environment: “At first, we intended to have three teams compete against each other and the housing corporation could choose the winner. Luckily, the participants said we want to collaborate rather than compete.”.

Builders

The most important lessons learned from the **consulting contractor** were (1) collaboration, (2) carbon pricing and (3) business model innovation. The collaboration form based on consent is something he regarded as a valuable lesson: collaborate based on trust instead of distrust (that currently occurs in construction sector). Regarding law and regulation, he endured that carbon pricing needs to be included (financial incentive), as well as lifting VAT from secondary materials. Finally, and most interestingly, taking a TCO and future-oriented value-perspective on property. They could not test it in this experiment, but continued the development in their own organization by exploring the possibilities to deliver a topping as a service. For the **operational contractor** the experiment, and especially being involved in the design phase together with other disciplines, was an eye-opener: “That (ed. deliberation about expertise) made me realize how linear the construction sector actually is. We pretend to be circular, every supplier has a circular product, but nobody thought about the infrastructure to take the product back at the end of a cycle.”. It made him realize that key for circular construction is to keep elements clean, which he applied in his company policy and their own concept dwelling. Furthermore, more incrementally, he learned about using secondary materials in construction, which was difficult due to: (1) limited availability of materials (takes time and energy), (2) regulatory obstructions (Building Decree) and (3) the role of the client who has to approve reused products (e.g. sanitary was a problem). For the **installation engineer** the most important lessons were, firstly *sectoral*, where the installation market is still focused on efficiency, which does not include reuse or refurbishment. Secondly, regarding *law and regulation*, stating that the division labour versus material is so large reuse will never be scaled up. Finally, the agent of the **maintenance company** learned most about the collaboration form based on consent and more incrementally about using secondary materials, in which there appeared to be a shortage of secondary materials and urban mining (installations).

What not

Interestingly, all stakeholders from the *builders* group mentioned they would have liked to experiment with new business models. This has to do with, first of all, the Total Cost of Ownership perspective from the client, as clarified by the architect: “If we collectively agreed that a certain solution from the TCO-perspective is the best solution, but the client does not want to invest more upfront, even though they can rent it out 30 years instead of 20 years, then we can talk as much as we like, but we will never realize the transition”. The initiator subsequently says that their organization is not ready yet to calculate with TCO, or the inclusion of other values, such as the environment, health or social value (interviewee 1). Secondly, the *builders* group wanted to work with product-as-a-service (PaaS) systems. Where the installation group wanted to experiment with modular heat pumps as a service versus regular heat pumps as a service (interviewee 4), the maintenance company wanted to experiment with wall decoration as a service (interviewee 8) and both the contractors wanted to test with delivering floor-toppings as a service. However, this also bumped into regulatory barriers: "We thought about delivering services to the client, but the housing corporation is not allowed to rent something out which is not their property. But we started the thought-process, how would maintenance work, who retains ownership of the dwelling and what would the business model look like (e.g. a monthly fee). This forced the group to take a long-term perspective and think about a structural approach.". (interviewee 6).

Table 4.4 Overview of the lessons learned by each stakeholder coupled to the respective learning loop. The colour indicates the role group (red for the advisors, blue for the builders and yellow for the initiator).

STAKEHOLDERS	CE RESEARCH THEME	SINGLE-LOOP	DOUBLE-LOOP
Housing corporation (client)	*Economic*: procurement and business model innovation *Sectoral*: collaboration *Governmental:* regulations	(1) Learned about the role of requirements to support a CE in the tendering process. (2) Dutch Building Decree obstructs reuse.	(3) Revised their own role for a CE: move focus from only cost price, towards a Total Cost of Ownership, where buildings resemble resale value (long-term focus).
Architectural firm	*Sectoral:* Collaboration	Improve design of experiment: include a project leader, document carefully and monitor in different phases (design, construction and use)	
Structural engineering company*	*Sectoral*: Information	Hard to transform existing single-floor dwelling into double-floor dwelling. Crucial role of information for reuse of dwellings.	
Innovation platform	*Sectoral*: Collaboration, characteristics	Focus on collaboration and transparency and not on competition (financial gains) when developing experiments	
Law firm	*Sectoral*: Collaboration	For circular developments a *contract* based on trust, transparency and dispute resolution is necessary. All risks should be discussed upfront.	
Installation company	*Sectoral*: CE interest *Governmental*: incentives	(1) No interest for circular activities in the installation supply chain. (2) governmental incentives necessary to support reuse.	
Construction company (consulting)	*Sectoral*: Collaboration *Governmental*: Regulations *Economic*: Business model innovation *Organizational*: perception	(1) The necessity for new collaborations to support a CE in the construction sector. (2) systemic governmental failures: stop VAT on secondary materials, start carbon pricing.	Revised their own concept dwelling: Researching delivering modular departments as a service. New business opportunity
Construction company (operational)*	*Sectoral*: Acting in a linear economy *Technical*: Construction techniques	(1) Made him realise how linear the construction sector is, no CE infrastructure in place. (2) Difficulties when working with secondary materials: availability, price and client	Integrated disassembly strategies in way of constructing: detach installations from structure.
Maintenance company	*Sectoral*: Collaboration, CE interest	(1) The way to collaborate in circular projects. (2) lack of secondary products/urban mining.	

Conclusion

When recalling *who should learn*, it became clear that the initiator and stakeholders from the builder's group (except the installation- and maintenance company) had no prior CE experience. It is therefore, also interesting to see that these are the stakeholders reflected in the double-loop learning column. This can imply that the experiment successfully *deepened* their knowledge on circularity. From these second-loop learnings two are focused on business/ownership models (the initiator and the consulting contractor), whereas the operational contracting company learned most from how to construct for disassembly (*technical learning*). For those, that did work on CE before, the lessons learned mainly reflected the *sectoral* research pillar, including how the process should be approached, with a focus on collaboration (interviewee 2; 7; 8; 9).

v

4.1.5. The outcome: To what effect?

From the previous subchapter it became clear that all the interviewed actors learned from the experiment. However, the question remains to what extent the knowledge of the experiment is used and diffused by the involved actors. This subchapter, zooms in on this question, by taking a post-experiment perspective, to what is referred to as the *outcome* of the experiment. This will be done by analysing three processes through which knowledge can be used or diffused: (1) deepening, (2) broadening and (3) scaling, as explained again in Table 4.5.

Table 4.5 Recall of the definition used for each diffusion mechanism in this research.

DIFFUSION MECHANISM	*OPERATIONALIZATION*
DEEPENING	Deepening relates to learning on the level of the experiment and how these are shared. Learnings can be single-, double- or triple-loop.
BROADENING	Broadening focuses on replicating or reproducing (elements of) the experiment in another context.
SCALING UP	Scaling refers to how knowledge from the experiment, obtained by the agent of the organization, is scaled up to a higher scale of the organization.

Deepening: knowledge sharing

The role of the innovation platform was crucial in this experiment for both the start as the diffusion of knowledge after it was finished. They did so by first of all sharing the results of the project via a field session for the 20 initial stakeholders involved in the masterclass. Next to this, the agent from the innovation platform also supervises the community of practice (CoP) of the province of Overijssel, in which 26 experiments for a circular built environment are included. One of them is the experiment on the Assinklanden, which was connected to the CoP after it had been finished (interviewee 7). Finally, the innovation platform is also working on a report with all the systemic failures encountered in the experiment regarding norms and regulations which they want to share with the ministries. For this, also the consulting contractor and the architect are involved and they sought support with another sectoral innovation platform called 'Cirkelstad' (interviewee 7). So, from this it can be concluded that the innovation platform makes sure that the lessons learned diffuse both locally (masterclass), regionally (province, CoP) and nationally (ministries). Furthermore, the client shares its lessons learned in an overarching network of 15 housing corporations located in the regional, called 'WoOn Twente'. "We thought how can we bring this further? (…) In WoOn we took the role as pioneer to support other corporations in the tendering process, who are less familiar with circular construction." (interviewee 1).

Scaling up

As agents of the organization learned in the experiment, it is not a given that these are shared or integrated in the organization. How this occurred will be explained in this section. For the client, the experiment on the Assinklanden was part of a series of four different pilots focused on circular construction. These are part of the 'workgroup circularity' which various agents of the company are involved in. The lessons learned are shared with different departments (e.g. finance) through voluntary knowledge sessions. The experiments will be evaluated at the end of 2021 and presented to the executive board and management team to decide the future course of action. The focus on residual value of their property and lease constructions will according to the initiator be the focus of the evaluation: "We explored the possibilities (residual value/lease constructions) in the experiment, but within the organization there was no support base nor expertise to start the modelling process. (…) but this is a quest we are currently working on." (interviewee 1). From this it can be concluded that the second-loop learning regarding ownership models requires a new mindset and capabilities within the organization.

For the **architect** the way he approached this experiment, by thinking in systems and integrating different disciplines in the design phase, is not a new way of working. Their agents are trained this way (interviewee 2). However, he did include the lesson learned regarding the necessity to document and monitor during the experiment in a new circular building project. The same reasoning became apparent from the **structural engineer** stating: "We often take part in these pilots where we try out different systems. We try to involve and update the rest of the personnel as well. Mostly, informally at the canteen table." (interviewee 5).

The **operational contractor** stated that they adjusted their construction technique so that it can be disassembled in the future. This is something he applied in new projects already, without the client asking for it. The lessons learned are shared informally on Friday afternoons, when all agents of the company come together. "Sounds funny, but then we share the most important things of the week. What did we do? Where did we run into? That is how it is shared internally." (interviewee 3). Interestingly, the agent of the **consulting construction company** takes a different approach. Next to sharing the lessons learned in the usual weekly board meeting, he states that you have change the mindset of all the employees: "Often the perspective of my colleagues is "Oh circular, that is second-hand". No, it is not. That is why I dragged all of them to the Assinklanden and showed them how it works. (…) That is really important, you have to practically change the mindset.". This can be regarded as a *triple-loop learning*, as this is a(n) (informal) learning structure to overcome the negative perception of circular construction of his colleagues. By practically showing them how a CE works is used as a new means to accomplish double-loop learning within their organization. Furthermore, he encountered several internal barriers towards integrating new circular business models (e.g. delivering modules as a service): (1) *uncertainties*, both financially (investment is fixed upfront, but monthly return is low and lead-time long) as practically (what happens when multiple users return the module) and (2) *sectoral*: "It is insanely busy in the construction sector, that means that all developing construction companies do what they always did. There is no mental space to revise and think about alternatives." (interviewee 6). The agent of the **maintenance company** shared the lessons learned informally via an internal communication platform, but there is not a formalized structure in place to integrate these lessons. Finally, the agent of the **installation company**, does not share the lessons learned directly with its employees, but informs them about the fact that they have done a pilot on circular construction. So, if there are questions regarding circularity: "come to the innovation department for more information" (interviewee 4).

Broadening

An interesting result from the analysis is that the architect, both construction companies, the installation company and the lawyer are all looking for a follow-up project. This can be seen from the perspective of the individual company as from the perspective of the consortium. Taken this first perspective, the lawyer is still looking for a project in which he can test the contract from the initiation phase onwards. He states there are two main barriers in this search: (1) the construction sector is conservative and collaboration forms have been fixed between contractors and subcontractors/suppliers and (2) the construction sector is in a busy period with high demand so there is no reason to change trajectory. Even though the sector knows that circular construction is upcoming: "It is the idealist on one side and the practical implementation on the other. These do not fare well in a busy construction market." (interviewee 9). Backed by the installation engineer who states that in these periods, projects like the Assinklanden are very rare (interviewee 4).

Taking the second perspective, the consortium stressed the value of following-up with the current group. The architect emphasized the importance of following-up on the knowledge gained in the experiment and taking it a step further. He tried to find a follow-up project together with the consulting contractor, but encountered difficulties as these are not abundantly available. The role of the client was also discussed in the group, but the high price of the development seems to act as a barrier: "The goal was to replicate the experiment, but unfortunately it became a one-off project, even though the client has numerous of these blocks of seven which need to be redeveloped. But

v

they said that they could not do it for that budget." (interviewee 6). The operational contractor further stressed the necessity of a follow-up project together with the consortium: "I would very much like to make a 2.0 version. My team responded: "If we could do it again, then I would make it this or that way" (…) See, we are all SME's and we innovate by doing. If we as partners can do 1 or 2 more of these projects, we can learn an awful lot. It does not have to be big, but can also be in small steps. But it is essential that the consortium collaborates further." (interviewee 3).

Conclusion

Several interesting facts can be derived from this chapter. First of all, small- and medium-sized companies share their lessons learned *informally* in their organization. For this, no dedicated moments are assigned. Secondly, an interesting finding is that for the initiator, not all competences are available to scale up the knowledge gained in the experiment. Regarding new ownership/business models their finance department is not able to calculate with these models. Therefore, suggesting that transition learning regarding circular construction should not be limited to the project leaders of the client, but that different departments of the organization get involved and gain the necessary competences/capabilities. Thirdly, to ensure that the process of deepening is not limited to the stakeholders involved in the experiment, the role of an external party, in this case the innovation platform, proved to be important to share the knowledge gained locally (masterclass), regionally (province, CoP) and nationally (ministries). Finally, the lacking opportunities to follow-up on the knowledge gained and to *broaden* knowledge on circular construction was seen as a missed opportunity (Interviewee 2; 3; 6; 9). Reasoning, from the MLP, these broadening projects are essential to build momentum and change unsustainable regime activities. Here, the role of initiators in tendering these projects seems crucial, but barriers, such as a high demand for traditional projects and high costs of this experiment seem to limit these (interviewee 1; 4; 6; 9)

4.1.6 Overall case conclusion

From the first case analysis, several key take-aways can be identified regarding *deepening*, *broadening* and *scaling up*. Deep learning, or deepening, in this experiment was obtained through firstly, masterclasses, which combined theory with field visits and introduced the stakeholders to key themes of circularity in the built environment. Secondly, by integrating various disciplines (initiators, builders and advisors) from the design phase onwards and providing room for collective visioning, reflection on each expertise took place. This stimulated reflection on the broader system and the interrelationships of each expertise in moving towards a CE. For this process, which took two years instead of the planned six months, the architect proved to be of importance in breaking routines of regime actors and stimulated actors to, both individually via research/'homework' and collectively via group deliberation, rethink the development process. Furthermore, those stakeholders that had no prior CE experience and are involved in regime activities (the initiator and the two construction companies) obtained double-loop learnings regarding new circular business/ownership models and more technically on how to construct for disassembly, so it retains future value.

However, the *deepening* process in the experiment could have been structured more accordingly, even though monitoring was applied in the construction phase, there were no monitoring activities in the design phase (documentation of design decisions or lessons learned) nor in the use-phase applied (how the new technologies perform). Furthermore, to determine focus in the experiment a clear vision of the client regarding future of the buildings can support focussing on an element of circular construction (e.g. design for disassembly, adaptability or long-lasting building) and increase the deepening process regarding the chosen focus. Also, from the analysis it becomes clear that in innovative circular building projects law and regulation can hinder the development process, for this the involvement of an actor in the *control group* can be of importance in a) show which laws and regulations obstruct a circular process and b) support finding solutions.

v

Regarding the effect of the lessons learned in the experiment, it becomes clear that the process of scaling up occurs rather informally in the respective organizations. This has to do with the fact that all involved stakeholders are small- and medium-sized companies. Furthermore, to prevent that only the stakeholders involved in the experiment learn, the role of an external organization in sharing knowledge beyond the scope of the experiment proves to be important for further sector-wide *deepening*. Ultimately, the lacking possibilities for the involved stakeholders to practically follow-up on the lessons-learned remains an important aspect in order to aggregate knowledge and replace existing regime activities. Conducting a series of experiments, or ensuring follow-up projects, via a process of *broadening*, can support the creation of momentum and is a topic which could be discussed in the initiation phase of the experiment.

4.2 Case 2. SUPERLOCAL – Circular deconstruction/newbuild dwellings

SUPERLOCAL is an urban area redevelopment with the ambition to reuse the materials of three high-rise flats for the development of 125 new dwellings. The idea is to close local material-cycles by putting a fictional fence around the area of the three flats where no materials can go in or out of the area (interviewee 12). To see which parts can be reused from the flats, a series of experiments on the building-level are being conducted. Before zooming in on these experiments, at first, a brief history, and the development of, the project will be given (4.2.1), to afterwards further elaborate on the four main research themes: the subjects (4.2.2), the learning process (4.2.3), the learning objects (4.2.4) and the effect of the lessons learned (4.2.5).

Table 4.6. Overview of interviewees in SUPERLOCAL.

INTERVIEWEE	COMPANY TYPE	COMPANY NAME	FUNCTION
10	Municipality	Municipality of Kerkrade	Sr. Project leader & Jr. Project leader
11	Architectural firm	SeC Architecten	Architect
12	Construction company	Bouwbedrijf Jongen	Innovation Manager
13	Demolition company	Dusseldorp	Planning engineer

4.2.1 Case introduction and development process

SUPERLOCAL is located in Bleijerheide, in the eastern part of Kerkrade, which consisted of 300 apartments spread over four ten-floor flats owned by housing corporation HEEMwonen. The flats were built in 1967 in times of population growth due to coal mining activities. However, soon after its development, the booming period came to an end via a wave of deindustrialization starting in the late 1960's. Fast-forward to 2012, the area is characterized by years of demographic decline and the flats no longer met the requirements and wishes of the housing corporation. The decision was made to redevelop the area and flat A was demolished later that same year. It was during this process that the housing corporation realized the amount of value destroyed, both in materials as in social value, and in 2014 the idea arose to reuse parts of the three remaining flats (Superlocal, n.d.).

Instead of the conventional urban redevelopment approach, through demolition and relocation of residents, the goal of SUPERLOCAL is to redevelop the area by closing existing material loops (material circularity) and restoring social qualities (social circularity) (Durmisevic, 2018). The flats act as a material bank for the development of 125 new buildings. To realise the idea, the housing corporation found support with IBA Parkstad in 2015 (Internationale Bau Ausstellung). IBA Parkstad is a transition programme focused on innovative projects and ideas with the aim to transform the seven municipalities of Parkstad and the province of Limburg into a desired economic, social and environmental direction (IBA Parkstad, n.d.). In 2016, the municipality of Kerkrade and the housing corporation signed a collaboration agreement to redevelop the area. Ultimately, in 2017, with the support of IBA Parkstad, the project is awarded a subsidy of €4.7 million by the Urban Innovation Actions fund (UIA) of the European Union. This launched the development of the project.

v

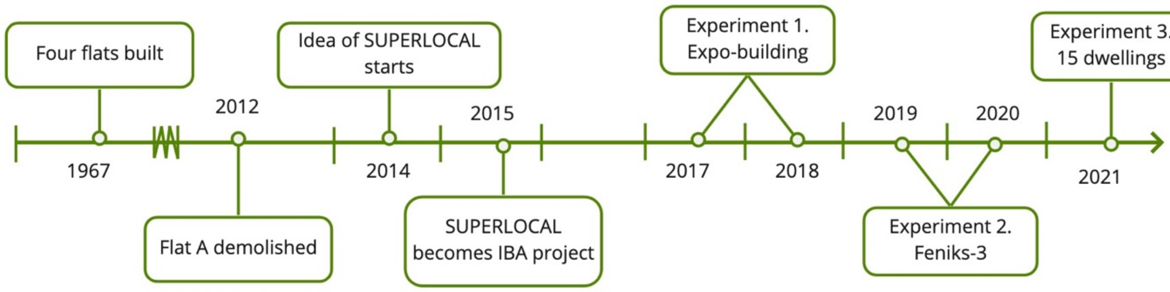


Figure 4.6 Timeline of major events of the SUPERLOCAL project.

Development process
With the financial support of the UIA in place, the client structured the development process into several distinct phases, as depicted in Figure 4.7 (Superlocal, 2017). The *initiative phase* started with the shared ambition by the client and the municipality to approach the area development following circular principles. The *indexation phase* was used to research the existing flats and share ideas on how to reuse these. From this phase it became clear that existing information did not match with performed tests, where for example, due to mining activities more reinforced concrete was used than indicated on the housing plan dating from 1967. The *play phase* encompassed experimentation to test the feasibility of different circular construction approaches. After this phase, the *decision* (what is going to be developed and how), *planning* (preparation phase) and *creation* (realisation of 125 social housing dwellings) phases should follow. At the time of writing, the project is still in the *play phase*, which is subdivided in three experiments, as depicted in Table 4.7, (1) the expo-building, (2) the three test-dwellings (Feniks-3) and (3) fifteen ground-bound dwellings. For this research the focus will be on the development of the three circular test dwellings, as these, in contrast to the expo-building, are built conform the Dutch Building Decree and, unlike the fifteen dwellings, have been developed, so evaluation is possible.

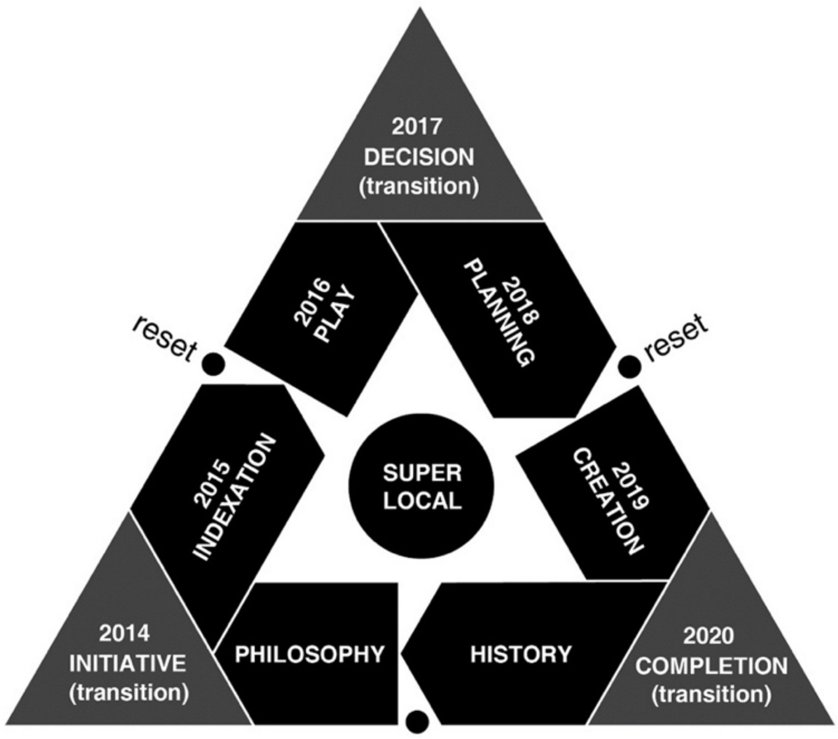


Figure 4.7 The development process of SUPERLOCAL. In the *play phase* experiments are conducted. *Reset* refers to reference points after which the course of action can be adjusted (Superlocal, 2017).

v

Table 4.7. Descriptive overview of the three experiments conducted in the play phase.

EXPERIMENTS	DESCRIPTION	DATE
1. EXPO-BUILDING	First experiment (demonstration) to test how elements of the flat can be directly reused (see Fig 4.2.3). Three structural elements of an apartment were hoisted out (middle) of a high-rise flat (left) and put together in an expo-building (right).	2017-2018
2. THREE TEST-DWELLINGS	In total three circular approaches tested: (1) hoist out one large element instead of three smaller ones, (2) reuse of single components (e.g. walls and floors), (3) recycled concrete made on site.	2019-2020
3. FIFTEEN GROUND-BOUND DWELLINGS	Further development of successful circular approaches of experiment 2.	2021 - present

Figure 4.8 Experiment 1: The development of the expo-building. (Superlocal, n.d.).

Figure 4.9. Experiment 2: The development of three test-dwellings, called 'Feniks-3'. On the left Type A, middle Type B and right Type C (Durmisevic, 2020).

Tendering process (initiation phase)

The *play phase* started with a clear vision from the client and the municipality (interviewee 12). In contrast to a traditional process, in which the architect designs and the client chooses a contractor based on the building specifications, the client started by inquiring demolition companies and construction companies to deliver their vision on deconstructing the flats with CE-principles in mind (Durmisevic, 2018). Of the five contacted demolition companies, Dusseldorp won the tender with an ambitious plan to hoist out a two-floor apartment (interviewee 13). Next to this, four contractors were invited to submit an offer based on pre-determined conditions about (1) circular ambitions, (2) desired living space and (3) target price. Through these conditions it was clear for the participants what the task was, what the financial reward would be and, consequently, how large the voluntary input of the participating organizations should be (interviewee 12). Most crucial award criterium for the demolition and construction company was their circular ambition and not their price offer (Durmisevic, 2018). After both the demolition- and the construction company were selected, a construction team was formed.

v

Design/construction phase
Prior to the design phase of Feniks-3, there were various lessons learned from the expo-building which formed the basis for the development of the three test-dwellings (Superlocal, 2018). Firstly, hoisting out three smaller elements is labour-intensive and therefore costly. This can potentially be reduced by hoisting out one large element, but would require a larger crane to do so. Secondly, direct reuse of products, such as window frames, was difficult due to asbestos. For the follow-up project, refurbishment (R5) or remanufacturing (R6) should be explored. Thirdly, a challenging component is insulation and making the dwellings wind- and waterproof. Ultimately, the expo-building (experiment 1) is not a dwelling, but registered as an artwork to deviate from applicable laws and regulation for dwellings. To scale it up, the dwellings need to comply to the Building Decree and installations, a bathroom, and insulation are necessary (Superlocal, 2018).

The design phase of the Feniks-3 differed significantly from a traditional design process. According to the architect, the design and construction phase were intertwined, as it was an iterative process of testing and sketching (interviewee 11). In the design process, the demolition company and the construction company took a central role and the team met every week in 3-hour long design sessions (interviewee 13). Every design proposal was subject to a judgement of the demolition company whether it was able to recover those materials without damaging the element or leaving the building in an unstable state (Durmisevic, 2018). Ultimately four types of dwellings were designed: Type A (74 m2), Type B (64 m2) and Type C (40 m2), as shown in Figure 4.9 (Durmisevic, 2018). The dwellings are built to test potential reuse techniques, but will be used as an office, a dwelling (rented out via the client) and as an information point of the area.

Dwelling **Type A** (two-bedroom) consists of a foundation which is made out of concrete from the flat which has been recycled on site (Figure 4.12). This cycle could not be fully closed, where 7% of new cement had to be added (Durmisevic, 2019b). Furthermore, the load bearing structure consists of a reused apartment, which has been hoisted out of the flat and put on the ground (Figure 4.10). Additionally, the partitioning walls and wooden door frames have been reused from the flat as well. Finally, the façade is made from modules of crushed concrete pieces from the flat, as seen in the top picture in the middle of Figure 4.11. Dwelling **Type B** (two-bedroom) consists of the same foundation and load bearing structure as Type A, as well as the partitioning walls. However, this building has reused insulation from the flats and the façade is made from brick modules which have been cut-out of the flat (two bottom left pictures in Figure 4.11). Dwelling **Type C** (single-bedroom) consists of the same foundation as Type A and B, but the load bearing structure and façade have been made from recycled concrete slabs, following the similar recycling technique as shown in Figure 4.12.

Figure 4.10. Circular construction technique 1: Direct reuse (R4 following Potting et al., 2017). Used for Type A and B (Durmisevic, 2019b).

v

Figure 4.11. Construction technique 2: Reuse by remanufacturing (R6 following Potting et al., 2017). On the left reused insulation from the flat (top) and brick modules (bottom left and middle) as used in Type B. Top middle is the crushed concrete as used in Type A. On the right the wooden door frames (top) which have been reused and the partitioning walls (bottom) (Durmisevic, 2019b).

Figure 4.12. Construction technique 3: Reuse by recycling (R8 following Potting et al., 2017)). On the left a pile of aggregate which has been processed on site (middle) for the development of the foundation of Type A, B and C (right) (Durmisevic, 2019b).

4.2.2 The subjects: Who learns?

This subchapter introduces the various actors involved in the experiment. There were some minor changes in the composition of the design team in the second experiment compared to the first experiment. The expo-building was developed by Maurer Architects, deconstruction company Dusseldorp and construction company Jongen. For the three test-dwellings Maurer Architects withdrew and SeC Architects joined the construction team. Furthermore, the design team consisted of the initiator (client), the controller (the municipality) and a structural engineer. These actors are visualized as the *core team* in team Figure 4.13. This subchapter further analyses these actors based on their general background (operating area, company size and focus), interest and role in the project and their resources. Furthermore, the role of each actor will be further defined under the header *subjects' analysis*, to finally shine light on which actors, or role groups, were absent in the experiment, under the header *missing actors*.

v

Table 4.8. Stakeholder analysis of Feniks-3.. The colour indicates their role group: green = initiators; pink = controllers; orange = advisors; and blue = builders.

STAKEHOLDER	BACKGROUND (GENERAL)	INTEREST (PROJECT)	ROLE (PROJECT)	RESOURCES
Housing corporation *(HEEMwonen)*	Social housing corporation in Kerkrade and Landgraaf Medium-sized: 100 fte.	Experiment with circular construction. Part of an internal CE working group	Financial responsibility, project lead	Financial resources, property
Municipality (*Kerkrade*)*	Municipality of Kerkrade, focused on delivering public services for their citizens. Large-sized organization.	Worked on pilots, but never on this scale. Joined because of goal to realize a CE in 2050.	Regulations expert, urban planning authority	Legal/political power, decision-making about public space
Architectural firm *(SeC Architecten)**	Architectural firm with focus on private market. Micro-sized (2 fte)	Learning project to gain more insight in circular construction	Visual designer	Architectural knowledge, time
Structural engineering company (*Palte BV*)	Regionally operating structural engineering and consultancy firm . Small-sized: 35 fte.	Were asked to collaborate in subsidized experiment	Structural construction expert	Structural calculations (for hoisting and newbuilt dwellings)
University of Applied Sciences (*Hogeschool Zuyd*)	University of Applied Sciences located in Heerlen	Testcase for academics to assess environmental impact of circular construction techniques	Environmental impact assessment, documenting	Scientific knowledge, students
Innovation platform (*IBA Parkstad*)	Transition programme for seven municipalities located in the province of Limburg	CE experiment as a tool to stir up economic activity in the region	Knowledge dissemination, fundraising	International network
Construction company *(Bouwbedrijf Jongen)**	Regionally operating construction company. Large-sized: 350 fte, part of VolkerWessels (6650 fte, 4th largest construction company (Cobouw, 2020)).	First project to fully experiment with circular construction. Only worked on subthemes (prefab and cross-laminated timber) before.	Assembly expert, connector	Operational knowledge, reputation (VolkerWessels)
Demolition company (*Dusseldorp*)*	Large-sized, nationally operating, deconstruction company. Part of ReintenInfra concern (large-sized, 654 fte, 31st largest construction company (Cobouw, 2020))	Focusing on new role in a CE. Created workgroup for it ('Rentmeester2050'). In 2016, many think tanks and discussion groups..	Deconstruction/ material expert, risk controller	Knowledge on deconstruction (work with large elements and heavy machines), risk analyses

*Interviewed // Company size: Micro-sized: < 10 fte; small-sized: < 50 fte; medium-sized: <250 fte; large-sized: >250 fte (RVO, n.d.-b)

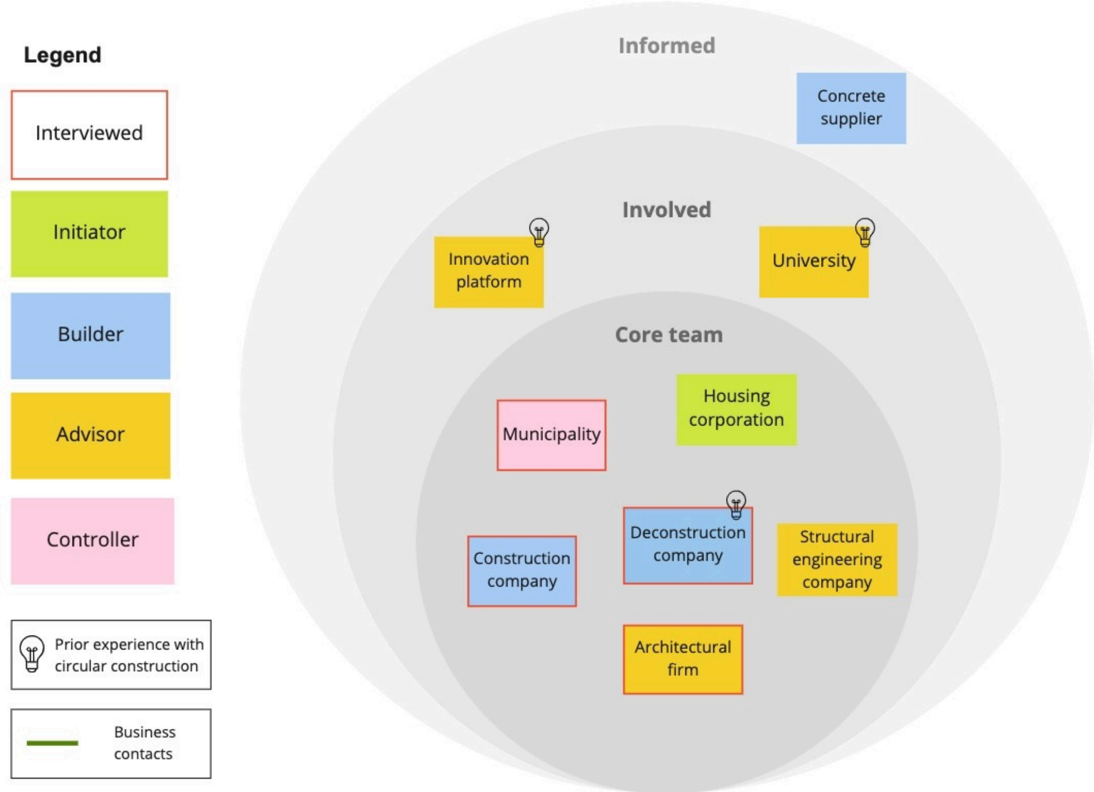


Figure 4.13 Overview of the different stakeholders involved in the development of Feniks-3. The core team consists of the design team.

v

Subjects' analysis
Based on the interviews it became clear the **demolisher** was the central actor in the design phase. The chain of activities starts with them, as they are the ones who could determine which elements from the flat could be retrieved and which risks are connected to it. Their role changed from demolisher, to material scout and material supplier (interviewee 12). The shape of the materials then determined the possibilities for the architect, which subsequently trickled down to which structural properties could be retained (structural engineer), and whether it is easy to assemble or not (builder). The group had to think beyond their own expertise to see which elements of the flat were feasible to harvest (interviewee 13). In the end, the design team was collaboratively responsible for the design of the building. Every actor at the table delivered input on the applicability of certain materials and their shape. "In that way, everyone was partly contractor, partly architect, partly a structural engineer, but everyone provided input from their own field of expertise." (interviewee 13).

The fact that the design process starts with the demolition company disrupts the traditional role division. Traditionally the **architect**, has full control over the design process. However, due to the fact that the choice of materials is limited, they are more dependent on the expertise of the demolisher and structural engineer. This was challenging and required a new way of thinking for the architect, as all actors in the core team could provide input on the design (interviewee 11). Furthermore, the role of the **structural engineer** changed, where instead of only doing the calculations and supplying the right information to the construction company, they became part of the design team, and took an extra role as consultant in the core team (J. Debije, in Durmisevic (2019)). For the **construction company**, traditionally, they become more involved as the project develops. Now, they were involved from start to give their view on what could be assembled or not. Their role changed from being a contractor to a *connector*: "It became clear that a lot of the retrieved materials needed to be processed before they could be reused in the building. There remains a grey area on who takes responsibility for this part. We took the role of connecting the demolition company to our supply chain. We searched for parties that could make building components out of it." (interviewee 12).

Finally, for the **municipality** it was new to be involved from the start in the design process, which differs from their traditional role in similar projects (interviewee 10). In the team, they acted as the *controller*, where they bridged the gap between innovative ideas and law and regulations. One of the barriers they faced was the fact that the ceiling height of hoisted out apartments, once on the floor, did not comply with the Building Decree anymore, as these standards have been raised in past decades. Ultimately, via consultations with different internal departments and even the Dutch Ministry, it had been decided that the dwelling could be regarded as a renovation project instead of a newly-built dwelling. The role of bridging the gap in law and regulations is not something the municipality is used to: "Our organisation is not programmed to even dare to think beyond the boundaries of law and regulations. However, we need to if we want to experiment with new circular approaches. It did result in resistance from my colleagues who found it hard to deal with." (interviewee 10). This way of working lifted the spirit in the group, where all parties, even a rigid organization like the municipality, positively thought along to make it a success (interviewee 11).

Missing actors
A missing actor group mentioned by both the construction as the demolition company was the involvement of their *suppliers*, or *partners* as they call them. They play a crucial role in lifting the possibilities, and successful implementation, of circular construction in the sector. An example was given by the construction company (interviewee 12). As the main material in the flat was concrete, they tried to involve their regular concrete supplier (*Geelen*), but after several unsuccessful attempts, they moved on. A year later, while they were concreting, they ran into the problem of

v

certification: “Nobody wanted to give us a KOMO-certificate[4], which completely blocked our process. It was until that moment that the same supplier realized that we were actually producing concrete ourselves and recognized the potential competitive threat. All of a sudden, they were very keen to collaborate and our problem disappeared like snow in the sun.” (interviewee 12). Next to the concrete supplier, it was also difficult to onboard *installation companies*. A valuable actor to move towards circularity, as often in traditional concrete constructions, the installations are integrated in the concrete structure, which eliminates the possibility for future reuse (interviewee 13). All in all, the necessity to include suppliers early on in the design process was deemed important by both *builders* to broaden opportunities for CE and to change their mindset.

Conclusion

So, from this analysis, it can be concluded that for circular construction traditional roles are broken down and new roles arise. The demolition company had an important role in the design phase, and became next to partly designer, also material scout and supplier. Furthermore, the involvement of an actor in the *control* role group, in this experiment the municipality, proved to be valuable to stretch the legal possibilities of such an innovative experiment. Their involvement in the design phase, together with the deconstruction and construction company, was emphasized as important to collaboratively search for design solutions. Next to this, involving the supply chain partners of the two *builders*, who can be identified as actors performing regime activities, early in the design phase can lift the possibilities of the experiment and support deepening of other actors in the value chain to break with regime activities. Even if they are not interested early on in the process, try to keep them informed about the process, which in SUPERLOCAL led to a later involvement of the concrete supplier. Finally, regarding *who should learn* all stakeholders in the construction team (core team), except for the deconstruction company, had no prior experience or knowledge regarding circular construction. Regarding size and activities, the municipality and construction company can be seen as influential actors performing regime activities.

4.2.3 The process: Learns how?

Now that the development process and the involved actors and their roles have been introduced, the focus will be drawn to the learning process in the experiment. As stated before, the development process did not follow the traditional development process of a building (draft design, preliminary design, definitive design up to construction). Rather, this should be seen as an iterative process from design to construction, and back to design again, as explained by the architect: “It was a constant process of three steps forward, two steps back. Construction would start and unforeseen events occurred, which urged us to go back to the design table. It was a constant process of anticipation.” (interviewee 11). This subchapter zooms in on the learning activities and conditions necessary to produce the learning outcomes.

[4] KOMO certificate declares that a construction product, element or system complies with the technical requirements necessary https://www.komo.nl/wilt-u-certificeren/komo-productcertificaat/

v

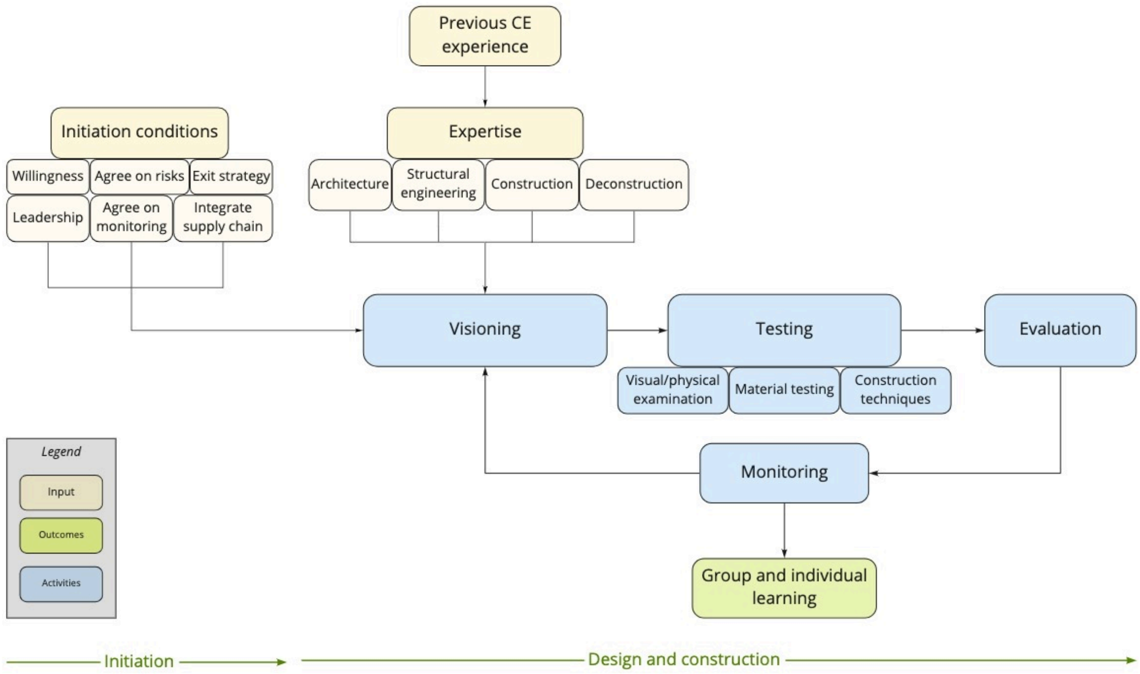


Figure 4.14 Overview of the learning activities (blue) in SUPERLOCAL. Learning occurred in the design and construction process, which was an iterative process of testing, monitoring and constructing.

Visioning

The development started with a visioning process in the weekly design meetings. Here, the group got together to think about reuse possibilities of the flat. For this process, the architect used a metaphor of the butcher and a cow: "The butcher wants to use every piece of the cow. There are the good pieces, but there is also waste meat, which is processed into a product as well. That is also how we approached the flat: What are the good parts and which parts do we first need to process?" (interviewee 11). This started a thought- and sketch-process, by questioning which units could be used, what size is desired and which architectural qualities should be retained. For this process creativity and improvisation is necessary (interviewee 12; 13). In this process, the role of the deconstruction company was essential in keeping an overview and urging a different working method of both the structural engineer as the architect. "The architects reasoned from an empty sketch book, but here you cannot, as materials and shapes are given. (…) Same goes for structural engineers, they are like calculators, they insert data and if the computer says no, then it is *no*. You have to guide them: What happens if you change this number, or do it this way?" (interviewee 13).

An example was given when the team was looking for an element to hoist out of the flat (interviewee 13). The architect found an element, which was on a constructive intersection and if used, would lead to a collapse of the entire building. If nobody kept the overview, then the architect would ask the structural engineer, he would model and three months later find out that it is not feasible, ultimately delaying the process. Finally, they found another element and were working on the calculation to get the element down. For this, there is no standard formula, as the element becomes mobile. Eventually, the structural engineer, based on his experience, got to a result which was so large that a concrete building for counterweight had to be built to take an element of a building down. "Of course, he is responsible, but that made no sense. So, we had to take him by the hand to think outside-of-the-box and eventually found a light-weight chain construction with the same structural requirements. (…) But it is a constant game you have to play between the parties. You have your own prior knowledge, practical experience and tools, but you have to constantly be aware that you think beyond your own expertise." (interviewee 13). It was in the visioning process that ideas were born, and if deemed feasible by the group, were tested (interviewee 11).

v

Testing

To break with traditional working methods, the demolisher dragged the team to the construction site. “People are used to draw designs from behind their computer. But there are so many unknowns. I dragged them to the construction site, so they get to know the building inside out.” (interviewee 13). Here, the central learning activity conducted by the core team was testing of creative ideas. Various *testing activities* were used: (1) visual examinations (measuring dimensions), (2), physical examination (how materials can be recovered without being damaged), (3) health testing (e.g. asbestos) and (4) material testing (taking concrete/brick samples) (Durmisevic, 2018). Material testing included various construction techniques, as shown in Figure 4.15 and if deemed successful, would make it in the design. Here, they tested for example the use of crushed concrete in masonry work (top-left Figure 4.15) or cutting out brick modules from the ground floor (right Figure 15). Ultimately, before and during the construction of the Feniks-3, various experiments have been performed to test the feasibility envisioned construction techniques.

In this process, all actors in the design team could insert ideas. For example, the architect suggested, to instead of only focusing on concrete, look into the possibilities of reusing the brick walls on the ground floor. At first, they tested individual bricks, but the mortar was too strong according to the demolition company. Then they tested using large modules (right picture in Figure 4.15), but these were, according to the contractor, too heavy due to lifting restrictions in safety regulations. “So, we ended up with a completely different size. Then in the construction phase we found out there were not enough bricks, and those harvested started to fall apart. So, if you look at building Type B (Figure 4.9), you can see that the bottom layer consists of the modules, then you have the individual bricks, and then a layer of white blocks which came from a donor building.” (interviewee 11).

Furthermore, in this process, it was hard to find a mason who was willing to cooperate. Ultimately, they found one, by not telling beforehand what the assignment was. “In the beginning the mason cursed about everything, but after emphasizing that it was fine if things fail, they started to get the hang of it, became creative and were doing mosaics in the end. (…) By taking this approach, and debating in a small group on how we can apply it, it changes their perspective from *“what a nonsense”* to “*we can actually create something*”. That shift is really important.” (interviewee 12). So, from this it can be deducted that the group learned by not solely figuring things out on the design table, but by actually inspecting and testing envisioned ideas. Through this approach, actually learning-by-doing, even subcontractors, such as the mason or concrete supplier, who initially were not keen to cooperate, eventually started to move along.

Figure 4.15 Various experiments with reuse construction techniques (Palte BV, n.d.).

v

Monitoring and reflective evaluation
Next to visioning and testing ideas, an essential learning activity mentioned by all interviewees was the monitoring process. By clearly documenting each step in the process, the group learned which techniques support the ambition and are most feasible to be scaled up. The university was responsible for this part, and provided input in the team meetings. The environmental assessments were performed during the design process as well as after realization and provided room to reconsider the approach. Furthermore, the documentation included man hours, actual costs and environmental impact. The construction company emphasized the importance of monitoring and documentation: "We invested a lot of energy in evaluation. It was not just 'this is the data, so this is the truth', but more, do we recognize these numbers? And what will we do with it? By asking these questions together and discuss these in-depth, you actually learn something. That way you break with arguments such as 'this sound circular' and an architect who says 'we will do it this way because it is more aesthetically appealing'." (interviewee 12).

From the group evaluation, it for example, became clear that the three construction techniques tested all resulted in environmental benefits. However, it became evident that it is difficult to reuse materials from buildings that are not made to be deconstructed. Reflecting on the developed Feniks-3, they came to the conclusion that they will face the same problem at the end of its first use-cycle (low-grade recycling), because they were not made for disassembly. By not obsessively focusing on the positive environmental figures, but by reflecting on the broader picture, the group learned that it is not about recycling volume, but about creating value for a long-term. If this perspective is not implemented in new construction projects than the reduced environmental impacts of complex (de)construction techniques are erased (Durmisevic, 2020). From this it can be concluded that *deep learning* was achieved through monitoring the process and collaboratively reflecting and evaluating on the results.

Learning conditions
From the interviews, different conditions were considered to be necessary to create a learning environment. The first is (1) **motivated project leader** that ensured the project moves in the right direction. The agent of the housing corporation had this role, who was a go-getter, glued the team together and ensured positivity in the group (interviewee 11; 13). Secondly, (2) **willingness**, which relates to the fact that organizations need to be willing to invest time and with that budget to learn in the experiment (interviewee 10). As the architect stated: "We invested a lot of time, and our financial compensation ran out very quickly. The rest was purely devoted to learning.". (interviewee 11). Willingness is also reflected in a different attitude. To make the project a success, actors have to be open for the opinion of others and allow them to have a say about their expertise. The strict boundaries of each expertise tend to become blurry in circular deconstruction experiments (interviewee 12).

With innovative experiments like these, it proved to be important to beforehand (3) **agree on risks and responsibilities**. If an initiator has such an innovative ambition, it cannot be the case that all risks remain for the contractor, as occurs in traditional projects (interviewee 13). For this, traditional collaboration forms need to be revised and it is essential that time and budget are allocated to thoroughly walk through this process. If not, then it is easy to fall back in the traditional way of working (interviewee 13). This was backed by the construction company stating that traditional collaboration forms rest on risk aversion. "A contractor cannot give full warranty on those three dwellings. Therefore, their only condition was: 'We participate and the goal is to build three dwellings, but it could also be the case that we span a red-white warning tape around the area'." (interviewee 12). From this, it can be concluded that traditional contracts are based on risks, limiting the freedom to experiment and therefore limiting the potential of the project (interview 12). Therefore, it is recommendable to create space and dedicate time to map the risks and think about how these will be dealt in a collaboration contract. A demolition company is more accustomed to this approach, as they are used to making risk analyses and endlessly discuss about these, but for a housing corporation this is less so (interviewee 13).

So, with the agreement on risks and responsibilities comes the acceptance of failure, which demands a certain attitude that there are uncertainties and that elements of the project can fail. Relating to this, the contractor stated that it is important to have a (4) **clear exit strategy**. Meaning that it is valuable and recommendable to break a large ambition in different smaller experiments and make agreements for a longer period, but to divide these agreements into smaller parts, and allow an exit after each part. “Due to the experimental nature, there should be a certain exit. Meaning we commit to this first experiment, this first phase, but we can also decide after each phase to step out or continue. This way you create commitment of we are going to do something, but there is an escape which makes it less heavy, large and complicated. That was a great strength of this project.” (interviewee 12). The worries of the construction company were dealt with by dividing the entire project (SUPERLOCAL) into several experiments (phases) and allowing actors to leave after each phase.

Furthermore, (5) **monitoring** proved to be an important condition, which includes agreeing beforehand on who will document, how will be documented and how and when this data will be used. “I consider it a precondition for a project like this. Through documentation we can recall precisely each step we took, and what the corresponding impact is. You do have to collaboratively agree on how to use this data” (interviewee 12). The agreement beforehand on how to use the documented data is an important condition, as emphasized by the deconstruction company who see a trend in the request for material passports: “We develop lists with X amount of kg steel, X amount of concrete, this many window frames etc. But if you do not how they are connected, then it is of no use. That is what I mean, everybody parrots, but nobody thinks beforehand: Why do I need this and what will I do with it?” (interviewee 13). Finally, based on the previous subchapter, another condition which supports transition learning is (6) **involving supply chain partners** early in the process (interviewee 12). By informing them about the experiment and challenging them to think along, also they acquire a shift in mindset necessary to break regime activities. For this it is important to include them early on in the process as their input can trigger the direction of the experiment (interviewee 12; 13).

Conclusion

Several conclusions can be drawn from the learning process. At first, the role of the deconstruction company was key to support *deep learning* in the experiment. He ensured that traditional (regime) routines, such as reasoning from an empty sketchbook (architect) or holding on to traditional calculation methods (structural engineer), were revisited and lead the visioning process. *Deep learning* was further achieved through collaboratively reflecting on the monitored results of the envisioned ideas. These were iteratively tested, constructed and revised again until they were deemed feasible for the dwelling. Through evaluation and reflecting on the monitoring results, the group learned about the importance of designing for disassembly, which could be tested in a follow-up experiment again. Finally, in order to acquire these learning processes, several factors were deemed important. First of all, from an individual actor’s perspective, the actors should be (1) *willing* to experiment, which is reflected in invested extra time (and with that budget) and an open attitude to reflect on each other’s discipline. Secondly, from a group perspective, the group should include (2) a clear project leader, (3) agree on risks and responsibilities, (4) agree on exit strategies (by dividing the area development in different experiments), (5) monitoring, and with that the agreement on who will document, how to use the data and when to reflect, and (6) *inform and integrate supply chain* partners early in the process.

v

4.2.4. The objects: Learns what?

Following up on the learning process, this subchapter focuses on the lessons produced by these activities. Based on the interviews the focus will be drawn to the main lessons learned of the involved stakeholders. These will be linked in Table 4.9 to the respective CE research theme and to what extent these can be regarded as single- or double-loop learning. At first, the actors in the *initiators group* will be discussed (client), secondly, the *controllers* (municipality), thirdly the *advisors* (architect) and finally, the *builders* (construction and demolition company).

Initiators

For the agent of the **housing corporation**, who shared their lessons learned in the evaluation reports ((M. Seegers, in Durmisevic (2019)), their main lesson involved the tendering process In which they learned that for such an innovative project, it is important to first clarify their own ambition and vision, what they want to achieve and how it will be assessed and awarded. Afterwards, parties must be approached qualitatively and those who fit the ambition and vision should be selected. Furthermore, he experienced that integrating parties early on and sharing responsibilities in the core team positively impacts the end-product (M. Seegers, in Durmisevic (2019)).

Controllers

The learnings of the agents of the **municipality** focused on three points: (1) their own organization, how well they are equipped to cope with experimental processes, (2) how to deal with issuing permits and regulations and (3) how to include residents of the surrounding area in a long-term innovative project (participation). Regarding the first two, inclusion in the design team forced the municipality to think creatively in the visioning process. This made them review their standard approach and processes, where municipal officials tend to think within the lines and their departments (silo-approach). For this experiment, creativity in regulations was necessary, which needs innovative rethinking and for that perseverance and the right people was deemed necessary (interviewee 10). Furthermore, the aspect of *social circularity*, by including residents in the decision-making process and making sure that the residents who have lived there for generations, including their social ties, return to the same area, was an important lesson for them (interviewee 10).

Advisors

The **architect** learned most about the (1) *design process* and (2*) construction techniques*. Instead of being in the lead and making design choices themselves, now they were involved in a web of opinions. This was challenging and required a different design approach, via testing instead of the usual sketching (interviewee 11). Secondly, a valuable lesson involved the construction techniques and the way of building. "A final conclusion was that it is difficult to disassemble and reuse bricks in existing buildings. How can we make those circular? For a follow-up project we found a stacking technique that does not use any mortar or glue. Those can be easily retrieved in 30-40 years." (interviewee 11). This technical learning, is regarded as a single-loop learning as it did not change their organizations policy, goals or approaches.

Builders

The **demolisher** learned most about (1) *the process*, (2) *construction techniques* and (3) *the sector*. Regarding the first, they stated the value of extending the scope of solely their own expertise and take the perspective of the final product. By doing this, they gained insight in the perspective of others as to why certain recovered materials cannot be assembled (contractor) or why a structural engineer cannot take responsibility for certain risks (interviewee 11). Secondly, an important lesson learned considered the construction technique of recycling, where Dusseldorp developed a new recipe for the production of recycled concrete, in which 95% of recycled concrete aggregate can be applied (Durmisevic, 2020). This changed the focus of the company, who next to their main focus of deconstructing a building, became a producer of circular concrete and developed a new concept:

v

"Nowadays we produce recipes of concrete mixtures of our mineral residual waste streams. Through this subsidy we developed concrete mixtures based on geopolymer, with which we can create new elements." (interviewee 13).

Furthermore, the **demolisher** learned that certification and guarantees are necessary to scale these materials. The difficulty here is that (1) certification requirements are very specific and focused on clean, virgin material streams. Due to this problem, (2) contractors cannot give a warrantee on the product. "If you have a certificate for butter, and it would say: it is a substance that should have a certain taste and should be spreadable. Then you can make a lot of varieties. But if you define every substance that has to be in there, then the product becomes more specific and easier to own and protect. Recycled material is not yet able to meet these requirements, (…) There remains a gap there." (interviewee 13). Related to this, before the start of this experiment, they believed that a material market place was necessary for a sector-wide adoption of secondary materials. However, based on this experiment they learned that it this would only create a pile of materials with no supportive information. Rather, he proposes refurbishment-hubs, where specialized companies are located. "If you create a hub, a company can specialize in reprocessing the materials and can drive up the quality to a certain certificate. With such a certificate the contractor can also shift their risks to the supplier of the material. That is what needs to be done for wider adoption." (interviewee 13).

For the **construction company** the most important lesson focused on design and construction techniques for future value. Of all the reuse-techniques they experimented with, the most important factor why a technique can be adopted are *costs*. The fact that recycling of concrete was the only technique that could be used again made him realize that step one should always be DfD, and with that think about a strategy for disassembly (interviewee 12). "Sustainability in the sector is focused on labels and choice of materials. However, the debate should not be on whether it is brick, concrete or wood, but on how do you make sure that it can actually be reused in the future. (…) With a CE we have the chance to break the endless cost-price debate and really think in value. Think in components with future value that have a reusability strategy. If we do not break this mindset, I am afraid we will be stuck with suboptimal solutions again" (interviewee 12). Furthermore, for a follow-up project they are looking into pre-fab elements which can be applied like LEGO-blocks. "Those are things we are looking into, there is a lot more to gain, but we learned that we can do things differently, and that we have to do it differently now, because otherwise people in 50 years' time will run into the same problems that we ran into in this project." (interviewee 12).

Table 4.9 Overview of the lessons the deepness of the lessons learned by actors involved in the core team, linked to the corresponding CE research theme.

ACTOR	CE RESEARCH THEME	SINGLE-LOOP	DOUBLE-LOOP
Housing corporation*	*Economic*: procurement	Set-out a clear vision and ambition and qualitatively select market parties who share this vision	
Municipality	*Regulations:* permits *Organizational:* silo-mentality	(1) Learned how to, as a municipality, move along in an innovative experiment, and (2) how to include local residents in the decision-making process	
Architectural firm	*Sector:* collaboration *Technical:* construction techniques	(1) Collaboration in design phase necessary for a deconstruction/newbuilt project, and (2) circular product (technique to stack bricks so they can be reused)	
Demolition company	*Sector:* collaboration *Technical*: construction technique *Sectoral:* CE infrastructure	(1) The necessity to include all expertise in the design and construction process	(1) Developed a recipe to recycle concrete aggregate and make new modular elements, (2) refurbishment hubs necessary for sector-wide adoption of secondary materials
Construction company	Sector: CE interest *Technical*: design and construction technique	Sector is only focused on labels and material choice for CE. Instead, should focus on long-term value and reusing strategies, instead of cost-price.	Reviewed their construction process: shift in constructing for disassembly. Producing modular construction elements.

v

Conclusion
From these results, it can be concluded that both actors involved in the *builders* group acquired double-loop learnings. Not unexpected, regarding the vision of the experiment to put a fictive fence around the area and only construct with the materials available in a closed material cycle. The technical focus of the experiment through selective deconstruction ensured a central role for the demolition company. They safeguarded the vision and guided the other actors in the experiment. Furthermore, it is interesting to see that of the researched stakeholders, the two largest companies, the *builders*, are also those that obtained second-loop learnings. So, regarding transition learning they have the most resources to break with regime activities and it is therefore valuable to find that they *deepened* their construction process. Furthermore, the approach of the entire project by dividing the large-scale area development into several smaller experiments and following-up on the lessons learned in each, makes that these technical learnings can be optimized and more easily integrated in the practices of the company (*the effect*), as explained in the next subchapter.

4.2.5. The outcome: To what effect?
From the previous parts it became clear who were involved in the design and construction process, how they learned and what the main lessons were. This chapter zooms in on how these lessons learned are shared to stimulate *deepening* processes beyond the scope of the experiment (*deepening, knowledge sharing*), how knowledge and innovation gained in the experiment is integrated in the respective companies and how these are broadened and scaled up (*scaling up)*.

Deepening: knowledge sharing
Knowledge sharing of the project was performed by IBA Parkstad and by Parkstad Limburg. The prior developed various evaluation documents at different development stages to share the main take-aways. Next to this, they organized various field visits, lectures and events for interested parties (interviewee 10). Furthermore, from the subsidy, budget was allocated for Parkstad Limburg, which is an administrative collaboration between seven municipalities, to evaluate the knowledge gaps in law and regulation and share these with the province, the ministry and the EU. "A large part of that subsidy was devoted to reporting and knowledge dissemination. Stadsregio Parkstad took that role to show: "We have experimented with European money for 3,5 years, these are the legal loopholes that need to be addressed."" (interviewee 10). A prerequisite of the European subsidy is the fact that the lessons learned are being shared nationally as well as internationally.

Deepening: integrating
For the agents of the **municipality**, parts of the lessons learned could be applied in new projects, for example using recycled aggregate for pavements and bicycle lanes, and the involvement of citizen consultation groups (participation) in urban area developments. However, they stated that it is not feasible to do it again on this scale, due to the administrative load that is part of the subsidy. It requires a lot of internal capacity to run a project of this size (interviewee 10). For the **architect**, as they are a micro-sized company (2 fte), lessons learned are easily shared internally and informally. They would like to repeat elements of the experiment, such as the concrete rubble façade or stacking bricks without glue or mortar, but demand in their market (private housing) is rather low. The experiment did not change their way of working as they are limited to their clients wishes: "That is also the problem for circular construction, it requires more time and energy and at this point the market is just overheated (…) Furthermore, construction for reuse requires a different mindset of our clients. People prefer to have a fixed masoned wall instead of a wall that can be disassembled." (interviewee 11).

The agent of the **construction company** noticed that the tendency of their parent company (VolkerWessels) changed as the project developed. "In the beginning they said: 'Oh well, corner of the Netherlands, as long as it does not cost us too much money, do your thing'. But after a while, as

v

we made certain CE strategies workable, they slowly started to ask questions and within no time it spread internally like an oil stain." (interviewee 12). Important lesson he learned from this experiment is that by actually doing, he understood the dynamics behind circular construction, how elements are connected, which requires a different way of thinking about real estate. This way of working he tried to implement within the wider concern: "You have to take people along in this philosophy and it is almost impossible to make a roadmap for a big company like VolkerWessels. So, I said, we should allow these experiments within every department and create an expert network, which we can evaluate. What is the common denominator and how can we include these in our existing concepts? Not based on theory, but from practice, because that is where our strength lies." (interviewee 12). From this statement it can be deducted that the agent learned how his company can learn in order to stimulate a CE, which can be seen as a *triple-loop learning*. According to him, through a series of experiments on CE in different departments of the company, a network of experts can be created that learned-by-doing and who have developed the necessary different way of thinking for a CE.

The **demolition company** continued working on the recipe of recycled aggregate concrete developed for the Feniks-3. To come up with a solution for disassembly, they created a product called 'BRX', which are modular blocks produced from the concrete of the flat (Figure 4.16). In the development of BRX they were looking for uniformity and developed a block which is in accordance with the standard dimensions and connections of sheet sizes, roof tiles and installations (interviewee 13). However, at this point they still run into several challenges: (1) ensuring shape stability in the production of the blocks, (2) proving wall stability, as it is regarded as a connection of constructions instead of a unit (like a masoned wall) and (3) social acceptance due to its rough profile.

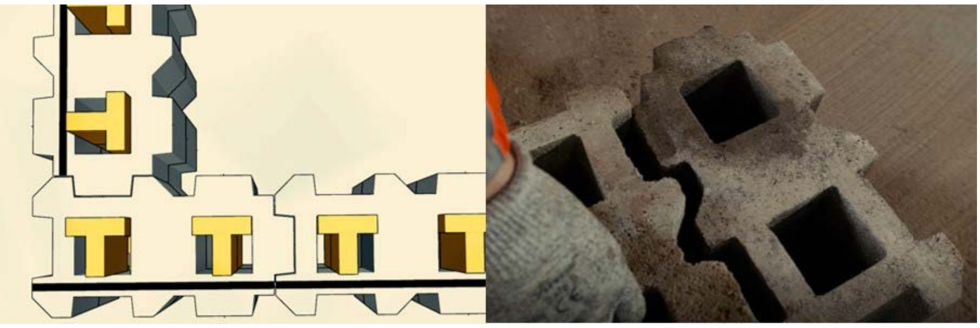


Figure 4.16. Product called BRX (derivative from bricks) developed by Dusseldorp, based on the recycling technique and recipe tested in SUPERLOCAL (Durmisevic, 2021).

Broadening/scaling up

The approach of SUPERLOCAL resembled the process of broadening and scaling up, where a series of experiments are conducted which build on each of the outcomes, as shown in Figure 4.17. The idea was to start with a demo-building, a prototype, to subsequently continue the experimentation process on a different scale, step-by-step. The *expo-building* focused on how one flat could be reused, which mainly focused on hoisting out three structural elements, but it did not comply to any housing regulations. This, in combination with other deconstruction techniques (reuse, remanufacturing and recycling) were tested in the second experiment *Feniks-3*. Of these experiments, it became clear that they all had environmental benefits, but due to the extra amount of labour and energy, only the recycling technique could compete financially to conventional dwellings (2,5 times more expensive). These buildings did comply to the Building Decree, however were not constructed with disassembly in mind, and therefore resembled no future value. Therefore, the first spin-off project, *15 circular dwellings*, the construction and demolition company worked together with the prefab supplier to, similar to BRX, work on demountable load bearing systems based on the recycling recipe developed in Feniks-3 (95% recycled concrete from the flat). This way the structural components still resemble high future value at the end of their first use-

v

cycle. Due to optimization processes of the demolition company, the design of this dwelling was 20% more expensive than a conventional dwelling (Durmisevic, 2021). Ultimately, a second spin-off project started in spring 2021 where the structure of the last remaining flat will be reused. Based on the first calculations, this experiment saves most CO2 per m2 (interviewee 13).

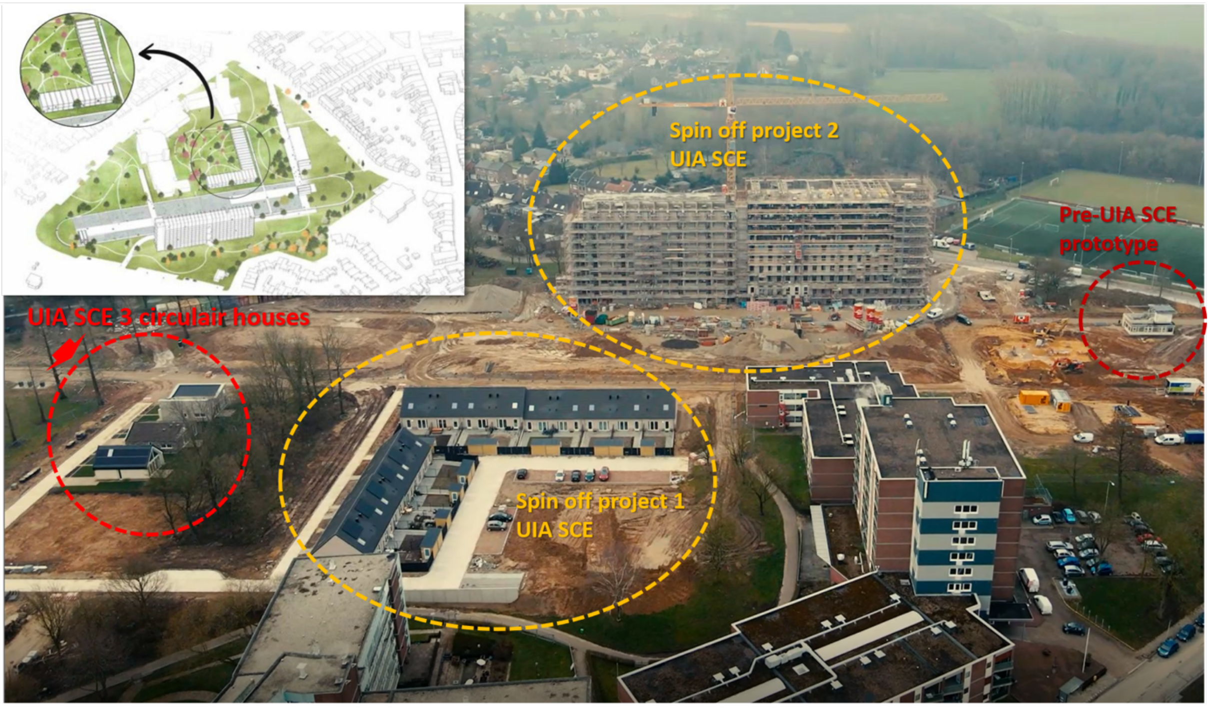


Figure 4.17 Overview of the different experiments. In red, the two experiments part of the EU subsidy. In yellow, the two spin-off projects which build on the lessons learned in experiment 1 and 2 (Durmisevic, 2021).

By designing the experiment as a series, and by scaling the scope of each experiment, each experiment had to deal with different challenges associated to that specific scale. This approach, by setting a clear project boundary per experiment and connect them in a series, ensured focus and the right discussion at the right time, as emphasized by the construction company: "For the 15 dwellings (spin-off project 1), we tested with demountable concrete floor and wall elements and we encountered the struggle of incorporated installations. So, we started the conversation with the prefab supplier and you realize that this is their biggest struggle too. So, you start to discuss what would happen if we standardize these, what would that do for logistics, cost price and you see that a lot of value shifts, as he is not dependable on a single client anymore. Then you can start the discussion about the business case, ownership etc. But if you just start with: 'We have a wall and we are going to connect it differently; and who owns this wall?', you skip so many steps that are crucial in this discussion." (interviewee 12). Here, he emphasized the necessity to go through this process and extend the scope of each experiment and include the parties in the value chain that are important for that scale.

The approach of SUPERLOCAL resembled the process of broadening, where a series of experiments are conducted which build on each of the outcomes. This approach was hailed by the two builders. "A showcase is beautiful, but you will never do it again. It is not scalable. In my opinion you should set up a series of experiments and grow from 40% to 50% to 70% and so on. Instead of doing one project which reaches 150%, but is so far off current processes that it can never get adopted. If you think about all these components of circularity – material choice, business models, dilemma of ownership – it is impossible to solve these in one project. (…) Instead of aiming for the egg of Columbus, improve stepwise." (interviewee 12). Here he emphasizes the necessity of experimenting

v

and seeking solutions which are scalable. For these, it is important to find solutions which can fit the current construction process (interviewee 12).

This was backed by the deconstruction company who stated that a circular construction process should fit with a normal construction process, otherwise it will never become mainstream, and can therefore not be scaled (interviewee 13). That is why the approach of this experiment worked. “What we learned, is that you have to stick to the current process, because otherwise you stack too many innovations and it is doomed to fail. What we did with the 15 dwellings, we co-developed these prefab elements made from recycled granulate of the flats. So, we have an innovative material, which they can use in their current building process and it complies with the stringent safety requirements. (…) At the moment you want to apply the lessons learned in a conventional project again, you do not want to disturb any processes. Unless you have a subsidy then you can mess things up again.” (Interviewee 13). Furthermore, he stressed that this technique based on secondary materials becomes more appealing due to landscape pressures. The demolition company stated they are currently extremely busy with reusing timber and concrete, as the price of virgin material sky rocketed in 2021. “That way reuse becomes more and more interesting” (interviewee 13).

Interestingly, the project resulted in a further collaboration between the construction and demolition company. Based on the developed recipe and recycling technique they have been further developing the entire infrastructure connected to it. They are currently working on how to design this process and develop a protocol for it. This will include how to extract the granulate, how to assess these and how to deliver these for the supplier of the prefab elements (interviewee 12). The construction company is applying this technology in a new series of 70 dwellings, outside of SUPERLOCAL, where they are also researching possibilities to separate installations from the concrete structure, so it becomes more modular. “Right now, we are scaling that infrastructure and exploring the possibilities to create a constant flow. (…) So, we are exporting those lessons learned out of SUPERLOCAL and into other areas and domains.“ (interviewee 12).

Figure 4.18. Modular load bearing circular concrete system, the concrete aggregate is supplied by the deconstruction company, developed by prefab concrete supplier and assembled by the construction company. Picture derived from Durmisevic (2021).

Conclusion

Due to the way SUPERLOCAL was designed, by setting up a series of experiments in which every experiment has a demarcated scope, ultimately innovations can mature and be scaled up to test regime activities. In Feniks-3, three construction techniques were tested of which the most feasible one (recycling aggregate concrete) was further *broadened* in the next experiment together with *deepened* expertise to design and construct for future value (disassembly). This process of *broadening* resulted in a construction and design technique that fits the current construction process and can financially compete with traditional construction process while ensuring a significantly lower environmental impact and resembling future reuse value. Therefore, this design ensures the creation of momentum so innovations can be scaled up from the niche, to the niche-regime and potentially even to the regime. The experiment resulted in a new collaboration form between the construction and deconstruction company, where the deconstruction company is the concrete supplier for the construction company. There still remain lessons to be learned regarding circularity, where the construction company is testing in follow-up projects outside of SUPERLOCAL how to not fix installations in the dwellings made from modular prefab elements.

4.2.6 Overall project conclusion

Based on the experiment, it becomes clear that in a highly innovative circular demolition/new construction process roles change significantly compared to traditional processes. In a traditional process, the architect acts as a system integrator, but in a circular demolition/new construction process the demolition company is in the lead. The architect is dependent on the materials that the demolition company can harvest and within conditions determined by the structural engineer. From this it becomes clear how important an integrated approach is in the design phase, where members of the core team have to broaden their scope. Furthermore, for this integral approach, and to ensure broader adoption, it proved to be valuable to inform and include existing partners further down the supply chain early in the experiment. This expands the solutions space of the experiment.

The environment, which can be seen as an urban laboratory, where trial and error is central and where failure is allowed, supported a *deepening* process through practically testing and experimenting. Key for this deepening process was monitoring through carefully documenting all the steps, the number of hours and the environmental impact of each envisioned idea. Through group reflection and evaluation, a broader system reflection was achieved. This technical focus, then resulted in double-loop learnings for the two *builders* who developed a new construction technique based on recycled aggregate from the flats and found ways to mould these in modular elements which can be easily retrieved after a first-use cycle. Interesting is then, that the way the experiment is designed, allows to directly follow-up on these second-loop learnings through further *broadening* activities in a spin-off experiment. In this experiment, the builders could further optimize the construction technique, making it economically viable (only 20% more expensive than conventional), and experience how it will perform in the traditional construction process. Through this, the construction technique builds momentum and the *builders* could scale these innovations also in traditional construction projects, for which they set up a new infrastructure and collaboration form.

Reasoning from the MLP, the experiment ensured *deepening* about niche innovations (e.g. reusing an entire apartment from a flat, reusing brick modules or recycling concrete aggregate) via monitoring and group reflection. These successful niche innovations were then *broadened* and connected to a different domain (from one building to fifteen terraced dwellings), which lead to an optimization process in which the niche innovation fits the current construction process and can compete on price level with traditional techniques. Through this process of broadening, the innovations could then be *scaled up* into the niche-regime, where the construction and deconstruction company, together with the prefab concrete supplier, developed an infrastructure and integrate the innovation in traditional follow-up projects.

v

4.3 Case 3. The Green House, Utrecht – Circular pavilion/New utility building

The third case is the Green House, a temporary pavilion, designed for disassembly and used following a circular concept. It is part of a larger development project ‘De Knoop’. It houses a restaurant, with its own greenhouse on the second floor, office spaces and a conference centre. The project started in 2016 and was delivered in March 2018. Before further introducing the case and its development process (4.3.1), this chapter will elaborate on the involved actors (4.3.2), the learning process (4.3.3), the lessons learned (4.3.4) and the effect of these learnings (4.3.5).

Table 4.9 Overview of the interviewees, their company and function of the Green House.

INTERVIEWEE	COMPANY TYPE	COMPANY NAME	FUNCTION
14	Central Government Real Estate Agency	Central Government Real Estate Agency	Consultant
15	Developing company	Strukton	Project leader
16	Structural engineering company	Pieters Bouwtechniek	Structural engineer
17	Property operator	Albron	Marketing director
18	Architect	Cepezed	Architect
19	Environmental consultancy	Alba Concepts	Consultant
20	Interior supplier	Maasdam	Commercial director

Figure 4.19. Impression of the Green House, the reused glass façade from the outside and the urban vertical farm from the inside (top-right) (cepezed, 2018).

v

4.3.1 Case introduction and development process

The area around Utrecht central station is part of an urban renewal masterplan called CU2030 (Rijksvastgoedbedrijf, n.d.). The masterplan is developed in several phases, and for the first phase the Central Government Real Estate Agency was requested to renovate and transform their military barrack, called the 'Knoopkazerne'. This building was built in the late 1980's, but did not comply with the envisioned appearance of the area. In 2014, the Central Government Real Estate Agency set out a DBMFO tender (Design, Build, Finance Maintain Operate), an integrated form of public-private partnership (PPP), and in 2015, the consortium of Strukton (developer), Ballast Nedam (construction company) and Facilicom (operating company), under the name of R-Creators, won the tender. Next to renovating and transforming the 'Knoopkazerne' into an office-building, part of the tender was to develop a vision for the adjacent vacant plot of land. For the period of 15 years, this plot would be unused, as it is part of a later development phase (start 2033). For the spatial interpretation, three tender requirements were defined: (1) the pavilion should include commercial functions for the period of maximum 15 years, (2) materials of the pavilion should entirely be reused after the first use-period and (3) the total surface area should be between 200 and 1000m2 (interviewee 14).

Table 4.10 Comparison of the two developments, which were part of the same tender.

PROJECT	CONTRACTING PARTY	SURFACE AREA	BUDGET	PERIOD
Transformation of the 'Knoopkazerne'	Consortium 'R-creators'	30.000 m2	€60.000.000	2015 –2018
Pavilion 'the Green House'	Consortium 'R-creators'	680 m2	€2.000.000	2016 –2018

Initiation phase

The Green House was a side-development next to the main priority of transforming the 'Knoopkazerne', as emphasized in surface area and total budget in Table 4.10. Due to this, the project did not receive much attention in the beginning (interviewee 15; 18; 20). It was during the construction of the 'Knoopkazerne', that a project leader of Strukton was pushed forward to lead the development of the Green House (interviewee 18). He was the one who made sure that the right parties were involved at the right time. The team had to conform to the three requirements of the client, but next to the reuse criterium, no circular labels or certificates, such as BREEAM or WELL, had to be met (interviewee 18). The absence of these labels, which can have financial repercussions, and no further limiting requirements, created flexibility and space for the team to deliver their own input and collaboratively start the design phase (interviewee 15). That was also the goal of the client, by providing a clear ambition without too many stringent requirements, freedom was given to the contracting parties to create a lively area (interviewee 14).

"What is interesting about the Green House is that the consortium, and not the client, took it up as an experiment. It was not a forced tender to create an innovative project." (interviewee 15).

Design phase

For the Green House, two types of designs were made: (1) a building design and (2) a concept design for the use-phase (interviewee 17). For the building design, the project leader of Strukton had a clear circular vision and ambition, he could be regarded as the circular building expert. For the concept design, he found his counterpart in the exploiting party, who ensured that circular principles were embraced during the use-phase of the building (interviewee 15). Together with the architect and the structural engineer they started the design process, which occurred rather informally as it was a project-in-a-project and the design team consisted of the same organizations as in the larger transformation (interviewee 18). The first preliminary design was already made during the tender process. In this design, the glass façade from the old 'Knoopkazerne' was incorporated and the consortium, together with the architect, determined it would be a mixed pavilion with a restaurant on the ground floor and conference area and office places on the first floor (interviewee 18). The fact that the consortium remained owner of the building, and the predefined reuse criterium,

v

triggered the team to choose a modular design that could be disassembled after its first use-cycle and reassembled for further use-cycles (interviewee 15; 18). In the end, the building is 85% demountable, where also the structural elements became modular (interviewee 17). No predetermined plans were made by the consortium for future use-cycles (interviewee 15).

Construction phase

In the definitive design the structural components of the building were defined, however, flexibility for further completion was given to the builders (interviewee 16). With the vision to construct for disassembly and the principles *reduce, reuse, recycle*, the construction company was responsible for finding secondary materials, which mostly came from their own depository (interviewee 17). In the end, construction took three months as most of the thought-process occurred in the design phase (interviewee 15).

Use phase

The Green House was designed as a circular pavilion, with the goal to inspire and catalyse sustainable behaviour. Therefore, several principles are included in the concept of the exploitation phase. For example, the menu is (1) plant-based, (2) focused on shorter supply chains and (3) vitality (less salt and sugar) and prepared in a plug-free kitchen. Furthermore, the installations, such as light, the elevator and interior are delivered as-a-service. To support a CE transition, they documented the development and made it open-source, based on their principle: *right-to-copy* (interviewee 17).

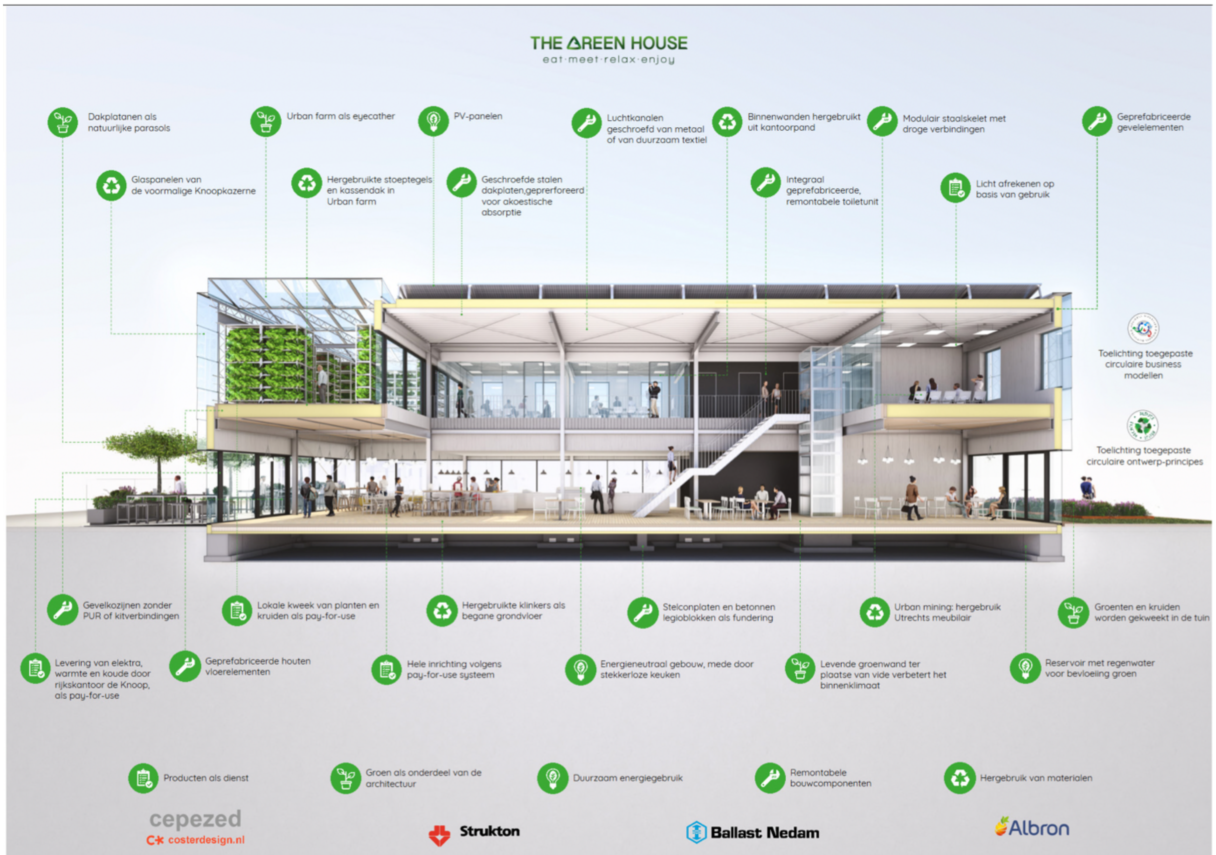


Figure 4.20 Overview of the various circular practices in the Green House, categorized by (1) reuse of materials, (2) demountable construction components and (3) PaaS (cepezed, 2018).

v

4.3.2 The subjects: Who learns?

This subchapter zooms in on the actors involved in the development of the Green House. As the Green House was a project-in-a-project, the main stakeholders that were involved were also involved in the main transformation of the 'Knoopkazerne'. Table 4.11 introduces all the stakeholders based on their background, interest in the project, role and resources. Only the environmental consultant and the interior supplier were not involved in the main transformation project.

Subjects' analysis

The client, the Central Government Real Estate Agency, had no direct role in the development of the Green House. They have been involved occasionally in design meetings, but mostly from a spectator point of view (interviewee 14). The consortium (*R-creators*) remains owner of the building and for the development of the Green House the developer (Strukton) and the operator (Albron) were seen as the initiators (interviewee 14). The project leader (*developer*) of the Green House had prior experience with circular construction, and acted as the circular catalyst for the building. The agent of the operating company had prior circular experience in circular concept design, as they participated in a tender for a similar circular pavilion called CIRCL, which they did not win. However, the agent of the operating company took the role of circular catalyst for the use-phase of the building, the concept design (interviewee 17). The architectural design was made by Cepezed (architect) who previously worked with DfD and stated that from a design perspective this was *standard practice* for them (interviewee 18). Furthermore, the same structural engineer was involved for the Green House as for the 'Knoopkazerne'.

New to the development of the Green House was a circular specialist from an environmental consultancy firm (Alba Concepts). They were responsible for monitoring and quantifying the environmental impact of the design and indicating the degree of circularity. To do so, they tested an index they previously developed (Building Circularity Index (BCI)), which translates the (1) material use and (2) disassembly possibilities into an output number (0 = not circular, 1 = very circular). They were involved from the definitive design until the use-phase (interviewee 19). Furthermore, several suppliers were approached to innovate from a business model perspective, such as the light supplier, the interior designer and the vegetable and herbs grower. For this research only the interior supplier could be interviewed from this group and will therefore be further elaborated on in Table 4.11 as well as in the rest of this case-analysis.

Table 4.11. Analysis of the involved stakeholder in the design and construction phase, based on their general background, interest- and role in the project and resources. The colour indicates their role group: green = initiators; orange = advisors; and blue = builders.

STAKEHOLDER	BACKGROUND (GENERAL)	INTEREST (PROJECT)	ROLE (PROJECT)	RESOURCES
Central Government Real Estate Agency (*Rijksvastgoedbedrijf*)	Responsible for managing real estate property of the central government (Ministry of Interior and Kingdom Relations) (2300 fte)	Provided room for the market to come up with creative ideas. Wanted to learn from these ideas and were not directly involved.	Spectator	Power to determine boundary conditions
Developing company (*Strukton Worksphere*)	Large-scale nationally operating engineering company (6650 fte). Can develop, construct, maintain and operate buildings.	Saw it as an opportunity to lift the 'circular' ambitions to a higher level.	Circular catalyst building design	Circular construction knowledge, individual competence (experienced project leader)
Operating company (*Albron*)	Nationally operating hospitality company (870 fte). Focus on catering formulas. Part of mother company Facilicom (31.000 fte).	Worked on another circular pavilion (CIRCL) before, but did not win the tender. Recognized commercial possibilities and wanted to test same conceptual vision.	Circular catalyst concept design	Knowledge on circular exploitation, network of suppliers
Architectural firm (*cepezed*)	Architectural firm with focus on flexibility, modularity. DfD	Interesting side-project to the larger development of	Building design (architect)	Knowledge of DfD

v

	standard practice (interviewee 18). Medium-sized: 98 fte.	the 'Knoopkazerne'. Allowing experiments in building design forms a new way of working.		
Structural engineering company (*Pieters Bouwtechniek*)	Regionally operating structural engineering and consultancy firm. Small-sized: 35 fte.	Experiment with demountable building structure	Structural construction expert	Knowledge in structural engineering
Environmental consultancy company (*Alba Concepts*)	Consultancy firm specialized in circular economy. Small-sized: 21 fte.	Test their Building Circularity Index (BCI)	Monitoring environmental impact, identifying opportunities	Quantifying impact of circular practices, providing 'proof' for degree of circularity
Construction company *(Ballast Nedam)*	Nationally operating construction company. Large-sized: 1900 fte.	Part of consortium, where in the lead for 'Knoopskazerne', not in the lead for the Green House	Material scout and assembly	Supplying secondary materials (from depot), status (large construction company)
Interior supplier (*Maasdam*)	Medium-sized furnishing company. Deliver complete furnishing, office interior and floors.	Contacted by Albron. Saw marketing potential, showcase, central location	Providing interior as-a-service	Private equity (to test with PaaS)

Company size: Micro-sized: < 10 fte; small-sized: < 50 fte; medium-sized: <250 fte; large-sized: >250 fte (RVO, n.d.-b)

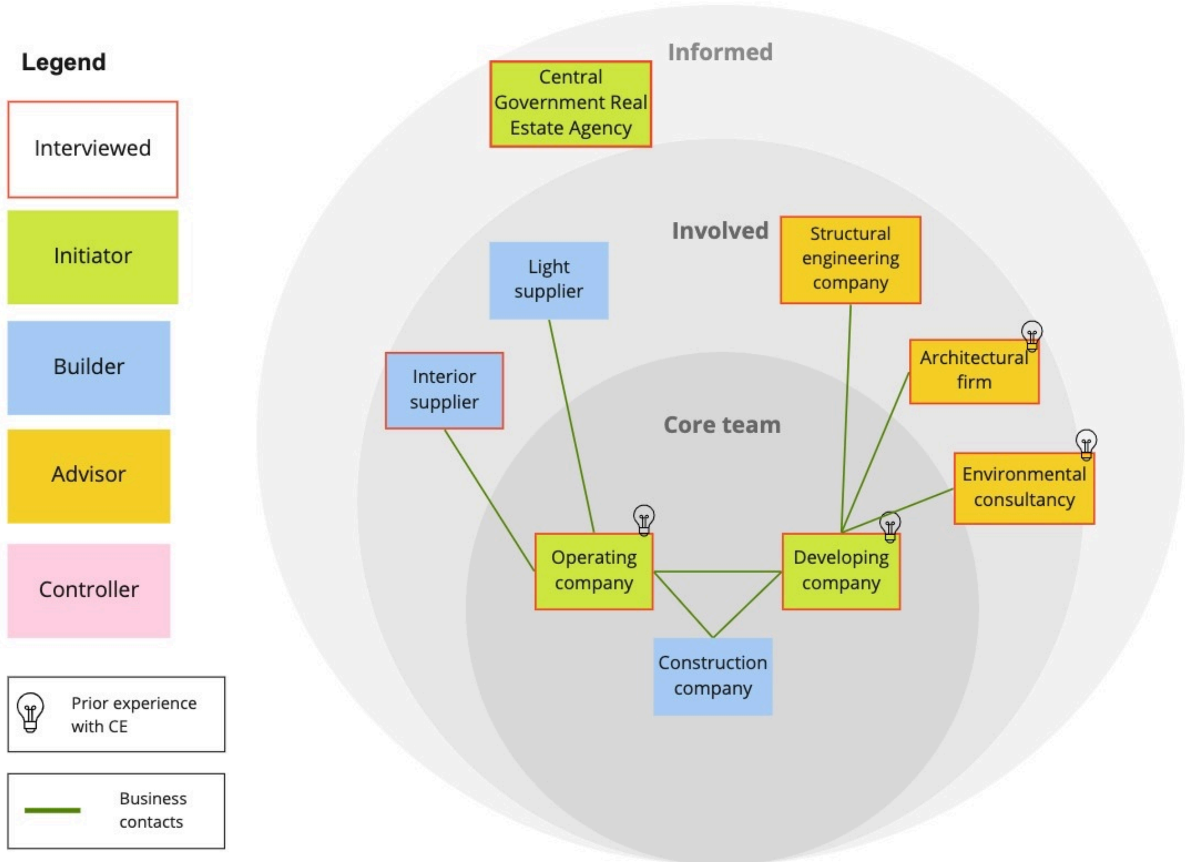


Figure 4.21. Overview of the key actors for the development of the Green House. The *core team* exists of the 'consortium' which are actors involved in all the phases, from design to deconstruction, *involved* refers to the stakeholders who have been involved to provide input or help the project move forward and *informed* those that are not directly involved but want to stay informed and can provide input when necessary.

Missing actors

The consortium (*core team*), as depicted in Figure 4.21, were the ones who could integrate other parties in the design and construction phases. However, from the interviews it became clear that there were some actors which could or should have been involved to improve the circular outcome of the project. Firstly, from Figure 4.21, it becomes clear that there is no stakeholder involved from the *controller* actor group. Here, it was mentioned by the operating company that **public controllers** of the municipality should have been involved in the development. "We are developing a building that can be disassembled and reassembled somewhere else. Then you have the municipality, who are not included in this circular philosophy, who fix all the pavements in the project area in concrete. That makes no sense, not everybody was on the same page." (interviewee 17). The developer further elaborated on this and emphasized the necessity to consider the different layers of a municipality. He stated that from an administrative perspective, not all departments are interconnected: "The licensors and real estate departments consider circularity, but the department responsible for public space does not. They have still a lot of room to become more sustainable" (interviewee 15).

Secondly, more **suppliers** could have been involved. The operating company tried to involve more suppliers, such as the kitchen supplier. Instead of buying a kitchen, he tried to find a supplier who was willing to offer the possibility to cook. This proved to be difficult as kitchens exist of different appliances from different producers and dealers, who protect each other on price agreements. "You come to understand that you have to seek for different parties than the ones who provide kitchens nowadays. Currently, we work with a maintenance company for our kitchens. What if this company says: 'I'll deliver a kitchen which never breaks down'. Then you have created a business model for a non-existing company." (interviewee 17). The rejections of the kitchen suppliers to participate in business model experimentation made them recognize the need for new actors in the field. The developer also emphasized the necessity to include suppliers, which he calls *co-makers*, as early as possible in the development.

Conclusion

From the analysis, several conclusions can be drawn about the involved actors. First of all, it becomes clear that in the group various actors have knowledge regarding circularity, where the agents of the operating company, developing company, the architect and the environmental consultant had prior expertise about circularity. This should be kept in mind when assessing who learns, but it can also influence how the learning process takes place. Furthermore, the actors involved in the *initiators* (green) and *builders* (blue) role group (except for the interior supplier) consist of large nationally operating companies involved in regime activities. In understanding *who should learn,* these are actors who can make an impactful contribution towards a CE transition, therefore considered important actors for transition learning. Furthermore, regarding *missing actors,* it can be recommended to not only involve stakeholders on the building level, but also inform those involved in the development of direct surroundings of the project area. By including the spatial planning department of the municipality, the undesired current situation, in which the building can be disassembled but the concrete pavement is still fixed, could be prevented. Furthermore, more suppliers could have been integrated early on in the development process to think about different ownership models.

4.3.3 The process: Learns how?

An interesting result from all interviewees involved in the design phase is that the circular ambitions of the Green House were catalysed by the agent of the developing company (interviewee 15; 16; 17; 18). The fact that the building needed to be disassembled after its first use-cycle and the ambitions of the municipality to become circular by 2030 triggered him to approach the project as a circular expedition, and with that create room for circular experiments (interviewee 15). This subchapter introduces his approach and how he catalysed a learning environment, which was structured according to a (1) strategic level (vision and ambition), (2) tactical level (integrating eco-network) and (3) operational level (transparent learning environment).

v

Strategic level: Visioning
The developer embraced the project as a circular experiment. He did so by driving the project from a role called the quartermaster (*kwartiermaker*), in which he motivated people (both the boards of the consortium members as the team), and finding technical solutions that support a CE (interviewee 15). The first step he mentioned multiple times was to set a clear vision and ambition and from that develop a strategy to realize it. The vision set out by the project leader was: "We wanted to create a circular pavilion, which could be disassembled and reassembled, and which should act as a circular hotspot with a feasible and scalable circular business case. That was our ambition, a circular meeting place." (interviewee 15).

With the vision in place, a solid strategy needs to be developed. The developer stated that for traditional projects, approval is required for nearly everything, but that this becomes even more explicit in innovative, potentially risky, projects, such as the Green House. To realize the vision, *commitment* and *willingness* is necessary (interviewee 15). In doing so, the developer emphasized the importance of starting on the strategic level, where the most important hurdle was to convince the management boards. "You have to take them along: 'What happens in their world, how can it be interesting for them and how can it put them on the map?' In general, directors find it difficult as it should not cost more than traditional projects (…) Even though they have their CSR ambitions, it took a lot of energy, but in the end we managed. We focused on residual value to get the boards along, and we decreased the size of the pavilion, but included flexibility for possible expansion. This saved 15% of the building sum." (interviewee 15). By being creative with the budget and not only focusing on the cost-perspective, but instead, reframing it from a revenue-perspective (residual value), the developer convinced the boards to experiment with circular construction practices.

Tactical level: Involving eco-network early on in the design process
In general, this design process followed the same phases as in traditional developments (interviewee 15; 18), however, an important difference is that key partners to realize the ambition are integrated upfront in the design process. This led to the inclusion of the operator early on in the design stage, who together with the developer searched for which suppliers could support their ambitions (interviewee 15). "For the design phase, it is important to include the *eco-network*, your co-makers or suppliers. Because for circularity, 20% of the suppliers determine 80% of the total environmental impact of the building." (interviewee 15).

Interesting, here, is the fact that *deep learning* occurred in the supplier's group, where the interior supplier developed a new circular concept based on the vision of the experiment (interviewee 20) and, according to the operator, the light supplier started a PaaS-model. "The luminaires in the Green House are not mine, I pay per hour of light. This system incentivizes them to extend the lifetime of the product. That model was completely new for them" (interviewee 17). They got involved via the developer, who instead of sending a digital inquiry, which often happens when including suppliers, invited the director personally (strategic level), presented their vision and emphasized their potential role in their eco-network. This process, of including co-makers who may not possess knowledge about a CE, requires intensive guidance and monitoring (interviewee 15). The guidance, by constantly emphasizing the vision, was provided by the developer. This was important to prevent the team from falling back in old routines, where for example the structural engineer initially opted for a fixed concrete foundation (interviewee 15). Monitoring was done by the circularity expert, who could measure the impact and reflect on design and construction choices (interviewee 19).

Operational level: Open learning environment
The vision of the Green House was to also act as a circular hotspot during the use-phase. Therefore, the operator uses the Green House as a living lab, as he calls it, in which now 100 experiments have been included, which should be 1000 experiments by 2030 (interviewee 17). One of these

experiments was to serve a menu with 80% plant-based and 20% meat, through which they found that 89% chooses a plant-based meal (interviewee 17). Furthermore, all the circular stories of the Green House are open-sourced with a *right-to-copy.* "All my competitors have paid a visit. I gave them a tour and explained everything. In the beginning this was hard, as I am programmed to protect my knowledge. But our goal is to catalyse circularity." (interviewee 17). Therefore, learning is not limited to the design and construction phase, but also during the use-phase.

Conditions
Different conditions were mentioned for a creating a learning environment. At first, a (1) **circular catalyst** is necessary, a project leader with a circular vision who can think in creative solutions (interviewee 15; 17; 18; 19). Secondly, (2) **monitoring** of the impact of these circular ambitions in order to guide the team and seek new possibilities (interviewee 15; 17). Thirdly, there should be (3) **budget** to realize the ambition and to rethink and measure the impact of the development process (interviewee 15; 18). Fourthly, a (4) **new collaboration form** should be developed, which rests on cooperation instead of a traditional rental contract (interviewee 15; 17). Fifthly, the team should (5) **select suppliers on goals** in order to create the right eco-network to fulfil the ambition. According to the developer this is important to break from regime activities: "Traditionally, large construction companies are used to work with specific suppliers, who get first choice and the one with the lowest price wins. That is really hard to break, but you can if you select suppliers on ambitions. That opens up a new network." (interviewee 15). Sixthly, (6) **sufficient time**, both in personal time (interviewee 17) as in lead time, where circular experiments require more time in the design phase (interviewee 15). Finally, (7) **flexibility in design**, both in ensuring that a building becomes adaptable as well as the stance of the designers, where initial plans might be changed (interviewee 16; 18).

Missing learning activities
From the analysis it became clear that guidance and monitoring of the developer and the circular expert was an important factor to stimulate the circular ambitions and learning process. However, the developer stressed the fact that there was no **plenary evaluation** of the involved stakeholders about the project and how to follow-up on the gained knowledge (interviewee 15). Furthermore, he envisioned that a **transparent** project environment should be created, in which co-makers are involved in an environment with an open budget and clarity about how will be monitored and assessed. "You need trust if you want to make different agreements about budgets. You create this by approaching a project transparently: open communication, open budget and clarity about which performance indicators will be used and how these will be monitored. That is currently not the case, but we should strive for it." (interviewee 15). This is an interesting feature, in order to break with regime activities (the dominant way of working), an environment of trust is necessary, which can be created via transparency in budget and project approach. Finally, **monitor from the start** the circularity expert was involved after the definitive design, which according to him was too late in the process (interviewee 19).

Conclusion
From this analysis it can be concluded that the learning environment was created by the project developer who with a clear vision and strategy convinced the management to regard the project as an experiment. Secondly, *deep learning* took place by integrating co-makers early on in the design stage, who were triggered to reflect on their role in the system and experiment with new business models. Furthermore, through safeguarding the vision (as performed by the developer) and constantly monitoring the design ideas, unsustainable regime activities could be prevented. For this a project leader with a clear circular vision (*the circular catalyst*) and a circularity expert who can monitor and assess design choices proved to be essential. Thirdly, learning during the use-phase was integrated by the operator to test new catering concepts, inspire guests and professionals via storytelling and right-to-copy.

v

4.3.4. The objects: Learns what?

Building on the learning process, this chapter zooms in on what the stakeholders actually learned. The objects, or lessons learned, of the seven interviewed stakeholders will be introduced, which are characterized based on their CE research theme and to what extent these can be regarded as single- or double-loop learning. These results will be further elaborated on below and summarized in Table 4.12.

Initiators

To start with the initiator's role group, the **developer** learned (1) how to organize such an innovative project, (CE research theme: *Organizational*) and (2) about the importance of value chain collaboration (CE research theme: *Sectoral*). His approach of starting with a clear vision and use this as a catalyst to strategically get all the important stakeholders along was an approach he did not use before. Secondly, *collaboration* through the early involvement of the eco-network (suppliers) in the design process to achieve a bigger impact is something he obtained from the experiment. This approach proved to be successful and something he could integrate in other projects (interviewee 15). The **operator** had obtained prior knowledge about circular business model strategies in a tender for another circular pavilion a year before. In this earlier tender, he acquired double-loop learnings about how their role, as a caterer, should be changed from striving for profit maximisation on moment X (linear) to establishing long-term collaborations with new business models, such as PaaS (circular). In the Green House, he further built on that knowledge and learned incrementally about how this works in practice. For example, the question arose how to pay per use for a chair. Instead of going for expensive sensors to measure the use-time, the interior supplier and the operator agreed upon a fee of 2.5% of the turnover (interviewee 20).

The **client**, the Central Government Real Estate Agency, learned about (1) the process (*CE research theme: Sectoral, collaboration*) and (2) procurement (*CE research theme: Governmental - incentives*). They stated that at the time of construction, circular construction was in its infancy, but due to the fact that the developer used it as a pioneering project they learned about the importance of value chain cooperation (interviewee 14). In order to break linear business models (regime activities), cooperation should be ensured within the value chain and beyond the project-level. "Cooperation should not be achieved for one project, but on a sectoral-level. If they agree about purchasing each other's products for a longer period and integrate these in their processing cycles, you can truly break linear construction activities" (interviewee 14). Furthermore, they learned about their own role to procure (*incentives*) not a product (e.g. heating system), but a service (e.g. comfortable climate), which opens the door to circularity. This way they reflected on not only thinking about circular materials, but also in ways to stimulate the CE (interviewee 14). This reflection on the system can be regarded as deep learning, and therefore a double-loop learning.

Advisors

From the advisor's role group, the lessons learned from the **architect** fit into the *technical* CE research theme. For the first time they designed with secondary materials, which led to some single-loop learnings, such as (1) how to test whether an old glass façade is still functioning accordingly, (2) be flexible during the process and compromise on external features (often less aesthetically appealing than virgin materials) and (3) how to design a modular foundation, which they never saw before (interviewee 18). The **structural engineer** mentioned two main lessons learned. The first was about how to develop a modular foundation with a steel structure on top (*technical* CE research theme) and how to approach a circular design process, in which an enthusiastic project leader is necessary, a vision which incorporates circularity as the main criterium and remain flexible as a designer in the process. However, it did not result in an organizational reflection, where he kept insisting that they have the knowledge in place and that it is not rocket science (interviewee 16). Therefore, the lessons learned can be regarded as single-loop. An important lesson learned from the

v

environmental consultant was the importance of starting with a shared vision and having a *believer* (or two) in the team who guard this vision. This requires flexibility of involved stakeholders as the end-goal is not predetermined (interviewee 19). Secondly, they tested their Building Circularity Index: "It was also the first big project in which we integrated the BCI and it formed the basis for further development of that tool." (interviewee 19). So, from an *environmental* research theme they further developed their tool.

Builders

Finally, *deep learning* identified in the experiment came from the builder's role group, where the **interior supplier** developed a new circular business model. They initially wanted to participate because of the prime location, which they could finance from their marketing budget. However, following several meetings with the operator they agreed upon a pay-for-use construction (interviewee 20). "We recognized the trend of CE already before, but I still had doubts how dominant it would get. Now, it is simple for me, it is going to make companies into losers and winners if you do not follow. The Green House was important catalyst and flywheel for us, where we used to operate very linear. Now we retain ownership, that is a radical business model innovation." (interviewee 20).

Table 4.12. Overview of the lessons learned of the interviewed stakeholders involved in the development of the Green House.

STAKEHOLDER	CE RESEARCH THEME	SINGLE-LOOP	DOUBLE-LOOP
Central Government Real Estate Agency (*Rijksvastgoedbedrijf*)	*Sectoral*: Collaboration *Governmental*: Incentives (procurement)	Value chain cooperation necessary for a CE	How to procure to incentivize circular solutions
Developing company (*Strukton Worksphere*)	*Organizational*: Knowledge/skills *Sectoral*: Collaboration	(1) Start with a clear vision and strategy and (2) integrate eco-network early in the design process, focus on cooperation	
Operating company (*Albron*)	*Economic*: Business model innovation	Learned about the practical implications of circular business models	
Architectural firm (*cepezed*)	*Technical*: Design *Sectoral:* Collaboration	(1) Learned about a technical innovation: modular foundation, (2) approach: remain flexible	
Structural engineering company (*Pieters Bouwtechniek*)	*Technical*: Design *Sectoral:* Collaboration	(1) Innovation: Modular foundation and steel construction, (2) approach: vision, circular leader and remain flexible	
Environmental consultancy company (*Alba Concepts*)	*Environmental:* Environmental impact assessment	Test their Building Circularity Index (BCI)	
Interior supplier (*Maasdam*)	*Economic*: Business model innovation	How to organize a PaaS in a bar/restaurant	Business model innovation, started a PaaS-interior line

What not

To convince initiators to implement circular business models, the developer mentions two aspects of circular business models which he does not have the answer to: (1) **incorporate financial residual value** and (2) **measure the societal impact** of a circular project. Regarding the first, it remains difficult to include the economic value of the building at the end of its first use-cycle. A waste, because if it is clear what the future economic value will be, more money can be invested upfront and circularity will be embraced more easily (interviewee 15). Regarding the second, according to the developer investors are working with *impact funding*, where next to financial impact also societal impact is sought. The open question remains, how to measure this societal impact. "A project such as the Green House, has societal value as it inspires and catalyses circular behaviour also in the use-phase and has social value as it is a healthier building. The question is: How do you measure this?" (interviewee 15). This is backed by the circularity aspect, who states that in real estate development three axes are included: the process-side, the technical-side and the economic-side. For circular construction, the first two are well managed, but the problem is in the economic side. How to include residual value, buy-back guarantees, fiscal matters, such as VAT, or how to manage ownership. Emphasizing the necessity to break existing systems to realize a CE (interviewee 19).

Conclusion
To conclude, from this analysis it becomes clear that deep learning in the experiment was mainly centred around circular business models. In the interviews this was emphasized as the *uniqueness* of the Green House (interviewee 15; 17; 18; 19). Resulting in double-loop learnings of those with no prior CE experience: the client and the material supplier (except for the structural engineer). When reflecting on *who should learn*, the client, considering their size and influence, can be regarded as an important actor to learn about a CE transition. The fact that they provided room for the market to come up with solutions, which ultimately led to new circular business models, made them realize how to procure to stimulate circular activities. Furthermore, the stakeholders with single-loop learnings, except for the structural engineer, all had prior experience with circularity and learned more practically about the development process (e.g. how such a project is approached, how to design with secondary materials, the importance of early collaboration, how to organize a PaaS system). Here, it should be noted that a limitation of these results is that the construction company could not be interviewed. Ultimately, regarding circular business models there remain lessons to learn, where it remains difficult to include financial residual value and how to measure societal impact.

4.3.5. The outcome: To what effect?

Now that the lessons learned are clear, it will be interesting to see how the lessons learned are shared beyond the scope of the experiment (*deepening)*, if the experiment or elements of the experiment are replicated (*broadening*) or if knowledge and innovation acquired in the experiment are implemented on an organizational level (*scaling up*).

Deepening: *Knowledge sharing*
The essence of the Green House was to realize a hotspot that functions as a catalyst during the use-phase incentivizing a CE. Therefore, as stated before, the entire project is open-sourced with the principle of a *right-to-copy*. Where online, as well as in the Green House itself, the circular construction techniques and business models are publicly made available. Furthermore, by ensuring a, what the operator calls a living lab, they include 100 experiments per year to support further *broadening* processes.

Scaling up
The **operator** stressed the necessity of experimenting for breaking with traditional practices. Initially it was difficult for him to convince the management board to participate, who were scared of risks and focussed on protocols. However, after the showcase that the Green House became, including its media attention, they received various inquiries of other large companies who also wanted a circular catering concept. "You should realize our phone did not ring for quite a while. Now all these big organizations are interested." (interviewee 17). This led to further *broadening* projects, where they further tested with interior and light as a service for Starbucks and a circular catering concept for Rijkswaterstaat. However, he emphasized that the main barrier in scaling up PaaS constructions is the lacking willingness of financial suppliers, the funders. They contacted all banks, but none of them were willing as it leads to unclarities about risks and ownership. "*Cost-controllers* calculate from a linear model, then PaaS never results in a positive output." (interviewee 17). So, from this the *deepening* process allowed the operator to revise their traditional operations, which due to market attention could be *broadened*. For the PaaS-innovations they applied in the Green House to be *scaled up*, willingness of banks or financial suppliers is necessary.

v

The experiment radically changed the business model of the **interior supplier**. They developed a new chain (*Maasdam Circulair*) based on the learnings of the Green House, which completely changed their operations. “Instead of a box shover (output), which we were, now we also take back products (input). We became our own repair and refurbish centre, a completely different competence.” (interviewee 20). However, he states that in order to further develop the PaaS-structure, which can technologically be further improved, he needs more of these follow-up projects (*broadening*), which are lacking (interviewee 20).

The **developer** emphasized that for an operator and supplier who work with formulas, the experiments in the Green House are easily scalable. However, he mentions that for the large construction companies, this is really difficult. “For them (Albron) it is scalable, but for Strukton and Ballast I can say that we barely succeeded. I find that scaling up, and integrating the learnings of experiments such as the Green House, mostly on process, that occurs horribly slow. I also see it with other large construction companies.” (interviewee 15). According to him, these two large construction companies lack a clear vision of how to implement change trajectories to break with unsustainable activities. Such a change trajectory requires internal capacity and dedication, for which the resources are currently not made available due to the high demand for traditional construction at the moment. “In order to transition, the most important actors that need to change are the clients, principal contractors and public buyers. They need a new approach.” (interviewee 15). Here, it should be noted that the project leader of the Green House was self-employed, and therefore was not involved in the post-experiment integrations process of the developing company.

The new role mentioned for public buyers was also a lesson learned which was obtained by the **client**, the Central Government Real Estate Agency. From the experiment, they learned that they have an important role in incentivizing the market to come up with circular solutions. One of these learnings, which they scaled up and made a standard approach in their operations, is to procure on a service instead of a product in new projects (interviewee 14). This learning was obtained in the Green House as well as in other circular building projects they have been involved in. From this it can be concluded that the client who are involved in regime activities, learned from experiments where practices are applied which deviate from the regime, tested these learnings in different projects via a process of *broadening* and integrated this in their standard way of working (*scaled up*). The developer further emphasized the important role of *public buyers* in order to transition: “Right now, we purchase timber per m3, but in the future we will purchase the *use* of a timber construction. The new role of the buyers will be to recognize who can supply this, who can engineer it and build trust with these companies to discuss about potential collaboration forms.” (interviewee 15).

The **structural engineer** mentioned that they evaluate the results and that they share their lessons learned informally within the innovation workgroup on sustainability, and with the management board (interviewee 16). However, it did not lead to further *broadening* activities. The **architect** approached it the same way, where they shared the design lessons internally, such as the integration of the green house and the modular prefab concrete foundation. However, for *broadening* or *scaling up* these innovations: “The difficulty is that these innovations cannot be copied 1 on 1. The conditions were really specific.” (interviewee 15). Finally, the **environmental consultant** integrated the lessons learned regarding the BCI, which they could further develop and scale up as a method to assess the circularity of a real estate object (interviewee 19).

Conclusion

From this analysis it becomes clear that the circular concepts tested in the Green House, the PaaS constructions, proved to be a scalable circular formula. Experimenting with these new ownership models, triggered the client to think differently on how to procure for a CE (by procuring a service instead of a product). Interesting, however, is that knowledge and innovations obtained from a circular construction perspective, were not easily scaled up, due to (1) context-specificness (architect and structural engineer) and (2) no internal capacity to integrate the lessons learned in the organization (two construction companies). The latter requires further elaboration, where this was especially the case for the two large construction companies involved in the experiment. Regarding their size and (unsustainable) regime activities, they have the resources to significantly contribute to a CE transition in the construction sector. However, there appears to be no internal learning structure available to embed, or institutionalize, the lessons learned. Within these firms, the lessons learned remain on the individual level. Furthermore, the current high demand for conventional construction projects limits the urgency for these companies to break with regime activities.

4.3.6 Overall project conclusion

The Green House is an experiment which was not originally designed as a circular building experiment. As part of a larger development of the Knoopkazerne, the client procured a commercial solution for an adjacent vacant plot of land for the period of 15 years, with one sustainability condition: the building should be reused after its first-use period. Based on this condition, the project developer, who had prior experience with circular construction, embraced the project as a circular experiment, not only constructively, but also conceptually during its use-phase. Together with the operator, also prior CE experience, they catalysed an experimental learning environment.

Deepening took place by setting out a clear circular vision, which was shared by the involved stakeholders and by integrating the right *eco-network* early on in the design process. By collaboratively reflecting on the system and what their role could be in this vision, the developer and operator triggered a different mindset of their suppliers. Instead of focussing on buying a product, they insisted on buying a service. This resulted in double-loop learnings of both the suppliers (new PaaS business models) and the client, who learned about their role in incentivizing a CE via procurement. Furthermore, during design and construction the vision needed to be (1) safeguarded by the project leader to prevent the team from falling in old (regime) routines and (2) monitored and assessed by an external circularity expert to measure the impact of design choices and identify new circular opportunities. Furthermore, the goal of the experiment was to support *deepening*, and a CE transition, also in the use-phase by giving a stage to circular activities and inspire by sharing the lessons learned of the development based on a *right-to-copy*.

In retrospect, there were four process changes which could have improved the learning outcome, as mentioned by the developer and the circularity expert: (1) start monitoring CE impact from the start, now they were involved at the end of the design phase, (2) include plenary evaluation to support reflection about the project and the system (supports deep learning), (3) create transparency about budget and process approach, (4) determine before the experiment about how lessons learned will be embedded in the organizations. Especially, the latter appeared to be of importance for large construction companies, where it appeared there is no agent responsible for integrating the lessons learned in the experiment. Regarding transition learning, these are the companies who can have a significant impact on breaking with regime activities and supporting a CE transition. Right now, it seems that the lessons learned remain on the individual level, which limits the potential of *scaling up*. This is further limited by a lack of *broadening* possibilities (architect and structural engineer) and the high demand for traditional projects. This limits the necessity to reflect and isolates the constructive lessons learned.

v

4.4 Case 4. Vondeltuin, Amsterdam – Circular pavilion/New utility building

The final case is the Vondeltuin, a pavilion housing a bar and restaurant located in the Vondelpark in Amsterdam. The municipality of Amsterdam wants to move towards a CE, and as part of the municipal transition programme '*Amsterdam Circular: Learning by doing*', wanted to experiment with circular construction principles in their own property developments. The Vondeltuin was the first pilot project, which started in 2018 and was taken into use in May 2020. This chapter will further elaborate on this experiment, by at first giving an overview of the context of the case, including its development process (4.4.1). Afterwards, more insight will be giving in which stakeholders were involved (4.4.2), how stakeholders learned in the experiment (4.4.3) and what the corresponding lessons learned were (4.4.4). Finally, the chapter takes a post-experiment perspective, by zooming in on how these lessons learned are institutionalized (4.4.5).

Table 4.13. Overview of the interviewees of the Vondeltuin, their company and function.

INTERVIEWEE	COMPANY TYPE	COMPANY NAME	FUNCTION
21	Municipality (client)	Municipality of Amsterdam	Project leader
22	Architectural firm	DOOR Architecten	Architect
23	Construction company	De Nijs	Director
24	Construction company	De Nijs	Project manager
25	Environmental consultancy (tool)	OMRT	CTO
26	Installation's consultancy	Cauberg Huygen	Consultant
27	Environmental consultancy (procurement)	Copper8	Consultant
28	Structural engineering company	Van Rossum	Structural engineer
29	Operating company	Vondeltuin	Catering manager

Figure 4.22. Impressions of the Vondeltuin. Both images on the left derived from Duurzaam Gebouwd (2020), both images on the right from DOOR Architecten (2020).

v

4.4.1 Case introduction and development process

In a large fire 2011, the previous building of restaurant '*de Vondeltuin*' was irreparably damaged and had to be demolished. This building, inspired by the Indonesian Batak-style, was built in 1929 and had an iconic status in the park (Gemeente Amsterdam, 2020). The idea to include circular design principles in the development of the new building date back to 2014, when the project leader of the real estate department of the municipality was informed by the sustainability department about the municipal CE transition programme (interviewee 21). In the search of finding a suitable pilot project for the programme and to experiment with circular principles in municipal real estate development, the project leader bumped into the Vondeltuin: "A perfect fit – because A) it is a small assignment, so accessible for experimenting with CE principles and B) it is located on a prime location, so it can attract attention and create publicity." (interviewee 21). The building surface area of the Vondeltuin is 120 m2 for a budget of €500.000,-, of which 20% was allocated for the design phase and 80% for construction. The budget was predetermined and transparently communicated in the procurement procedure.

Figure 4.23 Timeline of the different development phases of the Vondeltuin as derived from documents of the municipality (interviewee 21).

Initiation phase (procurement procedure)

The development process of the Vondeltuin followed the traditional building development process of initiation, design, construction and use, as depicted in Figure 4.23. However, a key feature of this experiment is that extra time and energy was invested in the initiation phase. For this, the municipality involved the expertise of an environmental consultancy company specialized in procurement processes for a CE (interviewee 21). Their role was crucial in guiding the agent of the municipality to create internal and external support (step 1. ambition phase) and ask the right question to the market (step 2. procurement phase) (interviewee 21). To create support, they organized four ambition sessions: two internally (including different municipal departments: Sustainability, Real Estate and Monuments), one with the user (the *operator*) and one with local residents. Based on these sessions, three central ambitions were identified for the development of the Vondeltuin: (1) a **circular development**, with the focus on energy, materials and water; (2) an **intensive collaboration** between market parties, the client, the operator and local residents; and (3) a **contemporary architectural design** in line with the design philosophy of the Vondelpark,

Based on these ambitions, the procurement procedure started (step 2 in Figure 4.23). This procedure, as further outlined in Figure 4.4.3, followed several phases and differed from a traditional procurement process on various points. At first, the question to the market was functionally formulated, "which feels like losing control, but it creates space for innovative ideas from the market" (interviewee 21). Secondly, the question was directed to architectural firms, as they were regarded as the ones having most knowledge about circularity within the construction chain (interviewee 21; 27). Based on 15 phone interviews with architectural firms in Amsterdam, 8 firms were invited for a preliminary interview, these were asked to share their vision about the ambition and how they would organise this. Thirdly, three architects were selected and asked to form a team, including a construction company and a team of advisors with whom they can realize the ambitions. After this informal preselection, three architectural firms and their teams were invited to start the formal procurement procedure, called 'limited tendering' (*meervoudige onderhandse aanbesteding*), in which the procedure is not directed to the entire market, but to a selected group of, in this case, architectural firms. The limited tendering phase consists of multiple dialogue rounds, as depicted in Figure 4.4.3.

Ultimately, after the second plenary dialogue round (step 5), the three 'construction teams' submitted their proposal, which were awarded based on *quality* rather than the lowest price (interviewee 21). These proposals were assessed by the three stakeholders: the municipality (55%), the operator (25%) and local residents (20%). For the assessment by the local residents a participation evening was organised, in which small groups of local residents assessed the presented proposals of the three teams. The team with the highest weighted average based on the three stakeholders was awarded the project. The municipality of Amsterdam then signed a 'construction team-agreement' based on a pre-determined, transparent, budget. Next to this, the team signs a mutual collaboration contract. Agreeing on the formal contract appeared to be difficult and ultimately time-intensive, due to the different development structure, in which not the (developing) construction company, but the architect was in the lead (interviewee 21; 22; 23; 26). This was due to the fact that the architect cannot be held responsible for any engineering errors (interviewee 21). In the end, the design phase started in March 2019.

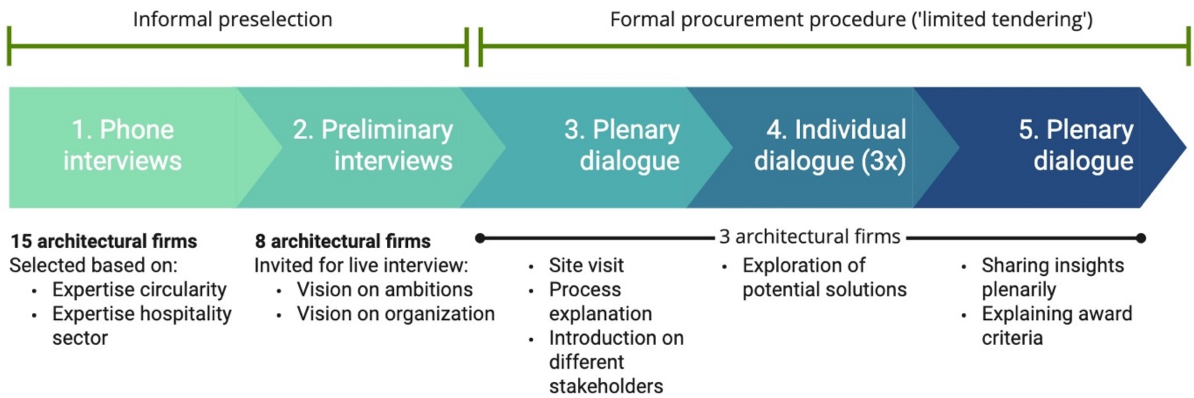


Figure 4.24. Explanation of the procurement procedure, including an informal preselection and multiple dialogue rounds. Based on documents from the municipality (interviewee 21).

This procurement procedure differed significantly from the traditional procedure, where the agent of the municipality and the supporting environmental consultant had to convince the *lead buyer* of the municipality to approach this project differently, and regard it as an experiment (interviewee 27). In the tender they wanted to receive the vision of the architect on their ambitions, but this was not a straightforward process: "The difficulty was that an architect wants to draw, but this design cannot be too detailed because then the procurement law says it has to be realized (…) but we wanted to keep the design process as open as possible. (…) In the end, we asked for a simple sketch and we only shared our ambition and wishes; we did not have a Programme of Requirements." (interviewee 21). Ultimately, the lead buyer was important to support the innovative procurement procedure and guided the agent of the municipality and the environmental consultant in moving around any obstructing regulations.

Design phase

The relative long initiation phase was not reflected in the amount of time made available for the design and construction phase. This was due to the fact that the restaurant, in their temporary form, closed in October 2019, which was the moment that construction should start so that they could open in springtime again. The design phase was regarded as complex by various stakeholders (interviewee 21; 22; 23; 26; 27), which was due to the high ambitions on both circularity and architectural design, as well as the inclusion of external stakeholders who had to agree on design choices. These included the municipal Commission for Spatial Quality, because it is a monumental

v

park, and local residents, who were mostly concerned about nuisance (interviewee 22). An overview of all internal design stakeholders will be given in Chapter 4.4.2. Regarding circularity, the design team focused on using local secondary materials for the building, as shown in Figure 4.25. These include locally sourced materials of the municipality (e.g. the plinth of unused kerbstones laying in Amstelpark, timber from old trees from Amsterdam) or from the construction company who were simultaneously involved in a redevelopment of an old office building in Amsterdam. The design team met every two weeks (interviewee 21; 22).

Construction phase
The construction phase had to be executed during fall and winter (from October-March) and started with deconstructing the temporary building. The released materials during this process did not conform the necessary standards and could therefore not be reused (interviewee 24). In the construction phase, the team encountered various challenges, where for example the design had to be revised and some secondary materials proved to be unavailable (interviewee 21). Due to specific internal dynamics, some circular construction ideas were not realised even though they were discussed and formalised in the design phase. This process which influenced the circular outcomes of the project will be further elaborated on in Chapter 4.4.3.

Use phase
In April 2020, the operator could use the building and open their doors from the 1st of June onwards. The operational management is in line with the circular philosophy of the building, where they serve a plant-based and locally-sourced menu, structured their waste management processes, set up a collaboration with their beer supplier for carbon neutral delivery (including PV-panels) and cook on electricity (interviewee 29). The operator has a contract for a use-period of 15 years.

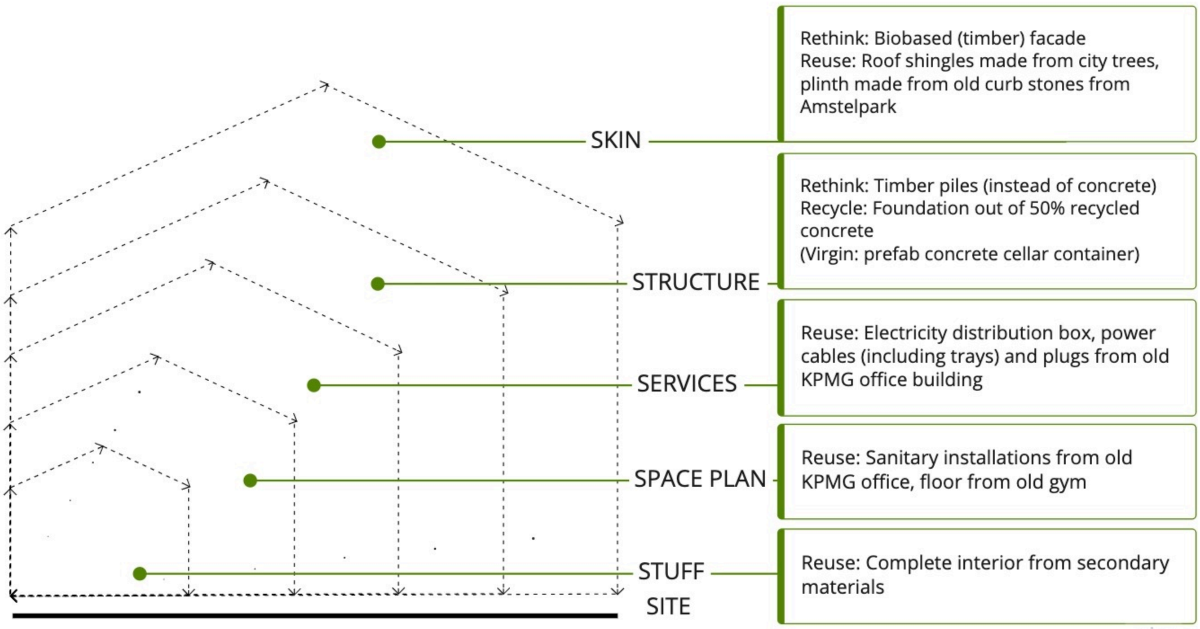


Figure 4.25. Overview of the different CE strategies (Potting et al., 2017) connected to the different shearing layers of Brand (1995). Most circular design principles are focused on using secondary materials.

4.4.2 The subjects: Who learns?
After an extensive description of the development process of the Vondeltuin, this subchapter introduces the internal stakeholders involved in the experiment. As stated in the previous subchapter, the 'construction team' was selected by the architect, who together with the municipality and the operator formed the *core team*, as visualized in Figure 4.26. The various

v

stakeholders including their background, interest, role and resources are further explained in Table 4.14. External stakeholders, such as local residents and the municipal Commission for Spatial Quality were also involved in the design phase. However, they are not included in this analysis as their role was limited to agreeing or disagreeing with certain design choices (limiting nuisance or preserving monumental character of Vondelpark) and are therefore not regarded as active internal stakeholders in the design and construction process of the Vondeltuin. Also, the landscape architect had been approached various times for an interview, but without success. This actor is therefore also not included in the analysis, even though they were part of the construction team.

Table 4.14. Overview of the different characteristics of the core internal stakeholders involved in the design and construction process of the Vondeltuin. The colour indicates their role group: green = initiators; orange = advisors; and blue = builders.

STAKEHOLDER	BACKGROUND (GENERAL)	INTEREST (PROJECT)	ROLE (PROJECT)	RESOURCES
Municipality of Amsterdam	Political target of the municipality to transition towards a CE. Agent of the Real Estate department involved. Large-sized organization.	Wanted to experiment with CE practices in own real estate developments	Project leader from the client	Financial resources,
Operating company	Owner of restaurant/bar Vondeltuin. Have multiple bars in Amsterdam. Small-sized organization (	Creating a permanent location for the restaurant, which is designed for functionality.	Safeguarding strategic choices for catering	Leverage on decision-making
Architectural firm (*DOOR Architecten*)	Architectural firm focusing on CE and integrating other disciplines in innovative developments. Small-sized: 15 fte.	CE project can support portfolio. Knew honorarium was low, but showcase can lead to more projects (interviewee 22).	Project leader in experiment, CE expert	Previous CE knowledge (own office is designed following CE principles)
Structural engineering company (*Van Rossum BV*)	Nationally operating structural engineering agency, offices in Utrecht, Amsterdam (2x) and Rotterdam. Medium-sized: 116 fte.	Interested in innovative projects, wanted to know more about the process of a circular development	Structural construction expert, designing a safe building	Knowledge in structural engineering, agent prior experience with CE
Environmental consultancy (*OMRT*)	Start-up (est. 2018) focused on optimizing design processes through digitalization (BIM). Small-sized: during Vondeltuin 4 fte, now 30 fte.	One of the first projects of the company. Tested their model, which integrates building energy and material energy.	Support design choices via environmental impact tool	Circular assessment tool
Environmental consultancy (*Copper8*)	Consultancy firm focused on supporting a CE, specialized in procurement procedures. Helping clients to ask the right question and stimulate cooperation. Small-sized: 15 fte.	Asked to support the municipality in the procurement procedure.	Process consultant in initiation phase	Prior experience in procuring for a CE, network
Installation's consultancy company (*Cauberg Huygen*)	Engineering firm focusing on building physics, installations and environment. Medium-sized: 118 fte	Acknowledge the urgency for a CE. Wanted to experiment with circular process.	Support architect in tender proposal (initiation) and building permit (design)	Energy and installations expertise
Construction company *(De Nijs)*	Developing and construction company focused on the Amsterdam Metropolitan Area. Large-sized: 307 fte (24th largest construction company (Cobouw, 2020))	CE is one of their four CSR pillars. Vondeltuin first experiment of a series of three to experiment with circular construction (learning by doing).	Developing contractor, material scout	Construction knowledge

v

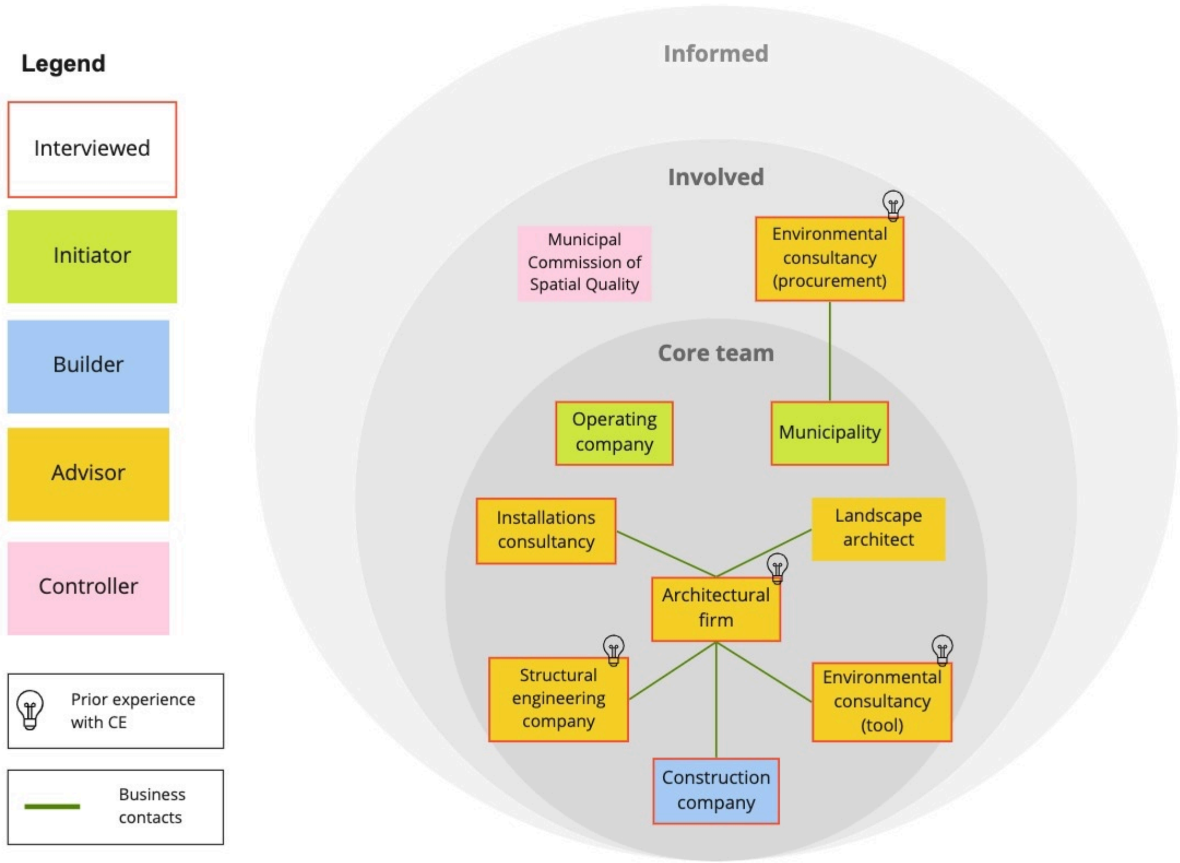


Figure 4.26 Overview of the involved stakeholders divided in three groups: core team, involved (involved during one phase of the development), informed (not directly involved, but want to be informed).

Subjects' analysis

The municipality, under supervision of the environmental consultancy, designed the cooperation in the project in such a way that the architect became the leader of the band and that they select a contractor and a team of advisors, as depicted in Figure 4.26 (interviewee 21). For the architect, this was the first time that they approached a development in such a manner. Stating that based on intentions it was a different approach, however, the legal agreement was still structured according to traditional agreements, in which the construction company signs a contract with the municipality, and the architect is one of the advisors of the construction company. "Based on intentions you can approach it differently, but formal agreements are hard to change. That has to do with responsibilities. An architect can simply not be held responsible for a building. We are not insured for it." (interviewee 22). Finding this legal agreement took a lot of time and energy in the early stages of the design phase (interviewee 21; 23, 26, 28), which lead to frustrations of the structural engineer and the installations consultancy (interviewee 26; 28). For the construction company this cooperation form was also new, as they are used to either (1) the initiator (in this case municipality) is in the lead or (2) the developer or contractor (in this case themselves) is in the lead (interviewee 23). This new collaboration form influenced the traditional hierarchy in the development process, which will be further elaborated in Chapter 4.4.3.

Conclusion

The construction team was selected by the architect, who had prior CE knowledge. Based on their experience, they involved an environmental consultant to develop a model to assess the environmental impact of various design choices. Regarding *who should learn*, based on the stakeholder analysis, it becomes clear that both the municipality and the construction company are large companies who conventionally work in traditional construction projects. These actors, who are involved in regime activities, seek to gain experience with circular construction practices in the experiment and it will therefore be interesting to see how and what they will learn from it. Ultimately, none of the respondents indicated that there were crucial stakeholders or stakeholder groups missing in the design and construction phases.

4.4.3 The process: Learns how?

The development process of the Vondeltuin has different stories, some positive and some less positive (interviewee 21; 23; 27). This subchapter will zoom in on these processes to understand what supported and what hindered transition learning of the involved stakeholders. To clarify this story, at first, those factors that supported *deep learning* in the initiation and design phase will be discussed. Then subsequently, key conditions which influenced transition learning and the circular outcome of the experiment will be discussed under the headers '*Commitment and continuity*', '*Budget and complexity'* and '*Monitoring'*. Finally, key conditions will be discussed that proved to be important from the analysis for the development of innovative circular building projects.

Deep learning in the initiation and design phase

The identified double-loop learnings in the experiment can all be traced back to the agent of the municipality. These learnings were acquired through *involving external expertise*, which started in the **initiation phase**. Here, the role of the environmental consultant, regarding circular procurement processes proved to be crucial in stimulating double-loop learning. "I knew I had to move away from the standard process, but I had no clue how. Then Copper8 (environmental consultancy) came in and they guided me through the process." (interviewee 21). The essence of their approach rests on, at first, setting a clear ambition, and from that, start a dialogue phase to experience how the market perceives this process and to ensure that the correct question is asked to the market (interviewee 27). Their involvement triggered a reflection on the municipality's own functioning: "This was an intensive process, but through this we could reflect on our procurement process. Is the question clear? Is there something that does not work or something that should be added? (…) An important lesson to first finetune the question and feel if it is correct, instead of simply throwing it over the wall. (…) Also, for my colleague, the *lead buyer*, she is used to work with standard tender guidelines, but now we created one ourselves. After several questions raised by the architect regarding this new guideline, she said 'I have never looked at it from that perspective'. That was such a good lesson for her to receive feedback and understand the bottlenecks of the tenderers." (interviewee 21).

Secondly, the role of a circular assessment framework, which was developed by an environmental consultancy (OMRT), supported *deep learning* in the **design phase**. The architect deliberately involved them, who based on parametric design (BIM), supported substantive decision-making regarding circular design choices: "We tried to support by actually measuring and quantifying circularity. This way you can integrally reflect on design choices and say 'Okay, it is maybe not 100% circular, but it is the best weighted average". (…) These tools are still in their infancy, but will be very important to get a grip of circularity in design" (interviewee 22). The tool, which models the embodied energy in materials vs. energy consumption in the use-phase of various designs, as depicted in Figure 4.27, appeared to be important to get all the stakeholders on the same page (interviewee 22). In the early stages in the design, these sessions included the municipality, the construction company, the architect and the environmental consultant. For the municipality it was an eye-opener: "Through them we reflected on shadow costs. We installed less PV, because they showed that the environmental impact during production was larger than the benefit during use. Imagine, and all my colleagues are shouting 'more solar panels!', but these shadow costs are always overlooked." (interviewee 21). This double-loop learning was only obtained by the agent of the municipality, and not by the agent of the construction company. The reason, however, could relate to certain internal dynamics which hampered transition learning, as discussed next.

v

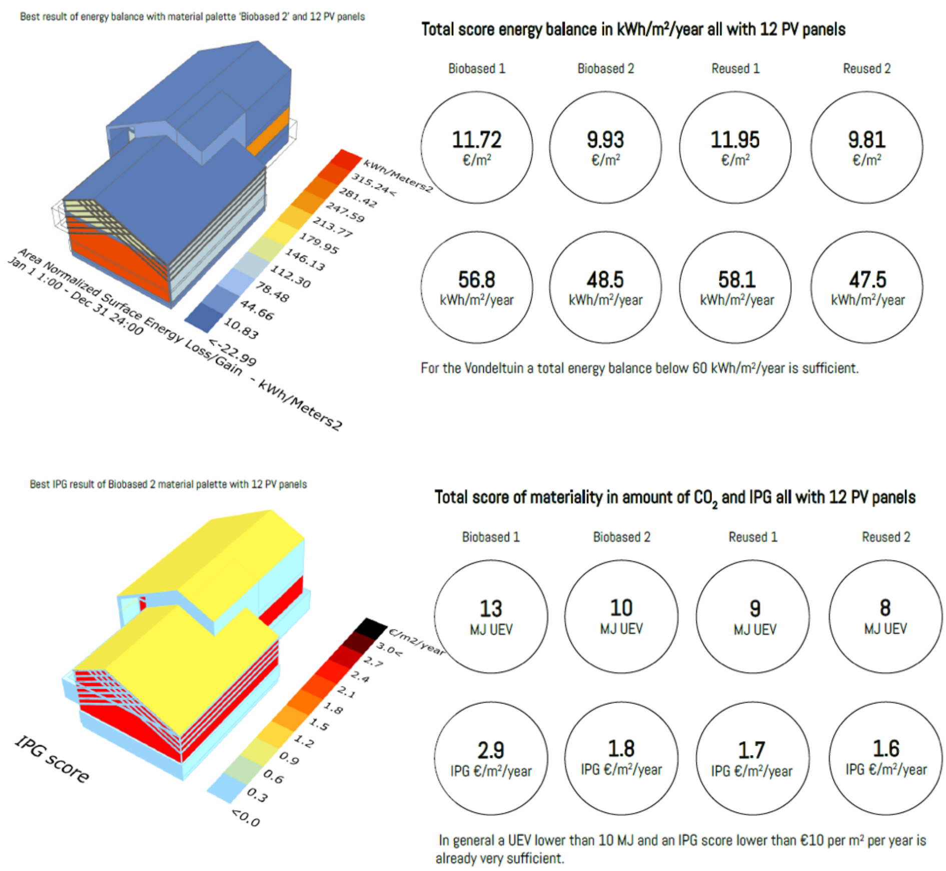


Figure 4.27. Overview of two output models of the circular assessment tool as developed by OMRT. Images derived from a document of the municipality (interviewee 21).

Commitment and continuity

Various stakeholders mentioned the lacking commitment of the construction company as a barrier in rethinking the development process and realizing the circular ambitions of the project (interviewee 21; 22; 23; 25; 27; 29). Initially, in the tendering process, the director of the construction company was involved herself. Based on their company's goals to learn more about circular construction, they had high ambitions and expectations of the project. However, when confronted with this finding, the director of the construction company was honest about their own role: "We also learned how not to do it. We simply put the wrong team on the project. One of the main lessons learned was that it is a different process, which requires different competencies. You need people who want to think differently and have a feeling for it. We cannot put our traditional team, with employees who have worked for 30 to 40 years in traditional projects, on it." (interviewee 23).

This was reflected in the reaction of the 'traditional' project leader involved in the design phase (interviewee 24). When asked how he experienced the process: "When we won the tender, we ended up in never-ending discussions. Every Friday from 09:00-18:00, and then a week later we would move 180 degrees the other direction. I am wasting my hours; I am already three times over my budget for a building of 100 m2. Endless discussions about a wooden plank. Can't we just buy a circular product? Come on, we need to build." (interviewee 24). This emphasizes the traditional way of thinking of the agent involved in the design phase of the construction company. Ultimately, the lack of commitment trickled down to the construction phase, in which certain virgin materials were chosen over predetermined secondary materials and elements were fixed in the construction, which limited the adaptability of the building (interviewee 21; 25).

According to the environmental consultant, a lack of commitment and willingness to do things differently was the root cause of why the process did not proceed as intended (interviewee 27). Backed by the architect who stated that for circular projects new paths need to be found and for this willingness is necessary: “An architect needs to be willing to design differently, the structural engineer must be willing and able to calculate it again and the contractor needs to be willing to revise their suppliers, search for new materials and construct these differently. You need each other to realize this, much more than in a traditional process.” (interviewee 22). Next to this, the architect also emphasized the importance of *continuing* commitment, where construction is characterized by different phases and often new agents of an organization enter a project after each phase. The architect stressed the importance of ensuring that these agents embrace the ambition and philosophy. “We kind of expected that to occur automatically, but in hindsight it did not. How to do it differently? In principle, devote attention to it. Ask questions and have agents express their commitment. Yes, it is all about personal drive and very soft.” (interviewee 22). So, from this the necessity to commit stakeholders and keep them committed during the entirety of the development process remains a key focus point to realize circular ambitions.

Budget and complexity

Next to the fact that the construction company should have deployed a different team on the project, various stakeholders mentioned the low budget made available to realize the complex project as a key barrier (interviewee 22; 23; 24; 25; 26; 27). The available budget was predetermined in 2014, but did not reflect the extra time and energy that was necessary to achieve the complex ambitions determined in the initiation phase (interviewee 27). For the environmental consultant (OMRT) in the design phase, it was not a big deal as it was one of their first projects (interviewee 25). For the architect neither, because they could use the project for their portfolio. However, they did state that it was a real bottleneck for the other advisors and the construction company (interviewee 22). The installations consultant was agitated by the process and mentioned that they burned their budget in the complex procurement phase, therefore had to reduce their hours as she had to clock her hours to her superiors as well (interviewee 26). The structural engineer stated that due to the limited budget they did not experiment with any new processes or designs: “We did not experiment with anything constructively. We wanted to and talked about it, for example, experiment with a modular foundation so it becomes adaptable, but there was no budget for it.” (interviewee 28).

Related to this, the agent of the municipality and the environmental consultant tried to free more funds in the initiation phase. However, in this process the environmental consultant bumped into traditional preconditions: “Then there is the question, who accepts that this is an experiment? The municipal project leader thought it was an experiment, the *lead buyer* agreed and used a different set-up because it was an experiment, but the municipal project manager who manages the budget did not think it was an experiment: ‘Good luck, this is the budget, not a euro extra’.” (interviewee 27). Further stating that if they would have received 10-20% more budget for the process, it would have resulted in a higher quality, adaptable, building which would need less maintenance: “That saves a lot of money, but nobody experiences it because these are future-costs and then it is not their problem anymore. This short-term thinking, in which the financial project managers are judged on the amount of money they spent that year, makes it very difficult to receive more funding for circular projects.” (interviewee 27). The key message here is that these innovative circular building projects are not more expensive in materials or construction, but that they do require more process-related budget for the time invested in research and deliberation (interviewee 27).

Monitoring to improve transition learning

The experiment was characterized by a new collaboration form, in which not the client nor the developer was in the lead, but the architect. This is not a natural role for the architect and various stakeholders experienced their approach as diffuse (interviewee 23; 25; 26; 29). “That is also not strange, see an architect is not a project management agency, they are designers. There was no structural documentation and time management in those meetings" (interviewee 26). Also, the construction company stated that it was difficult for them to work in this mixed-form, in which it was unclear who was really in charge (interviewee 23). Reflecting on this, the environmental consultant recognized that cooperation in the core team did not evolve as everybody had expected: "I think in retrospect the experiment needed somebody who could safeguard cooperation and retain the circular ambitions during development. We stayed a couple of meetings as we saw it was going to be a difficult trajectory and that cooperation did not occur naturally. However, this was out of our scope and we could not shape it as we desired" (interviewee 27). As cooperation differed from a traditional development process, in which more deliberation, research and mutual alignment was necessary, the development would have benefitted from a clear process consultant who could have documented and monitored the design and construction process.

Furthermore, to stimulate learning, the environmental consultant did evaluate the tendering process and the project leader of the municipality developed a post-experiment document regarding the lessons learned. However, no central group evaluation or dedicated reflection moments were implemented during or after the experiment: "A missed opportunity. I think we evaluate way too little in construction projects in general. We can stimulate en-route learning by dedicating reflection moments and zoom-out sessions to discuss the process and cooperation. How do we think it is going, how can we do it differently and what can be improved? This will result in learning points that you can build on." (interviewee 27). As each construction phase has different challenges, these dedicated reflection moments could be structured after each phase. Furthermore, reflecting on setting-up a learning agenda at the start of the project frustrated him: "It is something I see more often. It implies that learning is the goal and that you know about which subjects you want to learn. However, the essence of project management is that you have to realize a project – in this case a pavilion – only the way you realize that pavilion will differ, and from that different approach you can learn." (interviewee 27). From this, it can be derived that starting with a clear learning agenda in a project-environment – including limited budget, time and (potentially) lacking willingness – might be not the way to approach transition learning. However, dedicating reflection moments for evaluation and document the development process prove to be important aspects when performing innovative circular building projects.

Process conditions

All in all, from the respondents several process conditions could be derived which were deemed necessary to conduct an innovative circular project. (1) Start with a **clear ambition** and clarify what the end-goal regarding circularity will be. The ambition document for the Vondeltuin was regarded as an enabler, but the end-goal of the building was not for all design stakeholders clear (interviewee 26; 28): "The end-goal of the building was not determined (e.g. 100% future reuse, lower carbon emissions, a modular and flexible building, modular construction) and you need this to determine the scope" (interviewee 28). This further has to deal with *limiting complexity* in the ambition, as mentioned by both environmental consultants and installations expert, who stated that the context (including the external stakeholders), the high circular ambitions and architectural ambitions made it too complex for the relatively small size of the building (interviewee 25; 26; 27). (2) **Integrate important stakeholders early on** in the project, where builders have to think along in the design phase to find constructive, producible, solutions (interviewee 21; 22; 27; 28). (3) **Transparency in approach**, including how will be cooperated, reflected, documented and monitored (interviewee 23; 28). (4) **Devote enough time** for the design and construction phase, as stated by the municipality: "Most important lesson is that we did not take enough time. The planning was too tight from the start. Then people fall back in old routines." (interviewee 21). Further emphasized by the architect, stating that circular building projects require more deliberation and therefore more time as processes are not self-evident anymore (interviewee 22; 25; 28). Furthermore, as discussed in detail before, a (5) **realistic budget** for the determined ambitions (interviewee 21; 23) and ensuring (6) **commitment**, which is reflected in willingness of stakeholders but also flexibility and resilience if some things do not proceed as planned (interviewee 22).

Conclusion
Deep learning in the experiment was obtained by the agent of the municipality and was achieved by including external CE expertise in the initiation (procurement) and design phase (CE assessment tool). When reflecting on *who should learn*, the construction company was also regarded as an actor involved in regime activities who could benefit from transition learning. However, they did not acquire *double-loop* learnings due to the lacking commitment of their traditional project leader who approached it from a project-perspective, instead of allowing time to revise the process. Stakeholder commitment regarding the ambition, and ensuring this commitment every time new agents/organizations are involved proves to be essential for transition learning as well as realizing the circular ambitions. Furthermore, next to (1) a clear future vision for the building with a corresponding, (2) realistic, budget, (3) sufficient deliberation time to revise the process and (4) transparency in the approach, an interesting finding is that plenary evaluation and reflection moments after every development phase were missing, which could stimulate transition learning of the involved stakeholders. For the latter, an actor supporting this process could be recommended.

4.4.4. The objects: Learns what?
Further building on the involved stakeholders and the learning process, this subchapter introduces their lessons learned. These *objects* will be categorized according to their (1) CE research theme, *economic*, *governmental*, *environmental, sectoral* or *technical* and (2) whether this learning can be regarded as a single- or double-loop learning. The involved stakeholders will be ordered according to their role group as discussed below. Ultimately, Table 4.15 summarizes the various lessons learned.

Initiators
The agent of the **municipality** learned most about the *governmental* and *environmental* CE research themes (interviewee 21). The agent could reflect on 1) the tender and 2) the environmental impact of certain design choices. Regarding the latter, the developed tool ensured a system's perspective by weighing the embodied energy of materials vs. reduced energy consumption during the use phase. Secondly, regarding the tender, the agent learned about (1) starting with an ambition and keep the focus on the ambition throughout the project, (2) qualitatively approaching the tendering process (award on quality instead of price, integrate internal stakeholders early on, finetune the question, organize dialogue rounds and support parties during the tendering process). Furthermore, various single-loop learnings were identified regarding the *process*: create more time for finding secondary materials, keep involving other disciplines and include operational team in the ambition. For the agent of the **operating company** the main lessons relate to principles of project management: clearer communication, documentation (recording) and reflect on the main take-aways of the previous meeting, stating: "Assumptions lead to mistakes. I think I am going to tattoo this on my leg. It is all about managing expectations, which were not dealt with accordingly." (interviewee 29).

Advisors
For the **architect** the lessons learned relate to the *sectoral* CE research pillar, where they emphasized that technically not that much changes, but that the process changes. This includes how to find secondary materials, how and when to test these, how to integrate them in the design and how to keep all the stakeholders committed (relational) (interviewee 22). In the end, constructively no secondary materials were used as this required too much time, so from a process design perspective this should be investigated early on in the process (interviewee 22). This is further reflected in single-loop learning of the **structural engineer** stating that it is currently difficult to reuse a structure due to the lack of information available and there was not budget and time available for

v

them to experiment. He learned more from the process (*sectoral*), how such a 'construction team' functions when designing with secondary materials (interviewee 28). For the **installations consultant** the lessons learned were limited due to a complex tender and limited budget. Her lesson learned related to the *sectoral* CE research theme and included how to design the process: limit complexity and deliberation when dealing with a small budget (interviewee 26). The **environmental consultant (procurement)** learned most about their own role (*sectoral*) when supporting the tender of a complex project with high sustainability ambitions. In retrospect, the project needed process guidance during the design and construction (interviewee 27). For the **environmental consultant (tool)** the project was a first test case of their product (*sectoral)* which they further developed and used in other projects. Next to single-loop learnings regarding modelling the environmental impacts, they also reflected on their own role, where in follow-up projects they took a more focal, and leading, role as their tool becomes the centre of the design process (interviewee 25).

Builders

The agent of the **construction company** learned most from the process, therefore related to *sectoral* CE research theme. Their main take-aways were (1) assign the right team on an innovative development project; (2) ensure that the budget and available time is in accordance with the ambition and vice versa; and (3) take a more central role early in the project (tender and design phase) (interviewee 23). Their most important lesson was that a circular project requires a team that really embraces the ambition and is motivated to realize it. This requires different competences than the traditional project leaders that currently do most of the operational work (interviewee 23).

Table 4.15. Overview of lessons learned in Vondeltuin.

STAKEHOLDER	CE RESEARCH THEME	SINGLE-LOOP	DOUBLE-LOOP
Municipality (*Municipality of Amsterdam*)	*Environmental*: Assessment tool *Governmental*: Incentives (procurement)	Retain focus on ambition throughout the project	(1) How to procure to incentivize circular solutions, (2) System reflection based on environmental impact tool
Operating company	*Sectoral*: Collaboration	Project management: manage expectations, document and clearer communication.	
Architectural firm (*DOOR Architecten*)	*Sectoral*: Collaboration	(1) how to design the process, find secondary materials and integrate in design. (2) How to keep internal stakeholders committed (relational)	
Structural engineering company (*Van Rossum BV*)	*Sectoral:* Collaboration	(1) devote more time for researching reuse of constructive elements, (2) experience process of designing with secondary materials	
Installation and energy consultancy (*Cauberg Huygen*)	*Sectoral*: Collaboration	(1) less complexity and deliberation, more time and budget	
Environmental consultancy company (*Copper8*)	*Organizational*: Skills	(1) include a process consultant in a complex and highly ambitious project	
Environmental consultancy company (*OMRT*)	*Environmental:* Environmental impact assessment *Organizational*: Skills	(1) Test their circular assessment framework, (2) take a more focal role in design phase	
Construction company (*De Nijs*)	*Organizational:* Skills *Sectoral*: Collaboration	(1) Different team necessary for circular innovative projects, (2) Ensuring ambitions and time and budget are in accordance. Take a more central role in early stages of project.	

v

Conclusion
From these results it can be concluded that *deep learning* (second-loop) was only obtained by the agent of the municipality in the initiation and design phase regarding the procurement procedure and the environment assessment tool. For the others, single-loop learnings reflect the development process of a circular building experiment and how this could be improved. As various stakeholders were not happy with how the process proceeded (interviewee 23; 24; 26; 28; 29) it is of no surprise that most single-loop learnings reflect (improvements) of the development process. However, this limited the potential for *deep* transition learning, especially for the construction company.

4.4.5. The outcome: To what effect?
This subchapter zooms in on how the lessons learned obtained by the involved stakeholders are shared in their organization and whether these have subsequently led to any new *broadening* or *scaling up* processes. This subchapter therefore zooms in on this process of institutionalization. At first, the scaling up of the secondary learnings of the municipality will be discussed. Afterwards, a further elaboration will be given on the involved advisors and builders and which effect the experiment has had in their respective organizations.

Scaling up
A main lesson learned by the **municipality** revolved around their standard procurement procedure (interviewee 21). When asked about how he integrated these procurement lessons internally: "Starting with the ambition is something I could apply directly in another project. However, I am still working on integrating the lessons learned in our practice and standard processes, but these are activities that you have to do on the side as a project leader. My manager expects that I do this many projects per year and that does not include time to reflect on our practices. It is something I have to do in my spare time." (interviewee 21). From this result it becomes clear that there are no structures in place, or resources made available, to internally follow-up on the lessons learned. Interesting as the experiment has been addressed by the Sustainability department as an experiment to assess what circularity implies for municipal real estate development. Furthermore, the agent of the municipality emphasizes that even though there is political willingness to embrace the principles of a CE, he is one of the only supporters within his department: "I am one of the few of my colleagues and managers who pulls and wants to follow up on a CE. We are stuck in the philosophy 'If it costs money, then it is not possible'." (interviewee 21).

The fact that the lessons learned regarding procurement have not been scaled up is something the environmental consultant experienced as well: "We have put a lot of energy in developing a strategy on how to procure differently, with a focus on *quality* through more dialogue and understanding. Then you see the recently sharpened procurement policy of the municipality and they move 180 degrees the opposite direction: even more on price control and *quantity*. This shows they did not learn anything from it." (interviewee 27). To further build on this, according to him, the essence of realizing a high sustainability ambition and shaping cooperation is that parties are integrated and contracted early in the process. However, judging whether this is guaranteed in the tender rests on qualitative characteristics, which are not objectively measurable, not *hard*. Now, the tendering procedure is further obstructed with quantitative requirements. So, in the end, he states that regarding learning there are three pillars: (1) financial, (2) technical and (3) cultural. For these projects, it is not about technical learning, as technical experts have bright ideas about circular construction, but it is more about *cultural learning* and going against the broader dynamic of quantifying and making everything objective (interviewee 27).

For now, the lessons learned remain on the individual level, but the agent of the municipality is working together with the environmental consultant (Copper8) on a '*Learning history of the Vondeltuin'* document. For this, the environmental consultant emphasizes the importance of how to communicate the lessons learned. “It is not about how much information you share, but how to share the information in such a way that the message comes across.” (interviewee 27).

Builders

Prior to the Vondeltuin, the **construction company** developed a strategy to experiment with three circular construction projects. The Vondeltuin was one in which they experimented with mining secondary materials and constructing with these. In response to how they institutionalized these lessons: “We are currently further broadening our knowledge, because we want to show that circular construction does not mean solely building with second-hand materials. We are now developing a timber building, in which we are applying a circular façade. Not a façade that has been used before, but from stones which are made from a circular material. That way you can also work with circularity of course.” (interviewee 23). When reflecting on this quote and the two interviews, it appears that circularity within their company still involves an incremental technical improvement, of ‘simply’ replacing a brick for a circular brick, or instead of working with a concrete structure work with a timber structure. No reflections on end-of-life situations, regarding constructing for disassembly, residual value or new ownership models, apart from identifying a façade with a pay-per-use model in the sector, have been observed in the interviews. This further emphasizes the fact that the Vondeltuin did not result in *deep learnings* for the construction company.

A key lesson learned for them was that their employees were not suitable for experimenting with new development processes, as necessary for circularity. Regarding the question whether they need to be trained for a CE, she stated: “We have 14 project leaders, of which we want to have 2 or 3 who embrace the circular mindset, two on timber and one on secondary materials. You see that the number of circular projects is currently very limited, so we do not feel the urgency to reschool our people yet. We will if there are more assignments.” (interviewee 23). So, regarding the need to institutionalize these circular practices they point to the sector, where a lack of circular building projects and *broadening* possibilities, limits the necessity for them to change (interviewee 23). From this it can be concluded that even though the construction company found out that their employees were not trained to function in circular projects, it did not result in a third-loop learning; no new internal learning structure to support *deep learning* regarding circular construction. For them, sectoral demand appears to be crucial to change their (regime) practices.

Advisors

For the **architect**, as their focus was already on including circularity in building projects, the Vondeltuin did not change any company policies or goals. They are a relatively small firm (15 fte) and can easily share the lessons learned in the company, which occurs informally. However, a key take-away they further learned from this project is the importance of including assessment tools. “We often include assessment tools for the client as we know that not everybody believes us on our blue eyes and there are a lot of internal ‘blue’ people who need hard numbers to make an informed decision. It is not traced back directly to the Vondeltuin, but it is one of those projects in which we optimized our approach and build on the lessons learned.” (interviewee 22). They further emphasize the importance of a willing client in adopting circularity in construction projects. Finally, for the other advisors, no essential lessons learned were identified that needed to be scaled up, where the **installation consultancy** and the **structural engineering company** even stated that there were no lessons learned which needed to be shared internally (interviewee 26; 28).

Conclusion

An interesting result from the effect of the *deep* lessons learned regarding the procurement procedure for innovative circular building projects is that these remain on the individual level. Within the municipality there is nobody responsible nor receives the resources (hours) for ensuring that these lessons learned are institutionalized, and based on recent changes in procurement policy it appears that the municipality moves in the other direction than what has been learned in the experiment (quantity instead of quality). Even though it is a large organization with a lot of different departments, it could be recommendable to before initiating the experiment ensure that the resources are made available in order to institutionalize the lessons learned. The most appropriate way to do so remains to be researched.

4.4.6 Overall project conclusion
From the analysis, it becomes clear that the development of the Vondeltuin resembles an experimental process in a project-environment. For the agent of the municipality, the project could be regarded as an experiment, as for them they intentionally approached it as a circular project to learn from by actually doing. This was reflected in the time and energy invested in the procurement procedure (17 months) through an intensive and qualitative selection procedure. However, during the design and construction phases the “experiment” was under severe (traditional) project pressures: (1) as the restaurant closes in fall and opens in spring the development process was under time pressure, (2) the budget made available was based on a traditional development (predetermined in 2014), for a building of 120m2 it did not reflect the extra time and energy necessary to rethink the development process and (3) commitment in the core team was lacking, where the agent of the construction company approached it as a traditional process.

From this, it becomes clear that the conditions for setting-up such an innovative circular building project requires the right resources to revise the traditional development process, explore different possible design solutions, urban mining sources and construction techniques. From the initiator these resources reflect in: a *clear future goal* regarding the building, a *realistic budget* for the ambitions and sufficient development *time*. For the stakeholders involved in the experiment it requires *commitment* to invest extra time and energy to rethink the traditional development process, which includes willingness, flexibility if the process does not develop as expected and understanding the urgency and importance of a CE. These are individual competences project leaders of the builders’ role group not naturally possess, as became clear from the involved construction company.

Regarding transition learning, *deepening* occurred by integrating external environmental expertise, where an environmental consultancy company that supported deep learning in the procurement procedure (initiation phase) and another triggered deep learning by developing a dashboard to weigh embedded energy in (secondary) materials versus energy consumption in the use-phase. Interesting furthermore, is that there are no resources (time, budget or function) made available to institutionalize these lessons learned, therefore the effect of this deepening process remains on the individual level and limits the *scaling up* potential. To prevent this from happening in follow-up project this could be a point of discussion before starting the experiment. Furthermore, nobody was responsible during the experiment to monitor (document) and reflect on the process (reflection moments), or to post-experiment plenary evaluate the lessons learned. Even though it was found that this can support the transition learning. To this process, the role of a process consultant can be argued for.

v

Chapter 5. Results: Cross-case analysis

After studying the four elaborate individual case-analyses, it appears that *deep learning* is acquired by different stakeholders, about different CE themes and via different learning processes. This chapter compares the four cases to understand what the differences and similarities are. An overview of these matching or differing empirical results are summarized in Appendix F, which is used as the basis for this chapter. This chapter is structured around three parts. At first, in 5.1, the scope will be drawn to the level of the experiment to compare the results of the four main themes of the individual case analyses (the subjects, the process, the objects and the effect). Afterwards, an integrated perspective will be applied in Chapter 5.2 to assess how the results of the different subchapters relate.

5.1 Comparing the four different cases

This first subchapter compares the four different case analyses. How do the cases relate to each other? Which corresponding findings can be found and which results stand-out? To answer these questions, at first the *context* of the cases will be discussed (5.1.1), by zooming in on topics such as the scope, type of experiment and collaboration form. Secondly, the focus will be drawn to the involved actors, the *subjects* (5.1.2), aiming to give an answer on which stakeholders *should* learn in these experiments. Thirdly, the learning *process* (5.1.3) will be elaborated on, where next to the transition learning forms also the necessary learning conditions will be discussed. Then, fourthly, the lessons learned, the *objects* (5.1.4), will be included, with specific emphasis for those double-loop learnings. Finally, the *effect* (5.1.5) of these lessons learned will be discussed and how these have been shared in the sector, broadened and potentially scaled up in the respective organizations.

5.1.1. The context: The development process

Before comparing the deepening process of the cases, it is valuable to, at first, take a step back and put the development process of each case in perspective. Table 5.1 provides an overview of key characteristics of the different experiments and shows the similarities between Assinklanden and SUPERLOCAL (both social housing, both circular deconstruction and newbuild) and between the Green House and Vondeltuin (both a circular pavilion and both newbuild). These differences influence which circular practices will be applied and which stakeholders have a central role in the design process, as further elaborated on in Chapter 5.1.2.

Table 5.1. Overview of the differences in the context of the experiments.

CASE	ASSINKLANDEN	SUPERLOCAL	THE GREENHOUSE	VONDELTUIN
Function	Social housing (private)	Social housing (private)	Restaurant/bar (public)	Restaurant/bar (public)
Type of development	Circular deconstruction/newbuild	Circular deconstruction/newbuild	Newbuild	Newbuild
Circular practices (based on Appendix A)	*EoL*: Deconstruction; Reuse of products and components *Design*: DfD *Use:* Easy repair and adaptability	*EoL*: Deconstruction; Reuse of products and components; Closed-loop recycling *Design*: Design out waste; Design for standardisation	*EoL*: Reuse of products and components *Design*: DfD; Design for adaptability/flexibility *Use*: Easy repair and upgrade; adaptability; flexibility	*EoL*: Reuse of products and components
Budget	€600.000	€4.700.000	€1.000.000	€500.000
Number of buildings; size	7; 100m2	3; 74m2, 64m2, 40m2	1; 201m2	1; 120m2
Collaboration form	Consortium, based on consent, transparency and trust	Construction team	Consortium, DBFMO	Construction team

Type of experiment

When reflecting on the development processes of the different experiments, it becomes clear that the nature of experimentation differs. At first, when reflecting on the available budget, the development budget of SUPERLOCAL is significantly higher than the other three experiments. This experiment, subsidized by the EU, was also the only experiment in which the respondents did not mention, or follow, the traditional development phases of (1) initiation, (2) design, (3) construction and (4) use. Rather, an iterative process of designing and testing was applied to find optimal construction techniques that fit the circular ambition, in which constructive failure was allowed. That is an important, second, difference compared to the other three cases, as in these, the focus was on *designing* and redesigning a 'successful' building which implies preventing failure in the construction phase. This is also reflected in the large amount of time invested in the initiation and/or design phase of the other three experiments. From this, a difference in experimentation-environment can be observed. Where SUPERLOCAL was aimed at testing various new, innovative, construction techniques to develop a circular building from existing flats, the other three experiments can be seen as experiments in a pilot project-environment, including the pressures of meeting the client's expectations and wishes, within a defined time period and with a restricted budget. Therefore, involving pressures of expectations, time and budget in the development process.

Following the different logics of experimentation by Ansell & Bartenberger (2016), SUPERLOCAL can be regarded as a *Darwinian experiment* in which the focus is on increasing the number of construction experiments, *variation*, to find through a process of trial-and-error which circular construction techniques work (success) and which do not (fail). The other three cases can be seen as *generative experiments*, where the allowance of failure is low and the focus is on discovering and designing new solutions. The difference in testing and designing is key here. An example of these generative experiments according to Ansell & Bartenberger (2016) are *exploratory pilot projects*, which suits the development of Assinklanden, the Green House and Vondeltuin. This difference, supported by the availabiity of research budget, is pointed out clearly by the demolisher in SUPERLOCAL: "If you are in a more traditional environment, you do not want to disturb existing processes too much. Unless you have a subsidy and you want to research something. Then you can mess things up again." (interviewee 13).

Collaboration form

Next to the observed differences in resources and whether a project can fail or not, the type of collaboration form in the experiment also differs, as shown in Table 5.1. To understand the context, in Assinklanden and the Green House, collaboration was ensured in a *consortium*. Where for the prior, collaboration evolved from the masterclasses into a 'real-life case', which was formalised via an innovative contract between the seven market parties and the housing corporation based on (1) consent, (2) transparency and (3) trust. Next to a collaboration contract, a traditional contract regarding responsibilities was used in which the client could hold the two construction companies accountable, who in their turn had contracts with the involved advisors. For the Green House, collaboration was already formalized in a DBMFO-tender for the larger development of the 'Knoopkazerne', this ensured an integrated approach where the consortium (consisting of the developer, construction company and operator) was, next to all the elements of DBFMO, also responsible for the EoL situation of the bulidng after 15 years. As the plot of land needed to be empty after the first use-period and the consortium remained owner of the building, the project leader of the Green House convinced the consortium to focus on demountable construction techniques and with that stimulated the circular ambition leading to transition learning.

For SUPERLOCAL and the Vondeltuin, collaboration in the core team was ensured via a qualitative tender procedure to select parties that fit the ambition and was formalized via a 'construction team'-agreement. This is a contract in which cooperation between different parties, such as the contractor, client, architect, consulting engineer and/or installations company, from the design phase onwards is formalized (PIANOo, n.d.). It ensures an integrated approach aiming for coordination between the different fields of expertise early on in the project that can support the quality of the final product. From these different collaboration forms, it can be concluded that for circular building experiments collaboration contracts are signed which ensure the involvement, and cooperation, of different fields of expertise from the start of the project. However, which expertise is involved and which actor leads this process differs, as will be explained in the next subchapter.

5.1.2. The subjects: Who learns?

To further build on the collaboration form, it is interesting to compare who has been involved in the various experiments, how different roles are fulfilled and who should have been involved to meet the circular ambitions of the experiment. From the four case-studies, the subjects can be divided in (1) those with circular expertise, (2) those with no circular expertise.

Circular expertise

First of all, from the analyses it becomes clear that every experiment has a central actor who has previous CE experience and has the role of ensuring the circular ambitions of the experiment. The the type of stakeholder that took this role differs in the different cases. In two of the four cases (Assinklanden and Vondeltuin) it was the architect who had most CE experience and was therefore deliberately pushed forward to ensure the circular ambitions of the project, this occured informally (Assinklanden), where the architect was asked to lead the group, and formally (Vondeltuin), where various architects were qualitatively approached in the tender procedure. However, this is not a new finding, as traditionally the architect already takes the role of *systems integrator* in the design stage (Winch, 1998). In the Green House it was not the architect, but the project leader of the developing company who acted as the system integrator and catalyzed circular ambitions of the project. This is explainable, as the developer is part of the consortium who remains owner of the building.

Interestingly, however, is the new role for deconstruction companies in supporting transition learning. In projects where large buildings are transformed, as was the case in SUPERLOCAL, their role shifts from “simple” *demolishers*, who are rewarded for an empty piece of land, to *material scout and supplier*, who can identify which elements or materials of the building could be retrieved and reused. Their material and construction expertise proved to be valuable in ensuring the flow of exisitng materials and with that preventing the use of virgin materials. Here, it should be noted that the deconstruction company in SUPERLOCAL was selected based on their CE vision and high ambitions. From this, it can be concluded that a), a circular expert is necessary to support transition learning in experiments and they should take the lead in the design stage, and b), the actor taking this role depends on the project environment, where in cases where the process starts at the EoL of a building, it can be recommendable to involve a deconstruction company with a circular vision.

No circular expertise

From the findings mentioned above, another conclusion can be drawn regarding *who should learn*. It appears that, of the various role groups (initiators, advisors, builders and controllers) involved in the experiments, the advisors (often) *have,* and initiators and builders *have no*, prior experience with CE practices, as was the case in all the experiments. Furthermore, all the initiators and the construction companies involved in the experiments are medium- (housing corporations) or large-sized (public initiators and (de)construction companies) organizations involved in traditional, regime, activities. They are regarded as influential actors in supporting a transition due to their power in creating demand for circularity, central role in the value chain and assembling buildings with future value. They are therefore identified in this research as the actors that *should* benefit from transition learning and their active involvement can be seen as crucial in breaking with regime activities and, with that, supporting a CE transition.

A note of attention should be made regarding the role of structural engineers, who themselves state that, constructively, designing buildings with circular practices is not difficult and does not require new learnings (interviewee 5; 16; 28). However, the *circular experts* in the different experiments counter this, mentioning that a different mindset (regarding future reuse-cycles) is necessary of the structural engineers, which was not always apparent (interviewee 13; 15). Reflecting on transition literature, it appears that *culturally* (way of thinking and perspectives) structural engineers embrace circularity, however their *practices* (their habits, routines and way of doing things) still reflect the regime approach (Van den Bosch & Rotmans, 2008). Therefore, also structural engineers are regarded as a stakeholder that needs to learn for a CE transition in the construction sector.

Involving supply chain partners and controllers

Furthermore, a striking result from all the cases deals with the **early involvement of supply chain partners**. Contractors, albeit installation-, construction or maintenance companies, work with partners in providing their service, often formalized in longer term contracts. In order to break the unsustainable activities of these contractors, the involvement of their supply chain partners in the experiment is crucial to also deepen their knowledge regarding the current, unsustainable, sector and to support a CE transition. Interestingly, in the Green House the early involvement of supply chain partners was key to *deepening* processes (double-loop learnings) and the circular success of the experiment (new circular business models), even though more suppliers could have been involved (interviewee 15; 17). In Assinklanden, the involvement of supply chain partners was regarded as a missing element. Here, the installations contractor tried to unsuccessfully involve their partners. Next to trying to involve them early on, it is also important to keep them informed. This was crucial in SUPERLOCAL, where initially the concrete partner of the construction company was not willing to cooperate, but later, when they saw the progress and potential competitive threat, wanted to get involved. Their involvement proved to be essential in complying to existing safety norms and certificates. Due to their involvement the project could eventually realize, and later optimize, a technical niche innovation that is currently being tested in the niche-regime (modular prefab concrete elements made from 95% locally recycled aggregate).

Complying to existing rules and regulations, and especially the gaps in existing laws, regulations and norms, is also reflected in the second influential role group: **the involvement of *controllers***, which can enable or limit transition learning in circular building experiments. The involvement of public controllers who could bridge the gap between innovative ideas and constraining regulations was key in ensuring the high ambitions of SUPERLOCAL. In the Vondeltuin the involvement of the municipal procurement controller allowed an innovative procurement procedure, which supported the *deepening* process. The opposite occurred in Assinklanden and the Green House, where a lacking involvement of *controllers* limited the circular ambitions and with that transition learning. In Assinklanden the group ran into, and simultaneously reflected on, systemic failures which are the responsibility of public controllers, such as the barrier of the Building Decree for using secondary materials or the questionable VAT levy on secondary materials, but also *cost-controllers* of the housing corporation who were not yet able to calculate with residual value, TCO or new circular business models. In the Green House, the spatial planning department was not included in the vision of the experiment and poured a fixed concrete pavement around the building, resulting in a future situation in which the entire building can be disassembled with high future reuse value, but the pavement needs to be demolished and processed with no or low future reuse value. Next to this, in experimenting with circular business models there was no willingness from *cost controllers* of financial institutions.

v

Conclusion: Who should learn?
From this analysis it becomes clear that there are (1) stakeholders already involved in the experiment that need to learn and (2) there are stakeholders *not* involved that should learn in and from circular building experiments. Of those involved, it appears that clients, through procurement, have the resources to create demand circular buildings. They can incentivize the market to come with circular solutions. Next to this, (principal) builders, especially large-sized, have the power and resources to break patterns with their current suppliers, demand different materials and assemble for future reuse. It is interesting to see that the builders and initiators involved in the experiments are the ones with little previous experience with circularity, emphasizing the necessity for them to learn in experiments and break with regime activities. Next to this, there are actors that were not involved, but that should be involved in order to increase the circular possibilities of the experiment. These are *controllers*, which can be public (*lead buyers* or *urban planners*) or private (*cost-controllers* of financial institutions or housing corporations). At this moment, it seems that their traditional way of working is not equiped to calculate with future reuse value or new ownership models, such as PaaS. Involving these actors can increase transition learning in the experiments, where it was also found that a leading role is expected from the circular systems integrator, which can be an architect, developer or deconstruction company, depending on the project environment.

5.1.3 The process: Learns how
The four cases each reflect different transition learning processes, to conceptualise these, four *flavours* of circular building experiments can be distinguished: the Catalyst, the Laboratory, the Consultant and the Masterclass, as depicted in Figure 5.1. As the focus and context for transition learning differs in each of these experiments, at first, a brief overview of the different *flavours* will be given. To afterwards synthesise the various empirically found conditions that can support or prevent transition learning. These will be further elaborated on in this subchapter.

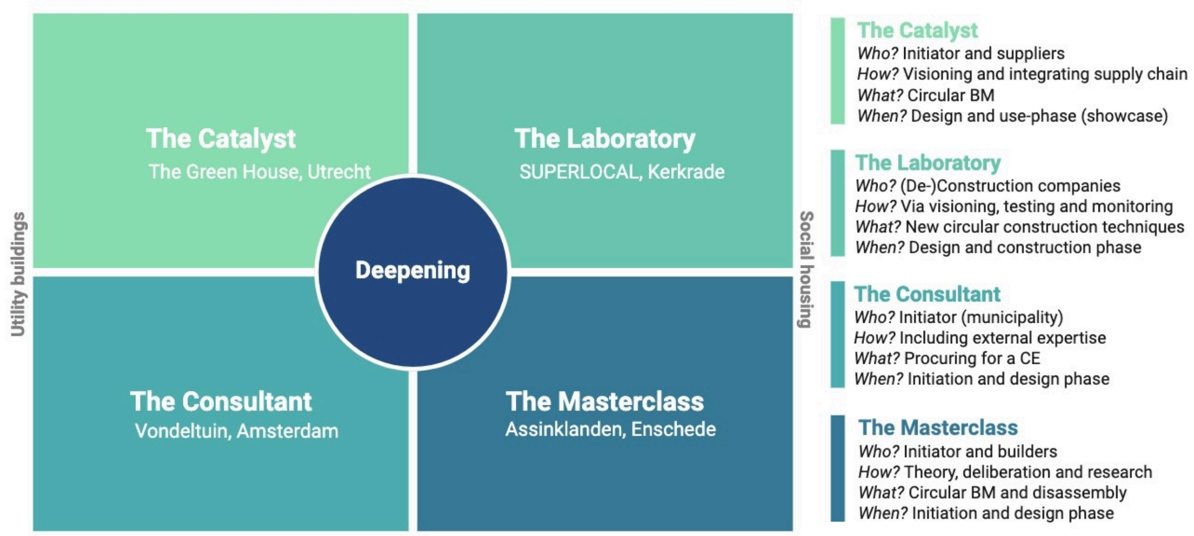


Figure 5.1. Four flavours of circular building experiments as conceptualized based on the four researched case-studies. In the legend a differentiation is made between *who learns* (double-loop learning), *learns how*, *learns what* and *when* (in which phase).

The Catalyst
In the context of the Green House, which was a smaller project in a larger development and initially not allocated as an experiment, the role of a visionary (project leader who acted as a circular catalyst) proved to be essential. By setting out a clear vision and involving important stakeholders on the *strategic level* (boards of consortium members) in that vision, the project leader of the Green House created an environment in which experiments were allowed. With the vision in place,

integrating the right stakeholders from the eco-network on a *tactical level* and having them embrace the vision, supported deep learning regarding circular business models in the experiment. Interesting, however, is that monitoring was included via a circular assessment framework, but there were no group reflection moments during the development process or after the development.

The Laboratory
Visioning was also a central theme in SUPERLOCAL, though here envisioned ideas were directly put into practice and tested to see how feasible they were. The visioning process, here, reflected an iterative process of sketching and testing, where *deepening* occurred through careful monitoring of each innovation and step in the process. The results of the monitoring process were reflected on by the group during the development process as well as afterwards in various reflective evaluation session. Here, reflection on the system: *"Are we doing the right things?",* supported double-loop learnings and follow-up actions. Environmental monitoring was performed by the university and the reflective evaluation process by an external process consultant. Discovering new circular building techniques was key here, where failure was accepted.

The Consultant
The Vondeltuin was regarded as an experiment by the agent of the municipality who labelled it a municipal pilot project to experiment with a circular procurement procedure. By integrating external expertise, via a CE consultant, a qualitative circular procurement procedure was applied through the following six steps: (1) determine ambition, (2) create internal support, (3) formulate market question, (4) collaborate with the market (dialogue), (5) award based on the ambition and (6) contract management. Through qualitatively approaching this procedure, *deep learning* was obtained by the agent of the municipality. However, time and budget made available for the other phases in the project were based on a traditional construction project, leading to regime pressures in the further development and limited transition learning in the design and construction phase.

The Masterclass
Deepening occurred, at first, in the initiation phase through a series of masterclasses in which reflection on the current system was applied and niche innovations were introduced. Then, in the design phase, deepening was achieved by integrating a heterogeneous group of disciplines (experts), who cooperatively deliberated and reflected on each expertise through a collaborative visioning process. Through this process, the group experienced how interrelated the disciplines are, what each discipline can do to support a transition and which current system barriers exist which hamper a transition. The role of the circular expert (architect) was important to ensure that each expertise revised their own (regime) routines, e.g., through homework/individual research.

The crucial role of monitoring and (super)vision
The transition learning structure differed in each experiment. Key to the success of SUPERLOCAL was the well-organized monitoring process, in which every step was documented, the impact calculated and collectively reflected on. This supported a process of not only reflecting on what was achieved, and how the product 'scored', but also on what these numbers mean, how these can be improved and how it fits in the wider system. In Assinklanden, group reflection proved key for the deepening process, however there was nobody responsible for documenting the lessons learned and following-up on the reflection moments. A process feature deemed missing that could have supported transition learning even further (interviewee 2; 6). These moments of group reflection were found to be missing in the other two experiments, where monitoring was only applied to understand how the building scores, but it did not support group reflection, group evaluation or monitoring of the (learning) process. As circular building experiments are performed to learn from, it can be recommended to agree on the monitoring process, have an internal or external actor responsible for it and dedicate moments of reflection after each key process step or development phase.

From the cases, it appeared that reflection (*do we do the right things?*) is not traditionally embedded in the culture of construction companies, who appear to focus on delivering their product, the building, as good as they can (*do we do things right?*). Providing room for reflection in these experiments can enable transition learning and can be integrated in existing processes. For example, in Assinklanden, it was found that monitoring based on a system of early warnings during the construction process supported reflection and that these could be integrated in the already planned two-weekly construction meetings. This prevented constructive failure, risks and most importantly ensured that the circular ambition retained a central focus also during the construction phase. Therefore, by beforehand thinking about the monitoring process and reflection moments, the transition learning potential of an experiment can be increased.

Table 5.2. Overview of the observed monitoring processes in the different experiments.

CASE	MONITORING PROCESS
ASSINKLANDEN	Environmental monitoring via MPG (3x), but no monitoring or documentation of the learning process in the design phase.
SUPERLOCAL	Clear monitoring of environmental impact (university) via LCC and learning process (external process consultant responsible for documenting and evaluation)
THE GREEN HOUSE	Monitoring design and construction phase via new circular assessment framework, but no monitoring, documentation or reflection of learning process.
VONDELTUIN	Monitoring of procurement procedure (external consultant) and circular assessment framework of design choices (external consultant), but no monitoring, documentation or reflection of learning process.

Ensuring commitment for transition learning

Another interesting finding from the four cases is the role of commitment in achieving *deep learning*. In all experiments, the importance of stakeholder commitment was mentioned as an enabler for transition learning and as a barrier for transition learning when missing. The latter became apparent in Vondeltuin, where a lacking commitment of the construction company in the design phase negatively influenced the learning process of the other stakeholders and trickled down to regime construction practices rather than circular construction choices as discussed in the design phase. Similarly, in Assinklanden, certain circular design choices were made, which were ignored in the construction phase due to a change of teams, emphasizing the necessity of ensuring commitment regarding the circular ambition in each phase in the development process.

The question then remains: How to realize an environment in which stakeholders remain committed? Interestingly, each experiment approached this differently. In the Masterclass *commitment* was formalized in a contract which safeguards stakeholder involvement in each of the phases. However, as stated before, commitment gaps in the operational team remained. In the other three experiments, commitment was sought through selecting project partners based on their vision regarding the project's ambition. In SUPERLOCAL and Vondeltuin this required a different tender procedure, where instead of selecting on cost-price, partners were selected based on their vision regarding the ambition. Through qualitatively approaching this selection process, central actors were found who could lead the circular experiment. In the case of the Laboratory, this required qualitatively approaching deconstruction and construction companies, for Vondeltuin this required a qualitative selection of regional architects with prior circular experience. Due to the large scope of SUPERLOCAL, commitment was ensured by dividing the entire area development in different smaller experiments and including a clear exit strategy after each experiment. Finally, in the Green House, commitment of the consortium was already ensured for the larger development and external partners from the *eco-network* were selected based on their ambition.

v

Enabling conditions for transition learning

Next to the essential elements of monitoring and commitment, various other conditions were found which support a transition learning environment. The conditions can be divided into (1) *initiating conditions,* which relate to the client, and potentially the supporting advisors, who determine the preconditions for the experiment, (2) *individual conditions*, which relate to the necessary characteristics of the stakeholders involved in the experiment and (3) *group conditions*, which deals with the necessary relational features between the stakeholders in the team. In trying to keep it concise, these are listed and described in Table 5.3.

Table 5.3. Overview of the enabling conditions for transition learning in circular building experiments. *√= important and present*; *X = important and missing; √/X = partly present; – = not empirically found*.

	CONDITIONS	**DESCRIPTION**	**THE MASTER-CLASS**	**THE LAB**	**THE CATALYST**	**THE PROCURE-MENT**
INITIATING	Clear future vision	Initiator needs clear vision regarding the EoL situation of the building. This determines scope for CE strategy.	X	√	√	X
	Functional question/ requirements	Functional market question and demands leave more room to the market to submit circular design solutions.	√	√	√	√
	Realistic budget	Ensure that ambition and available budget are matched.	X	√	√	X
	Sufficient lead time	Circular experiments require more research time in design phase. Dedicate time for this.	√	√	√	X
	Circular expert/ project leader	A believer who keeps the circular ambition high. Preferably with project gmt.. skills.	X	√	√	X
	Collaboration	Involving more expertise (builders) in the design-phase supports deep learning and building quality	√	√	√	√
INDIVIDUAL	Willingness (commitment)	Involved stakeholders need to be willing to revise the process and approach it differently.	√/X	√	√	X
	Sense of urgency	Stakeholders need to feel a sense of urgency to learn and have a personal/professional goal	√	√	√	√
	Flexibility	As the process differs from traditional projects, flexibility in process and attitude is required from all involved stakeholders	√/X	√	√	√/X
	Time	Circular building experiments do not deliver financial gains in short term, investing more time for to a traditional fee is often necessary.	√	√	√	X
GROUP	Agree on risks	Circular construction deviates from the beaten path. This includes new risks which need to be discussed and agreed upon from the start.	√	√	–	X
	Agree on monitoring	Agree on the process approach: How will be monitored and documented, who will do this and when will be evaluated/reflected.	X	√	X	√/X
	Environmental impact tool	Environmental impact tool (MPG, LCC, BCI circularity dashboard) supports reflection	√	√	√	√
	Transparency (open budget and communication)	Circular experiments require a transparent environment through open budget and communication, this can support trust.	√	√	√	√/X
	Trust	Trust is necessary to collaboratively explore new processes.	√	√	√	X
	Ensuring continuity in commitment	Construction projects are characterized by different agents per phase. Include new agents in the philosophy and ambition of the experiment.	X	√	√	X
	Clear exit strategy	Especially for technically innovative projects, an exit strategy needs to be included to lower the risks.	-	√	-	-

v

Conclusion: How should be learned?
It becomes clear that there is no one-size-fits-all approach for transition learning in circular building experiments. From the analysis, various experimental *flavours* can be derived, which support transition learning for different target audiences: *The Masterclass* (Assinklanden), *the Laboratory* (SUPERLOCAL), *the Catalyst* (the Green House) and *the Consultant* (the Vondeltuin). However, as these experiments are conducted to learn from and that it is empirically found that group reflection and evaluation can stimulate system reflection and deep learning, it is remarkable to find that in three of the four experiments the monitoring process is not, or partly, applied. It appears that monitoring is used as a measurement tool to determine the 'circular success' of the experiment, but it does not support the internal learning process by reflecting on what has been done, what worked and what could be improved. In designing circular building experiments, this can be a key focus point in supporting transition learning processes. Furthermore, an environment should be ensured for stakeholder commitment to break with old regime routines. Therefore, this subchapter introduced the empirically found preconditions for which extra attention should be paid when designing a circular building experiment in order to support transition learning.

5.1.4 The objects: Learns what?
Building on the learning process, this subchapter zooms in on the actual lessons learned. Before zooming in on these double-loop learnings, an interesting result came from the two interviewed consultants focusing on a CE in the construction sector (Alba Concepts and Copper8). They both stated that for a CE transition, changes are required in three areas: (1) *technical* (design and construction innovations), (2) *economic* (business model innovations and ownership models) and (3) *process* (organization and collaboration). When comparing these to the five CE research themes as derived from the literature review, the *technical* and *economic* themes overlap and *process* now entails elements of both the *governmental* (such as organizing a circular procurement procedure as an incentive strategy) and *cultural* CE research theme (such as collaboration). Reflecting on the results of the double-loop learnings of each case, these three areas provide a useful, more demarcated, overarching conceptualization to draw conclusions on what has been learned in the four circular building experiments, compared to the five CE research themes.

This is due to the fact that there is a difference in what is being experimented with and what affects this experimentation process. The three themes, *technical, economic* and *process* are central topics to experiment with, for example, experiment with a new organization structure (*process*), new circular business models (*economic*) or circular design techniques (*technical*). The *governmental*, *sectoral* or *environmental* themes are then themes that can have an enabling or constraining influence on the central three themes (e.g. an environmental impact tool can support the experimentation process of a new technical innovation, or a law or regulation can enable or prevent the implementation of a new circular business model). Therefore, these can be regarded as mediating themes that can have an impact on the three main research themes. These three areas, should not be seen in isolation, as depicted in Figure 5.2, because a technical innovation (*technical*) can have a new business model (*economic*) through which it can lead to a new collaboration form (*process*). The main differences and similarities between the *deep* lessons learned will be discussed here, as listed in Table 5.4.

v

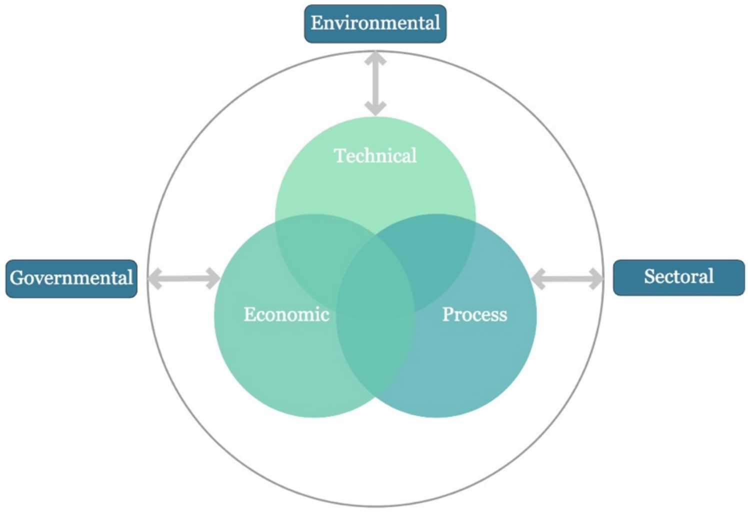


Figure 5.2. Overview of how the learning objects conceptually relate to another. Technical, economic and process-learning are directly experimented with in the experiments as found empirically, which influence and are influenced by the other three themes.

Transition learning flavour

A first observation from the case comparison in Table 5.4, is that the different experiments yield different double-loop learning outcomes. In Assinklanden, emphasis was put on treating all relevant circular construction aspects theoretically and then implementing these in practice, resulting in deep learning regarding circular business/ownership models and construction for disassembly. For SUPERLOCAL, where the focus was on technical innovation, it comes as no surprise that deep learning concerned the *technical* learning theme and the corresponding infrastructure necessary to mainstream this (*process*). In the Green House deepening was focused on new circular business models, which was new for the material supplier and where the client learned how to incentivize this via tendering. Furthermore, double-loop learning in the Vondeltuin related to external expertise regarding the procurement procedure.

Table 5.4. Overview of the double-loop learnings per experiment, characterized based on learning theme: technical, economic or process.

CASE	TECHNICAL	ECONOMIC	PROCESS
ASSINKLANDEN	*Builder*: Construction for disassembly, revised own product.	*Initiator*: New ownership model (TCO) *Builder*: Circular BM (PaaS)	–
SUPERLOCAL	*Builders:* New circular construction technique Construction for disassembly	–	*Builder*: Refurbishment hubs for sector-wide secondary material adoption
THE GREEN HOUSE	–	*Builders*: New circular BM (PaaS interior)	*Initiator:* Procurement
VONDELTUIN	–	–	*Initiator*: Procurement

Deepening of initiators and builders: Circular business models and procurement

A second interesting observation relates to *who should learn*. When reflecting on Chapter 5.1.1, it became clear that the involved builders and initiators were influential actors with limited prior circular experience. It is therefore, also striking to see that these are the ones, with two exceptions[5], who acquired double-loop learnings. *Process* learning was mainly acquired by the two initiators, who learned how to approach a procurement procedure in order to stimulate circular solutions. This

[5] Except for the construction company in the Vondeltuin and in the Green House (not interviewed)

included a) setting a functional question, such as demanding a service instead of a product, which can stimulate extended producer responsibilities (the Green House), and b), a qualitative approach to the tendering process (award on quality instead of price, integrate internal stakeholders in tender, finetune the question, organize dialogue rounds and support parties during the tendering process). From Figure 5.4 it becomes clear that those double-loop learnings acquired by the *builders* reflect the technical and economic CE themes. *Technically*, these encompass how to construct a building so that it has high future reuse value. This can result in different assembly and construction strategies, as in Assinklanden, or in actual new material and construction techniques as was the case in SUPERLOCAL. *Economically*, lessons learned reflected a different perspective on initiators property through a Total Cost of Ownership, in which buildings resemble future residual value (Assinklanden), and through *resource slowing business model experimentation* (e.g. light, interior or even facades as a service), which resulted in actual business model innovations for the interior supplier (the Green House). What the effect of these lessons learned has been and to what extent these have been integrated will be addressed in the next subchapter.

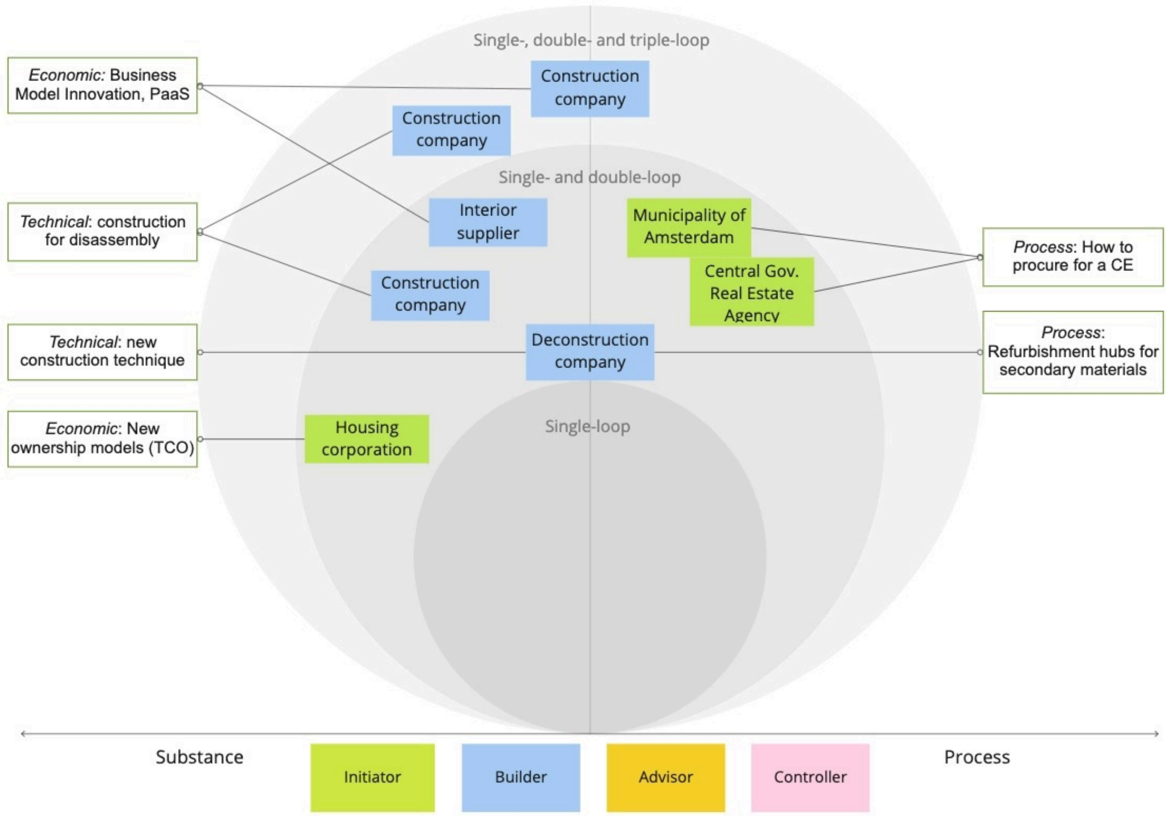


Figure 5.3 Overview of double-loop learnings identified in the different cases, arranged according to stakeholder role group and linked to the three learning themes: process, technical and economic.

5.1.5 The effect of lessons learned

As transition learning should not be limited to the agents involved in the experiment, this subchapter takes a post-experiment perspective and analyses how knowledge and innovation (1) has been shared beyond the scope of the experiments (external deepening), (2) how it has been institutionalized in the respective organizations and (3) how it resulted in a change of organizational activities (the effect). Regarding the institutionalization process, the three levels of how organizations learn as operationalized by Crossan et al. (1999) in Chapter 2.5.1 will be used. To recall, these three levels include (1) individual level (through agents in experiment), (2) group level (integration process in company) and (3) organizational level (through institutionalization, e.g. new procedures or routines, also operationalized as *scaling up*). From the analysis different overarching headers could be found, which will be discussed below.

v

External platform key for knowledge dissemination (external deepening)
In aiming to reach a larger audience for the innovative insights gained in the different experiments, the role of an external platform proved to be important. Even though the cases were selected based on their involvement in a transition programme, it might be of no surprise that this is a corresponding result between the cases. However, the dissemination approach differs, especially between the private- and the public-sector initiated cases. Regarding the latter, Assinklanden and the Green House, an external knowledge and innovation platform has been involved from the start of the experiment and was responsible for documenting and disseminating the results. In both experiments this was done through an internal group evaluation, collecting the main lessons learned as well as systemic failures in the current regime which prevent the breakthrough of circular construction (*niche*) innovations. The external platforms then bundled this information and shared it in a sector- and province-wide 'Community of Practice' (Assinklanden) or directly to the responsible public institutions on a local, national and even European scale (SUPERLOCAL).

This differed from the public-sector initiated experiments, the Green House and the Vondeltuin, where there was no external platform directly involved. The Green House was used as a pilot project in the transition programme to inspire and share the successes of circular pilot projects ('City Deal Circulaire Stad') and the Vondeltuin only focused on a part of the development process (the procurement procedure in a municipal transition programme). In both experiments there was no reflection on how to follow-up on the lessons learned or overcome the systemic failures or regime barriers that hamper a transition in the construction sector. Therefore, it can be recommended to inform or involve an external innovation platform or knowledge institute that can support and take responsibility of the documentation and monitoring process in order to disseminate lessons learned. This can improve the leverage of transition learning and support the external deepening processes.

SME's: Informal knowledge integration
Regarding knowledge integration, as the process of how knowledge and innovation flow from the agent(s) in the experiment back to the organizations, it appeared that the size of the different companies influences how this takes place. For small- and medium-sized organizations (19/29 organizations), lessons learned are shared informally in the organization. This occurred informally at the desk of the agent, via lunch breaks, staff outings or via internal communications platforms. From these, it proved that for SME's, lessons learned easily receive a stage and the attention of other agents. When referring to Crossan et al. (1999), it is shown that these lessons learned are integrated on a *group-level* via shared understandings and mutual adjustments. However, clear coordinated follow-up actions or institutionalization processes could not be derived from the interviews.

LSE's: Not always a knowledge integration infrastructure in place
For LSE's, following-up on the lessons learned internally occurred in varying ways, as depicted in Table 5.5. At first, there are the green shaded organizations, which have ensured follow-up integration actions. Often, these take place on the group-level where there is a CE workgroup dedicated to evaluate the lessons learned (5/7). These five organizations are in an exploring stage, where the experiments are part of a series of pilot projects to experiment and learn from the various circular construction themes (e.g. secondary materials, DfD, biobased etc.). For the other two green shaded organizations (under the Green House), the lessons learned actually resulted in a change of company's actions, through a process of institutionalization, also operationalized as *scaling up*. The Central Government Real Estate Agency, embodying the political will to realize a CE by 2050, took a leading role by initiating a circular construction knowledge platform (CB'23) in 2018 and expressed in a recent publication that they want to have their real estate maintenance and all procurement procedures fully circular in 2030 (Rijksvastgoedbedrijf, 2020). For the operational company, as they work with catering formulas, a circular concept could be used as a formula and due to post-experiment market demand could be institutionalized and scaled up relatively easy.

v

Table 5.5. An overview of the knowledge integration process of the 11 large-sized enterprises (LSE's) researched. Between brackets the level of organizational learning: individual, group and organization from Crossan et al. (1999).

LSE	ASSINKLANDEN	SUPERLOCAL	THE GREEN HOUSE	VONDELTUIN
Client	Housing corporation: Experiment was part of CE workgroup with four pilot projects (*group*)	Municipality: Remains on individual level (*individual*)	Central Gov't Real Estate Agency: Part of series of experiments and later initiated knowledge platform (CB'23) (*organization*)	Municipality: No resources made available to follow-up (*individual*)
Construction company	Ter Steege: Part of workgroup on CE & sustainable innovations, conduct various pilot projects (*group*)	VolkerWessels: CE group, signed a covenant in 2019 to experiment in 7 circular projects (*group*)	Strukton & Ballast Nedam: No workgroup/change trajectory (*individual*)	De Nijs: Part of workgroup on CE with 3 CE pilot projects (*group*)
Deconstruction company	-	Dusseldorp: Part of workgroup on CE (Rentmeester 2050) (*group*)	-	-
Operational company	-	-	Albron: Work with catering formulas, institutionalized through market demand (*organization*)	-

Secondly, and interestingly, are the red shaded organizations in Table 5.1.5, for which no resources were made available to follow-up on the outcome of the experiment(s). For the municipality this is striking, as even though there is high political willingness, there is nobody responsible to internally connect the results of pilot projects. Therefore, lessons learned remain on the individual level and it will depend on the perseverance of that agent as to which integration will take place. Furthermore, it appeared that the two large construction companies (Strukton and Ballast Nedam) involved in the Catalyst had no internal workgroup or change trajectory in place to link the lessons learned of the experiment to. It appears that transition learning remains limited to the individual level when there is no organizational learning structure in place, which limits the transition learning potential. Due to the size of SME's sharing knowledge and lessons learned is a manageable process and occurs, and *can* occur, informally. Here, the lines between agents and departments are short and therefore it is easier to tap into collective knowledge. For LSE's tapping in collective knowledge is not self-evident, and if there is no structure, such as a workgroup or department, appointed which bears the responsibility, it could be the case that transition learning remains limited to the individual level.

The effect of the double-loop learnings

To build upon this, the individual case analyses also highlighted the effect of the double-loop learnings and to what extent this resulted in a change of action of the company. Table 5.6 recalls the double-loop learnings of Chapter 5.1.3 and indicates in the shaded colour whether the double-loop learning changed the company's practices (green) or did not influence the organization's practices (red). Interestingly, the *technical* lessons learned could be integrated and changed the routines of the companies, as well as the new circular BM of the interior supplier in the Catalyst. Also for the initiator of the Green House, the Central Government Real Estate Agency, double-loop learnings regarding procurement for a CE (tendering a service instead of a product) changed their practices. However, there are various red boxes as well, the remainder of this subchapter addresses the barriers and enablers for the institutionalization process of the double-loop learnings.

v

Table 5.6. The effect of the double-loop learnings as found in Chapter 5.1.3. Green-shaded lessons learned are broadened or scaled up, red-shaded lessons learned are not (yet) broadened or scaled up.

CASE	TECHNICAL	ECONOMIC	PROCESS
THE MASTERCLASS	*Builder*: Construction for disassembly, revised own product.	*Initiator*: New ownership model (TCO) *Builder*: Circular BM (PaaS)	–
THE LABORATORY	*Builders:* New circular construction technique Construction for disassembly	–	*Builder*: Refurbishment hubs for sector-wide secondary material adoption
THE CATALYST	–	*Builders*: New circular BM (PaaS interior)	*Initiator:* Procurement
THE CONSULTANT	–	–	*Initiator*: Procurement

At first, regarding the *economic* theme, it proved that circular business models in which extended producer responsibility is ensured, appeared to be difficult for the constructive elements of a building. In the Masterclass, the client tried to experiment with a façade as a service, however this became impossible due to **regulatory obstructions**. Once a constructive element or product (e.g. façade) is assembled in a building, regulations enforce that legal ownership shifts to the entity owning the building. This prohibits supplier or producer ownership and therefore makes circular business model experimentation for circular construction difficult. These circular business models, such as lease constructions appear to be more applicable for the inner shearing layers, such as the services, space plan and stuff (Brand, 1995), as was found in the Catalyst (PaaS interior). Next to this, the construction company in the Masterclass tried to implement a topping as a service for their own property, however a **negative perception** of other colleagues due to economic and practical uncertainties prevented the institutionalization process. Thirdly, in the Assinklanden and the Green House, the cases where DfD was applied, it proved that cost-controllers have difficulty in modelling with financial residual value. These **lacking internal competences** form a third barrier for institutionalizing double-loop learnings regarding business model innovations.

Regarding the *technical* lessons learned, the *builders* mention the **overheated construction market** and the remaining high demand for traditional construction projects as a persistent barrier to changing their, regime, routines. Furthermore, and in line with this, they mention the **limited market demand for circular (follow-up) projects** as a root cause for not further transitioning. Here, the contracting parties state that there are not enough projects available to follow-up on the lessons learned (*builders* and *advisors*), whereas the client of Assinklanden stated that such a circular building experiment is too costly to perform multiple times. There appears to be a mismatch there. Furthermore, a barrier regarding the *technical* learnings of the Green House was its **context specificness**, where the technical lessons learned were too specific for further follow-up projects.

Interestingly, however, is that these three mentioned barriers can be addressed when designing an experiment as a broadening process. In SUPERLOCAL, in which a large experimental project (a circular area redevelopment) was broken down in several smaller experiments that follow-up on each other. Through this approach, the developed innovations could be optimized in every consecutive experiment, limiting the barrier of context specificness, and supporting the scaling up process. Leading to a situation that a new circular construction technique (technical) could economically (price) and procedural (regime construction process) compete with regime practices. In such a situation, the barrier of limited market demand would be overcome and the high demand in the construction sector could provide further scaling up opportunities. However, this process of broadening was found as an essential missing feature for the *builders* of Assinklanden stating that a next experiment with the same construction team could have stimulated the scaling up process of other circular practices, such as integrating secondary materials in regime projects.

Regarding the *process*, the deconstruction company found that in order to scale up their modular elements derived from locally recycled concrete aggregate, and to bypass the regulatory obstructions, collaborations with refurbishment hubs are necessary to comply to existing norms. However, this step was hampered by current high demand for regime projects and missing governmental incentives for secondary materials or levies on primary resources, which limits the necessity for concrete producers to orientate on new business models (such as becoming a refurbishment hub). Secondly, the municipality in Assinklanden found that **lacking internal resources for follow-up** obstructed the further integration of the double-loop learnings regarding a qualitative procurement procedure. All in all, it can be found that experiments support double-loop learnings which have changed routines of organizations, especially actors from the *builder's* role group. Next to this, various barriers occurred that negatively influenced the institutionalization process. In order to instigate a transition these barriers should be addressed and overcome.

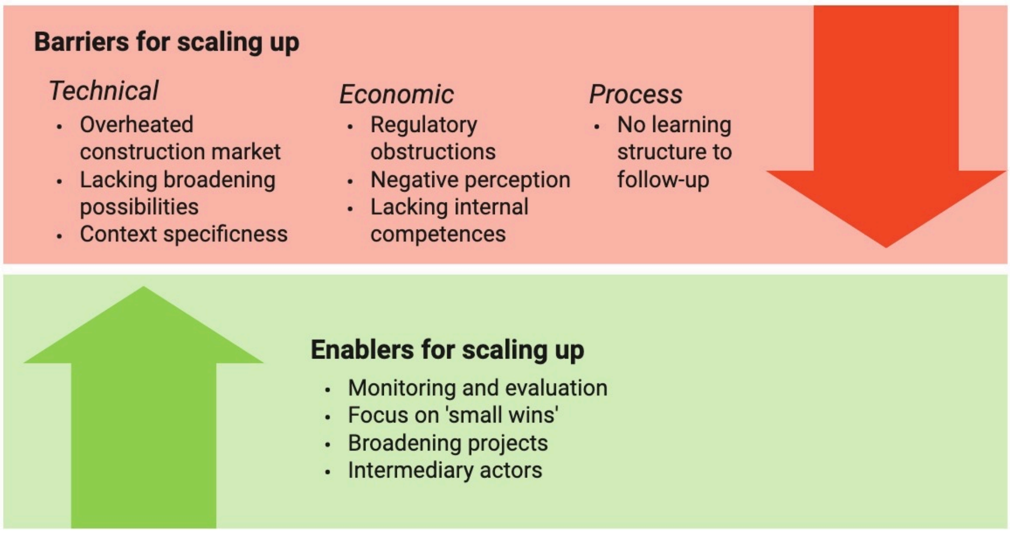


Figure 5.4 Overview of the barriers and enablers for broadening and scaling up

Conclusion

In order to maximize the impact of transition experiments for circular construction, post-experiment knowledge dissemination is key, which can occur *externally* through knowledge sharing with the sector and *internally*, through knowledge integration in the organization. Regarding the first, this research found that intermediary actors are crucial to disseminate lessons learned, but also identifying and addressing systemic regime barriers that obstruct circular niche innovations from breaking through. Monitoring and documenting these barriers on the operational level and sharing these with on the regime level appears to be important for a CE transition. When designing a circular building experiment, it can be recommended to inform and involve an intermediary actor.

Furthermore, the cases show that careful attention should be paid to the process of knowledge integration. For SME's, this occurred informally, where due to the size of the organization collective knowledge can be easily accessed. However, for LSE's this process is more difficult due to scattered departments and large number of employees. Some of those did implement a *formal* structure and dedicated a workgroup to it, where the experiment is connected to. Yet, for four large regime actors this was not the case, and there was no formal structure implemented to connect the lessons learned to nor resources made available to integrate these lessons learned. To prevent knowledge to remain on the individual level, it can be valuable to before the start of the experiment discuss how agents are planning to integrate the lessons learned and explain what potential approaches are. Next to these organizational barriers, several sectoral barriers hinder the scaling up of niche innovations. Broadening is necessary for technical learnings to develop and mature. Here, the role of clients is important who can provide follow-up projects and ensure a series of experiments.

v

5.2 An integrated perspective

This subchapter combines the subjects, the process, the objects and the effect, to get an integrated understanding of transition learning. When putting these in perspective, it is found that clients and principal contractors have the least circular expertise and are, referring from a regime perspective, important stakeholders to learn in and from circular building experiments. It is, then, interesting to find that these are also the stakeholders that obtained double-loop learnings in the experiments, which cover technical, economic and process learning themes.

When reflecting on how to achieve deep learning for the builders, it can be found that the practical experiment, SUPERLOCAL, and the more theoretical experiment, Assinklanden, are important means to generate deep learning in the builder's role group. Even though the prior focused on actually testing envisioned circular reuse techniques and the latter was focused on theory and group deliberation, both experiments share a common denominator: time to reflect. It proved that these moments of reflection (individual, group and/or systemic reflection) triggered deep learning for (de-)construction companies and that raising the question '*do we do the right things?'* (double-loop) is traditionally not embedded in the culture of construction projects. These experiments could conceptually be seen from the niche-level in the MLP, which is free of regime pressures, and prove to be an effective means to stimulate double-loop learnings for construction companies.

Interestingly, the builders did not learn (double-loop) in the experiments which were influenced by regime pressures, such as restricted time, budget and high aesthetic requirements (the Green House and the Vondeltuin). However, these projects did stimulate double-loop learning for the *clients*, which focused on the process (procurement) and the economic side (TCO) and was achieved through either a *passive* role of the client (providing room for the market to come up with solutions and learn from those, as in the Green House) or through an *active* role of the client (by involving circular procurement experts to guide the process (Vondeltuin) or participating in initiation and design process (Assinklanden)). Recalling the difference between a project and an experiment from Chapter 2.4, it can be concluded that transition learning in a project environment (the Green House and Vondeltuin), in which niche innovations are included in a regime setting (van Bueren & Broekhans, 2014), can trigger double-loop learnings for clients, but less so for the construction companies.

Building on the actual *effect* of these lessons learned, it proved that technical double-loop learnings could be scaled up and institutionalized more easily than the economic or process-related double-loop learnings (as seen in Table 5.6). This was due to two facts: a) constructing for disassembly could be applied by the construction company themselves and applied in their own concepts, for this there was no dependence on any other department or organization, and b) because of broadening activities technical innovations could be optimized and with that more easily implemented in existing processes to compete with regime routines (SUPERLOCAL). For the other lessons learned, it proved that organizational factors, such as a negative perception, lacking internal competences or lacking internal resources available to follow-up on the lessons learned, as well as an overheated construction market and the lack of circular tenders, acted as main barriers in institutionalizing/scaling up the double-loop learnings. From this, two conclusions can be drawn: (1) an important role is set aside for the *initiators* to provide the projects to continue the experimentation processes (broadening) and (2) *organizational transition learning*, as the process of how an organization needs to change for a CE, should gain a more central role in circular building experiments to overcome organizational barriers and support the scaling up process.

v

Chapter 6. Discussion

This chapter discusses the results and approach of this research. At first, the main scientific findings are further addressed to understand the scientific contribution, where the concept of the learning *flavours* is further deepened. Secondly, the answers to the four sub-questions are given and embedded in literature. Ultimately, a reflection on the main methods used, the research process and key limitations are introduced. In Chapter 7, the main conclusion will be given, including recommendations for further research and practical implications and recommendations.

6.1. Scientific contribution

Before zooming in on the main findings of this research, the relevance of the results needs to be addressed. When reasoning from the MLP, Geels (2019) indicated four phases through which a transition comes to fruition: (1) experimentation, (2) stabilisation, (3) diffusion and disruption and (4) institutionalization and anchoring. Currently, the Dutch construction sector resides in this first phase of experimentation (2018-2023). Circular building experiments should, through a process called *deepening,* trigger "*radical new ways of thinking and new ways of doing*" (Platform CB'23, 2020). The results of this research, first of all, proved that experiments are important for a CE transition in the construction sector, where it has been shown that circular building experiments have the capacity to bring about *deep learning* and organizational change for stakeholders involved in the design and construction phase. Secondly, this research aimed to answer how circular building experiments could be designed to stimulate transition learning. Based on that question, a main conceptual take-away is that for transition learning in circular building experiments different learning *flavours* exist. Each *flavour* resembles a different learning structure, which were dominantly present in each case. The scientific contribution of these *flavours* will be further addressed here.

Building theory: Transition learning flavours

To understand whether the flavours resemble a typology for transition learning in experiments, how many flavours exist and whether combinations can be made, at first, a brief recall should be given of how *deep learning* took place in each of these experiments. In Assinklanden, double-loop learning was achieved through collaborative reflection in a diverse group of experts (group learning). In SUPERLOCAL, physically experimenting and testing resulted in deep learning (practice-based). In the Green House, deep learning came from one circular expert who catalysed a learning environment (individual expertise). Whereas, in the Vondeltuin deep learning came from external expertise (CE consultancy) who created a learning environment (external). To further disentangle these *flavours* and to understand whether more flavours *can* exist, two axes can be understood of how learning took place. The first is based on *learning activities*, where there is a difference between theory-oriented learning (*generative* exploratory pilot projects with no constructive failure) and practice-oriented learning (*Darwinian* experiments with constructive failure) (Ansell & Bartenberger, 2016). The second axis rests on *expertise* to learn from, where expertise can stem from a group, an individual (inside-out), or from an external expert (outside-in). Expertise is defined as having the theoretical and practical knowledge to implement (an element of) circular construction. These two axes have been empirically found to stimulate transition learning.

However, when looking for rival explanations and extending the thought-experiment, one could also argue that an experiment can be conducted without any expertise. Therefore, a fourth category, *no expertise*, can be added to the expertise-axis. With these elements, a 2x4 table can be constructed, indicating eight theoretically possible flavours of how can be learned in an experiment, as shown in Table 6.1. Next to the four *flavours* found empirically in the cases, three *new flavours* have been found. These need further explanation. To start top-left, for no expertise in combination with theory-based learning does not result in a new flavour. Conceptually, it could be seen as self-thought learning, but then still external expertise is necessary and overlaps with that category. No expertise can, however, be combined with a practice-based approach, in which a do-it-yourself kind of flavour

v

(*the DIY*) occurs. This implies practically experiencing what circular construction entails without having expertise or involving external expertise. Moving to the next column, if there is individual expertise (inside-out) and this would be combined with theory-based activity this results in *the Catalyst*, whereas a practice-based activity results in *the Laboratory* (both found empirically). Then, including external expertise (outside-in) in a theory-based environment corresponds to *the Consultancy*, but in a practice-based environment would reflect an apprentice-like experiment, therefore *the Apprentice*. Ultimately, group expertise in combination with theory-based learning activities results in *the Masterclass*, as found empirically. An experiment in which grouped expertise would be applied in a practice-based environment can be understood as an *Eco-industrial park*-situation. All in all, from this thought experiment seven transition learning flavours can be found.

Table 6.1. Possible flavours based on the emphasised learning structure found in the case-studies.

	NO EXPERTISE	INDIVIDUAL EXPERTISE	EXTERNAL EXPERTISE	GROUP EXPERTISE
THEORY-BASED	-	The Catalyst	The Consultant	The Masterclass
PRACTICE-BASED	The DIY	The Laboratory	The Apprentice	The Eco-Industrial Park

To understand the applicability of these flavours and whether combinations can be made, the flavours are tested on the four conducted case-studies, as depicted in Figure 6.1. From this analysis, it is found that multiple *flavours* have been combined in the case-studies to support transition learning. With that providing evidence that *flavours* should be seen as dynamic elements in an experiment and can be complementary. Each case has one dominant learning flavour, indicated with a larger hexagon, emphasizing the main learning characteristic of that case. Furthermore, Figure 6.1 shows that time is important, where in each phase of the experiment different flavours can be combined. The arrow connected to a hexagon indicates a constant activity until the experiment has been finalized. The *new* flavours from Table 6.1 have not been found empirically.

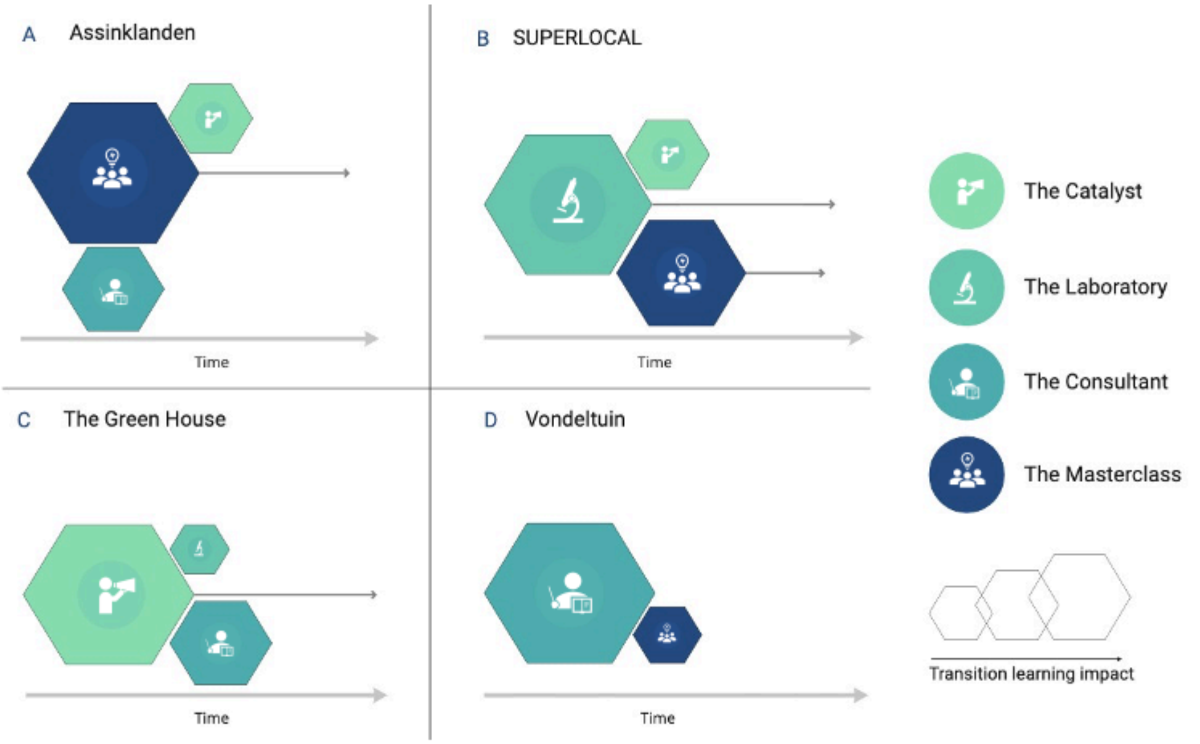


Figure 6.1 Overview of how the learning flavours are reflected in the conducted case-studies.

v

To further illustrate how the learning flavours have been reflected in the cases, the example of Assinklanden will be further explained. Assinklanden started with a group of construction experts (*The Masterclass)* who signed up for a series of workshops. In these workshops external experts were asked to share their knowledge regarding a specific CE theme (*the Consultant*). After the workshop series, the group continued to work collaboratively with a diverse group of expertise *(the Masterclass*), on the design of several circular buildings. This collaborative approach continued until the experiment was completed, as indicated by the arrow to the right. Next to this, during the design phase, the architect acted as a circular catalyst by preventing different disciplines to fall back on old routines when the group did not find the circular answer to a design problem (*the Catalyst*).

To conclude, in view of the wider academic strand of transition literature, various scholars have indicated the importance of deepening in transition experiments (Van den Bosch & Rotmans, 2008; van den Bosch & Taanman, 2006) or system innovation projects (Beers et al., 2016; Van Mierlo, Arkesteijn, et al., 2010). However, knowledge of how these learning processes occur in transitions and how they can be conceptualised was lacking (van de Kerkhof & Wieczorek, 2005; van Mierlo & Beers, 2020). As indicated by Van Mierlo & Beers (2020, p.255):

> *"Many transitions scholars underscore the importance of learning in sustainability transitions, but the associated learning processes have hardly been conceptualised."*

This research contributes to this knowledge gap by adding a typology of *how* deepening takes, and can take place, in transition experiments. Theoretically, seven transition learning flavours have been found which can be used as conceptual building blocks when designing a circular building experiment, as indicated in Figure 6.2. Depending on the context of each experiment, where time is an essential variable for how many *flavours* can be combined, can be constructed in a different way, where the *flavours* resemble the toolbox. Through this concept a deeper understanding can be achieved on how to stimulate transition learning in an experiment.

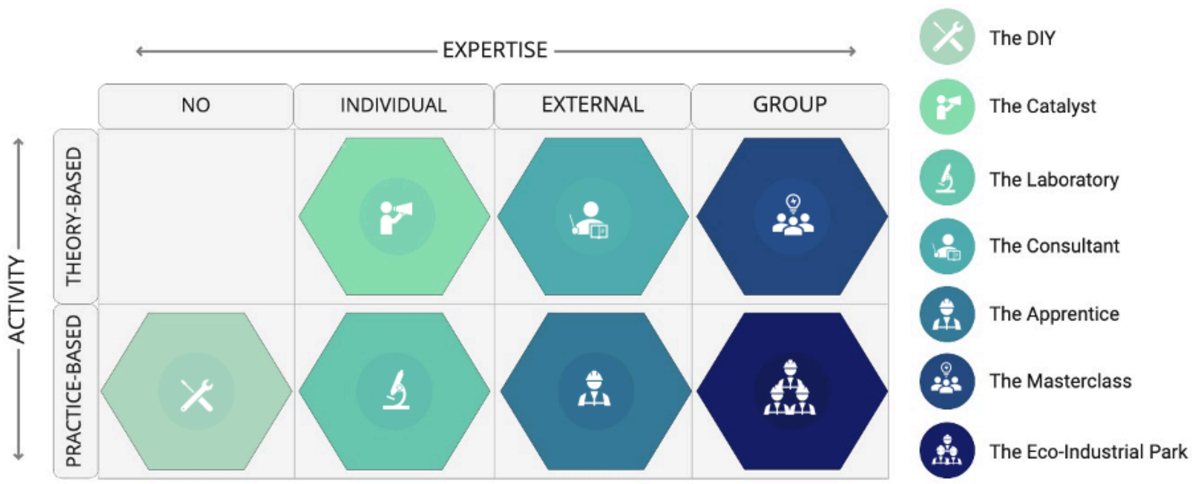


Figure 6.2. The transition learning flavours as building blocks.

Sub-questions

Next to a conceptual understanding of how transition experiments could be designed to stimulate transition learning, several sub-questions have been raised to support the main research question. These results offer a rich understanding of the learning subjects, process, objects and the effect. The answers to these questions are introduced below and further embedded in literature from the theoretical review.

RQ 1: Who learns - Which stakeholders involved in the design and construction process need to learn from circular building experiments?
Regarding the first sub-question, it proved that clients, principal contractors and structural engineers are stakeholders involved in the design and construction phase that still *need* to learn for a CE. Here, the client and principal contractors are seen as influential regime actors, as they have the resources to create demand and provide the conditions for a CE on a project-basis (the client via procurement) or in the value chain (contractors via partnerships). Furthermore, from the results it proved that structural engineers do embrace circularity *culturally* (shift in way of thinking), however their practices still reflect a regime approach and therefore still need to learn about circular *practices* (shift in routines and doing things) (Van den Bosch & Rotmans, 2008). Next to those which were involved in the design and construction phase, the results proved that *controllers*, both public (regulators) as private (cost-controllers), and supply chain partners (subcontractors, such as suppliers), should be involved to learn about new *structures* of circular buildings (shift in organizing the physical, institutional or economic context) (Van den Bosch & Rotmans, 2008). These results provide a richer understanding about actor learning for circular construction and add to earlier findings on the important role of clients (Adams et al., 2017; Leising et al., 2017) and supply chain partners (Leising et al., 2017) in stimulating the uptake of CE principles in construction projects.

RQ 2: Learns how - How do stakeholders learn in circular building experiments?
To address the second sub-question and to further elaborate on actor learning processes, a main scientific contribution of this research is the typology of transition learning. Combinations of these *flavours,* which represent learning structures, can yield different learning outcomes for different stakeholders. Next to the difference between practice- or theory-based learning and the diversity of expertise (the two axes), several corresponding aspects for transition learning could be found. A crucial activity that stimulated double-loop learning was reflection, which could be individual reflection (on own expertise), group reflection (on each other's expertise) or system reflection (on the wider construction sector), confirming previous findings of Brown & Vergragt (2008).

To support reflection, several activities were deemed important to achieve double-loop learning. At first, *collaborative visioning* about potential design strategies supported higher order learning in the design phase. This corresponds with earlier findings on circular building pilots by Leising et al. (2017). Secondly, this research found empirical evidence of the importance of *monitoring and evaluation* for double-loop learning. A new finding, as this has not been empirically proven for the Dutch construction sector yet. Monitoring includes both quantitative monitoring of the *success* of the building (via environmental impact assessment MPG, BENG or integrated form or circularity score), which was found in each experiment, as well as qualitatively monitoring the learning process, which was only found in one experiment. Reflecting on both of these supported double-loop learning. Carefully monitoring the learning process was also found in literature, where an example is fourth generation evaluation (Guba & Lincoln, 1989), which was also mentioned by Loorbach (2010) as a tool to collaboratively reflect on the learning/transition process, supporting agenda setting and discussing follow-up steps. The added value of combining qualitative and quantitative monitoring for double-loop learning is referred to as reflexive monitoring in literature (Van Mierlo et al., 2010).

To achieve these activities, several conditions were deemed important. At first, a *collaborative approach* is necessary in which diverse stakeholders are integrated from the start of the experiment, as also indicated by Leising et al. (2017). Secondly, include *diverse expertise* as it was found that reflection on each other's expertise supported double-loop learning. This also includes the involvement of supply chain partners and public- and cost-controllers. Thirdly, as circular construction encompasses many different aspects, setting a *clear vision* with the client before starting the design phase proved to be essential in determining a scope for the learning direction. Fourthly, *ensuring commitment* and keeping the team committed, as previously found by Van Mierlo

& Beers (2020). Fifthly, *transparency*, which was achieved through an open budget and open communication, and previously empirically found (Luederitz et al., 2017; van de Kerkhof & Wieczorek, 2005). A transparent environment also supported *trust* between the actors, which is the sixth condition that supports deep learning. Furthermore, ensuring that *time and budget* are in line with the ambition, this correlates with findings of Brown & Vergragt (2008). Finally, a*gree on risks and approach*, where for circular construction a lot of uncertainties exist. In line with Luederitz et al. (2017), these need to be addressed at the start of the collaboration and how they will be managed in the process (e.g. through a system of early warnings). A transparent approach and an understanding of how risks will be managed supports trust and commitment, which enhances the learning environment.

RQ 3: Learns what – What do stakeholders learn and to what extent can higher order learning be identified among stakeholders involved in the circular building experiment?
At first, from literature several CE themes were found, which were inspired on the six pillars of Pomponi & Moncaster (2017) and integrated with various other categories found in literature that can influence what is being learned about circular construction. Pomponi & Moncaster (2017) propose a holistic perspective of six 'pillars' for CE research in the built environment, meaning that each pillar influences another pillar. However, this research argues that for the scope of circular experiments on the building-level, three main experimental learning themes exist (economic, process and technical) and that the other themes have a mediating influence on this learning process, as depicted in Figure 5.2. This perspective provides a deeper understanding of the interdependence between the themes than the holistic pillars of Pomponi & Moncaster (2017) and can be helpful for further research.

Furthermore, this research showed that double-loop learnings were obtained by the clients and actors from the builder's role group and that these related to technical, economic and process-related learning. *Process*-related double-loop learnings included how to procure for a CE, where it was found that functionally defining the requirements instead of specified requirements triggers the market to come up with CE solutions. This is in line with, and confirms, previous findings by Leising et al. (2017). Next to this, it was found that actors needed to be qualitatively approached and assessed based on their goals and ambitions instead of price. *Technical* learnings referred to new design techniques in which designing or constructing for disassembly proved a central theme, as also indicated by Regina-Munaro et al. (2020), and new construction techniques to set-up an infrastructure to recycle concrete aggregate and process these in modular elements that can be reused. *Economically*, clients and builders learned from new business models, where buildings designed for reuse resemble future value, which includes a new revenue-model. Furthermore, the inner shearing layers of a building prove to bode well for PaaS-models and triggered double-loop learning for an interior supplier. Ultimately, a lesson that still needs to be learned is how to assess the multiple values (beyond solely economic) that circular buildings create.

RQ 4: The Effect - How are learnings from circular building experiments embedded and diffused by involved stakeholders in order to support a transition in the construction sector?
Interestingly, the only new technical innovation that could be scaled up was due to designing the experiment as a series, where each consecutive experiment further optimized the main lessons learned. This emphasises the importance of broadening as a mechanism that can support the scaling up of technical innovations (Van den Bosch & Rotmans, 2008). Furthermore, the results backed the theory of *small wins* by Termeer et al. (2017), where instead of focusing on solving the entire system in one experiment, focus on a part of the system and ensure continuous transformational change through a series of experiments. Where it was found that lacking broadening possibilities, context specificness and an overheated construction market acted as main barriers for institutionalizing the technical lessons learned. Next to this, it was found that the economic double-loop learnings could

v

only be institutionalized for the inner shearing layers (interior supplier), where constructively PaaS-models are hindered by regulations, negative perceptions of other colleagues and lacking internal competences to model with residual value.

The results of this research, furthermore, emphasize the importance of external platforms and knowledge institutes to disseminate knowledge and innovations and avoid the lurking danger of fragmentation of niche innovations (Geels, 2019). These external platforms, are called *intermediary actors* in transition literature, where Kivimaa et al. (2019) recently developed a typology of five different types of intermediary actors for sustainability transitions. These actors are important for aggregating the lessons learned, facilitating new connections, disseminating these and translating them from local experiments to policy-makers (Geels, 2019). Involving them early on in circular building experiments is then also key for increasing the effect of transition learning.

Last but not least, an important finding was that not all organizations have a learning structure in place to connect lessons learned to. For SME's this appeared to be less important as knowledge can diffuse informally. However, for LSE's this needs to be formally organized, which for most was organized via workgroups focused on CE, but for four organizations there was no learning structure in place. Therefore, reducing the possibility of tapping into collective organizational knowledge and limiting the effect of double-loop learnings of the experiment. This emphasizes the necessity to not solely focus on learning in the experiment, but also include organizational change in the experiments. Through deliberately discussing and supporting follow-up actions as well as a post-experiment evaluation, fragmentation of lessons learned can be prevented. This can support the effect of transition learning, as in the end organizations need to change to transition towards a CE.

6.2. Methodological reflection and limitations

6.2.1 Methodological reflection

Scope and approach

This research was explorative of nature where there was no prior academic research which combined transition literature to CE experiments in the construction industry in the Netherlands to build on. Therefore, the initial approach of this research was to be comprehensive and aimed to understand all the processes from start of the experiment, until the end of the experiment, to even the post-experiment institutionalization process. A multiple case-study approach proved to be valuable to understand the complex phenomena in circular building experiments and did provide a rich and extensive understanding of the different learning processes in and after circular building experiments. A drawback to this comprehensive scope was the large number of stakeholders that had to be interviewed. Where it proved challenging to interview all stakeholders involved in the design and construction phase of four case-studies and a lot of time was invested in planning and setting up the interviews and especially transcribing and analysing the interviews leading to an extended lead-time of the research. In retrospect, there were interviews with advisors that were part of the construction team and therefore initially deemed important, but which did not provide new insights or input regarding transition learning. On the other hand, it did result in saturated data, as the degree to which new data repeats previous findings (Saunders et al., 2018), regarding the learning component in these phases and provided in-depth stakeholder results. Furthermore, given the fact that there was no previous data to build on, this complete and comprehensive approach proved to work well.

Learning loops

Next to reflecting on the scope of the research, a reflection on the methods used should also be addressed. This research operationalized single-, double- and triple-loop learning to assess the results of deepening in an experiment. In this research, double-loop learning was operationalized as those lessons learned which resulted in a reflection on the current company routines (policy, goals and practices), whereas single-loop learning was defined as those lessons in which organizational reflection was missing (Argyris & Schon, 1974). For the analysis, this distinction proved to work well and has been applied in other research as well (e.g. Aminoff & Pihlajamaa, 2020; Brown & Vergragt, 2008; Ersoy & Van Bueren, 2020). However, a methodological reflection that was initially not taken into account was the fact that stakeholders can also acquire higher order learning in previous projects or experiments. This could lead to a distorted image of *what is learned* and what the actual effect of the experiment was on the organization (*to what effect)*. Luckily the data provided insights in the previous CE experience of each stakeholder from which it could be derived which practices were new for certain stakeholders and which not.

Furthermore, it was found that for the scope of this research the operationalization of triple-loop learning did not result in the desired results and received little attention in the results. Triple-loop learning was operationalized from an organizational perspective, as: "*a shift in the learning ability of an organization via new learning methods, strategies or ability to utilize single- and double-loop learnings*" (Bartunek & Moch, 1987; Romme & Van Witteloostuijn, 1999). There were multiple reasons why this did not work out as initially hoped for: a) only one agent of each organization was interviewed, b) the broad scope of research questions resulted in limited time available to discuss organizational learning structures and c) not all interviewed agents were responsible for organizational learning structures. It requires a larger scope to clearly understand how triple-loop learning occurs in an organization and how 'collective knowledge' develops and is organized, as Romme & Van Witteloostuijn (1999, p.440) state: "*triple loop learning is about increasing the fullness and deepness of learning about the diversity of issues and dilemmas faced, by linking together all local units of learning in one overall learning infrastructure as well as developing the competences and skills to use this infrastructure."*. Indicating a research focus on the organization , where this research primarily scoped on the experiment.

To what effect

This research tried to integrate various methods from transition literature that assess the *effect* of knowledge and innovation produced in experiments. From the perspective of transformational change Termeer et al. (2017) reason about *sensemaking*, *coupling*, and *integrating*; from an Urban Living Lab-perspective Von Wirth et al. (2019) propose *embedding*, *translating* and *scaling*; and from the perspective of transition experiments Van den Bosch & Rotmans (2008) argue for *deepening*, *broadening* and *scaling up*. These knowledge diffusion mechanisms all resemble similarities, but they argue from a different level of abstraction. Ultimately, deepening, broadening and scaling up were used, as these reason from a MLP-perspective and were operationalized from an organizational perspective to assess the *to what effect*. Here, deepening for this sub-question resembled which organizations share knowledge with the sector and how; broadening reflected any replications of the experiment; and scaling up related to the institutionalization process of knowledge and innovation gained. However, *to what effect*, as often used in policy learning (e.g. van de Kerkhof & Wieczorek, 2005), includes how knowledge derived from the experiment influences further decision-making practices, which was not thoroughly investigated due to limited number of agents interviewed of each organization and the large number of topics that had to be addressed in the interview.

6.2.2 Limitations

A main point of attention of case-study research relate to generalizability and validity of the results (Yin, 2009). Here, *data saturation* is an important aspect, where it is found that not reaching saturation impacts the quality of the conducted research and with that its generalizability (Saunders et al., 2018). Referring back to the final paragraph of Chapter 6.2.1, the data of the *to what effect* sub-question was not saturated and the results can therefore not be extrapolated to the wider population. Conversely, the typology of transition learning rests on a comprehensive research approach for which learning in the experiment has been verified by at least five stakeholders involved in each experiment. This process resulted in no further new information and data regarding this part of the results can therefore be seen as saturated. To further strengthen the validity of the developed *flavours*, three activities as proposed by Yin (2013) have been conducted, (1) using logic models, which has been addressed in each of the cases; (2) looking for rival explanations, through this process three new flavours were found in the discussion section; and (3) the typology has been tested on the case-studies to prove its validity and applicability. Here it should be noted that the *flavours* can only be generalized to the scope of circular building experiments. Further research should prove whether these *flavours* are also applicable to other domains.

Furthermore, for replicability purposes *and* the validity of the results*,* several limitations occurred in the data collection process. The first deals with the fact that data about an organization stems from a single source. This especially limited the validity of the *to what effect* results as indicated in the previous paragraph. A second limitation dealt with the fact that not all interviewed agents were directly involved in the experiment due to a change of positions. This was the case for the municipality in SUPERLOCAL, the housing corporation in Assinklanden, the architect in the Vondeltuin and the client in the Green House. This obstructed the potential of assessing how they learned and limited the analysis from only obtaining second-hand information, mostly about successes and problems of the experiment. It did not allow for qualitative reflection of how they experienced the process. Thirdly, even though a large set of respondents were interviewed, not all crucial stakeholders could be interviewed. Especially for the Green House and SUPERLOCAL stakeholders indicated that they were frequently approached for research which limited their willingness and availability.

For the Green House, the construction company could not be interviewed, which could have influenced the results for who obtained double-loop learnings. Furthermore, the project leader of the developing company was self-employed making the provided information regarding the institutionalization process vulnerable for this theme. For SUPERLOCAL, the housing corporation and the structural engineer did not want to be interviewed. This could have influenced the results, where potentially double-loop learnings were achieved which have not been indicated in this research. As this case was carefully documented, their experiences could be derived from evaluation reports (Durmisevic, 2019a), however, this did not provide the depth necessary to assess whether higher order learning could be identified. For the Vondeltuin and Assinklanden all stakeholders in the design and construction phase could be interviewed.

Ultimately, for replication purposes it has to be addressed that the research was conducted in times of a global pandemic. Because of this, all interviews had to be conducted online via video calling. It is found that video calling for qualitative research can limit the quality of the data, such as body language, the physical context as well as technical issues of losing connection or time-lags (Krouwel et al., 2019). From a researching perspective, there were no decisive moments where this occurred, though it has to be addressed that in theory this could have had an influence on the validity of the results.

v

Chapter 7. Conclusion and recommendations

7.1 Conclusion

This explorative research aimed to understand how transition experiments for circular buildings could be designed in order to stimulate transition learning among stakeholders involved in the design and construction process. Here, the motive was to assess why these experiments should be conducted and how they can contribute to a CE transition in the construction sector. Transition experiments were defined as: "*practice-based and challenge-led initiatives, which are designed to promote system innovation through learning under conditions of uncertainty and ambiguity."* (Sengers et al., 2019). From literature, it was derived that learning in the experiment (*deepening*) should lead to a radical shift in practices (doing), cultures (thinking) and structures (organizing) (Van den Bosch & Rotmans, 2008). To assess how and whether deepening occurred, the three learning loops of organizational learning literature were used (Argyris & Schon, 1974; Bartunek & Moch, 1987), where for transitions next to single-loop (incremental improvement) also double-loop (improvement with organizational reflection) and triple-loop learning (reflection on how the organization should learn) is necessary (Kemp & van den Bosch, 2006). These were connected to the diffusion mechanisms of broadening and scaling up and operationalized from an organizational perspective, to understand the effect of these lessons learned (Van den Bosch & Rotmans, 2008).

Based on a qualitative analysis of four circular building experiments in the Netherlands, it was found that each experiment triggered double-loop learning and with that provide the evidence of the added value of experiments for a CE transition in the construction sector. Next to this, based on the results, this research provided a typology for transition learning and found that seven different *flavours* exist that can trigger double-loop learning. Of these seven, four have been empirically validated, where in each case one *flavour* was dominant and combined with other *flavours*. These include the *Masterclass* (theoretical learning via group expertise), the *Laboratory* (practice-based learning from individual expertise), the *Catalyst* (theory-based learning from individual expertise) and the *Consultant* (theory-based learning from external expertise). Depending on the context and available time, combinations of flavours can be made per experiment. Here, a group approach can be recommended to stimulate the variety of transition learning. The *flavours* can be seen as a toolbox to stimulate transition learning when designing circular building experiments.

This research further emphasized the necessity of paying careful attention to how deep learning will be addressed in the experiment. For this, **reflection** proved to be essential, which could be individual reflection (on own expertise), group reflection (on each other's expertise) or system reflection (on the wider construction sector), confirming previous findings of Brown & Vergragt (2008). Reflection can then be designed in experiments via different practice- or theory-based activities. Where this research showed that (1) **collaborative visioning** about potential design strategies and (2) **monitoring and evaluating** the environmental impact of construction choices *and* the learning process, directly influenced deep learning in the experiment.

To implement these activities and to create a learning environment, several conditions were found to be important. At first, a **collaborative approach** is necessary in which diverse stakeholders are integrated from the start of the experiment. Secondly, **diverse expertise** needs to be included, as it was found that reflection on each other's expertise supported double-loop learning. This also includes the involvement of supply chain partners and (cost-)controllers, which were not always involved, but can lift the circular ambitions of the experiment and support the deepening process. Thirdly, as circular construction encompasses many different aspects, a **clear vision** needs to be set to determine the learning focus. Fourthly, **commitment** is necessary, where it was found that a lack of commitment limited individual and group transition learning. Fifthly, **transparency**, which was achieved through an open budget and open communication, which also enhanced **trust** between the actors, which is the sixth condition that supports deep learning. Furthermore, ensuring that **time**

and budget are in line with the ambition proved to be essential. Finally, **agree on risks and approach**, where for circular construction different uncertainties exist. Discussing beforehand how these will be managed can prevent a mismatch of expectations and stimulate transition learning.

Dedicating specific attention to the monitoring, evaluation and documentation process when designing circular building experiments is regarded as a key conclusion, which appears to be an activity which is not standard for innovative circular constructions projects and transition experiments. The role of an external knowledge and/or innovation platform appeared to be valuable in documenting the process, sharing the lessons learned with the sector as well as addressing the regime barriers found in norms and regulations that obstruct niche innovations from breaking through. Their role proved to be important in supporting internal as well as external deepening.

These (double-loop) lessons learned could be grouped to three main learning themes for circular construction and were obtained by the *initiators* (client) and the *builders* (contractors, deconstruction company and suppliers). The learning themes include: (1) the *process* (procurement procedure and collaboration), (2) *economic* (circular business models, such as Total Cost of Ownership and PaaS) and (3) *technical* (circular design and construction techniques). These three themes provide important directions for *what* needs to be learned in circular building experiments.

However, when zooming on the effect of these lessons learned and to what extent these *actually* changed the practices, cultures or structures of an organization, it appeared that not all organizations have a learning structure in place to connect the lessons learned to. Where it appeared that for four regime actors transition learning remained on the individual level as there were no resources made available to follow-up on in the organization. This is an important finding as the most important hurdle to overcome in a transition is *fragmentation* of lessons learned, where they remain isolated on the individual level and fail to build momentum (Geels, 2019).

This research furthermore, highlighted barriers for the scaling up process of the lessons learned. Where it proved that technical learnings are hindered by (1) **lacking broadening possibilities** in follow-up projects, (2) **context specificness** and (3) an **overheated construction market**. Furthermore, the scaling up of economic lessons learned regarding new circular business models were hindered by (4) **regulations**, (5) **negative perceptions** of other colleagues and (6) **lacking internal competences** to model with residual value or PaaS-models. The results of this research further emphasized **the importance of broadening** (Van den Bosch & Rotmans, 2008) and the theory of 'small wins' by Termeer et al. (2017), where conducting a series of experiments, where each experiment builds on the previous findings supports double-loop learning and, more importantly, facilitates scaling up.

All in all, this research proves that experiments are an important means to trigger transition learning and with that have the capacity to trigger radical organizational change, as was found in four organizations. From the cases it also became clear that a 'learning-by-doing'-mentality works for the construction industry, however, this should not imply an unaddressed learning structure in the experiments and in the involved organizations. Ultimately, it is not the final product, but the lessons learned (knowledge and innovation) that contribute to a CE transition in the construction sector. Therefore, this thesis argues the importance of carefully addressing the design of the experiment, where more emphasis should be devoted to achieving deep learning *in* the experiment and *in* the involved organizations to ensure that knowledge and innovation will be valorised. To support practitioners, clients and academia in setting up and designing circular building experiments, this research provided a conceptual toolbox (the *flavours*) to evaluate and design transition learning in circular building experiments. Next to this, a practical roadmap with checklist questions has been developed. As will be further addressed in the next subchapter.

v

7.2 Scientific recommendations

Various recommendations for further research could be derived from this thesis. First of all, this research found seven *flavours* for transition learning based on two axes of in total six categories (2x4). These are regarded as comprehensive, within the scope of this research and the empirical evidence provided. However, more research should be conducted to assess whether other categories, or even axis, exist. If so, this would result in more transition learning *flavours*. For example, Beers et al. (2016) provided an integrated perspective on social learning in system innovations projects and included, next to activities and expertise (as in this research), also relations (as the interdependencies between actors) as an important aspect influencing the social learning outcome. Further research should be performed to understand whether this can be seen as a new axis and how that would impact the typology of transition learning.

Furthermore, the applicability of these learning *flavours* for new circular building experiments should be assessed, whether the rationale of this typology holds true for every circular building experiment and how learning in new *flavours*, such as *the DIY* or *the Apprentice*, occurs. These can be applied to different types of circular building experiments, following Sengers et al. (2019), or the long-list of cases found in Appendix D. Next to this, it should be researched whether the *flavours* are also applicable to other sectors and domains. Ultimately, more empirical evidence should be conducted to understand the further applicability and completeness of the *flavours* and poses an interesting research avenue.

Focus on power

Furthermore, an important, but not included, scope for analysing sustainability transitions is the role of power (Avelino & Wittmayer, 2016). This was also regarded as a point of critique to the MLP, which was not included in the entire story of how transitions take place (Geels, 2019). As transitions lead to shifting power relations (Rotmans & Loorbach, 2009), it can be interesting to assess the role of experiments in power shifts in the wider context of a CE transition in the construction sector. For this, the power typology by Avelino & Wittmayer (2016) can be a fruitful starting point. Also Sengers et al. (2019) stressed the necessity for further research on micro-politics, power and agency in experiments, including how decision-making is organized, how negotiations and resistance is dealt with and who is included or excluded. This research, for example, showed the new role of the demolition company, who traditionally are at the end of a lifecycle process with limited power, now becoming a material supplier and taking a central role in a design process in the transformation of buildings. This shift can lead to new distribution of power in the construction sector and can be important in understanding the wider transition. Therefore, for further research it can be recommended to include the role of power in experimenting with circular construction.

The effect

Furthermore, as this research found that not all clients or principal contractors have a learning structure in place, more research should be conducted on the *effect* of circular building experiments on these organizations. As data saturation was not achieved regarding this sub-question, these results were not generalizable (Saunders et al., 2018). Therefore, it is recommended to conduct more research on the *effect* of transition experiments on influential regime actors and take a post-experiment perspective to analyse how these lessons learned are institutionalized. Based on such research, which involves interviews with different agents of different departments, enablers or barriers for change processes to break from regime activities can be identified. These can subsequently guide stakeholders before conducting an experiment on how to get different departments of the company along in the transition. For this triple-loop learning could also be used to assess whether organizations 'learn how to learn' for a CE in the construction sector.

Scoping on type of actor or development phase
As there was no prior empirical data regarding transition learning circular building experiments, this research applied a comprehensive research scope including all stakeholders in the design and construction phase. However, building on the results of this thesis, it can be recommended to continue with more scoped research to provide more in-depth results. For which several options are recommended. The first is **focusing on regime actors**, e.g. the client or principal construction company. Taking regime actors as a starting point can be supported with the interactive learning tradition from innovation studies (see Appendix B), which was neglected for this research, but could be useful. It takes the incumbent regime actors as a starting point which focuses on processes of *forgetting* and *unlearning* to change daily practices (van Mierlo & Beers, 2020). Another possibility, would be to **focus on an actor role group**, grouped on activities (designers, builders, initiators or controllers). For example, from this research it became clear that *advisors* had more previous CE experience, especially architects. It could hold true that these stakeholders learn earlier in a CE transition than *builders* or *initiators.* However, it would need a longitudinal study to adequately conclude such a statement. Another possibility would be to **focus on a certain phase** of the development process of an experiment, which can provide more in-depth results. For example, this research showed the importance of the procurement procedure for setting the right conditions for transition learning, which could be assessed for a larger set of circular building experiments in the Netherlands. Scoping on regime actors, role groups or a single-phase in the development of circular building experiments remains a research avenue for future research.

Valuing circular construction and research scope
A lesson *not* learned in the cases relates to “proving” the added value of circular construction. Valuing circular construction, not only economically, but also the added value on ecology, society (e.g. healthier in construction processes or in the use phase) and the long-term added value remains an understudied theme. Capturing these values in the circular business model value mapping tool (Bocken et al., 2018) could be a first step, but objectifying these with *hard* data proves to be a more difficult one. A recent publication of Cirkelstad (2021) also indicates the importance of economic valuation for the scaling up process, but emphasize the necessity to also *measure* or *objectify* these other values, which are not solely expressible in economic terms. The urgency for including these values in the business case was also stressed by two interviewees (interviewee 15; 19). Furthermore, this research took the scope of a building, but it would be interesting to assess how such a business case, which includes *multiple value creation*, would look like when extended to the scope of an area development. Involving circularity on this scope will make the assessment more complex as multiple systems work together, with other challenges, such as climate adaptation, energy production and nature-inclusivity. Objectifying the added value of a CE on this level proves an interesting research avenue for the Industrial Ecology-domain given its emphasis on systems-perspective and society’s metabolism (Graedel, 1996).

7.3 Practical implications and recommendations

Next to the scientific contribution of this research, several practical implications and stakeholder recommendations can be retrieved from the data. These are addressed in this subchapter, which is structured according to the four role groups which obtained a central role in this research: advisors, initiators, builders and controllers. First of all, as this research was conducted in collaboration with consultancy firm Over Morgen, the recommendations for the advisors will be addressed. This includes a practical roadmap with checklist questions that can be used when setting up future circular building experiments.

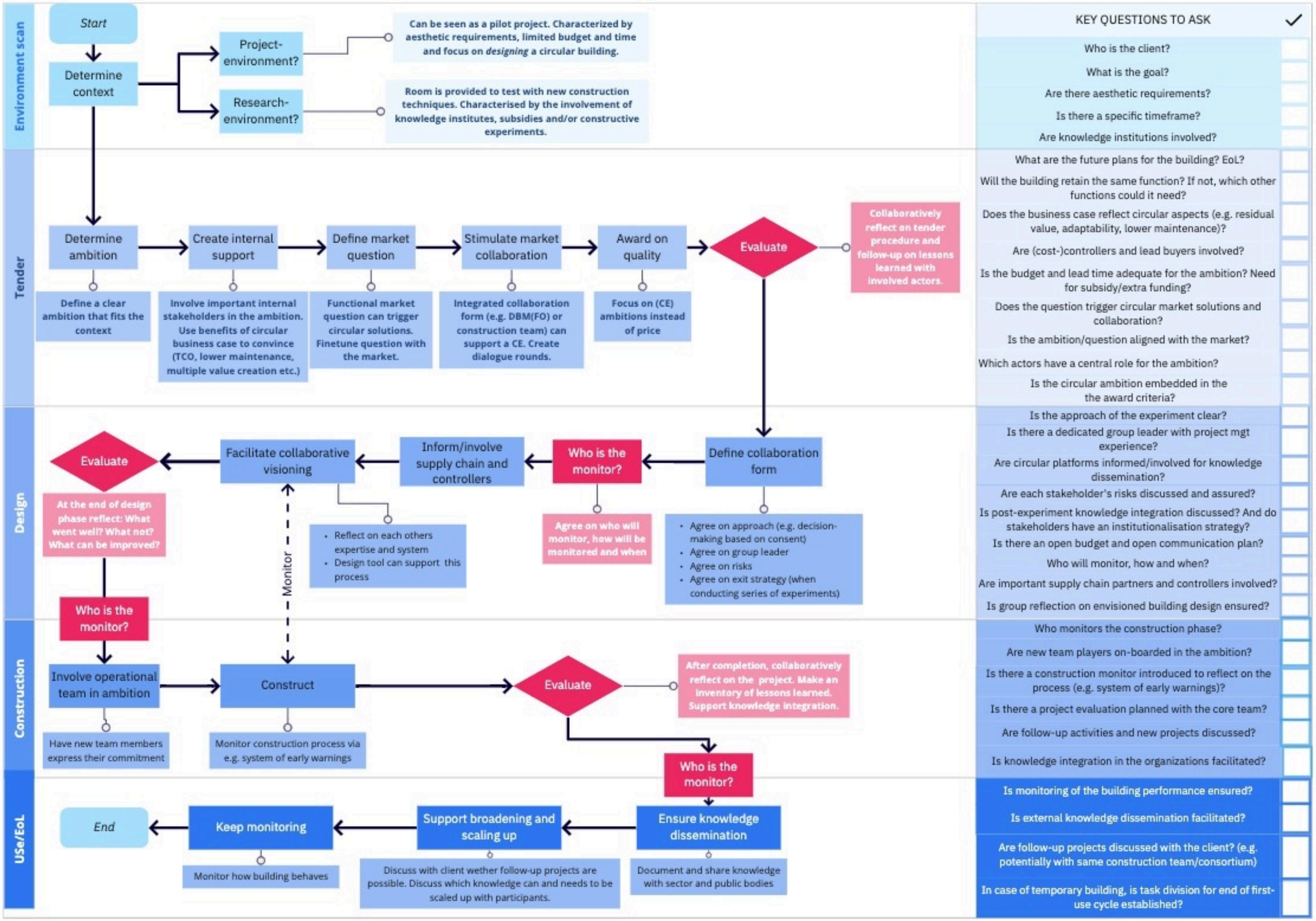
For **consultants**, at first, based on the results of this research, experiments prove to create positive impact for circular construction and provide the means for change. So, a first recommendation would be to use the results of this research as leverage in convincing more clients to experiment with circular construction. Secondly, the results also indicate that not all clients or builders have a learning structure in place. It can be recommended to guide these actors in setting up a learning structure to take the company along in the transition towards a CE. What would it mean for the company's goals? And how would it impact various departments? By collaboratively addressing these with the client (be it a municipality, project developer, housing corporation or construction company) and using experiments as a hands-on test case, a 'circular construction change package' can be created. The importance of including the financial department in this change process should be emphasized here. These two can be used as a proposition to instigate radical change in the Dutch construction sector.

When doing so, careful attention should be paid to how to design these experiments or circular building projects. This research showed that reflection is key in stimulating *deep* learning in transition experiments. To provide the practical tools to implement these reflection moments, a third recommendation would be to apply a *reflexive monitoring* system when involved in a circular building experiment. Van Mierlo et al. (2010) developed a guide for monitoring systemic innovation in innovation projects. This guide provides different tools which can be used for practitioners to stimulate reflection on the current system and its institutional barriers and interactive learning, of which (1) system analysis, (2) dynamic learning agenda, (3) reflexive process description and (4) timeline and eye-opener workshop provide interesting tools to further apply in circular building experiments. It can be recommended to include these moments of intervision.

Furthermore, to funnel the enormous amounts of valuable information from this research, the main findings of this research have been merged in a **roadmap with checklist questions**. This checklist roadmap is processed as a practical implication of this research and a fourth recommendation for consultants would be to use this as a checklist when setting up a circular building experiment, or when involved in a (phase) of a circular building project. This roadmap highlights five phases, as depicted on the left side, for which key questions are determined per phase, depicted in the checkbox on the right side. If it is a research-envionment, the dashed line between *collaborative visioning* and *construct* is in effect, reflecting the iterative process of visioning, testing and monitoring as found in the SUPERLOCAL. Furthermore, after the final reflexive evaluation moment, follow-up steps as well as knowledge integration (institutionalizing) should be facilitated. The red boxes indicate the moments for collaborative reflection and the fact that these should be monitored and carefully documented. These can also be incorporated in different steps for which they are not explicitly mentioned.

Before applying this roadmap, careful attention should be paid to: (1) aggregate previous lessons learned by connecting with prior experiments to further build on their relevant results, (2) connect with existing intermediary actors in the niche to support further aggregation activities and (3) convince and guide the client to conduct a series of experiments to prevent fragmentation of knowledge and innovation.

v


Environment scan
Tender
Design
Construction
USe/EoL
Start
Determine context
Project-environment?
Research-environment?
Can be seen as a pilot project. Characterized by aesthetic requirements, limited budget and time and focus on designing a circular building.
Room is provided to test with new construction techniques. Characterised by the involvement of knowledge institutes, subsidies and/or constructive experiments.
Determine ambition
Create internal support
Define market question
Stimulate market collaboration
Award on quality
Evaluate
Collaboratively reflect on tender procedure and follow-up on lessons learned with involved actors.
Define a clear ambition that fits the context
Involve important internal stakeholders in the ambition. Use benefits of circular business case to convince (TCO, lower maintenance, multiple value creation etc.)
Functional market question can trigger circular solutions. Finetune question with the market.
Integrated collaboration form (e.g. DBM(FO) or construction team) can support a CE. Create dialogue rounds.
Focus on (CE) ambitions instead of price
Evaluate
Facilitate collaborative visioning
Inform/involve supply chain and controllers
Who is the monitor?
Define collaboration form
At the end of design phase reflect: What went well? What not? What can be improved?
Reflect on each others expertise and system
Design tool can support this process
Monitor
Agree on who will monitor, how will be monitored and when
Agree on approach (e.g. decision-making based on consent)
Agree on group leader
Agree on risks
Agree on exit strategy (when conducting series of experiments)
Who is the monitor?
Involve operational team in ambition
Construct
Evaluate
After completion, collaboratively reflect on the project. Make an inventory of lessons learned. Support knowledge integration.
Have new team members express their commitment
Monitor construction process via e.g. system of early warnings
Who is the monitor?
End
Keep monitoring
Support broadening and scaling up
Ensure knowledge dissemination
Monitor how building behaves
Discuss with client wether follow-up projects are possible. Discuss which knowledge can and needs to be scaled up with participants.
Document and share knowledge with sector and public bodies
KEY QUESTIONS TO ASK
✓
Who is the client?
What is the goal?
Are there aesthetic requirements?
Is there a specific timeframe?
Are knowledge institutions involved?
What are the future plans for the building? EoL?
Will the building retain the same function? If not, which other functions could it need?
Does the business case reflect circular aspects (e.g. residual value, adaptability, lower maintenance)?
Are (cost-)controllers and lead buyers involved?
Is the budget and lead time adequate for the ambition? Need for subsidy/extra funding?
Does the question trigger circular market solutions and collaboration?
Is the ambition/question aligned with the market?
Which actors have a central role for the ambition?
Is the circular ambition embedded in the the award criteria?
Is the approach of the experiment clear?
Is there a dedicated group leader with project mgt experience?
Are circular platforms informed/involved for knowledge dissemination?
Are each stakeholder's risks discussed and assured?
Is post-experiment knowledge integration discussed? And do stakeholders have an institutionalisation strategy?
Is there an open budget and open communication plan?
Who will monitor, how and when?
Are important supply chain partners and controllers involved?
Is group reflection on envisioned building design ensured?
Who monitors the construction phase?
Are new team players on-boarded in the ambition?
Is there a construction monitor introduced to reflect on the process (e.g. system of early warnings)?
Is there a project evaluation planned with the core team?
Are follow-up activities and new projects discussed?
Is knowledge integration in the organizations facilitated?
Is monitoring of the building performance ensured?
Is external knowledge dissemination facilitated?
Are follow-up projects discussed with the client? (e.g. potentially with same construction team/consortium)
In case of temporary building, is task division for end of first-use cycle established?

This research showed that **architects** have an important role, as circular experts, in circular experiments and circular projects. Instead of solely drawing the requirements of the client (bluntly said), now architects also gain a central management role in these projects. This is a new role and requires more project management skills of the architects. With that, the recommendations for them based on the findings of this research are to further develop skills in project management and monitoring to manage stakeholder expectations and to ensure a learning environment. It could be recommended to use the tools of agile working and/or reflexive monitoring for this. Furthermore, for **structural engineers** it can be recommended to also constructively experiment with circular practices. This implies that instead of (traditional) theory-based experimentation, which occurred in three of the four cases, also practice-based experimentation is necessary. For example, when reusing constructive elements often the necessary information is missing, limiting the constructive circular ambitions in two of the four cases. However, to retain the high ambitions it could be the case that practical experimentation is necessary, for which the client needs to be willing.

For **initiators**, this research emphasized the crucial role they have for guiding the CE transition. A first, straightforward, recommendation would be to stimulate the market by tendering more projects. Secondly, it can be recommended to approach these as a series, where each experiment builds on the previous experiment. Thirdly, try to involve other departments in experimenting with CE as well. This research showed the importance of business model experimentation for which cost-controllers are key. Currently, circular building projects need to compete with traditional projects based on price. A hopeless battle at this stage, as circular buildings are (currently) more expensive. However, if the scope extends from price to the total lifecycle, including residual value, circular buildings provide a revenue-side which traditional projects do not possess. Further developing this TCO-perspective, as well as other benefits such as (1) lower procurement costs due to smarter design (decoupling), (2) lower maintenance costs due to higher quality buildings and (3) multiple value creation can level this unequal playing field and stimulate a further adoption.

For **controllers,** this research revealed several governmental barriers which need to be addressed. Regarding the reuse of materials, it appeared that technically not that much changes for builders, however that in the *process* due to obstructing norms and regulations (new norms, extra qualification procedure, extra VAT) it became a time consuming and more costly endeavour than “simply” buying virgin materials. In limiting the demand for finite resources and stimulating the uptake of existing materials policy-makers can levy non-biobased virgin materials (e.g. a carbon-tax) or stimulate demand for secondary materials via lifting the VAT on secondary materials. Furthermore, the importance of having policy-makers and/or public controllers informed and involved in these experiments seems crucial in this stage of the transition. This process should be facilitated by connecting responsible policy-makers and controllers to institutional barriers experienced on the ground. Especially, given the current period in which 80,000 houses need to be built annually to meet demand (Circle Economy, 2020), emphasizing the important role of policy-makers to seize this opportunity and incentivize circular construction.

For **builders**, it can be recommended to strategically address the necessary change process for a CE. This research showed the important role of principle contractors for a CE and argues that circular construction is here to stay. With that, there is a strategic opportunity to take a pioneering role. Furthermore, this research showed the importance for *deep* technical learning in experiments which are free of regime pressures. Therefore, it is recommended to become involved in these experiments and involve supply chain partners in the process. It is recommended to start the conversation with them to understand how future collaborations and potentially new infrastructures could look like. All in all, it is recommended to take a leading role in the transition towards a CE, and a first step would be seeking change through experimentation both practically as well as in the organization.

Bibliography

Adams, K., Osmani, M., Thorpe, T., & Hobbs, G. (2017). The role of the client to enable circular economy in the building sector. *Proceeding of the International HISER Conference on Advances in Recycling and Management of Construction and Demolition Waste*, *June*, 118–121.

Adams, K., Osmani, S., Thorpe, T., & Thornback, J. (2017). Circular economy in construction: Current awareness, challenges and enablers. *Proceedings of Institution of Civil Engineers: Waste and Resource Management*, *170*(1), 15–24. https://doi.org/10.1680/jwarm.16.00011

Aminoff, A., & Pihlajamaa, M. (2020). Business experimentation for a circular economy - Learning in the front end of innovation. *Journal of Cleaner Production*, *275*, 124051. https://doi.org/10.1016/j.jclepro.2020.124051

Ansell, C. K., & Bartenberger, M. (2016). Varieties of experimentalism. *Ecological Economics*, *130*, 64–73. https://doi.org/10.1016/j.ecolecon.2016.05.016

Arditi, D., Arditi, D., & Gunaydin, H. M. (2004). Total quality management in the construction process Total quality management in the construction process. *International Journal of Project Management*, *7863*, 235–243.

Argyris, C., & Schon, D. A. (1974). Theory in practice: Increasing professional effectiveness. In *Theory in practice: Increasing professional effectiveness.* Jossey-Bass.

Avelino, F., & Wittmayer, J. (2016). Shifting power relations in sustainability transitions: A multi-actor perspective. *Journal of Environmental Policy and Planning*, *18*(5), 628–649. https://doi.org/10.1080/1523908X.2015.1112259

Baarda, B., Bakker, E., Fischer, T., Julsing, M., Peters, V., Velden, T. van der, & Goede, M. de. (2013). *Basisboek Kwalitatief onderzoek: Handleiding voor het opzetten en uitvoeren van kwalitatief onderzoek*. Noordhoff Uitgevers.

Bartunek, J. M., & Moch, M. K. (1987). First-order, second-order, and third-order change and organization development interventions: A cognitive approach. *The Journal of Applied Behavioral Science*, *23*(4), 483–500.

Baxter, P., & Jack, S. (2008). Qualitative case study methodology: Study design and implementation for novice researchers. *The Qualitative Report*, *13*(4), 544–559. https://doi.org/10.1039/c6dt02264b

Beers, P., Van Mierlo, B., & Hoes, A. (2016). Toward an integrative perspective on social learning in system innovation initiatives. *Ecology and Society*, *21*(1). https://doi.org/10.5751/ES-08148-210133

Bennett, C. J., & Howlett, M. (1992). The lessons of learning : Reconciling theories of policy learning and policy change 1 . Introduction : Policy change and the ambiguities of policy learning. *Policy Sciences*, *25*(3), 275–294.

Bocken, N., de Pauw, I., Bakker, C., & van der Grinten, B. (2016). Product design and business model strategies for a circular economy. *Journal of Industrial and Production Engineering*, *33*(5), 308–320. https://doi.org/10.1080/21681015.2016.1172124

Bocken, N., Schuit, C., & Kraaijenhagen, C. (2018). Experimenting with a circular business model: Lessons from eight cases. *Environmental Innovation and Societal Transitions*, *28*(December 2017), 79–95. https://doi.org/10.1016/j.eist.2018.02.001

Boons, F., & Howard-Grenville, J. A. (2009). *The social embeddedness of industrial ecology*. Edward Elgar Publishing.

Brand, S. (1995). *How buildings learn: What happens after they're built*. Penguin.

Brown, H. S., Vergragt, P., Green, K., & Berchicci, L. (2003). Learning for sustainability transition through bounded socio-technical experiments in personal mobility. *Technology Analysis & Strategic Management*, *15*(3), 291–315.

Brown, H. S., & Vergragt, P. J. (2008). Bounded socio-technical experiments as agents of systemic change: The case of a zero-energy residential building. *Technological Forecasting and Social Change*, *75*(1), 107–130. https://doi.org/10.1016/j.techfore.2006.05.014

Bueren, E. Van. (2009). *Greening governance An evolutionary approach*.

v

Bulkeley, H., Coenen, L., Frantzeskaki, N., Hartmann, C., Kronsell, A., Mai, L., Marvin, S., McCormick, K., van Steenbergen, F., & Voytenko Palgan, Y. (2016). Urban living labs: governing urban sustainability transitions. *Current Opinion in Environmental Sustainability*, *22*, 13–17. https://doi.org/10.1016/j.cosust.2017.02.003

cepezed. (2018). *The Green House* (Vol. 14, Issue 5).

Circle Economy. (2020). *Bouwen aan een houten toekomst: Scenario's voor bouwen met klimaatpositieve materialen*. www.circle-economy.com

Circulaire Bouweconomie. (2021). *Circulaire Bouwprojecten*. https://circulairebouweconomie.nl/circulaire-bouwprojecten/

Cirkelstad. (2021). *Circulair Waarderen - Green Paper*. https://www.cirkelstad.nl/inspiratie/circulair-waarderen-2021/

Cobouw. (2020). *De 50 grootste bouwers van Nederland*. https://www-cobouw-nl.tudelft.idm.oclc.org/marktontwikkeling/nieuws/2020/11/dit-is-de-bouw-top-50-van-2020-101290093

Crossan, M. M., Lane, H. W., & White, R. E. (1999). An Organizational Learning Framework: From Intuition to Institution. *The Academy of Management Review*, *24*(3), 522. https://doi.org/10.2307/259140

De Bruijn, H., & Ten Heuvelhof, E. (2008). *Strategies in Networks: the Essence*.

Debacker, W., Manshoven, S., Peters, M., Ribeiro, A., & De Weerdt, Y. (2017). Circular economy and design for change within the built environment: preparing the transition. *International HISER Conference on Advances in Recycling and Management of Construction and Demolition Waste*, *June*, 114–117.

DOOR Architecten. (2020). *Parel voor het Vondelpark*. https://doorarchitecten.nl/portfolio/horecapaviljoen-vondeltuin-gemeente-amsterdam/

Durmisevic, E. (2018). *UIA The Super Circular Estate project - Journal 1* (Issue November).

Durmisevic, E. (2019a). *UIA Expert's Reports*. https://www.superlocal.eu/sce-en/

Durmisevic, E. (2019b). *UIA The Super Circular Estate project - Journal 3* (Issue November).

Durmisevic, E. (2020). *UIA The Super Circular Estate project - Journal 4* (Issue March).

Durmisevic, E. (2021). *UIA The Super Circular Estate project - Journal 5*. https://www.uia-initiative.eu/fr/news/super-circular-estate-project-journal-no-5-municipality-kerkrade

Duurzaam Gebouwd. (2020). *De Parel van het Vondelpark*. https://www.duurzaamgebouwd.nl/artikel/20201007-de-parel-van-het-vondelpark

Eberhardt, L. C. M., Birgisdottir, H., & Birkved, M. (2019). Potential of Circular Economy in Sustainable Buildings. *IOP Conference Series: Materials Science and Engineering*, *471*(9). https://doi.org/10.1088/1757-899X/471/9/092051

Eisenhardt, K. M. (1989). Building Theories from Case Study Research Published by : Academy of Management Stable. *The Academy of Management Review*, *14*(4), 532–550.

Ellen MacArthur Foundation. (2019). *Circular Economy Systems Diagram*. https://ellenmacarthurfoundation.org/circular-economy-diagram

Engelman, R. (2013). Beyond Sustainababble. In *State of the World 2013: Is Sustainability Still Possible?* (pp. 3–16). Island Press/Center for Resource Economics. https://doi.org/10.5822/978-1-61091-458-1_1

Ersoy, A., & Van Bueren, E. (2020a). Challenges of Urban Living Labs towards the Future of Local Innovation. *Urban Planning 5(4)*, 89–100.

Ersoy, A., & Van Bueren, E. (2020b). Challenges of Urban Living Labs towards the Future of Local Innovation. *Urban Planning*, *5*(4), 89–100. https://doi.org/10.17645/up.v5i4.3226

Fuenfschilling, L., Frantzeskaki, N., & Coenen, L. (2019). Urban experimentation & sustainability transitions. In *European Planning Studies* (Vol. 27, Issue 2, pp. 219–228). Routledge. https://doi.org/10.1080/09654313.2018.1532977

Geels, F. (2002). Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study. *Research Policy*, *31*(8–9), 1257–1274.

https://doi.org/10.1016/S0048-7333(02)00062-8
Geels, F. (2019). Socio-technical transitions to sustainability: a review of criticisms and elaborations of the Multi-Level Perspective. *Current Opinion in Environmental Sustainability*, *39*, 187–201. https://doi.org/10.1016/j.cosust.2019.06.009
Geels, F., & Deuten, J. J. (2006). *Aggregation activities. Local and global dynamics in technological development: a socio-cognitive perspective on knowledge flows and lessons from reinforced concrete*. *33*(4), 265–275.
Geissdoerfer, M., Savaget, P., Bocken, N. M. P., & Hultink, E. J. (2017). The Circular Economy – A new sustainability paradigm? *Journal of Cleaner Production*, *143*, 757–768. https://doi.org/https://doi.org/10.1016/j.jclepro.2016.12.048
Gemeente Amsterdam. (2020). *Over een kleine Vondelparktragedie*. https://www.amsterdam.nl/nieuws/achtergrond/vondelparktragedie/
Ghisellini, P., Cialani, C., & Ulgiati, S. (2016). A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner Production*, *114*, 11–32. https://doi.org/10.1016/j.jclepro.2015.09.007
Ghisellini, P., Ripa, M., & Ulgiati, S. (2018). Exploring environmental and economic costs and benefits of a circular economy approach to the construction and demolition sector. A literature review. *Journal of Cleaner Production*, *178*, 618–643. https://doi.org/10.1016/j.jclepro.2017.11.207
Glaser, B. G., & Strauss, A. L. (1968). The discovery of grounded theory; strategies for qualitative research. *Nursing Research*, *17*(4), 364.
Google Maps. (n.d.). *Assinklanden 379*. https://www.google.nl/maps/@52.1901027,6.9016103,3a,75y,322.27h,90.39t/data=!3m6!1e1!3m4!1siyLTR68G3U5L_rwmyeROZA!2e0!7i16384!8i8192
Graedel, T. E. (1996). On the Concept of Industrial Ecology. *Annual Review of Energy and the Environment*, *21*(1), 69–98. https://doi.org/10.1146/annurev.energy.21.1.69
Guba, E., & Lincoln, Y. (1989). *Fourth generation evaluation*. Sage.
Hart, J., Adams, K., Giesekam, J., Tingley, D., & Pomponi, F. (2019). Barriers and drivers in a circular economy: The case of the built environment. *Procedia CIRP*, *80*, 619–624. https://doi.org/10.1016/j.procir.2018.12.015
Hennink, M., Hutter, I., & Bailey, A. (2020). Qualitative research methods. In *SAGE Publications Limited*. https://doi.org/10.4337/9781781001295
Hertwich, E. G. (2005). Consumption and the rebound effect: An industrial ecology perspective. *Journal of Industrial Ecology*, *9*(1–2), 85–98. https://doi.org/10.1162/1088198054084635
Hoogma, R., Kemp, R., Schot, J., & Truffer, B. (2002). *Experimenting for sustainable transport*. Taylor & Francis.
Hoogma, R., Weber, M., & Elzen, B. (2005). Integrated long-term strategies to induce regime shifts towards sustainability: the approach of strategic niche management. In *Towards environmental innovation systems* (pp. 209–236). Springer.
IBA Parkstad. (n.d.). *Wat is IBA Parkstad*. Retrieved July 24, 2021, from https://www.iba-parkstad.nl/wat-is-iba-parkstad
Kemp, R., Schot, J., & Hoogma, R. (1998). Regime shifts to sustainability through processes of niche formation: The approach of strategic niche management. *Technology Analysis and Strategic Management*, *10*(2), 175–198. https://doi.org/10.1080/09537329808524310
Kemp, R., & van den Bosch, S. (2006). Transitie-experimenten. *Kenniscentrum Voor Duurzame Systeeminnovaties En Transities*.
Kirchherr, J., Piscicelli, L., Bour, R., Kostense-Smit, E., Muller, J., Huibrechtse-Truijens, A., & Hekkert, M. (2018). Barriers to the Circular Economy: Evidence From the European Union (EU). *Ecological Economics*, *150*, 264–272. https://doi.org/10.1016/j.ecolecon.2018.04.028
Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. In *Resources, Conservation and Recycling* (Vol. 127, pp. 221–232). Elsevier B.V. https://doi.org/10.1016/j.resconrec.2017.09.005

v

Kivimaa, P., Boon, W., Hyysalo, S., & Klerkx, L. (2019). Towards a typology of intermediaries in sustainability transitions: A systematic review and a research agenda. *Research Policy*, *48*(4), 1062–1075. https://doi.org/10.1016/j.respol.2018.10.006

Kivimaa, P., Hildén, M., Huitema, D., Jordan, A., & Newig, J. (2017). Experiments in climate governance – A systematic review of research on energy and built environment transitions. *Journal of Cleaner Production*, *169*, 17–29. https://doi.org/10.1016/j.jclepro.2017.01.027

Krouwel, M., Jolly, K., & Greenfield, S. (2019). Comparing Skype (video calling) and in-person qualitative interview modes in a study of people with irritable bowel syndrome-an exploratory comparative analysis. *BMC Medical Research Methodology*, *19*(1), 1–9. https://doi.org/10.1186/s12874-019-0867-9

Leising, E., Quist, J., & Bocken, N. (2017). *Circular Economy in the building sector: Three cases and a collaboration tool*. https://doi.org/10.1016/j.jclepro.2017.12.010

Loorbach, D. (2010). Transition management for sustainable development. *Governance: An International Journal of Policy, Administration and Institutions*, *23*(1), 161–183.

Loorbach, D., Frantzeskaki, N., & Lijnis Huffenreuter, R. (2015). Transition Management: Taking Stock from Governance Experimentation. *Journal of Corporate Citizenship*, *2015*(58), 48–66. https://doi.org/10.9774/gleaf.4700.2015.ju.00008

Loorbach, D., & Rotmans, J. (2006). Managing Transitions for Sustainable Development. *Understanding Industrial Transformation*, 187–206. https://doi.org/10.1007/1-4020-4418-6_10

Luederitz, C., Schäpke, N., Wiek, A., & Lang, D. (2017). Learning through evaluation – A tentative evaluative scheme for sustainability transition experiments. *Journal of Cleaner Production*, *169*, 61–76. https://doi.org/10.1016/j.jclepro.2016.09.005

Palte BV. (n.d.). *UIA Woningen*. https://www.paltebv.nl/portfolio/uia-woningen/

Peng, Y., Wei, Y., & Bai, X. (2019). Scaling urban sustainability experiments: Contextualization as an innovation. *Journal of Cleaner Production*, *227*, 302–312. https://doi.org/10.1016/j.jclepro.2019.04.061

PIANOo. (n.d.). *Traditionele contractvormen GWW (RAW, OMOP en Bouwteam)*. https://www.pianoo.nl/nl/sectoren/gww/contractvormen/traditionele-contractvormen-gww-raw-omop-en-bouwteam

Platform CB’23. (2019). *Framework Circulair Bouwen*. 1–41. https://platformcb23.nl/framework

Platform CB’23. (2020). *Meten van circulariteit: Werkafspraken voor een circulaire bouw*. https://platformcb23.nl/downloads/2020

Platform CB’23. (2021). *Circulair ontwerpen*. https://platformcb23.nl/downloads/2021

Platform31. (2019). *Praktijkvoorbeelden Circulaire Woningbouw*. https://platformcb23.nl/downloads/2019

Pomponi, F., & Moncaster, A. (2016). Embodied carbon mitigation and reduction in the built environment – What does the evidence say? In *Journal of Environmental Management* (Vol. 181, pp. 687–700). https://doi.org/10.1016/j.jenvman.2016.08.036

Pomponi, F., & Moncaster, A. (2017). Circular economy for the built environment: A research framework. *Journal of Cleaner Production*, *143*, 710–718. https://doi.org/10.1016/j.jclepro.2016.12.055

Porter, N., Claassen, M., & Timmermans, J. (2015). Transition experiments in Amsterdam: Conceptual and empirical analysis of two transition experiments in the WATERgraafsmeer program. *Technological Forecasting and Social Change*, *90*(PB), 525–537. https://doi.org/10.1016/j.techfore.2014.02.010

Potting, J., Hekkert, M., Worrell, E., & Hanemaaijer, A. (2017). Circular Economy: Measuring innovation in the product chain - Policy report. In *PBL Netherlands Environmental Assessment Agency* (Issue 2544).

v

Quist, J. (2007). *Backcasting for a sustainable future: the impact after 10 years*. Eburon Uitgeverij BV.

Raven, R. P. J. M., Heiskanen, E., Lovio, R., Hodson, M., & Brohmann, B. (2008). The Contribution of Local Experiments and Negotiation Processes to Field-Level Learning in Emerging (Niche) Technologies. *Bulletin of Science, Technology & Society*, *28*(6), 464–477. https://doi.org/10.1177/0270467608317523

Regina Munaro, M., ergio Fernando Tavares, S., & Bragança, L. (2020). *Towards circular and more sustainable buildings: A systematic literature review on the circular economy in the built environment*. https://doi.org/10.1016/j.jclepro.2020.121134

Rijksoverheid. (2016). Nederland circulair in 2050. In *Het ministerie van Infrastructuur en Milieu en het ministerie van Economische Zaken, mede namens het ministerie van Buitenlandse Zaken en het ministerie van Binnenlandse Zaken en Koninkrijksrelaties.* https://bouwenuitvoering.nl/duurzaam/nederland-circulair-2050/

Rijksvastgoedbedrijf. (n.d.). *Utrecht, Rijkskantoor de Knoop*. Retrieved August 4, 2021, from https://www.rijksvastgoedbedrijf.nl/vastgoed/vastgoed-in-beheer/utrecht-rijkskantoor-de-knoop

Rijksvastgoedbedrijf. (2020). *Marktstrategie Rijksvastgoedbedrijf 2021 - 2024*.

Romme, A. G. L., & Van Witteloostuijn, A. (1999). Circular organizing and triple loop learning. *Journal of Organizational Change Management*, *12*(5), 439–453. https://doi.org/10.1108/09534819910289110

Rotmans, J., & Loorbach, D. (2009). Complexity and transition management. *Journal of Industrial Ecology*, *13*(2), 184–196. https://doi.org/10.1111/j.1530-9290.2009.00116.x

RVO. (n.d.-a). *Energy Service Company (ESCo)*. Retrieved August 31, 2021, from https://www.rvo.nl/initiatieven/financieringsvoorbeelden/energy-service-company-esco

RVO. (n.d.-b). *MKB-Toets*.

Saunders, B., Sim, J., Kingstone, T., Baker, S., Waterfield, J., Bartlam, B., Burroughs, H., & Jinks, C. (2018). Saturation in qualitative research: exploring its conceptualization and operationalization. *Quality and Quantity*, *52*(4), 1893–1907. https://doi.org/10.1007/s11135-017-0574-8

Schot, J., & Geels, F. W. (2008). Strategic niche management and sustainable innovation journeys: Theory, findings, research agenda, and policy. *Technology Analysis and Strategic Management*, *20*(5), 537–554. https://doi.org/10.1080/09537320802292651

Sengers, F., Wieczorek, A. J., & Raven, R. (2019). Experimenting for sustainability transitions: A systematic literature review. *Technological Forecasting and Social Change*, *145*, 153–164. https://doi.org/10.1016/j.techfore.2016.08.031

Seto, K. C., Güneralp, B., & Hutyra, L. R. (2012). Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. *Proceedings of the National Academy of Sciences of the United States of America*, *109*(40), 16083–16088. https://doi.org/10.1073/pnas.1211658109

Smith, A., & Raven, R. (2012). What is protective space? Reconsidering niches in transitions to sustainability. *Research Policy*, *41*(6), 1025–1036. https://doi.org/10.1016/j.respol.2011.12.012

Steenhuis, J., & De Bruijn, E. (2004). Building theories from case study research: the progressive case study. *Journal of Chemical Information and Modeling*, *53*(9), 1689–1699.

Stichting Pioneering. (2020). *Circulair bouwen in Stroinkslanden: geen 'eilandjes '!*

Superlocal. (n.d.). *Expogebouw*. Retrieved July 25, 2021, from https://www.superlocal.eu/superlocal/expogebouw/

Superlocal. (2017). *SUPERLOCAL Play publicatie*.

Superlocal. (2018). *Evaluatierapport Superlocal (fase 1: Expo-gebouw)*.

Taanman, M. (2014). *Looking for Transitions*. In *Drift: Vol. PhD Thesis.*

Termeer, C. J. A. M., Dewulf, A., & Biesbroek, G. R. (2017). Transformational change: governance interventions for climate change adaptation from a continuous change perspective. *Journal of Environmental Planning and Management*, *60*(4), 558–576.

https://doi.org/10.1080/09640568.2016.1168288
UN. (2019). World Urbanization Prospects 2018: Highlights. In *World Urbanization Prospects 2018: Highlights*. https://doi.org/10.18356/6255ead2-en
van Bueren, E., & Broekhans, B. (2014). Individual Projects as Portals for Mainstreaming Niche Innovations. In *Constructing Green* (Issue September). https://doi.org/10.7551/mitpress/9780262019415.003.0007
van de Kerkhof, M., & Wieczorek, A. (2005). Learning and stakeholder participation in transition processes towards sustainability: Methodological considerations. *Technological Forecasting and Social Change*, *72*(6 SPEC. ISS.), 733–747. https://doi.org/10.1016/j.techfore.2004.10.002
Van den Bosch, S. (2010). Transition Experiments. In *Drift: Vol. PhD Thesis*.
Van den Bosch, S., & Rotmans, J. (2008). Deepening , Broadening and Scaling up. A framework for steering transition experiments. *Knowledge Centre for Sustainable System Innovations and Transitions (KCT)*, 3–64.
van den Bosch, S., & Taanman, M. (2006). How innovation impacts society: Patterns and mechanisms through which innovation projects contribute to transitions. *Paper Presented at Innovation Pressure Conference*, *March 2006*.
van der Helm, R. (2009). The vision phenomenon: Towards a theoretical underpinning of visions of the future and the process of envisioning. *Futures*, *41*(2), 96–104. https://doi.org/10.1016/j.futures.2008.07.036
Van Mierlo, B., Arkesteijn, M., & Leeuwis, C. (2010). Enhancing the reflexivity of system innovation projects with system analyses. *American Journal of Evaluation*, *31*(2), 143–161. https://doi.org/10.1177/1098214010366046
van Mierlo, B., & Beers, P. (2020). Understanding and governing learning in sustainability transitions: A review. *Environmental Innovation and Societal Transitions*, *34*(August 2018), 255–269. https://doi.org/10.1016/j.eist.2018.08.002
Van Mierlo, B., Regeer, B., van Amstel, M., Arkesteijn, M., Beekman, V., Bunders, J., de Cock Buning, T., Elzen, B., Hoes, A., & Leeuwis, C. (2010). *Reflexive monitoring in action. A guide for monitoring system innovation projects*. Communication and Innovation Studies, WUR.
von Wirth, T., Fuenfschilling, L., Frantzeskaki, N., & Coenen, L. (2019). Impacts of urban living labs on sustainability transitions: mechanisms and strategies for systemic change through experimentation. *European Planning Studies*, *27*(2), 229–257. https://doi.org/10.1080/09654313.2018.1504895
Wamelink, H., Geraedts, R., Hobma, F., Lousberg, L., & De Jong, P. (2010). *Inleiding Bouwmanagement* (p. 433).
WEF. (2016). *Shaping the future of construction – a breakthrough in mindset and technology, World Economic Forum: Vol. null*.
Williams, J. (2019). Circular cities. *Urban Studies*, *56*(13), 2746–2762. https://doi.org/10.1177/0042098018806133
Winch, G. (1998). Zephyrs of creative destruction: understanding the management of innovation in construction. *Building Research & Information*, *26*(5), 268–279.
Wittmayer, J. M., Avelino, F., van Steenbergen, F., & Loorbach, D. (2017). Actor roles in transition: Insights from sociological perspectives. *Environmental Innovation and Societal Transitions*, *24*, 45–56. https://doi.org/10.1016/j.eist.2016.10.003
Woods, M., Macklin, R., & Lewis, G. K. (2016). Researcher reflexivity: exploring the impacts of CAQDAS use. *International Journal of Social Research Methodology*, *19*(4), 385–403. https://doi.org/10.1080/13645579.2015.1023964
Yin, R. K. (1994). Discovering the future of the case study. Method in evaluation research. *Evaluation Practice*, *15*(3), 283–290.
Yin, R. K. (2009). *Case study research: Design and methods* (Vol. 5). sage.
Yin, R. K. (2013). Validity and generalization in future case study evaluations. *Evaluation*, *19*(3), 321–332. https://doi.org/10.1177/1356389013497081

v

Appendix A. Circular building practices

Overview of circular building practices and their corresponding circular business model type. These are referred to throughout the research project. Different circular building practices according to their life cycle stage (Adams et al., 2017), connected with the circular business model strategy (Bocken et al., 2016).

LIFE CYCLE STAGE	CE ASPECT	BUSINESS MODEL
DESIGN	Design for Disassembly (DfD)	Slowing
	Design for adaptability and flexibility	Slowing
	Design for standardisation	Slowing
	Design out waste	Narrowing
	Specify reclaimed materials	Closing
	Specify recycled materials	Closing
MANUFACTURE AND SUPPLY	Eco-design principles	Narrowing
	Use less materials/optimise material use	Narrowing
	Use less hazardous materials	Narrowing
	Increase the lifespan	Slowing
	Design for product disassembly	Slowing
	Design for product standardisation	Slowing/closing
	Use secondary materials	Closing
	Take-back schemes	Closing
	Reverse logistics	Closing
CONSTRUCTION	Minimise waste	Narrowing
	Procure reused materials	Closing
	Procure recycled materials	Closing
	Off-site construction	Narrowing
IN USE AND REFURBISHMENT	Minimise waste	Narrowing
	Minimal maintenance	Narrowing
	Easy repair and upgrade	Slowing
	Adaptability	Slowing
	Flexibility	Slowing
END OF LIFE	Deconstruction	Closing
	Selective demolition	Closing
	Reuse of products and components	Closing
	Closed-loop recycling	Closing
	Open-loop recycling	Closing

v

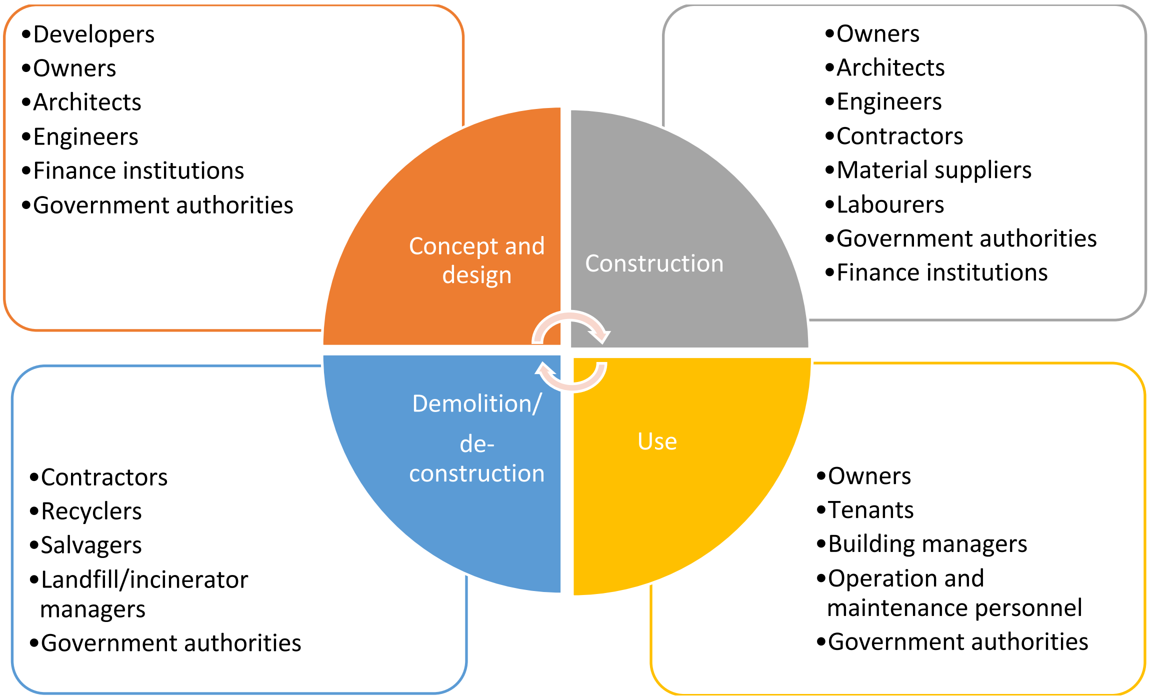
Appendix B. Different learning traditions

Learning traditions from four different theoretical backgrounds which are linked to sustainability transitions (van Mierlo & Beers, 2020). Their applicability and/or added value for this research is provided in the right column. Ultimately, organisational learning is used as a scope for learning in this thesis.

Literature strand	**Description**	**Relevance/added value for this research**
Collaborative learning (educational sciences)	Focuses on individual (cognitive perspective) and group (constructivist perspective) learning processes. Communication in groups is key, and often relates to teacher-learner interaction.	<u>Less relevant</u>, not often linked to transition studies. Transition experiments can be seen as collaborative learning environment.
Organisational learning (management studies)	Is often referred from the multiple loops of learning (Argyris & Schon, 1974), indicating that learning happens when individuals experience a mismatch between expected/desired and actual actions and adapt to this situation through reflection. This can result in single- or double/triple-loop learning. Effective learning is hampered by (1) limited cognitive abilities, (2) defensive attitudes and reasoning and (3) lack of accurate feedback.	<u>Highly relevant</u>, single-loop and double-loop learning (or superficial and deep learning) can be helpful to understand how organisation learn to change their daily practices. Furthermore, conditions that support or hamper deep learning can be useful (see chapter 2.7.2)
Social learning (natural resource management)	Social learning emphasizes the integration of knowledge from different perspectives and occurs when heterogeneous actors share their knowledge in an interactive process. Goal is to produce new knowledge, trust and joint-action (Pahl-Wostl, 2006). Focus on actor diversity, open communication, room for change and facilitation, has similarities with transition literature.	<u>Relevant</u>, distinction between *learning process* (emergence of trust, new social networks) and *learning outcome* (new insights or innovative solutions) seem applicable for analysing transition experiments.
Interactive learning (innovation studies)	Takes incumbent actors as a focus point, 'learning-by-interacting' is key: a process of increasing knowledge by integrating codified (can be written down) and tacit knowledge (gained from personal experience). Learning is a process of forgetting and unlearning to change daily practices.	<u>Less relevant</u>, as it starts the analysis on the regime level.

v

Appendix C. Overview of construction stakeholders



The different stakeholders that are potentially involved per stage in the building development process as stated by (Van Bueren, 2009)

v

Appendix D. Long-list of circular building experiments

#	Project name	Initiator	Project partners	Goal	Scope	Buildings	Activities (what does it include?)	Duration	Type of experiment (Sengers et al., 2019)	Building-level?	Evaluation possible?	Link
1	Proeftuin Circulariteit deltaWonen (Zwolle)	Housing corporation	Consortium	Build a circular building without waste. Use learnings for future buildings	Building-level	1	Experimenting, testing plans and applying innovative ideas on building level	2020 - 09/2021	Transition experiment	Yes	No	link
2	Proeftuin Circulaire Bouw 'De Kleine Aarde' Boxtel	Woonstichting JOOST (lead)	FAAM Architects, Heijmans Woningbouw en Waterschap De Dommel	Knowledge enhancement on circular and biobased building	22 social housing appartments	1	Developing an open innovation system, in which business, academia and government can research, test and learn on three pillars: (1) Develop bio-based and renewable materials for building sector, (2)Design for reuse, (3) Design circular methods for waste, water treatment and sewage	2019 - unknown	BSTE	Yes	No	link
3	Drenthe Woont Circulair - De Proeftuin	8 housing corporations		Developing an affordable, scalable circular dwelling for social housing	6 projects: 40 demolish and 70 new-built dwellings	110	Collective testing of circular innovations, collaboration forms and business models. Create space for experimenting.	01/2018 - ongoing	Transition experiment	Yes	No	link
4	De Woonplaats Assinklanden	Housing corporation (de Woonplaats)	Consortium	Pilot to experiment with circular construction	7 newly built dwellings	7	Pioneering, to experiment with circular building techniques (biobased and renewable) based on equality and trust.	09/2017 - 2019	Transition experiment	Yes	Yes	link
5	Novito Almelo	Project developer		Develop 14 modular carbon neutral buildings	Building-level (14 buildings)	14	Novito develops prefab and modular structures. Does not seem to be very experimental, though learning about dismountability is central	11/2020 - 08/2021	Transition experiment	Yes	No	link
6	Het Hof van Cartesius (Utrecht)	Cooperation of individuals		Physical site to experiment with circular economy activities, of which circular building is one branch	Circular office buildings		Creative, sustainable entrepeneurs develop their own buildings.	2017 - 12/2021	Grassroots experiment	Yes	Yes	link

v

7	Living Lab 040 (Eindhoven)	Initiated by two individuals, supported by municipality, province TU/e and developer (Amvest)		Experiment with affordable circular dwellings	119 compact and affordable dwellings	119	Urban Living Lab of 15 years in which experimentation of circular building techniques (e.g. modular) is key. Users (residents) are also included in experiment	02/2021 - ongoing	BSTE	No	No	link
8	Ecodorp Boekel	Cooperation of individuals		Eco-village that supports all SDGs	Neighbor hood level	30	Climate adaptive and positive village, off-grid with own energy supply and water treatment.	2019 - 12/2021	Grassroots experiment	No	Yes	link
9	SUPERLOCAL (Kerkrade)	HEEMwonen (housing corporation) & Municipality of Kerkrade	Gemeente Kerkrade, IBA Parkstad, Dusseldorp (breaker), Volker Wessels (developer), Maurer United Architects	Transformation of three high-rise flats to 125 circular social housing. First three circular pilot dwellings realized to experiment with reusing local resources	Building-level (3 dwellings)	3	Three circular trial home (*proefwoningen*) to find out if it is possible to realize dwellings from 90% reused materials out of the area. *Slow-less-local-*principle. Eventually 125 social dwellings from local reused materials	2017 - 12/2019	Transition experiment	Yes	Yes	link
c	De Loskade (Groningen)	Van Wijnen Groep (developer)	29 official partners	Pop-up neighborhood (until 2030) in which experiments for circular construction innovations are facilitated.	Building-level. (14 dwellings, 32 studio's)	14	Experimenting with remountable housing concept and rents these as short-stay appartments. Residents contribute to research (LL environment)	2019-2030	BSTE	Yes	Yes	link
11	Olstergaard, Olst-Wijhe	Municipality of Olst Wijhe	Future residents, water board and local community	Experimenting with how a municipality can procure circular building development	Neighbor hood		Urban experiment to test a new building process by including future residents (participation) early in the process. They can search for architect etc.	06/2018 - ongoing	Transition experiment	No	Possibly	link
12	PuraVerde	Aannemersbedrijf Jongen	Gemeente Venlo, C2C ExpoLAB	Pura Verde ("green throughout"), based on circular cradle-to-cradle principles. 50 private sector dwellings	Neighbor hood-level	50	Municipality did not allow new housing projects unless it was innovative, sustainable and distinguishable.	2013 - 2020	Sustainability experiment	No	Yes	link

v

13	BuildinG Proeftuin	BuildinG	Economic Board Groningen, Hogeschool Groningen, TNO, Bouwend Nederland	Independent knowledge and innovation platform for future resilient construction in Noord Nederland. Site for experimentation of materials, constructions and prototypes	Building level		Testing hall for new innovations. Heijmans, PolyCiviel and Straw Blocks Systems make use of their area to test innovative products.	2019 - ongoing	Niche experiment	Yes	No	link
14	Circl	ABN Amro	TU Delft, BAM, Cie Architects	Realizing a building which is energy efficient and demountable according to circular principles	Building level	1	Circular building consisting of wooden, demountable supporting structure and reused components. Also functions during use-phase as a debate center about circular economy.	2014-2017	Sustainability experiment	Yes	Yes	link
15	Schoonschip	Cooperation of individuals	space&matter, Waterloft, Metabolic	Sustainable floating village in Amsterdam North.	Neighbor hood	46	Community of floating villas in Amsterdam North. Off-grid, self sufficient energy system, waste water treatment with resource recovery and circular building practices.	2008-2020	Grassroots experiment	No	Yes	link
16	Groene Toren Living Lab (Amsterdam)	AMS Institute & Bajes Kwartier Ontwikkeling C.V.	AM, AT Captial en Cairn, WUR, TU Delft	Testing and applying new innovation on sustainable area development	Area developm ent	1350	At the previous Bijlmerbajes area 1350 new residences will be developed. One of the 6 remaining towers will be reused as a living lab in which innovations will be tested on 7 pillars, of which circular material use is one.	01/2021 - ongoing	BSTE	No	No	link
17	Glaskring Eindhoven	Woonbedrijf (housing corporation)	A. Van Liempd (demolisher), Inbo Architects, 12N Urban Matters, VolkerWessels and Baetsen, 6 residents	Circular demolishment and construction of 20 social housing dwellings	Building-level (20 buildings)	20	Citizens included in experiment.	2019- Failed	BSTE	Yes	No	link
18	Circulaire Bouw in BlueCity	BAM & BlueCity	Not applicable	BlueCity and BAM join forces to realize circular innovation in the entire construction chain. BAM facilitates circular	Tranform ation, building-level	1	Gaining knowledge about circular transformation with the goal to disseminate the lessons learned.	2019-2021	Transition experiment	Yes	Yes	link

v

				transformation of the former Tropicana building								
19	Active Reuse House (Concept House Village)	DoepelStrijkers (architect)	DoepelStrijkers (architect), DWA (installatieadvies), IMD (constructie), Studio Bouwhaven (bouwkosten) en Waal (engineering en realisatie).	Demo-building to understand the principles of reuse for circular building practices. Experimental site to test with local stakeholders from the construction sector.	Building level (3 dwellings)	3	New sort of collaboration based on testing and seeking ways to market the practices in the future. Design was in 2015, but unclear if it is developed.	2015- unknown	BSTE	Yes	Yes	link
20	Brainport Smart District (Helmond)	Brainport Smart Distriction Foundation	Consists of: Municipality Helmond, Province Noord-Brabant, Brainport Development, TU/E, Tilburg University	Brainport Smart District wants to become the smartest neighbourhood on earth.	Neighbou rhood-level	1500	Experiments will be facilitated on circular building practices, health, mobility, data and energy. Circular neighbourhood 'ReGen Villages' focuses on sustainable architecture, circular material choice and infra design, local food chain, circular waste management.	2018 - current	Transition experiment	No	No	link
21	De Vondeltuin	DOOR Architecten, De Nijs, iCell, and BMN	Gemeente Amsterdam, Copper8	Tender of the municipality of Amsterdam to develop a circular restaurant/bar. Part of city-wide program 'Amsterdam Circular: Learning by Doing'	Building-level	1	Developing a restaurant based on reusable and biobased materials. "It was really learning by doing"	2019- 07-2020	Transition experiment	Yes	Yes	link
22	gemeentehuis Brummen	Municipality of Brummen	BAM, RAU and Turntoo	First building developed as a resource depot. Municipality was looking for a semi-permanent housing (min. 20 years)	Building-level	1	During design-process have RAU (architect), BAM (contractor), Turntoo and the municipality thought about how the building could be demounted after use period. After-use, the materials will be taken back by the suppliers and producers.	2011-2013	Sustainability experiment	Yes	Yes	link
23	M'DAM	BMB Ontwikkeling	Finch Buildings (prefab), De Groot Vroomshoop (production facility)	62 apartments consisting of prefab wooden modules which are remountable	Building-level (62 apartmen ts)	62	Wooden modules are prefabricated industrially and demountable designed. Building period will take 5 months.	2021	Sustainability experiment	Yes	No	link

v

24	PIT Lab (Amsterdam)	DOOR Architecten, Eigen Haard (housing corporation), Pieters Bouwtechniek, Robuflex, CBOX (containers)		Experiment for circular business park. A little community of red sea containers near Sloterdijk station, Amsterdam.	Building-level	1	Circular building made of reused, reusable and bio-based materials Basis is a system of sea containers. Developed a new collaboration form with founding fathers and lessons learned will be used in other projects.	2017	Sustainability experiment	Yes	Yes	link
25	WikiHouse	Residents, Municipality of Almere and Woningbouw Atelier		Affordable, digitally produced wooden timber frame, which residents can design and assemble themselves.	Building-level (14 buildings)	14	Future residents design WikiHouse digitally which will be milled by a computer controlled saw. All the separate parts can be assembled and re-assembled by the residents. Timber-construction, low income self-build project.	2018	Grassroots experiment	Yes	Yes	link
26	RWS Wolphaartsdijk	RWS, R&B Wonen, Marsaki, Impuls		Turn 10 old dwellings into 6 circular ones. All materials need to be reusable in 50 years.	Building-level (6 dwellings)	6	Seems small-scale to learn and take lessons from. Experiment to build circular buildings between four housing corporations. Want to create a material bank. Not much further information available.	2020 - unclear	Sustainability experiment	Yes	No	link
27	GTB Lab Heerlen	Stichting GTB Lab	BA Parkstad Stichting GTB Lab Zuyd Hogeschool Avantis BAMB Stadsregio Parkstad Limburg Gemeente Heerlen Rabobank	GTB Lab is a lab for circular construction. It researches future construction practices and how products can be reused after demolishment.	Building level	1	First phase will start in the summer of 2021.	2021- unclear	Niche experiment	Yes	No	link
28	De Warren	Collective of individuals	cooperative	Want to develop a toolbox for circular construction for cooperative living. In this way, this knowledge is made available to future groups who cherish the same dream of living.	Building level	36	Timber building that should connect and inspire, climate adaptive design with a focus on nature. Adaptable building.	2021 - current	Grassroots experiment	Yes	No	link
29	Green House Utrecht	Consortium of R-creators	R-creators, cepezed, Rijksvastgoedbedrijf	Circular pavilion that can be disassembled after 15 years, should inspire during use	Building level	1	Modular building, reused facade, circular exploitation	2016-2018	Transition experiment	Yes	Yes	link

v

Appendix E. Interview Topic List

1. Introductie (5-10 min)

Introductie Sietse

a. Achtergrond SGPL, master IE, persoonlijke interesses komen samen in circulair bouwen: ruimtelijke ontwikkeling en circulaire economie. Samenwerking met Over Morgen.
b. Onderwerp thesis: leren van circulaire bouwexperimenten

Formaliteit

c. Vanwege de AVG dien ik toestemming te vragen of ik dit onderzoek mag opnemen. Gaat u daarmee akkoord? Opname zal gebruikt worden om het interview te transcriberen.
d. Kan ik uw persoonlijke naam en functie gebruiken of wenst u liever anoniem meegenomen te worden in het onderzoek?
e. Wilt u het transcript controleren zodra die gereed is?

<u>Start opname</u>

Introductie respondent

f. Kunt u zichzelf voorstellen? Persoonlijk, functie en bedrijf.
g. Hoe houdt uw bedrijf zich bezig met circulair bouwen?
h. Wat waren eerdere ervaringen op het gebied van circulair bouwen? Welke projecten/activiteiten?
    (1) *<Voeg hier nav Google search evt eerdere projecten toe met circulaire ambities>*

2. Het project (5 min)

a. Wat was de aanleiding voor het project en wat was voor jullie een reden om mee te doen? (*interest*)
b. Wat was uw rol in het project? (*resources*)
c. Hoe zou u het doel van het project omschrijven? (*experiment of niet?*)

3. Het circulair bouw-ontwikkelproces (20 min)

a. Hoe zag het ontwikkelproces eruit? (*Ga door op iedere fase, zie hieronder*)

Initiatiefase

b. Wie waren betrokken in de initiatiefase? Wie vervulde welke rol?
c. Welke activiteiten vonden plaats in de initiatiefase?
d. Hoe verliep de samenwerking? Wat was belangrijk voor de samenwerking?
    (1) In welke mate speelde openheid (transparantie) en vertrouwen een rol?
    (2) Zo ja, hoe werd er voor transparantie gezorgd? (*rapporten, openbare resultaten etc*.)
e. In hoeverre waren er andere partijen betrokken vanaf het begin?
    (1) Hoe beïnvloedde dit het proces? (*verbetering van de inhoud? Nieuwe mogelijkheden?*)
f. Wat waren de belangrijkste resultaten van deze fase?

Ontwerpfase

a. Wie waren er betrokken? (*nieuwe spelers die normaal niet in het ontwerpproces zitten?*)
b. Hoe zag het ontwerptraject eruit?
    (1) Jullie komen samen, wordt er dan een probleem gedefinieerd?
    (2) Hoe werd een beoogd circulair ontwerp opgesteld? (*Visievorming?*) Wie leidde dit proces? (*visueel gemaakt dmv images? Doelgericht?*)

v

(3) In hoeverre werd monitoring/reflectie en evaluatie meegenomen in het gehele proces?
(4) In hoeverre werd impact gemeten?

c. In hoeverre was er sprake van gezamenlijk leren? Was er van tevoren een leeragenda vastgesteld?
d. Wat waren de belangrijkste lessen/resultaten in de ontwerpfase?

Constructiefase

a. Wie waren er betrokken in de constructiefase?
b. Werd er gezamenlijk gereflecteerd/geëvalueerd op het proces gedurende de constructiefase? (*wie bij betrokken*)
c. Zijn er interpretaties vanuit het bouwteam over hoe het probleem moest worden aangepakt veranderd gedurende het project?
d. Wat waren de belangrijkste lessen/resultaten in de constructiefase?

Gebruiksfase/EoL-fase

a. In hoeverre zijn jullie of andere partijen nog betrokken in de gebruiksfase of EoL fase van het gebouw?

Algemeen

b. In hoeverre was het ontwerp- en ontwikkelproces anders dan een traditioneel bouwproces?
c. Via welke processen heb jij geleerd in dit experiment? (*ook informeel? Aan het bureau*)
d. In hoeverre was er spraken van gezamenlijk leren? Veranderde dit je perspectief?

4. Leren/geleerde lessen (20 min)

Technologisch

1. Hoe stonden de CE-principes centraal in het ontwerp van het gebouw?
2. Hoe heeft het experiment tot nieuwe inzichten geleid op het gebied van circulair bouwen? (*bouwtechnieken, hergebruik, ontwerp etc.*) Heeft dit zich door vertaald in nieuwe concepten?
3. Hoe worden deze technieken/concepten verder toegepast binnen het bedrijf?
4. Hoe wordt deze kennis verspreid binnen de sector? (*link met andere experimenten?*)

Financiële plaatje/Verdienmodel

5. Hoe zag het verdienmodel eruit en werden er nieuwe verdienmodellen verkend en getest?
6. In hoeverre speelde investeringskosten en financiering een rol in het realiseren van de CE-ambities?
7. Hoe zijn de lessen geïntegreerd in het bedrijf/vervolgprojecten? (*integrating*)
8. Hoe transparant zijn jullie met het delen van deze kennis? *(broadening/scaling*)

Cultureel
a. Bedrijf

9. In hoeverre heeft het experiment uw kijk op duurzaamheid/de circulaire economie beïnvloed? En binnen de bedrijfscultuur? (*waarden*)
    a. Heeft zich daar een verandering voortgedaan?
10. Hoe heeft het project uw referentiekader beïnvloed? *Daarmee bedoel ik of uw oorspronkelijke invalshoek (als architect, bouwer of opdrachtgever) is veranderd in het experiment?*

v

11. In hoeverre heeft het experiment het bedrijfsbeleid (beleid en regels) met betrekking tot circulair bouwen beïnvloed? (*normen*) *(zijn er nieuwe processen, beleid, of methodes opgesteld nav het experiment?)*
12. In hoeverre hadden jullie alle kennis en kunde in pacht om de CE-ambities van het project te realiseren?
    a. Waar werkte jullie organisatie goed en waar minder?

b. Sector

13. Welke lessen zijn er opgedaan met betrekking tot de samenwerking in het experiment?
14. In hoeverre is dit meegenomen in vervolgopdrachten?
15. Hoe werd kennis gedeeld? (*broadening, scaling)*
    a. Welke kennis wordt gedeeld?
16. In hoeverre denk je dat de transitie naar een circulaire bouwsector gerealiseerd zal worden?
    a. Welke factoren kunnen dat bevorderen of belemmeren? (*eigenschappen sector: competitief, complex, conservatief)*

Wet- en regelgeving

17. Waar werkte wet- en regelgeving goed voor het realiseren van de CE-ambities en waar minder?
18. In hoeverre speelden publieke partijen een rol in het stimuleren of realiseren van de CE-ambities van het project? (*aanbesteding, financiële prikkels, gemeentelijke steun*)

Milieu/duurzaamheid

19. Hoe zijn de milieueffecten van nieuwe CE-toepassingen in het experiment gemeten? (*PSS, nieuwe constructiemethoden, selective demolition etc.)*
20. Werd daar gedurende het experiment op gereflecteerd? *(stond dit centraal?)*

5. Afsluiting

a. Wat zou je bij een volgend experiment anders doen? Hoe zou je dat doen?
b. Wat is er nodig om het experiment op te schalen?
c. Zijn er nog andere mensen die ik over dit experiment moet spreken?
d. Wilt u zelf nog iets kwijt?

v

Appendix F. Overview of the cross-case analysis

	CASE	THE MASTERCLASS	THE LABORATORY	THE CATALYST	THE CONSULTANT
CONTEXT	Type of development	Circular deconstruction/newbuild	Circular deconstruction/newbuild	Newbuild	Newbuild
	Function	Social housing (private)	Social housing (private)	Restaurant/bar (public, Central gov. real estate agency)	Restaurant/bar (public, municipality)
	Budget	€600.000	€4.700.000	€1.000.000	€500.000
	Number of buildings; size	7; 100m2	3; 74m2, 64m2, 40m2	1; 680m2	1; 120m2
	Tender process	Via masterclass, tender based on vision of housing corporation	Qualitative tender focused on finding a deconstruction and a construction company with a clear vision/ambition	DBMFO tender	Qualitative tender focused on architects with CE experience who select a construction team themselves
	Collaboration form	*Consortium*, collaboration contract based on (1) consent, (2) open communication, (3) system of early warnings, (4) stepped dispute resolution	*Construction team*, including housing corporation (client), deconstruction company, construction company, architect and structural engineer.	Consortium (R-creators) DBMFO, (operating company, developer and construction company) + Architect and structural engineer.	Construction team, but architect informally in the lead
	Circular practices (based on Appendix A)	*EoL*: Deconstruction; Reuse of products and components *Design*: DfD *Use:* Easy repair and adaptability	*EoL*: Deconstruction; selective demolition; Reuse of products and components; Closed-loop recycling *Design*: Design out waste; Design for standardisation	*EoL*: Reuse of products and components *Design*: DfD; Design for adaptability and flexibility *Use*: Easy repair and upgrade; adaptability; flexibility	*EoL*: Reuse of products and components
WHO LEARNS	Core team composition (design until use-phase)	*Initiator*: housing corporation *Advisors*: architect, structural engineer *Builders*: two construction companies, installation engineer, maintenance company and material supplier	*Initiator*: housing corporation *Advisors*: architect, structural engineer *Builders*: deconstruction company, construction company *Controller* (!): municipality Environ impact: municipality New roles	*Initiator*: Developer, Operating company *Builder*: Construction company *Advisor*: architect, structural engineer and environmental consultant (tool)	*Initiator*: Municipality, operator *Advisors*: Architect, installations consultancy, structural engineer, environmental consultancy (tool) *Builders*: Construction company
	Size of companies	Mostly SME's Two large-sized: Ter Steege (construction company) and Loohuis (installations)	Micro: architect Medium-sized: housing corporation Large-sized: deconstruction and construction company	Medium: advisors Large-sized: builders (Strukton, Ballast) and initiators (Central gov Real Estate Agency)	Small/Medium: Advisors Large-sized: Initiator (municipality) and construction company (De Nijs)

v

	Circular expertise	Architect in the lead	Deconstruction company in the lead, central actor	Developer, central actor	Architect in the lead
	Missing actors	*Builders*: large scale construction companies, traditional companies and their supply chains partners *Controllers:* Governmental controllers to experience how norms and regulations hinder CE practices.	*Builders*: Supply chain partners, keep them informed and potentially involved.	*Builders*: Suppliers *Controllers*: Municipality (spatial planning department)	-
	Who should learn (no CE expertise)	Builders and housing corporation	Housing corporation (not interviewed), structural engineer (not interviewed), architect, construction company, municipality Supply chain partners: concrete supplier (not interviewed)	Construction company, organization of the operating company and organization of the developing company (even though agents have CE knowledge), Central Gov Real Estate Agency Suppliers (light and interior) Structural engineer.	Construction company (large), municipality
LEARNS HOW	Learning activities	**Group learning:** Masterclass, deliberation via visioning and reflection. **Individual learning**: research, rethink	**Group learning**: Visioning, testing and monitoring/evaluation	Visioning with supply chain partners, guiding and monitoring. Open learning environment (use-phase)	**Group learning**; Involving external CE expertise in initiation (procurement) and design (tool) phase
	Learning phase	Initiation and design	Design and construction	Design and use	Initiation and design
	Conditions (group)	Trust and transparency (open communication, incl. budget) via contract based on consent	Agree on risks and responsibilities, clear exit strategy, monitoring and involving supply chain partners	Monitoring of impact in design and construction, (new collaboration form), Select suppliers on goals	- Integrate important stakeholders early on in design - Transparency in approach
	Conditions (Individual)	Personal goal/ambition, time, **commitment**, (ensuring continuity)	Willingness	Willingness, commitment and time, flexibility of designers	- Commitment (essential)
	Conditions (initiator)	Clear future vision, functional requirements, realistic budget	Clear project leader	Circular catalyst, realistic budget, sufficient lead time	- Clear future vision (limiting complexity) - Realistic budget - Devote enough time
	Missing process features	- Clear future vision; - Clear project leader; Monitoring in design-phase (documentation, follow-up)	-	- Plenary evaluation; - Monitor from the start; - Transparent project environment (open budget and approach) - Discuss how lessons learned will be institutionalized (large companies)	- Plenary evaluation at the end - Reflection/evaluation moments per phase - Commitment - Realistic budget

v

LEARNS WHAT	Double-loop learnings	**Economic**: Initiator: procurement and new business/ownership models Construction company 2: new business models, topping as a service **Technical**: Construction company 1: construction for disassembly (technical)	**Technical**: Deconstruction company: New construction techniques Construction company: constructing for disassembly (two large-scale companies)	**Economic**: Suppliers: Circular business model innovation **Governmental**: Client: Procurement (how to for a CE)	**Governmental:** Client: Procurement (start with ambition and procure qualitatively not on price, finetune the question)
	Single-loop learnings	Process-related	Various	Process-related	Process-related

	CASE	THE MASTERCLASS	THE LABORATORY	THE CATALYST	THE CONSULTANT
TO WHAT EFFECT	Deepening (knowledge dissemination)	Role of external stakeholder (innovation platform), locally (via masterclass), regionally (via CoP province), nationally (ministry)	Role of external stakeholder (IBA Parkstad) for sector-wide knowledge sharing. Parkstad Limburg (collaboration between 7 municipalities) for political leverage (law- and regulations)	Living lab during use-phase, *right-to copy,* open learning environment via presentations etc.	Evaluation document; Transition programme of municipality only reflected procurement procedure.
	Scaling up	Lessons learned are shared Informally for SME's;	Micro-sized: informally share knowledge Large-sized: Workgroup CE Through a series of experiments (broadening) technical innovations can mature which fit the construction process and be scaled-up.	Large builders: lessons difficult to scale due to: 1. context-specificness 2. No internal capacity/structure to integrate lessons Medium-sized: Architect, structural engineer: Informally	Municipality (large-sized): 1. No internal resources made available to integrate lessons learned. Construction company (large-sized): even though their employees are not trained to function in CE projects, they point towards limited market demand to think about a new learning structure. Architect (small-sized): informally
	Scaling up barrier	- Overheated construction market, no time for reflection - For housing corporation: Cost controllers cannot model new business models (PaaS).	Overheated construction sector (architect).	- Cost controllers (banks) for PaaS - Calculate with residual value and social impact of circular buildings - No follow-up projects - High demand in construction sector (developer)	- No demand, so no necessity to change (construction company)
	Triple-loop learning	Bring all construction employees to the site to learn about circular construction (consulting construction company)	Set-up CE experiments in every department of the company, to create an expert-network.	-	-