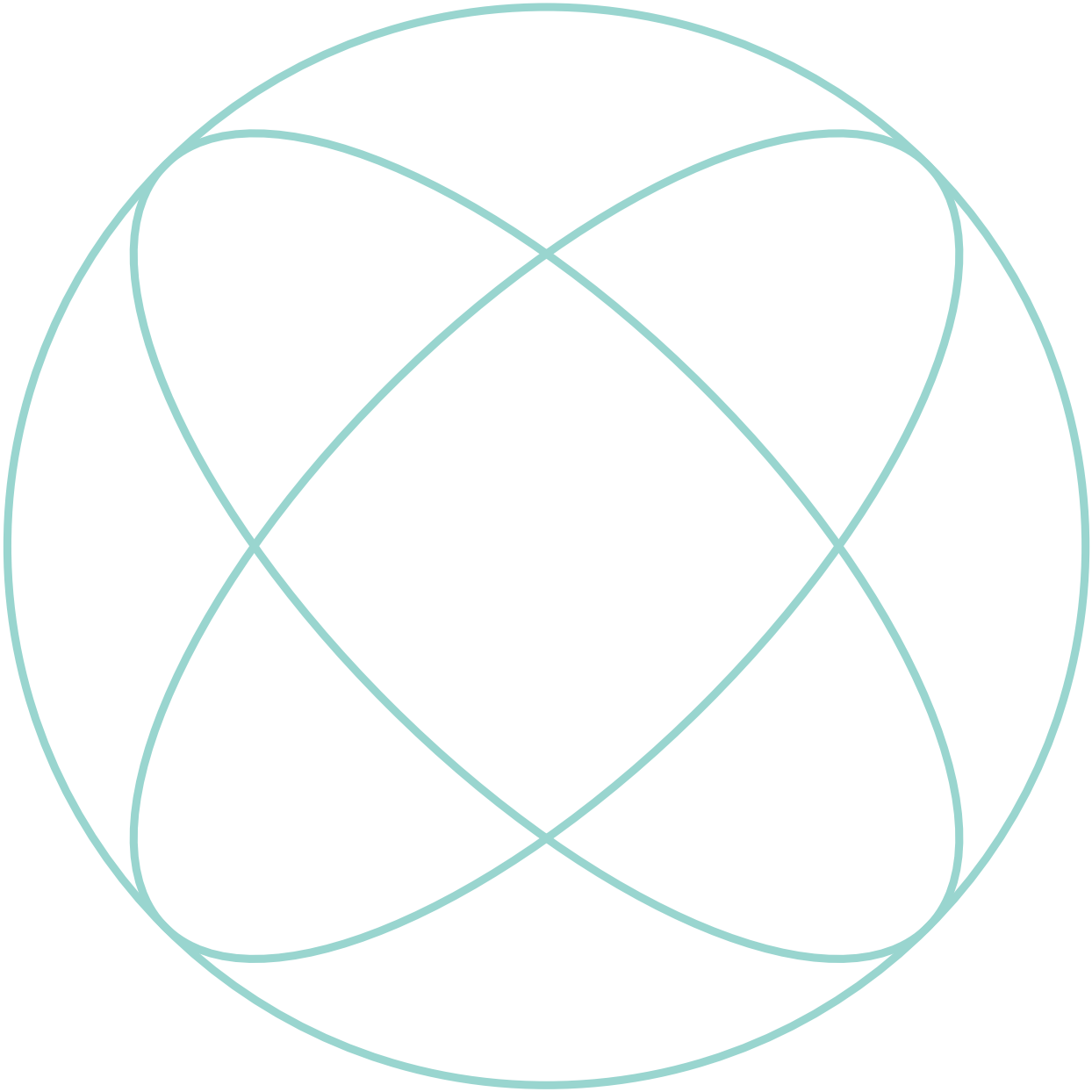

Real Estate Development in a Circular Built Environment

A research on what the current and future role of the real estate development process is in delivering circularity in the built environment

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August 28 2020

Graduation Thesis

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Preface

Over the course of my studies, I have developed a passion for sustainability and real estate development. The basis of this research originally stemmed from my frustration about why the built environment is not implementing the circular economy on a large scale. Soon, however, I was presented with the fact that the built environment is more complicated than anticipated, and that realising radical change is going to prove quite complex.

Therefore, I decided to conduct research on circularity in the built environment. After discovering that the real estate development process was absent in the literature, the purpose of this thesis became apparent: Investigating the current and future role of the real estate development process in delivering circularity in the built environment. With this thesis I aspire to present practitioners of real estate development an overview of current and future practice, and how their role might change in the future.

However, I would not been able to deliver the current product that is presented to you, were it not for four significant contributors: Firstly, I would like to state my thanks to my first mentor, Professor Doctor Paul Chan, who has been a major source of inspiration, motivation and stress relief. Secondly, I would like to thank my second mentor, Tuuli Jylhä, for her advice, guidance and no-nonsense mentality. Thirdly, I would like to thank my girlfriend, Sarah, for her unconditional love and significant contribution to the structure and readability of this thesis. Fourthly, I want to thank my parents for their mountainous support, love and understanding throughout my studies.

Abstract

The built environment is a major polluter of the environment and a significant contributor to carbon emissions. It is responsible for more than half of the world's raw resource extraction. After a review of 337 previous studies on circularity in the built environment, 40 have been identified useful for the study. The literature is organised in five key themes: circular strategies, circular business models, management reporting systems, organising systems in construction practice and the resource processing. However, while the literature seems to be focused on questions surrounding the five themes, the real estate development process is underrepresented. Hence the research question this research paper focuses on is: *What is the current and future role of the real estate development process in delivering circularity in the built environment?* By conducting interviews with various practitioners engaged in circular real estate development processes, current practices and future aspirations have been identified. Additionally, barriers have been identified and analysed. The thesis ends with a proposed circular real estate development process, harbouring flexibility in the construction phase, mitigation regarding government regulations, a changed value proposition for materials, involvement of stakeholders with the same, open mind set and the use of material passports in the design, construction, exploitation and end of life phase.

Keywords

Circular economy, real estate development process, built environment, barriers, current practice, future aspirations

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Abbreviations

BIM	Building information modelling
CE	Circular economy
EoL	End of life
FP	Football Principle
LCA	Life cycle assessment
MP	Material passport
PSS	Product service systems
MFA	Material flow analysis

Executive summary

Introduction and problem statement

In recent years, it has become increasingly more apparent that the built environment is a significant contributor to greenhouse emissions an pollution. Not only does the built environment extract resources on a quicker rate than the planet can sustain, it also perceives these resources as single-use items. This perpetual exhaustion of resources is causing severe damage to the environment, with rising temperatures and sea levels taking toll on economies, ecosystems and human society. The built environment is the largest consumer of raw materials, annually extracting 400 million tonnes of raw materials. Research also points out that the built environment causes 25 to 40% of all global carbon emissions, causing the atmosphere to warm up (Pomponi et al.,2017; GoContractor, 2019).

The Circular Economy in the built environment

This perpetual motion of emissions and pollution has signified the need for other economical systems. One of these systems is the circular economy. The CE aims to decrease the environmental impact by implementing processes that encourage resource loops to be lengthened or closed, creating indefinite cycles of resource use. (Ellen MacArthur Foundation, 2019). By keeping resources within these loops, raw resource extraction is significantly reduced, resulting in a healthier environment. Moreover, the CE provides a way to achieve an economy in which environmental and societal capital is being prioritised rather than prioritising economic growth. Due to the polluting nature of the built environment, the societal and environmental benefits as a result of circular approaches have gained an increasing amount of interest.

This thesis therefore has researched the relation between the circular economy and the built environment according to a literature review starting with 337 papers. The review of previous studies revealed five key themes that research can be categorised in. These are circular strategies, circular business models, organising systems in construction practice, resource processing and management reporting systems. These are shown in Figure 1 (own figure) on the next page.

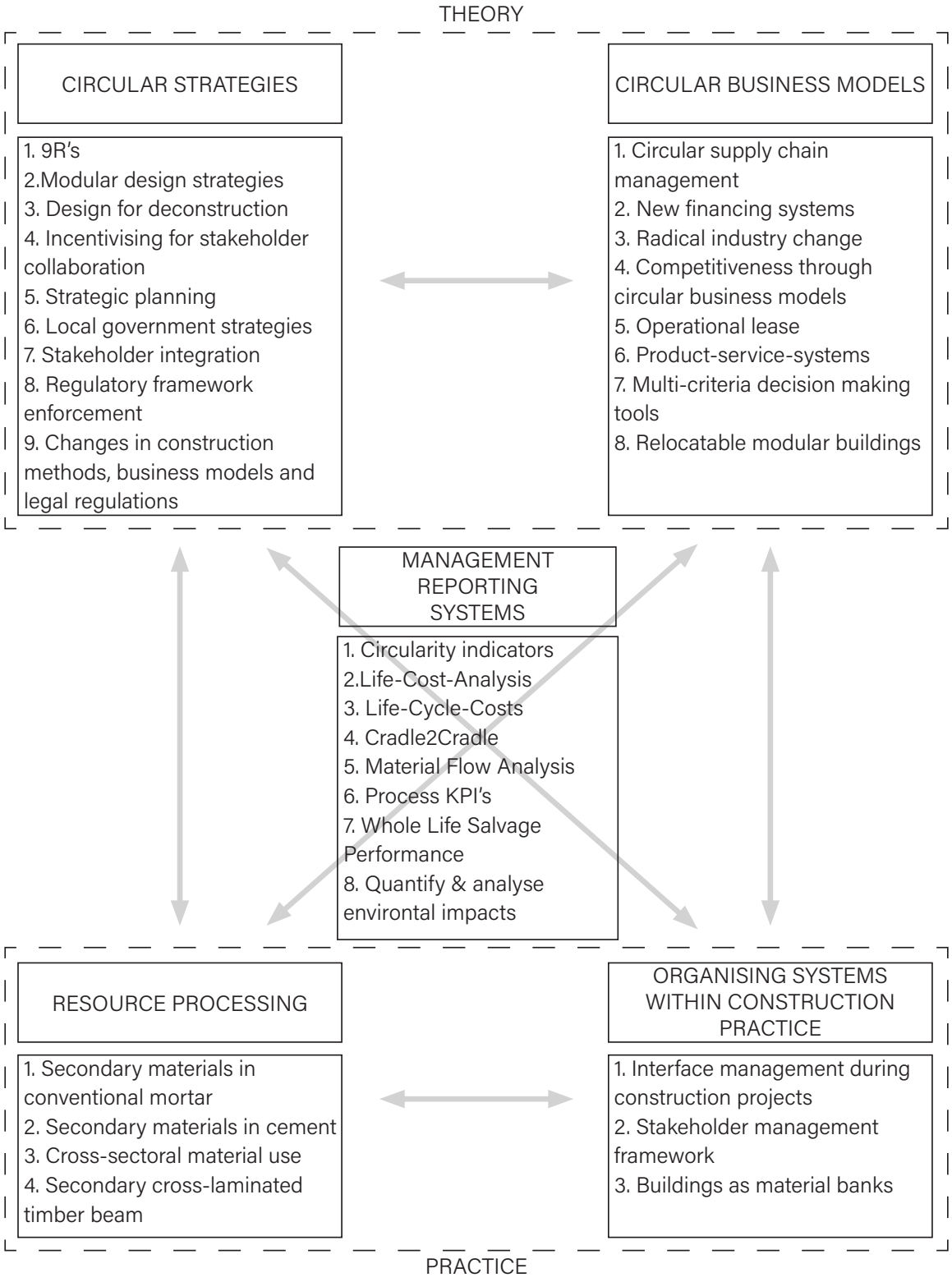

Figure 1: Circular Built Environment Framework (own figure)

The framework consists or three main parts, a theoretical, practical and a reflection part. The theoretical part consists of theoretical entities like circular strategies and circular business models. These are categorised as theoretical since strategies and business models originate from thinking processes. The theory is then put to practice in resource processing and organising systems within construction practice. These practical entities are products from strategies and business models. An example of this is a design strategy: For instance, if a design strategy indicates included modular construction, this strategy will be implemented during the organisation (or stacking) of materials during the construction process. Similarly, resource processing is also influenced by this design strategy, in the sense that it determines the way the building is processed if the space and/ or materials have become obsolete.

There is a constant literacy between the theoretical and practical part, which is measured by management reporting systems. Management reporting systems reflect on how the theory is operationalised into practice and provides feedback for optimisation of circular strategies or business models. Likewise, management reporting systems also work the other way around, providing feedback on organisation systems within construction practice and resource processing.

Gap

Although previous studies reveal that there are numerous ways in which the circular economy is practiced in the built environment, there is a lack of attention on the real estate development process. Therefore, the aim of this research was to investigate the current and future role of the real estate development process in delivering circularity in the built environment. In order to gain a more thorough understanding of the process, the real estate development process has been described according to present literature.

The real estate development process

the RE development process is a complex process, characterised by change of land use and/or a new or altered building in a process that combines land, labour, materials and finance and is under constant public attention. It sets itself apart from other production processes by its tendency to encompass longer amounts of time, the product being perceived a more permanent fixture and every development being a unique endeavour. Furthermore, the process brings together various stakeholders that all play different roles throughout the different RE development process phases. The RE development process consists of the initiative, design, construction, exploitation and end of life phases in which 8 main bodies of actors play a role: the RE developer, financial services, regulators, contractors, planners, consultants, users and facility managers. These are key players as described in the traditional RE development process, though. This thesis therefore also asks the question about which stakeholders play a key role in the circular RE development

process. It was suspected that suppliers would play a big role in the circular RE development process, since their business models focus on materials and their flow. Additionally, the timeline that is shown in this chapter is a process that has been constructed according to the literature read. This is a traditional, linear process. Therefore it can be concluded that there is a lack of an end-to-end, or circular RE development process according to the literature.

Main research question and method

Having described the RE development process, the circular economy and its relation to the built environment, the main question that is answered in this thesis is:

"What is the current and future role of the real estate development process in delivering circularity in the built environment?"

The main research question has been answered by conducting case study research. The cases consisted out of buildings for which the aim was to build as circular as possible. The units of analysis consist of their development process. In total, 6 case buildings, realised in the Netherlands have been investigated according to a total of 9 interviews.

The research has served two purposes: to provide an overview of current practices, future views and aspirations and barriers in circularity in the RE development process. Additionally, the results have been discussed and recommendations have been proposed. To add to that, the research has proposed a circular real estate development process in which knowledge gained throughout this thesis is translated into recommendations that support concrete action throughout the RE development process.

Main findings

Results has revealed that current practices and future aspirations differ from what is described in the literature. The circular economy can be delivered by the RE development process from five of key processes and changes: The first of which is to start the RE development process with stakeholders that aim to engage in a circular RE development process. Having a mindset that is open for ideas, and being flexible is key. Furthermore, stakeholder management in the initiative phase should aim to reduce uncertainty and risk by involving key stakeholders in the first meeting. Given the fact that every development process might be different, it is pivotal that the key stakeholders determine and define the manner of involvement. Secondly, mitigation of performance indicators set by regulators could be mitigated in order to make second hand materials available. Thirdly, another important process that stimulates the creation of a circular process is the ability to stretch phases which enables ad hoc resource availability and providing incentive to pitch ideas which promote a circular development process. The fourth change is that buildings should be perceived as material banks, and should be issued a material passport. This serves two purposes: The first purpose is that during the exploitation phase, the location, performance and other properties become clear, which eases maintenance. The second purpose is that

materials that have a material passport can also be sold, since the properties are known. Fifth, with new business models on the rise, the value propositions of the RE developer may change, together with other key players that might depend on circular business models. RE developers might change their value proposition to trading only space, to also trading in materials. Moreover, the question arises what exactly key players are going to own, and what to lease. The key findings of this section have provided the foundation for the circular real estate development process which is revealed in the chapter ten.

The circular real estate development process

After discussing current practice, future aspirations, gaps, barriers and recommendations, a thorough understanding on the current and future role of the RE development process in delivering circularity has been developed. This chapter serves to propose a new RE development process in order to execute a RE development process in a circular manner. The general idea of the circular real estate development process is that it differs from the current linear RE development process in a few ways: The main difference between the traditional and circular RE development process is that the traditional process is linear, whereas the circular process is circular, meaning that the overall aim of the circular RE development process is to optimise the performance and lifetime of materials. To achieve this, there are multiple processes in place through different phases, which are mentioned in the following sections.

The second difference is that the circular RE development process can be applied to both an individual building and an asset portfolio, while the linear lies the focus on just one building. Thirdly, key stakeholders remain involved longer in the circular process compared to the traditional process. For instance, the RE developer stays involved throughout the building's lifecycle to operate and maintain it, provided that the client does not acquire the building after delivery. This differs from developer to developer, given the fact that there are RE developers who sell the development after construction, whereas others keep the building in the asset portfolio. Therefore, it is important to notice that the circular RE development process provides a foundation for organisations to act, but that it is adaptable according to a RE development strategy.

The process model is revealed in Figure 2 (own figure) and consists of three key elements. The first element is the inner set of loops. The inner set of loops contains three sub-loops. The outer loop represents the RE development phases (initiative, design, construction, exploitation, end of life), and eventually, this loop transitions in the 'donor building', or middle loop, in which the asset becomes a material bank for a new development process or maintenance of another building. This is where the cycle starts over again at the initiative phase. This enables multiple donor buildings to be included in the RE development process of one new building. New development can be exercised within the asset

portfolio, but also outside of the asset portfolio. In case new development happens outside of the asset portfolio (i.e. development by another company with another asset portfolio), the donor building will be put on the market for second hand materials). The most inner loop represents other sectors, like the shoe or clothing industry, provoking a cross sectoral market. As can be seen, elements from the donor building can be exchanged with different sectors, and vice versa. In short, the RE development process starts with (re)development and delivers a building, which eventually becomes a donor building serving for new development processes or maintenance of existing building stock.

The second element, the outer set of circles represent the stakeholders, and at which point in time they are involved. The third element is the set of yellow beams that reveal the involvement of key stakeholders, during which phase and actions that could be undertaken. Notice that some beams go through both the development process and the donor building circle, meaning there could be a donor building involved in the development process of a new building. Whereas the inner set of circles revealed in Figure 2 (own figure) represents the real estate development process, the process can also be perceived as the flow of materials.

There are many aspects determining the outcome of this development process, given the presence of the discussion about what is owned and leased. This dramatically influences the outcome and availability of second hand materials during the RE development process. Furthermore, it is important to notice that there is not one format for RE development. This process model is a suggestion that can be applied and adapted to multiple development strategies (for instance one where the RE developer keeps the asset in the asset portfolio, whereas in other instances the asset being commissioned by/ sold to the client).

With the general outlay of the model explained, the following sections go deeper into the circular real estate development process.

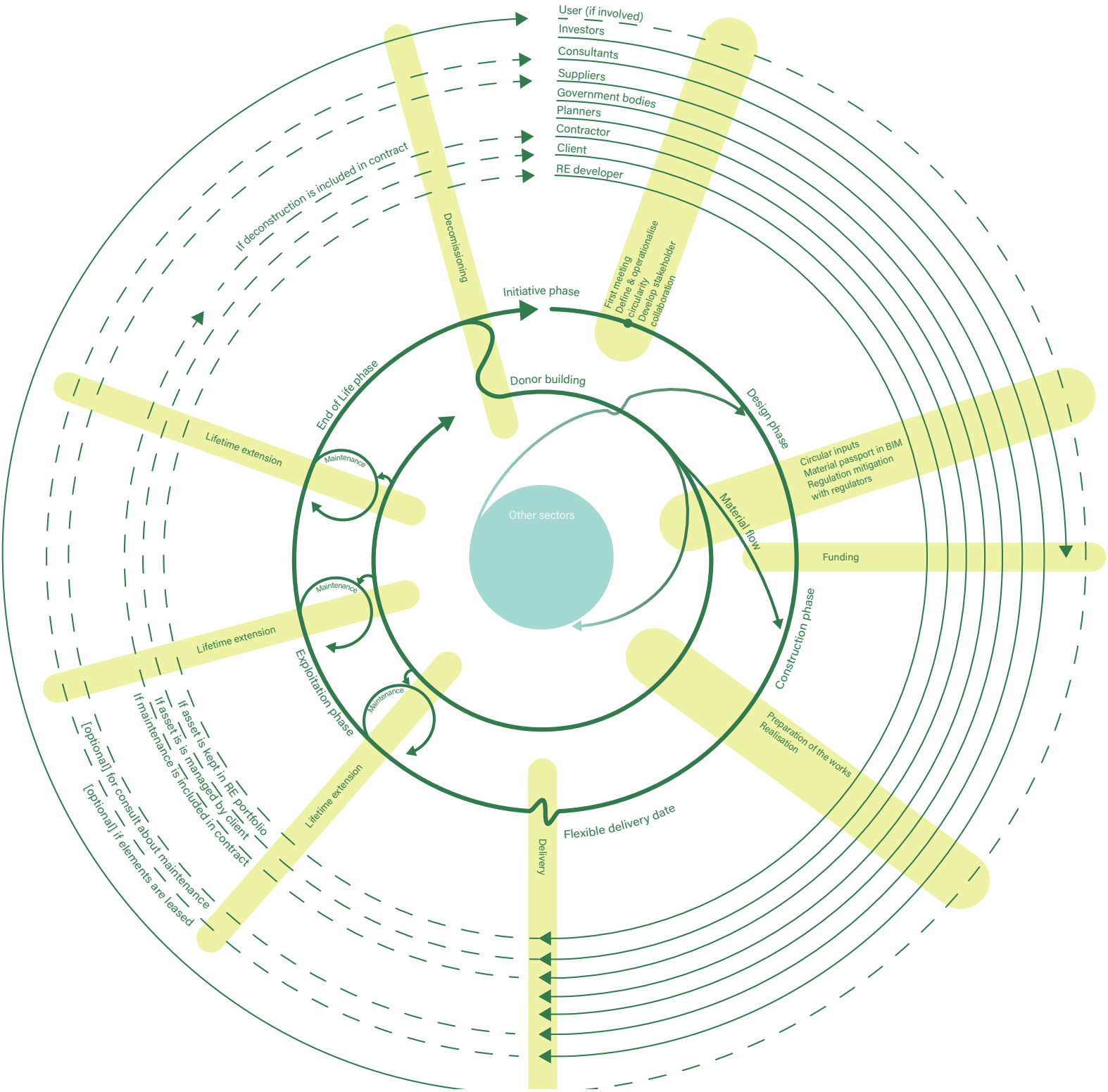

Figure 2 The circular real estate development process (own figure)

Initiative phase

The initiative phase plays a significant role in determining the manner of involvement of key stakeholders, contract formation and defining and operationalising circularity. In the proposed process, the following 8 key players are represented:

- RE developers
- Clients
- Planners
- Contractors
- Regulators
- Suppliers
- Consultants
- Investors

As recommended during the discussion of results, the manner of collaboration should be developed in the first meeting. It is recommended that this meeting is attended by the key stakeholders, preferably with a similar circular mindset. The first goal of the first meeting might be to operationalise circularity in the built environment and how to adhere to it according to the key player's abilities. Therefore, honesty and an open mindset are key. Additionally, an open mindset can be incentivised by implementing contracts that allow flexibility regarding timeliness during phases. The creation of a healthy, circular RE development process combined with a healthy business case in which all stakeholders get a fair share of profit can create a successful RE development process.

In the initiative phase, every player has a different task. The duty of (circularity) *consultants* is to raise awareness about the advantages of circular construction compared to traditional construction for both the financial, social and environmental side throughout the process. An example could be that the implementation of PSS facades increases the robustness of the product and that it takes worries away for the client and/ or developer. Alternatively, for the supplier of these facades, there is a long-term business model attached which ensures long-term cashflow. A societal advantage of the circular economy in the RE development process could be the involvement of people with a distance to the labour market which enable resource upcycling.

Similarly, *investors* could incentivise the development players to thoroughly think about circular processes by issuing financial resources only if a circular design is achieved. However, this could lead to tensions within the project team, because the investor is in a position of power in this example. To prevent this, agreements could be made in the

initiative phase that enable cashflow from the investor towards the development if certain operationalised goals are achieved, such as a deign process that creates a remountable design.

Other means to incentivise a circular RE development process in the initiative phase is by *regulators* indicating willingness to provide incentives for a circular RE development process and mitigation of regulations regarding performance of materials. This raises the barrier of certain second hand materials not complying with strict regulations.

The task of the *planners* in the initiative phase is to use their knowledge about circular design to influence and spread knowledge to the key players about circular design principles. During the development of the concept of the building, the planners can already discuss with the *contractor* and *suppliers* about the possible availability of materials. The earlier knowledge about the availability of second hand materials is made available, the bigger the chance that it could be implemented during the development process.

Throughout the initiative phase, and the coming phases, the *RE developer* is the spider in the web that needs to manage the stakeholders and bring the development process to a success. He or she also needs to provide feedback to the client, provided there is one involved. Being the bridge between the client and the other key players, the RE developer has a difficult task if the client does not want to have a circular RE development process. Therefore, the RE developer might be able to persuade the client to engage in a circular RE development process if he or she has expert knowledge on the topic and can persuade the client by proving its advantages.

Design phase

During the design phase, things become interesting, and can have multiple outcomes. A reason for this is that in this phase, decisions about what is going to be owned or leased by who are made. Possibly, the *RE developer* or *client* could own the structure of the building, and lease facades, interior, installations, etc.. This promotes circularity, provided that *suppliers* have processes in place to process the materials in a circular manner at the end of life stage. Additionally, the question is raised whether the RE developer has an asset portfolio with a possible donor building. This is where processes take on a soft side and agreements about the origin of building materials are made. Furthermore, design strategies that allow for generic design also make way for ad hoc implementation of secondary materials that are found during the construction phase. Therefore, *planners* should be involved until the project delivery date, so they can see if secondary elements fit in the design, or if design changes need to be made. The *regulators* keep its significant role in this phase, since the local municipality can influence which building elements can be used or not. Mitigating strict government regulations in order to implement secondary materials can increase the level of circularity of the building during the RE development process.

During the design phase, it is pivotal that the building is given a material passport, which proves immensely useful during the exploitation and end of life phase of the building.

Construction phase

During the construction phase, stakeholder collaboration and design strategies from the initiative and design phase are put into fruition. In this phase, it is still possible to change the design provided that second hand materials become available. To realise this, close communication between the contractor, RE developer and/ or client and planners is paramount. If necessary, suppliers and consultants could also be included in the decision making process. Just as during the traditional RE development process, the successes or setbacks in the construction phase mostly arise out of choices made in the initiative and design phase. The main difference between the proposed and traditional development process in the construction phase is the flexibility of the construction phase. It can be lengthened by i.e. the sudden availability of second hand materials which can used to add value to the building. A concern might rise regarding the extra time and profits, since there is a longer period that wages that has to be paid. Therefore, assessing the feasibility of lengthening the construction phase becomes important.

Exploitation phase

In this phase, the building is put to use by users. In the first few months after delivery of the building, it becomes clear whether design strategies, lease constructions, and second-hand material application as a result of a predetermined RE development strategy pay off. In any case, the exploitation phase provides the opportunity to maximise the lifetime of the building. A tool that can enable this, is the material passport that has been issued during the design phase. The reason for this is that during the maintenance of the building in this phase, the size, performance, weight, etc. is known, which speeds up the process of maintenance. Having a strong maintenance strategy as a result of a strong design strategy could increase the building's lifetime by decades. Important enablers for this are design processes that provide easy access for maintenance or replacement such as modular and remountable design strategies.

Consultants might still play a role in advising circular facility management practices. Therefore, they are included in the exploitation phase. Yet, the intensity of their involvement becomes low. The same goes for suppliers. They still might play a role in the exploitation phase, provided that they work together with the RE developer or client to supply materials during maintenance. In case of the building already being part of an asset portfolio with a donor building in place, materials could also originate from the donor building. Alternatively, materials can be purchased from a donor building outside the asset portfolio. This depends on what is owned by the RE developer or client, and what is leased.

End of life phase

The end of life phase starts when lifetime extension by maintenance, renovation or restoration is not financially feasible anymore. Again, this is where the material passport proves its use. It is recommended that materials present in the building are put up for sale a few years before the building is supposed to be decommissioned. Then, when the day comes that the building is officially decommissioned, there are four things that can happen.

1. PSS suppliers come to collect their products. This is why they are involved throughout the entire RE development process.
2. Materials that are owned by the client or RE developer can be sold to other parties. This can be enabled by a material passport that is attached to a secondary material market place.
3. Materials that are owned by the client or RE developer are extracted to be used for another development within the asset portfolio.
4. Materials are exchanged on a cross-sectoral level.

When the end of life phase starts, the initiative phase of another development process aspiring to use a building as donor building might have already started, and that is where the loop repeats itself.

Conclusion

Current practices include circular design strategies, product-service-systems, financial leverage, buildings as data banks, stakeholder alignment, buildings as material banks, making social impact, use of biomass and digitalisation of resources. The most surprising findings were the ability to lengthen the construction phase in consultation with the client. The significance of recommending the construction phase to be flexible in terms of the delivery date originates from the social, financial and environmental advantages that were gained during the implementation of this strategy.

Future aspirations include circular portfolio management, a change of mind set, deferring focus to mainly financial gain, change in market systems, supply chain integration, being able to measure circularity, digitalisation, process management, stakeholder collaboration, resource availability and reduced resource alterations. The most radical change of these aspirations is circular portfolio management, in which buildings become part of the pool of materials embedded within the asset portfolio. Buildings could become materials banks that are able to exchange materials or serve as donors for new developments.

Another striking finding is that the value proposition of the real estate developer might change to trading spaces to also trading materials, since the CE surrounds this topic. The future of circularity in the RE development process might answer the question of what the RE developer is going to own, and what it is going to lease. This means that the business model of RE developers could change as well in the future, and not only that. Suppliers

and contractors also might have to adapt to changing value propositions. Especially if the market for second hand materials might become so mainstream that raw resources might become more expensive. This also provides an interesting question for financial services. What are banks going to finance if the value proposition changes from owning assets to owning access to materials?

It seems that there are a considerable number of barriers challenging the built environment from developing circular real estate on a large scale. However, there are some practical guidelines that support concrete action to raise these barriers. At the foundation of change lies the overall change of perspective, mind set and behaviour. By introducing circularity in the academic environment, students and young practitioners can spread awareness and knowledge about the significance of the topic. Additionally, clearly defining the project, involving like-minded parties, defining what circularity entails for the development process and defining the stakeholder collaboration and alignment in the first meeting of the development process can provide the foundation for a development process without unnecessary discussions, misunderstandings and non-cooperativity. Furthermore, second-hand materials should be perceived as valuable, rather than scrap. This prevents the destruction of value.

Digitalisation of processes has great potential in raising barriers regarding the availability of second hand materials. An interesting approach is to provide buildings that are planned to be deconstructed in one year with a materials passport. Then, embedding these material passports within BIM software enables the materials to be implemented and retail value.

Furthermore, regulatory intervention by means of laws, regulations and incentives can play a big role in steering the transition of the built environment towards the circular economy. Regulators can use disincentivising strategies like excise that reduce the use of raw or highly polluting materials like concrete.

In short: the current role of the real estate development process in delivering circularity in the built environment mainly consists of the application of strategies that enable the implementation of second hand materials and flexible phases throughout the development process. Circularity also is delivered by digitalisation processes, enabling materials to be documented, easing the process of retrieving materials. Circular business models also play an important role in delivering circularity in the built environment, since they pave the way for sparking a large-scale market for lengthening lifetimes of buildings, leasing building elements and sharing spaces.

The future role of the real estate development process in delivering circularity in the built environment is the change of focus on the individual building to the asset portfolio, enabling availability of second-hand materials. Furthermore, the real estate developer

might possibly become a trader in both space and materials, and own access to materials, rather than owning them as an asset might play a significant role in delivering circularity.

Another finding that might enable financial feasibility and incentivise a higher amount of up-front investment is the football-principle. However, this thesis has not gone deep enough into this phenomenon. Yet, it is a very interesting concept. Therefore, future research could be conducted into creating a feasible business model.

Secondly, future research could focus on what the future value proposition of the RE developer could be. This could also be done from the perspective other RE development process players. Additionally, future research should emphasise the importance of the existing building stock and how real estate management practices can be optimised in order to extend the lifetime of an asset. Finally, since practitioners mentioned that the built environment is fragmented, further research could also focus on the fragmentation of the built environment, and how the built environment could become a less fragmented industry.

1. Introduction

The built environment consists of man-made structures, features and facilities in which we live and work (Oxford languages, 2019). In recent years, it has become increasingly apparent that the built environment is a major contributor to pollution of the environment and exhaustion of the Earth's resources. Not only does the built environment extract resources on a quicker rate than the planet can sustain, it also perceives these resources as single-use items. This perpetual exhaustion of resources is causing severe damage to the environment, with rising temperatures and sea levels taking toll on economies, ecosystems and human society. The built environment is the largest consumer of raw materials, annually extracting 400 million tonnes of raw materials. Research also points out that the built environment causes 25 to 40% of all global carbon emissions, causing the atmosphere to warm up (Pomponi et al.,2017; GoContractor, 2019). In addition to harming the planet, the built environment also harms itself. Since 2019, the Netherlands suffers from a nitrogen crisis, since the Dutch policy on reducing environmental impact has not met European guidelines, which caused 18.000 building projects to be on hold (Boerop, 2019). Consequently, the building sector in the Netherlands is suffering from financial loss and bankruptcy, causing societal problems such as demonstrations, dissatisfaction and tensions. These environmental, financial and societal problems have created a need for sustainable solutions that are capable of cutting back on resource exhaustion and pollution, both in the short and long term. There are initiatives that aim to enable this cutback, one of which is the Circular Economy (CE). The CE aims to decrease the environmental impact by implementing processes that encourage resource loops to be lengthened or closed, creating indefinite cycles of resource use. (Ellen MacArthur Foundation, 2019). By keeping resources within these loops, raw resource extraction is significantly reduced, resulting in a healthier environment. Moreover, the CE provides a way to achieve an economy in which environmental and societal capital is being prioritised rather than prioritising economic growth. Due to the polluting nature of the built environment, the societal and environmental benefits as a result of circular approaches have gained an increasing amount of interest. Therefore, this thesis begins with addressing how circularity in the built environment is manifested by defining the CE followed by a systematic literature review on what previous studies examining circularity in the built environment have focused on. The further outline of the thesis is made clear in the following section.

1.1. Thesis layout

Chapter 2: The circular economy

This chapter aims to define what the circular economy is, what its schools of thought are and which applications it has. Since it was mentioned before that the circular economy in the built environment has gained an increasing amount of interest, the concept should be defined. The knowledge gained from this chapter is used in chapter 3.

Chapter 3: The circular economy in the built environment

This chapter consists of a systematic literature review that investigates what previous studies have focused on when studying circularity in the built environment. Additionally, appendix 1 reveals how the systematic literature review has been conducted. This chapter serves as a means to identify how the circular economy is manifested in the built environment and provides a foundation for identifying research gaps. There are five main bodies of research, which have been visualised in a theoretical framework. However, the systematic literature review reveals that there is a lack of focus on the whole building life cycle and that the real estate (RE) development process is underrepresented throughout the literature.

This results in the following problem statement:

The real estate development process is underrepresented in delivering circularity in the built environment and there is a lack of focus on the whole life cycle of buildings.

Therefore, this thesis aims to research what the current and future role of the real estate development process is in delivering circularity in the built environment. Consequently, the real estate development process needs to be understood. Chapter 4 serves this purpose.

Chapter 4: The real estate development process.

This chapter aims to identify what the real estate development process is, what phases it consists of and which stakeholders are involved at which point. It provides relevant knowledge for answering the research question at stake.

Chapter 5: Research aims, objectives and research questions

This chapter states the aims of this thesis and provides the foundation of developing the research questions. After identifying the context of this research, twelve focused sub-questions are developed to address what the current and future role of the real estate development process is in terms of delivering circularity.

Chapter 6: Methodology

This section describes how the research questions have been answered. Namely, the research questions were answered by conducting interviews with practitioners according to cases covering real estate development processes. The cases have been selected on various criteria according to the circular economy. Afterwards, the interviews have been coded with Atlas.ti to deepen the understanding of how the RE development process delivers circularity in the built environment.

Chapter 7: Results

This section reveals the findings emerging from conducting interviews and conducting document research. The goal of the results section is to structurally describe what answers have been found from the interview questions and document research.

Chapter 8: discussion of results

In this section, the results from chapter 6 are being discussed in relation to findings from previous studies. In detail, this section provides insight into what the results mean, how they are similar and how they differ. Moreover, this section points out surprising findings of the current research. Interesting current and future practices have emerged as a result of the case studies, which differ from previous studies.

Chapter 9: The circular real estate development process

This chapter proposes a new, circular real estate development process. The goal of this process is to prescribe how the real estate development process can change in order to strike a stronger integration with CE practices.

Chapter 10: limitations

This chapter indicates limitations of the research, and provides a reflection for the author. The limitations are complemented by possible improvements of this research that can be investigated in the future. One of which is the assumption that the RE development process had been included in the literature, which was not the case.

Chapter 11: conclusion

This chapter is the final conclusion in which the most surprising findings are highlighted, and recommendations for further research have been provided.

1.2. Relevance

The significance of the real estate development process in a circular built environment

The development of real estate encompasses the process of creating something tangible which creates value. According to Bulloch et al. (2010), the process is characterised by conceptualising, designing, constructing and occupying physical space in which we live

The development of real estate is complex. Winch (2009) states that projects are information processing systems. In order for these processing systems to function, organisations must monitor their environment, make decisions, communicate their intentions and make sure that what is intended to happen, actually happens. Additionally, the initiative phase of the RE development process harbours a lot of uncertainty. The combination of uncertainties during the start of RE development projects, and the infancy of the CE principles create an environment in which mistakes in the initiative and project definition phases could potentially have catastrophic effects at later stages in the development project. Therefore, it is paramount for the implementation of CE approaches to define what is currently practiced, to define future aspirations and barriers, and consequently solve these by practical guidelines for concrete action.

This research aims to contribute both to science, as well as society. Furthermore, in this section, the relation between the graduation project topic and the MSc Management in the Built Environment, provided by Delft University of Technology is elaborated.

Scientific relevance

Circular practices in the built environment harbour the potential to severely decrease environmental impact (Ellen MacArthur Foundation, 2015; Ellen MacArthur Foundation, 2019). Therefore, this research contributes to the literature concerning the ability of the real estate development process to deliver circularity in the built environment. Consequentially, a better understanding of the processes that entail the development of circular buildings is created. This results in increased effectiveness in processes, which cascade down from theory to practice, like supply chain management of materials and human resources, decreased waste generation, less uncertainty and enhanced decision making. This eventually results in a decrease of the environmental impact of the built environment.

Societal relevance

Changes in the environment are felt by the entire human population. If climate change continues on the current rate, people will eventually run out of vital resources such as water. There have already been speculations about ‘resource wars’ in which countries or populations fight over these vital resources. However, climate change can be supressed by creating a healthier built environment, which this research aims to contribute to.

This research also proves value to clients, architects, suppliers, contractors, real estate developers and investors since the research has identified them as key stakeholders in the development process.

Relation between graduation project topic and MSc Management in the Built Environment

The MSc Management in the Built Environment track focuses on the managerial dimension and the processes involved within architecture, construction and the built environment, and that insight, knowledge and skills in process and management are greatly important to professionals in these fields. (TU Delft, 2020). An understanding on what the current and future practices are is e created by investigating the real estate development process. Secondly, prescribing how the process can adapt by means of practical guidelines that support concrete action provides a way for stakeholders present in the RE development process to adapt to the new paradigm. Hence, the relation between this graduation research and the MSc is that managerial and process skills are used to define and prescribe how current and future practices in the circular real estate development process deliver circularity in the built environment.

With the general outlay and relevance of the research presented, this thesis continues with the theoretical part in which the circular economy, its relation to the built environment, and the RE development process are defined.

2. The circular economy

Early authors have described the history of environmental concerns and how the CE came about. The first explicit concern about the environment in science was expressed by Thomas Malthus in 1798, in which he addressed the rapid expansion of the human population and explored what effects this could have on the environment, stating his concern about populations expanding to overtake the development of sufficient land for crops (Lacy et al. 2015). Fast forwarding one hundred years, and the first environmental protests started to occur, with the goal to conserve natural resources. Additionally, the first campaigns to save wilderness all occurred in the late nineteenth century. The Ellen MacArthur Foundation (2019) states that the idea of closed-loop cycles is ancient, but the idea gained momentum after its revival in industrialised countries after the Second World War. The reason behind this, is that technological innovation in computer systems revealed the complexity of the world we live in, seeing it as a metabolism (input-output-input) rather than a machine (take-make-waste). The practical applications of the circular economy became apparent in the 1970's, led by a small number of academics, thought-leaders and businesses. Papers concerning the origins of the circular economy mention early scholarship being introduced by environmental economists Pearce and Turner in 1998, which in turn built their framework on previous studies conducted by ecological economist Kenneth Boulding (1966), who wrote about the earth as 'spaceship Earth' (Ghisellini et al. 2015; Wautelet, 2018).

2.1. Spaceship Earth

The first explicit mention of a closed loop system in academic literature was conducted by Boulding in 1966. Boulding describes the Earth as a closed system with practically no exchanges of matter with the outside environment (the emptiness of space) and that the paradigm of an economy as a circular system is pivotal for the maintenance of the sustainability of human life on Earth. Boulding also points out that the Earth is often seen as a container of limitless resources, on which the 'cowboy economy' thrives. The cowboy economy is also dubbed the linear economy, where resources are treated in a take-make-waste flow with a total disregard for secondary functionality of a resource. The linear economy, as Boulding (1966) states, is a flawed perception of the physical possibilities of the Earth, in the long run. Therefore, he proposed to perceive the Earth as a spaceship, harnessing a 'spaceman economy' in which the economy and environment are identified by a circular relationship, where all used resources provide input for other functions. This input-output-input relationship resonates with the circular economy as defined by the Ellen MacArthur foundation, mentioning the metabolism which it refers to.

2.2. The performance economy

The performance economy was introduced in 1976 and revolves around the concept of an economy in which we utilise closed loops favouring reuse, repair and remanufacturing of products over manufacturing of new goods (Stahel et al, 1981). In their study, Stahel et al. focused on car manufacturing and building construction and analysed the potential to substitute manpower for energy. They found that the performance economy creates a positive impact in terms of economic competitiveness, job creation, waste prevention and resource savings. Later, in 2010, Stahel wrote a book about the performance economy, in which he further elaborated on "the Performance Economy as a set of strategies to overcome the shortcomings of the present industrial economy which is characterized by a combination of continuously high resource consumption with related high waste volumes, rising public debt often accompanies by persistent unemployment and slow economic growth." (Stahel in Wautelet, 2018). The performance economy adheres to the principles of the CE by its goal to closed loops over waste production and high resource consumption. Additionally, the performance economy can be utilised as a strategy within the built environment to increase competitiveness and create jobs while decreasing environmental impact.

2.3. Industrial ecology

Industrial ecology was first mentioned in the 1970s with the argument that human economic activity is causing unacceptable environmental changes because industrial systems were perceived decoupled from environmental systems. Similarly to the circular economy and performance economy, industrial ecology aims to change from an open-ended economy system (take-make-waste) to a closed loop system (Pierce et al., 1989). More concretely, industrial ecology aims to close material loops within industrial processes, creating an ecological cycle in between inputs and outputs, meaning that outputs of processes can be used as inputs for other processes. Ausubel (1994) builds on industrial ecology and emphasises on the socio-economic and environmental benefits of industrial ecology by aiming at a more 'elegant', less wasteful network of industrial processes, creating more wealth with fewer resources.

Erkmann (1997) aims to concretise industrial ecology by providing four key principles on how to reorganise industrial processes.

1. Waste and by-products must systematically be valorised

This principle relies on smart networks which perceive waste as secondary input for other industrial processes. For instance, the residue of one company can be and input for another company. A modern-day example is that sawdust from a milling company can be used as an input for making fertiliser that can be used to grow trees.

2. Loss caused by dispersion must be minimized

Resources, products and services must be designed to keep dispersion at a minimum and/ or eliminate harmful effects on health and the environment

3. The economy must be dematerialized

In order to minimize total material flows, we have to consider transitioning from a material-driven economy to a service economy. This process entails that the capabilities of use are regarded more important than selling. This approach ensures dematerialization.

4. Energy must rely less on fossil fuels

This is a relatively commonly known part of our modern-day society already. Efforts are being made to reduce the environmental impact of the world economy by implementing sustainable ways of energy production such as wind, solar and water energy generation. These ways of energy production rely on 'endless' energy sources like wind, water, and to some degree the sun.

Lastly, Graedel (2003) provides a more general definition on how industrial processes can be made less wasteful, by defining that the underlying concept of industrial ecology relies on a systemic, comprehensive and integrated analysis of these industrial processes and all its components within its environment, considering them as a joint ecosystem.

Industrial ecology therefore has the potential to reduce the environmental impact of the built environment by analysing how industrial processes can be optimised to close resource loops. For instance, factories producing prefabricated building elements can be analysed on their assembly process in order to cut back on resource utilisation and the use of toxic materials to reduce impact on the environment. Secondly, industrial ecology adds to the circular economy by optimising industrial systems from a micro-level perspective to global-scale economies in which products and processes remain the highest value throughout their serviceable lifetime. This approach also promotes a transition from open to closed cycles, causing less waste and harm to the environment in industrial processes.

2.4. Cradle to cradle

Cradle to Cradle (C2C) was first mentioned by Braungart and McDonough in 2002 and emphasises on increasing positive impact on the environment, rather than decreasing negative impact. In other words: C2C is about working on the right products and systems, rather than making wrong things less bad. To make their concept more tangible, the authors provide an example that states that a car that runs very efficiently on fossil fuels is still bad for the environment. Whereas a car that uses fossil fuels is still bad for the environment, the 'right' product would be a car that runs on electricity generated by solar panels on its body. Secondly, C2C is about reducing cradle-to-grave processes, reintroducing resources and harbouring their value by upcycling (improving the quality or application), reusing or rethinking (innovation or finding completely new uses for the

resource). C2C emphasises on using the right products and systems, rather than making the wrong things less bad. This may prove a way that the built environment can look into its processes, and assess whether the right things are being done, or that there is a need for radical change in the way products are produced, used and processed.

2.5. Extended producer responsibility

Extended producer responsibility is an environmental policy approach in which a producer's responsibility for a product is extended to the post-consumer stage of a product's life cycle (European Commission, 2014). This means that producers take over responsibility to take back or collect used products and consequentially, processing them in a way that they can be recycled. Extended producer responsibility aims at internalising environmental externalities and serves as an incentive for producers to evaluate environmental considerations during the product's life cycle. Therefore, extended producer responsibility cvauses deeper thinking about the product on the front-end. Extended producer responsibility also incentivises the creation of more robust products. The link between extended producer responsibility is that resources stay in loops longer, products become more robust, and that there are processes in place for processing the product at the end of its usable life which minimise waste production and maximise value retention.

2.6. Regenerative design

In his book "regenerative design for sustainable development", John T. Lyle (1994) introduces regenerative design as studies that put the emphasis on the development of community support systems, capable of being restored, renewed, revitalised or regenerated by integration of natural processes, community action and human behaviour (CalPolyPomona, 2019). More concretely, it takes on a holistic approach to the ecosystem, in which every output is another input for a process. Regenerative design is being studied in the Lyle Centre, where students and professionals are continually debating topics surrounding regenerative studies. According to the Ellen MacArthur foundation, Lyle contributed to laying the foundations for the circular economy framework, which gained popularity by McDonough, Braungart and Stahel.

2.7. Biomimicry

Biomimicry is defined as an approach that aims at fostering innovation inspired by nature, taking note that there is no waste in nature. It could be perceived as a new paradigm in which radical change of modern-day business is needed. Biomimicry takes on a new definition of how we should perceive symbiosis between industry and the environment, creating a healthy relationship between current industrial ecosystems and nature, resembling an ecosystem that functions like a forest. This entails that there is no 'waste' and that everything can and should be reintroduced within industrial flows. The term was first used by Beynus in 1997, arguing that nature already has solved many problems that humanity is coping with, and we should seek learnings from solutions that date back since

life began about 3.85 billion years ago. The biomimicry institute defines biomimicry as *"… an empathetic, interconnected understanding of how life works and ultimately where we fit in. it is a practice that learns from and mimics the strategies used by species alive today. The goal is to create products, processes, and policies – new ways of living – that solve our greatest design challenges sustainably and in solidarity with all life on earth. We can use biomimicry to not only learn from nature's wisdom, but also heal ourselves – and this planet - in the process."* (The Biomimicry Institute, 2020). Learning from nature's wisdom and applying its lessons to the built environment, involving other ways of living, can enable circular economy approaches within the built environment.

2.8. Natural capitalism

The concept of natural capitalism entails a new approach that serves not only to protect the earth, but also improves profits and competitiveness (Harvard Business Review, 2007). Capitalizing nature is what modern-day capitalism might become if the largest category of capital "natural capital" are properly valued. Nature capitalism is firstly mentioned in the book "nature capitalism" by Paul Hawken, Amory Lovins and L. Hunter Lovins and published in 1999. The approach involves four shifts within current business practices.

1. Dramatically increase the productivity of natural resources

By means of drastic changes in design, production and technology, natural resources can be created to increase the value of the material, extending its lifespan and consequently reducing its environmental impact. Other advantages are a reduction in costs, capital investment and time.

2. Shift to biologically inspired production models

Similar to biomimicry, natural capitalism aims to be inspired by nature and create closed-loop production systems with no generation of waste. Also adhering to the principles of biomimicry are the aims to use output ('waste') as input for other manufacturing processes or be reintroduced into the ecosystem harmlessly.

3. Move to a service-and-flow business model

A service-and-flow business model is aimed at providing value through a continuing flow of services (leasing, renting), as opposed to the traditional sale-of-goods business models. A service-and-flow business model applies not only to natural capitalism, however. There is a continuously extending body of literature conducting research on service-and-flow business models.

The Harvard Business Review calls this point the "move to a solutions-based business model", meaning the same thing. However, a solutions-based business model can be interpreted differently than a service-and-flow business model, causing ambiguity concerning the exact meaning of the third shift.

4. Reinvest in natural capital

Hawken et al. (1999) state that companies depleting their own capital are eroding the bases of their future prosperity. There is a pressure to restore, sustain and expand natural capital as human needs expand, costs of deteriorating ecosystems are rising and the environmental awareness of the consumer increases. However, an advantage of is this is that this creates a demand from the customer's side, resulting in business opportunities.

In the built environment, business model adaptation to more natural resource use in construction could create competitiveness is sustainable development in, for example, tenders for circular buildings.

2.9. Green economy

The UN (2020) defines the green economy as a low carbon, resource efficient and socially inclusive economy where growth, employment and income are driven by investments into such economic activities by public and private entities. The objective is to reduce carbon emissions and pollution, better energy and resource efficiency and preventing the loss of biodiversity and ecosystem services. The built environment could adhere to this by incentivising investors to invest in developments that aim to reach the goals set by the UN's Green Economy.

2.10. Blue economy

Pauli mentioned the blue economy first in 2010, regarding it as an open-source movement with the goal to inspire entrepreneurs to change the rules of the game, implementing new innovative business models which adhere to the basic needs of all that is locally available. The two most dominant characteristics of the Blue Economy are innovative business models and competitiveness in which innovative business models are a key enabler for competitiveness while constructing social and natural capital. It builds on the currently prevailing Red economy, in which entrepreneurs focus mainly on one core business and niche. Also, it builds on the Green economy, which solely focuses on merely one single advantage without looking at a holistic, global picture. The Blue economy perceives resources as cascading nutrients and energy which are locally available. An example of a cascade is a waterfall, which requires no energy due to gravity, transporting nutrients for micro-organisms, which feed plants, which feed animals, which feed animals. In short, the Blue economy is a relatively young concept which paves the way for innovative business models to be implemented in local environments, sparking competitiveness through innovation and promoting a cascade of resource flow.

A business-model related example is given by Pauli in 2016 in which a coffee company has three revenue streams that apply the cascading approach. Primary income is generated by coffee sales, secondary income is generated by the sale of mushrooms

farmed on coffee waste and the third revenue stream comes for the feed for animals as residue from the fungi farm.

The cascading principle can also be used in the built environment. A wood mill can eradicate its need to acquire wood from an external seller by using the sawdust as fertiliser for the creation of a forest owned by the mill, enabling sustainable foresting.

2.11. Shared value

In 2011, trust in business was low. Public opinion pointed into the direction that capital was made at human expense. Therefore, Porter and Kramer (2011) created the idea of 'shared value', which aspires to create a synergy between capitalism and societal needs. Their research lead to the creation of a framework, aimed to create value by addressing social and environmental needs. This implies that company success connects to social progress and that the two are interdependent. If a company has success, so has society. This prevents people being off worse as a result of a company being successful. This requires a rethink of capitalism. This can be put in the circular economy context by providing an example. Currently, the amazon rain forest is being cut down at an alarming rate, disregarding social wellbeing (being the ability to have a stable environment and breathing clean air provided by trees). A shared value solution is to sustainably acquire wood by planting a tree for every tree that is cut down or engage in a sustainable way to chop wood. This way, societal capital is retained (stable climate, clean air).

2.12. Doughnut economy

The doughnut economy serves as a visual representation to meet the needs of all within the power of our planet. It ensures that nobody is deprived from life's essentials like food, water, education, a political voice and housing while not collectively overshooting the ceiling of life supporting systems that our planet provides. These supporting systems are a stable climate, fertile soils and an ozone layer, protecting us from the sun's harmful radiation. (Kate Raworth, 2019).The doughnut economy could be seen as a sort of assessment and awareness raising tool of how humanity manipulates its surroundings. It shows how much emphasis is put on certain aspects in the environment and society, and where there is a lack of attention. A similar assessment tool could be provided for the built environment with key performance indicators that create a holistic overview on how the built environment has an impact on the planet.

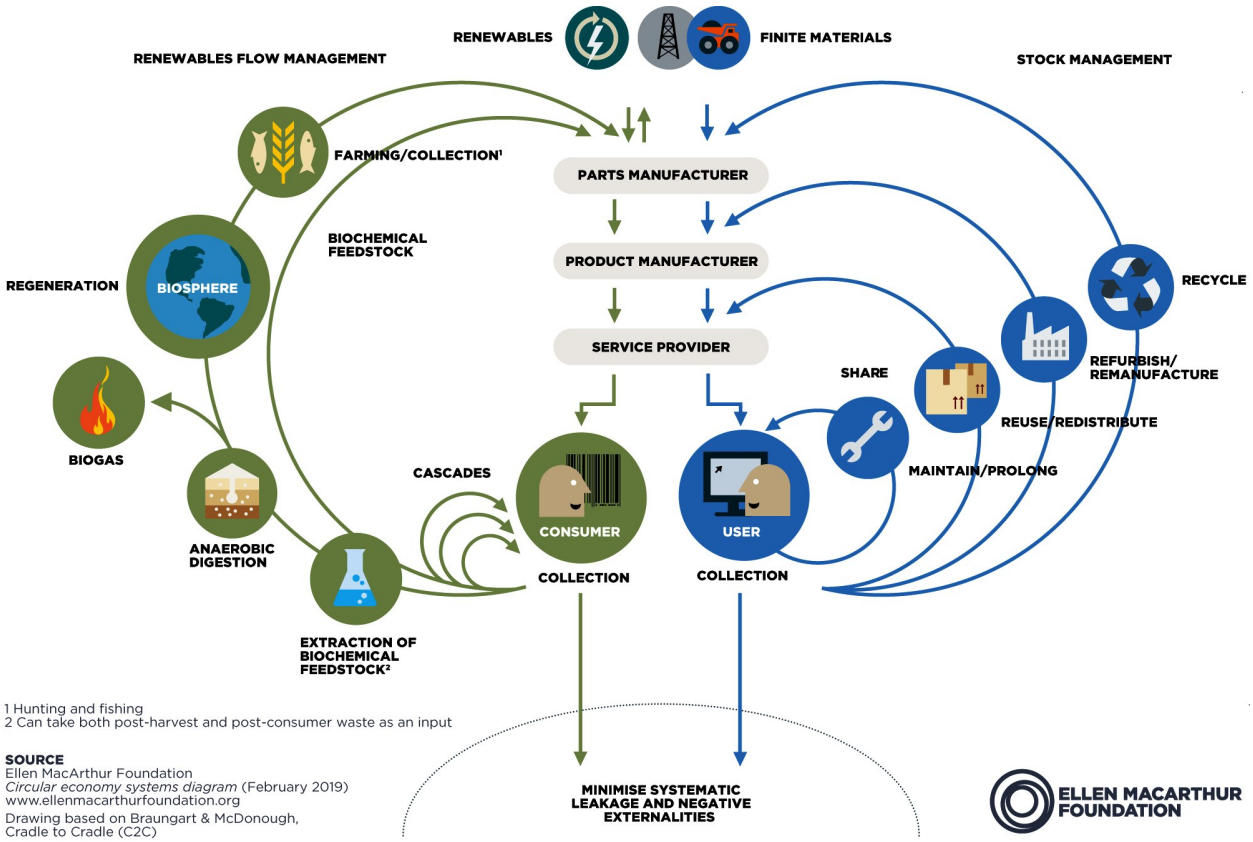

Figure 3: butterfly model by the Ellen Macarthur foundation (2019)

2.13. Main findings

In conclusion, the origins of the circular economy date back till ancient history but have been explicitly exercised since the 1970s, and contains many schools of thought, but they all revolve around increasing processes enabling material efficiency and lengthening/ closing loops, except for the doughnut economy, which is perceived as an assessment/ awareness raising tool. Additionally, a number of schools of thought emphasise on natural resources, business models and/ or industrial processes. These have been visualised in Table 1 (own figure).

	Closed loop system	Emphasis on natural resources	Business models	Industrial processes	Social impact
Spaceship Earth	■				
Performance economy	■		■		
Industrial ecology	■			■	
Cradle to Cradle	■				
Extended producer responsibility	■				
Regenerative design	■	■			
Biomimicry	■	■			■
Natural capitalism	■	■	■		
Green economy	■		■		
Blue economy	■		■		
Shared value	■				■
Doughnut economy	■				■

Table 1: Focus of previous research regarding the Circular Economy (own figure)

In the circular economy, economic activity is centred around building and rebuilding overall system health and perceiving processes being loops, rather than linear. It aims to provide a long-term solution to environmental challenges, and strives for systemic changes that build long-term resilience, generate economic opportunities and businesses, while providing environmental, financial and societal benefits. It is a paradigm in which material loops are lengthened and/ or closed by following principles of designing out of waste and pollution, keeping products and materials in use, regenerating natural systems. It encourages economic activities that are restorative and regenerative by design and aim to keep products, components and materials at their highest utility and value at all times,

distinguishing between technical and biological cycles (Ellen MacArthur Foundation, 2015; Ellen MacArthur Foundation, 2019). The Ellen MacArthur Foundation has developed a Butterfly Model to visualise both cycles.

Biological cycles entail the processing of food and biologically based materials like cotton or wood, and reintroducing them into the system. This is done by, for example, composing or anaerobic digestion (microorganisms breaking down organic material). Biological cycles regenerate living systems like soil, which in turn provide renewable resources for the economy (compost provides energy for trees to grow, which can be used for construction). The technical cycle on the other hand, focuses on recovery and restoration of products, components and materials by means of strategies like the 10 R's (refuse, rethink, reduce, reuse, repair, refurbish, remanufacture, repurpose, recycle, recover

The circular economy aims to decrease the environmental impact by implementing processes that encourage resource loops to be closed. By keeping resources within these loops, raw resource extraction is reduced, resulting in a healthier environment. It is a new industrial paradigm aiming to transform the linear economy to a more integrated industrial ecosystem which is shown in figure 1 (Ellen MacArthur Foundation, 2015).

2.14. A note on resources

This section aims to define the term 'resource'. In the circular economy, authors talk about resources (Boulding, 1966; Erkmann, 1997; Ausubel, 1994; McDonough & Braungart, 2002; Pauli, 2016; Ellen MacArthur Foundation, 2015; Ellen MacArthur Foundation, 2019). These resources refer mostly to natural resources, environmentally friendly management of those resources and how to reduce raw resource extraction. Although, whereas natural resources may prove to be the main concern or performance indicator in decreasing the environmental impact of the built environment, there are underlying processes at play that enable natural resources to be processed in a way in which harm to the environment is prevented or reduced. These processes require resources other than just materials. Resources can be distinguished by tangible and intangible resources. Tangible resources are resources that can one is able to physically touch, like plastic, electronic components, bricks, wooden beams, equipment, and buildings. Intangible assets are defined by Edvinsson and Malone (1997) as resources which have no physical existence but are still of value to a company or process. Intangible resources include human capital, which refers to resources like knowledge, skills, qualification, education and friendliness of staff (Zigan & Zeglat, 2010). In fact, previous studies prove that organisational performance is more and more related to such intangible resources (Pike et al., 2005; Zambon, 2002; Guthrie, 2000 in Zigan & Zeglat, 2010). Joroff et al. (1993) distinguish resources in five: capital, people, technology and information, and real estate as the fifth resource. Johnson and Scholes (1998) have a similar view: the management of financial resources, human resources

(people), physical resources (property) and the management of information resources (knowledge).

The main take-away here is that the environmentally friendly processing process of physical resources requires non-material/ intangible resources like human resources, knowledge and education as enablers. In the built environment, this can be translated into real estate management, architectural/ engineering knowledge, the ability to communicate clearly, strategy development, project management, etc..

Chapter 2 has defined the CE, its origins and possible applications in the built environment. Having acquired a deeper understanding about the CE, chapter 3 elaborates on how the CE is implemented in the built environment.

3. The circular economy in the built environment

3.1.Circular strategies

Circular strategies aim to create a ‘way of doing’ in the early stages of a circular process. They serve as the foundation on which problems are solved, and circular opportunities are created. This section explores the 9 R’s, as explained by the Ellen MacArthur Foundation (2017), strategies for incentivising stakeholders, top-down strategies and circular design strategies.

The 9 R’s

Strategies concerning the CE in the built environment are advocated by the Ellen MacArthur Foundation (2017). The foundation describes ten ways to reduce environmental impact that can be applied to all sectors. The 9 R’s are numerated from most circular (R0) to least circular (R9). R0 till R2 are smarter product use and manufacturing strategies.

1. *Refusing* is the act of making a product redundant by letting go of a function or creating the same function with a radically different product. An example of this is to refuse the use of plaster wall finishing and leave a wooden wall as it is. This prevents unnecessary resource use and increases the demountability of the wooden panel.

2. *Rethinking* happens when a product is, for example, shared amongst different people instead of being kept individually. This example of sharing is already happening as of 2020 by sharing means of transport (bikes, cars and mopeds) and heavy machinery in common workplaces for i.e. woodworking.

3. *Reducing* is a strategy aiming for increasing the efficiency of a product’s manufacturing process or using fewer raw resources.

R3 to R6 are strategies that aim to extend the lifespan of a product and its parts. From most effective strategies in reducing impact to least effective are as follows:

4. *Reuse* is a strategy widely seen as of 2020. It is the act of offering a product that is still in good condition a second/ third/ etc. life by offering it to another consumer, fulfilling its original function. An example of this practice in the Netherlands is the Madaster, an organisation that creates material passports from buildings in the Netherlands. The real estate owner sends documents to this organisation, and they will generate an up-to-date material passport of the building containing the quantity, quality, location and financial and circular value of materials (Madaster, n.d.).

5. *Repairing* is the act of repairing a product by removing broken components and adding (preferably) secondary, working components in order for the product to regain its function.

6. *Refurbishing* is the process of taking a product, restoring it and bringing it up to date. An example of this is that a single-glass window frame is adjusted to fit double or triple glazing, making it up to date.

7. In *remanufacturing*, parts of a discarded product are being placed into a new product with the same function.

R7 to R9 are strategies that look into the useful application of materials.

8. *Repurposing* is similar to remanufacturing, but the difference is that the parts of the discarded product are being used into a product with a different function, like Zainescu et al. (2018) managed to do with remanufacturing leather fibres in bio-composites as will become clear later in section …

9. Recycling entails processing materials to obtain a higher, same or lower quality. It is mostly referred to as *upcycling* if the material obtains a higher quality. An example of recycling is the use of concrete granulates in highway construction. An example of upcycling is the use of discarded shipping containers and turning them into dwellings.

10. *Recovery* is the least circular approach. It often encompasses the incineration of materials while recovering the energy that it generates in the process. Waste or biofuel like wood, for instance, are used for electricity generation.

These strategies can be used as a decision making tool throughout the development of a building and for creating a long-term vision for circular elements, buildings and cities. For instance, during the design phase, a project team can decide to refuse the use of toxic materials and adhesives, and opt for designing for the possibility for deconstruction.

Incentivising strategies for stakeholder involvement

Stakeholder collaboration plays a significant role in enabling the circular economy to prevail, since processes within the paradigm are designed by humans and for some processes there is a need for personal ambition (Leising et al. 2018). The built environment is an industry that is fragmented and deeply rooted in traditional ways. Therefore, there is a need to incentivise stakeholders to implement the CE in their projects. Hence, Górecki et al. (2019) conducted research on how to convince players in the built environment to effectively implement the CE. The authors state that changes in business models, construction methods and legal regulations are pivotal for an effective implementation of the CE. After a literature review of strategies for effective implementation of the CE in the construction sector, the authors collect data from companies to get an overview of their current feasibility for transition. Companies that operate in developed countries have a good chance of transitioning to the CE since those economies harbour the technological, economical and societal requirements to make the transition. Furthermore, there should be

a vertical integration of companies, industrial parks, communities, countries and international bodies. Additionally, a horizontal involvement of industries and sectors is required. Companies will notice that it is worth investing in circular solutions if there is a top-down regulatory system on macro-economic level implementing regulations that make the CE attractive. If implemented correctly, the CE can become the flywheel of an economy.

Top-down strategies

Top-down strategies are strategies that find their origin in the 'top' of society, such as governmental bodies. An example of this is a local government having policies requiring buildings to become CO2 neutral, or use a certain percentage of reused materials in an urban area development. Governmental involvement in the CE is researched by Bolger et al. (2019), investigating how local governments can facilitate CE initiatives by strategic planning. A comparative case study of the use of strategic planning in the cities of Melbourne and Malmö pointed out that governmental strategies enhance knowledge about the CE. However, there is still a lack of knowledge concerning the CE model, which is why local governments need to find a way to communicate this to the people. The authors conclude that we need a deeper understanding of how all levels of government, corporations and communities can play a part in creating a radical shift from our current production and consumption systems and the CE to thrive. Another way to communicate knowledge about the CE is to operationalise it by circularity indicators as mentioned by Heisel et al (2020). Ghaffar et al. (2020) add to the circular strategy literature that there needs to be integration and collaboration between scientists, policymakers, government ministers and companies in order to manage construction and demolition waste. Furthermore, it requires a strategy or tool that incentivizes stakeholders to invest in closed loop construction, and on-site preparations must be improved and put in practice in order to see improvements in overall resource processing.

Dewick et al. (2019) research what the role of the regulatory framework in a wider contextual condition are in facilitating or hindering regenerative eco-innovation. Eco-innovation is described as a concept associated with new ideas regarding products, processes, organisational approaches or intra-/entrepreneurial ventures that aim to reduce environmental or social burdens. Their case study research, which focuses on extracted material in the UK, shows that the current regulatory framework is not adequately supporting regenerative eco-innovations. The current framework is multi-instrumental and stringent. However, it is also under-enforced, inflexible and disproportionate. It is important to notice that strategies regarding circularity should be enforced, in order for them to work. This can be done by creating feasible government policies and open communication with stakeholders regarding flexible regulations.

Circular design strategies

Circular design strategies focus on implementing the right design for a building in order to create as many circular opportunities as possible. These strategies form the foundation for the design and realisation of the building. Design strategies are developed early in the process, where they cascade down towards construction practice. Design strategies are being implemented in the design, realisation, operating and end of life phase. The literature on circular strategies touches upon the subject of modular construction and design for deconstruction (Kyrö et al., 2019; Voordijk et al., 2016; Rocha et al., 2015; Akinade et al, 2019). Both modular construction and design for deconstruction pave the way to waste minimization and material reuse due to their demountability, non-use of adhesives and the use of smart design solutions. Modular buildings also have the advantage that the modules create flexibility and can be prefabricated in factories. Minunno et al. (2018) seek strategies for applying the circular economy to prefabricated buildings, and to overcome barriers for implementing the CE. The paper recommends seven strategies that create an opportunity for overcoming CE barriers and propose guidelines for the implementation of these strategies. The guidelines include strategies for the design and production phase, aiming to use smart solutions that allow for disassembly, the use of secondary parts, waste minimisation and the use of management reporting systems to track materials within the supply chain. Hence, design strategies play a significant role in the implementation of design solutions that minimise waste, improve flexibility and extend material loops.

Main take-aways and discussion

Strategies concerning the circular economy in the built environment entail base strategies on how to process resources (the 9 R's) and can be an important decision-making tool. The reason why they are base strategies is because they provide a means for selecting an approach, rather than specifically explaining how to process certain resources. Plainly the word 'remanufacturing' does not entail specific steps on how to process a material. It is perceived as a theoretical instrument, which is translated into practice. Further strategies in the CE in the built environment are strategies to incentivise stakeholders to implement the CE, and how stakeholders can be managed in collaborative settings. Stakeholder collaboration, as well as the importance of it, seemed to be repeatedly emphasised as a field wherein further research is required.

3.2.Circular business models

Previous studies on CE in the built environment also touch upon the aim to create circular business models that adhere to the radical change required to achieve a circular economy.

Circular supply chain management

Circular supply chain management requires firms to rethink their supply chains to generate less waste. Sustainable supply chain management concepts have been developed simultaneously to the circular economy, which rose in popularity after being published in

the industrial ecology literature (Ehrenfeld, 1995). McDonough and Braungart (2002) elaborate on circular supply chain management as a system in which production processes continuously reuse output, while stimulating economic growth. Sarkis et al. (2011), add to Braungart by stating that sustainable supply chain management aims to reduce the environmental impact by integrating environmental concerns in firms and reducing waste of resources in production processes.

On a comparative note, Nasir et al. (2017) compared linear and circular supply chains within the construction industry according to a case study in which an LCA assessment was performed. The material used for the case study was a unit of Rockwool Insulation. The research focused on the implications of utilising sustainable alternatives in various contexts and applications and found that circular supply chains exhibit lower CO2 emissions within its production life cycle. However, carbon emissions caused by transport in the circular supply chain were higher than in the linear supply chain due to the collection of secondary materials. Circular supply chains may seem promising. Interviews, however, pointed out that stakeholders are questioning the economic viability of circular supply chains. Leising et al. (2018) investigate this problem by conducting research about supply chain collaboration and new ways in which supply chain collaboration contributes to the transition to the CE in the Dutch building context. Therefore, they developed a conceptual framework including CE visions, network dynamics and business model innovation, which then was tested on three cases in the Netherlands. Cases were analysed by document study and interviews. Results included that CE in supply chains requires personal ambition and a holistic focus on the supply chain management in order for it to work. The business models had been mapped, whereas more in-depth follow-up work could enhance our understanding of circular business models in the built environment. While Leising et al. focused on the impact of supply chain collaboration, Casas-Arredondo et al. (2018) focus on the material and decision flows in supply chains by identifying stakeholders, key materials and waste streams. Their research shows material and decision flows during a building fit-out and maps the decision-making process in the supply chain and how materials are processed after demolition by conducting a Material Flow Analysis (MFA), which is defined as a quantitive procedure for determining the flow of materials and energy through the economy (Zeman, 2012a) and is considered one of the key tools in industrial ecology (Boulding, 1966) and highly regarded as sustainability issues in metropolitan areas (Zeman, 2012b). Supply chain management adds to the CE in the built environment by reducing waste in supply chains. They also seem to play a significant role in circular business models. However, public opinion seems to question the viability of circular supply chains. Although Leising et al. point out that this problem can be tackled by personal ambition, it raises the question on how this personal ambition can be incentivised.

Product-service-systems

Other business models focus on product-service systems (PSS). The aim of PSS is to perceive products as a service rather than something that is owned. An example of this is to have a contract to rent an elevator for 20 years, the service being vertical transportation through the building. This rids the consumer of having to worry about the product at the end of life stage, and enables the producer to seek methods to reuse, refurbish or remanufacture the product. Azcárte-Aguerre et al. (2018) investigated the potential of product-service-systems (PSS) in the CE in the built environment. By literature review and 64 expert interviews, the authors found that PSS systems have the potential to permanently bridge the technical, financial and legal knowledge gap between producers of building technologies, builders, managers and clients. The authors add that buildings should be perceived as a continuing service. By applying new financing mechanisms, architects considering decisions based on a modular interaction between components, a radical change in the industry and an altered perception of the CE in the building industry, PSS could provide a good solution for reducing environmental impact. Although these recommendations appear valid, the question about how radical change can be operationalised is raised. Bertoni (2019) integrated stakeholder management with PSS, investigating how multi-criteria decision making models can be applied to down-select PSS concepts from a value perspective. Multi-criteria decision making models prove to create a synergy between environmental and financial value in PSS. Bertoni also mentions that multi-criteria decision making models are suitable for creating a hub where argumentations related to value and sustainability can be systematically captured. This idea of a hub is very interesting, and elaborating on this concept could provide insights to increase performance of PSS and other circular business models.

Another example of the advantages of BIM are emphasised by Fargnoli et al. (2019), who created a BIM-based PSS approach for the material management of maintenance operations of building equipment. The authors create a BIM-PSS maintenance management framework, which shows potential benefits regarding the integration of BIM for the development of PSS solutions, improving the maintenance activities. Kyrö et al. (2019) add to the conversation of buildings as services by researching the potential of relocatable modular buildings, following principles of circularity, while offering usability to address space needs by modularity. According to the data collected from case studies, semi-structured interviews with key stakeholders along with onsite observation, they found that modular buildings are promising for the CE in the built environment. However, they are susceptible for customizations, jeopardizing the business model. Customization takes time, such as participatory design, just like in traditional building projects. Apparently PSS have great potential in the CE by increasing the producer's responsibility to deliver a robust product. It would be interesting to conduct further research into how PSS can be used on different scales (element, building, city).

Cross-sectoral circular business models

The benefits of cross-sectoral circular resource management practices with regard to financial value are proven by Zainescu et al. (2018). The authors discovered that leather fibres from the shoe industry prove a valuable resource in bio-composites in the building industry. The article suggests that the fibres can be used to make paving blocks for infrastructure. This research paves the way for rethinking how different sectors can be linked towards each other in order to realise circular economy concepts. This research opens the conversation about cross-sectoral circularity and it would be interesting to research more of these applications.

Tools regarding circular business models

Similar to quantifying environmental impacts as described by Sanchez et al. (2019) in section 4.1.4, there are initiatives to quantify existing housing stock, and attach a financial dimension to it. Arora et al. (2019) investigated how a bottom-up method of estimating the availability of used building components can help to estimate supply to the secondary market. By means of a general model, inflows, stocks and outflows were estimated based on annually constructed floor area, total number of buildings, apartments, or total floor area and demolition data. The authors aim to quantify existing public housing stock, annual material and building components inflows and material outflows associated with building demolitions in Singapore. Their findings suggest that Design for Deconstruction, combined with a close relationship between architect and manufacturer and a shift in material ownership to product service systems (PSS) harbours capabilities to increase efficient reuse and secondary resource use. The research recommends that the focus in the CE should be on components' circularity, rather than materials circularity. For example, a DfD wood-skeleton wall should be reused as a component, rather than be broken apart into the individual materials like beams, insulation, wooden plates, etc. Components' circularity enables for quicker processing compared to breaking the component down. Further, the authors note that there may be an attractive market in peri-urban (denoting or located in an area immediately adjacent to a city or urban area (Google, 2020a)) and rural housing demands, where the approaches prescribed in the paper potentially create opportunities regarding the reuse of building components, enabling environmental sustainability and practicing the CE. This research shows that components' circularity might be a good solution to take secondary materials to the market.

Main take-aways and discussion

In conclusion, the financial aspects of the CE in the built environment encompass supply chain management practices, new ways of looking at products by means of product service systems, management of human resources and cross-sectoral business. What seems to be recommended repeatedly in the literature is the recommendation to have close stakeholder relationships in the front-end phase of a building project (Azcárte-Agurerre et al., 2018; Arora et al., 2019; Bertoni, 2019). However, the literature lacks depth

in this recommendation. Hence, future research could aim to investigate the importance of close stakeholder relationships within circular business models, how different stakeholders are represented, what they are doing, and what they ought to be doing. Additionally, further research can point out the economic, environmental and social gain of using close stakeholder relationships by implementing tools to quantify environmental impacts into financial resources.

3.3.Organising systems within construction practice

We define the act of organising systems within construction practice as how things are organised in circular construction projects throughout the different phases, and how the act of organising activities regarding circular construction projects is exercised.

Stakeholder management during construction projects

As mentioned in section 4.3.1., Honic et al (2019) provide a stakeholder management framework for the implementation of BIM-based Material Passports, and how to enable stakeholders to work together efficiently to accomplish circular goals, as mentioned earlier in the literature research.

Eray et al. (2019) take this to a next level by investigating how to improve communication between stakeholders by the interface management. The authors do this during an adaptive reuse project, since this kind of projects are considered highly complex. After a literature review, the authors identified barriers in adaptive reuse projects and interface problems in construction projects. Afterwards, they validate these barriers by conducting a case study. Consequently, an interface management model is developed, mapping interface points, interface stakeholders, interface agreements, interface action items, interface control documents/ drawings, leading up to interface agreement deliverables, which is the end product of an interface management process. These interface agreement deliverables can be used as input for further stakeholder management processes. The authors create a decision flow chart, advising that interface management systems software can significantly reduce complexity in projects that aim towards a circular economy.

Modular construction

Under circularity in the built environment, modular construction is regarded as a promising construction method. This way of creating buildings also produced less waste due to more precise purchasing, planning, cutting of materials. Additionally, at the end of a modular building's life cycle, the building can be taken apart, and be refurbished or reused. Inasmuch as the business model level is concerned modular construction provides the, kind of flexibility that enables firms to serve a variety of customer needs. Variations in the product have limited impact on the production and assembly process which allows the customer to customise a product without the producer consuming too much time and energy. Additionally, product modularity also accounts for a higher product quality. These

factors are both reducing energy use, hence decreasing environmental impact (Voordijk et al., 2016; Rocha et al., 2015)

Kyrö et al. (2019) research the benefits of modular construction by embodying circularity through usable relocatable modular buildings, in which they research what the potential of relocatable modular buildings is, following principles of circularity, while offering usability, to address space needs. In their research, Kyrö et al. conduct in-depth case studies of a limited number of cases, semi structured interviews with key stakeholders along with onsite observation for a means of data collection resulted in modular building practices being perceived as promising for the CE, but susceptible to customizations, jeopardizing the business model. This is supported by the simple fact that customization takes time. It seems as if modular construction has great potential for implementation in the CE due to its allowance for flexibility and healthier fabrication process. Future research could point the feasibility of using modular construction on a city-scale out in order to find out how circular approaches can be implemented on a large scale.

Design for deconstruction

Another construction system that proves promising in the CE is Design for deconstruction, which entails taking design measures that allow a building to be deconstructed at the end of its life, or if a building element needs to be replaced. This has been elaborated by Akinade et al, (2019). Design for deconstruction entails no use of adhesives and poured materials such as concrete which leads to fully reconstructible buildings. Enabling a building to be fully deconstructable creates opportunities for component reuse, adhering to CE principles. Both the principles of modular construction and DfD could increase component flexibility in building units, allowing for waste reduction.

Main take-aways and discussion

Organising systems mainly involve the management of stakeholders and how building materials are organised (modular, DfD) during the act of construction. The term ‘organising systems’ is perceived as a way of organising (human) resources during an act or process within the lifecycle of a building project. In the building phase for example, components and elements (resources) are organised in such a way that they are easily replaceable in case of component/ element failure.

3.4.Processing of resources

Resource processing covers processes in which resources and materials are reintroduced in material loops. This happens either within the built environment, or across sectors. This key theme covers how secondary materials are reintroduced in either new or secondary materials, enabling the built environment to reduce raw material extraction and reduce its pressure on the planet.

Use or secondary materials in conventional adhesives

There is a number of academics interested in using secondary materials in conventional adhesives like mortar and cement. These alterations cause interesting properties, such as weight reduction and increased strength. The overall goal, however, is to reduce the environmental impact of the adhesives by using secondary materials. The act of processing resources in the CE in the built environment is firstly discussed by Lozarno Lunar et al. in 2018. The researchers investigate how steelwork dust can be used as secondary material in conventional mortars. After testing, it appeared that the mortars containing steel dust are stronger, since the particles are smaller, filling certain voids within the substance. Another study considering mortars is conducted by Saeli et al. (2018). By using slaker grit and biomass fly ash to make mortars, they found that the manufacturing process was highly cost effective. Additionally, the combination of lime slaker grits and biomass fly ash is proved suitable for innovative applications in the built environment. Pavlikova et al. (2019) conducted research on biomass ash in mortar, striving to make a lightweight version of the material. According to the tests, biomass ash could potentially represent an eco-efficient and low-cost alternative to other pozzolans (a type of volcanic ash that can be used in mortar or cement that hardens under water (Google, 2020b)) commonly used in the built environment.

Martinez et al. (2019) reduce the environmental impact of the built environment by experimenting how industrial wastes from stone and furnace industries can be reintroduced as raw materials for the design of new high belite (substance in Portland cements that is responsible for ‘late’ strength) cements. In their research, industrial wastes, such as chamotte and marble sludge were investigated as possible raw materials and appear to provide feasible solutions in terms of financial and physical aspects. The biggest gain, however, was that it offers significant environmental advantages, due to a decreased need for energy to create the product. Sticking with wastes, Menendez et al. (2019) conduct research on fine-particle reintroduction by checking how secondary fine particle products can be reintroduced as material for the built environment. They find that fine particle products can be reintroduced as raw material for mortals, concrete, grey clinkers, white cement and ceramics, thus upcycling quarry tailings. Ali et al. (2019) promote the feasibility of using galvanized steel scrap from the automobile industry in Voronoi façade systems through a cross-sectoral supply chain. Findings suggest that through a systematic approach, a true closed-loop supply chain of materials can be activated between two (or more) different industries.

With the exception of Ali et al., there are a lot of applications for secondary fine particles for new products. However, mortars and cement are highly polluting substances. As Braungart and McDonough state, creating a healthier environment is about working on the right products and systems, rather than making wrong things less bad.

Secondary use of wood

The reintroduction of materials and components made out of wood also adheres to the principle of the circular economy. Rose et al. (2019) see the potential to use secondary cross laminated timber as building products. After a comparison of a secondary cross laminated timber beam with a new beam, results showed that there were virtually no differences between the two products in terms of strength and stiffness. Additionally, wood is also a renewable resource. In contrast to focusing on making cement and mortars less bad, more research could point out the possibilities of using secondary wood in the built environment.

Embedding socio-economic systems to improve physical resource organisation

Within the CE, the social aspect also plays a crucial role. The socio-economic embeddedness of the circular economy is investigated by Laurenti et al. (2018). They ask how the material perspective in the CE can be put into larger socio-economic systems, in which the CE is embedded for improvement of physical resource organisation. Findings suggest that connecting material flows, together with socio-economic drivers that result in changes to these flows are capable of having a positive impact on CE initiatives. It is, however, not known which physical entities are affected by the decision-making process relating to specific circular material flows. Further unclearness arises on which stakeholders have a stake in exercising the CE initiatives and how stakeholders should interact and ask how stakeholders have an influence in the front-end phase of a project and how they affect the CE implementation to the CE initiatives. Consequently, the authors recommend that the CE should be developed as a solution of systems integration.

Main take-aways and discussion

The main field of the act of processing resources is looking at how resources can be reintroduced. The literature shows that there are many opportunities for resource processing on a cross-sectoral level. Further research shows the socio-economic embeddedness within physical materials, but the decision-making process and stakeholder interaction are still unknown territory. The majority of the literature captures the processing of secondary materials in adhesives like mortars and cements. Although these ways seem future-oriented, these adhesives have a great impact on the environment. Braungart et al. (2002) stated before that less bad is still not good since cement or mortar may be less polluting to the environment with modifications, it still remains a polluting substance. In order to decrease the environmental impact of the built environment, there is a need for redundancy of concrete and mortars. Wood, as mentioned by Rose et al. (2019) provides a healthier alternative, given the fact that - in case it is sustainably extracted from the Earth - wood is a renewable resource. Literature concerning resource processing should pay more attention to renewable resources, like wood, mudbrick and strawbales. Focussing on renewable construction materials also enables the possibility for cascading, as described by Pauli (2016).

3.5.Management reporting systems

Literature on CE in the built environment starts with tools that provide a means for evaluating the degree of circularity within a building, a process, or both. These systems assess how circularity is managed, and reported accordingly. Therefore, these are called 'management reporting systems'. The literature embraces four subjects:

1. Circularity indicators, which assess the circular performance of a material or building.
2. Life Cycle Assessment (LCA), which assesses the resource consumption and environmental impact of a product.
3. BIM-based management reporting systems, which aim to digitally prescribe the degree of circularity by using Building Information Modelling software.
4. The quantification of environmental impacts, which enables environmental impacts to be perceived as financial resources.

Circularity indicators

Circularity indicators serve as units to indicate the level of circularity within a material or building, with Jiménez-Rivero et al. (2016) having researched the management performance of a building at the end-of-life (EoL) stage. They monitored the processing process of EoL gypsum from demolition to reproduction by conducting audits according to 17 BPI's, set up as a result of a literature review. These 17 BPI's are structured in a table containing the processes in place to process the gypsum. Among these processes were dismantling, tracing, transport, reception, storage and processing. In their study, they found that the BPI's enhance stakeholders' understanding on how to contribute to EoL management practices and provide a foundation for improvement. Furthermore, they found that the BPI's can be replicated for implementation to other EoL products rather than gypsum. Heisel et al. (2020) had a similar approach on a larger scale. They calculated and evaluated circularity indicators for the built environment using the case studies of UMAR and Madaster. These case study buildings map the potential of material passports platforms. The authors conclude that these buildings have a high grade of circularity, and that interdisciplinary teamwork is majorly important in the design and construction phase in order to reach this grade of circularity.

Further research on these circularity indicators was conducted by Nuñez-Cacho et al. in 2018. As a result of their concern about the environmental impact of the built environment, they conducted a research covering the development of a circular economy measurement scale for the built environment. The research recognises that the lack of scale in indicators about circularity is one of the most important challenges for the future of the CE, and aims to create a validated scale of measurement, which can be applied to the built environment.

The product of their research is a scale of measurement that allows for establishing the position on how building companies and their stakeholders implement long-term sustainability of the company, and to assess the degree in which the company implements the CE.

The circular economy in the built environment is operationalised by circularity indicators. They can provide key assessment criteria to assess the degree of circularity within a building, process, company and organisational structure. Therefore, operationalising circularity with these indicators provides a concrete way to measure it. Future research on circularity indicators could be pointed towards more specific processes like the design, stakeholder management or development process.

Life Cycle Assessment (LCA)

Life cycle assessment (LCA) is a reporting method which assesses the resource consumption and environmental impact of a product. It is a management reporting tool that is scientifically based and an International Organization for Standardization (ISO)-standardized method for assessing resource consumption and environmental impacts of a given product, system or service over its entire life cycle (EN, 15978, 2012; ISO, 14040, 2008; ISO, 14044, 2006; ISO, 21931-1, 2010 in Eberhardt et al, 2018) and can also be utilised as a decision making tool (Pomponi et al. 2017). As a result of a literature review, Eberhardt et al. (2018) identified a lack of commonly used method for how to credit reuse in the life cycle of a building in LCA, and the uncertainty of future circumstances in which environmental benefits and drawbacks present itself. To tackle these problems, Eberhardt et al. developed a simplified method, dividing a more equal share of the impacts between potential use cycles. Consequently, they used their simplified method and conducted an LCA on a Danish office building that has been designed for disassembly (DfD). DfD is a design strategy that provides an overview on how the product or building can be deconstructed at the end of life stage, resulting in the product or building being able to easily and rapidly be taken apart, enabling components to be reused. The findings of the LCA suggest that a material's composition greatly influences the building's embodied environmental impact. Additionally, a building's embodied environmental impact is affected by reuse cycles of components, service life and the service life of the building. The longer the lifespan and the more reuse cycles, the better. Yet it is important to understand interdependencies that material compositions have on environmental performance of different building types.

Similarly, Cruz Rios et al. (2019) perform a comparative Cradle to Cradle (C2C) LCA between a steel structure, designed for deconstruction, and a wooden structure, designed for single use. The research compares the environmental impact of building and rebuilding the steel structure three times, and building three new, identical wooden structures. The study found that the benefits of reuse depended on multiple reuses, aggressive reuse rates, short transportation distances and embodied energy of insulation materials.

Secondly, they found that wooden structures cannot be disassembled efficiently. Hence, End-of-Life (EoL) wooden structures become redundant and replacing them with new structures becomes the norm. The authors conclude that C2C comparative LCA studies should identify key variables of influence and investigate their impacts and that more research is needed to map the benefits of reusing building materials.

Hossain et al. (2018) aim to improve the accuracy and completeness of LCA in different stages of the lifecycle of a building by adding the amount of raw material waste and the disposal impacts, renovation and replacement of components of the building and their treatment and material/ waste treatment at the End-of-Life period of the building. Through data collection on waste generation during the construction, renovation and EoL state, waste management strategies were identified, and new ones were developed based on previous studies. Thereafter, data and considerations were both analysed for a control scenario concerning traditional waste approaches, and an alternative scenario comparatively. It was found that this new strategy, called the resource recovery principle, can reduce 63% of the total amount of environmental impact compared to the base scenario. Hence concluding that waste management during construction, use and the EoL stage can significantly reduce the environmental impact of a building over its lifecycle.

It seems as if the main focus of research concerning LCA is studying the environmental effects of materials in relation to case studies and comparing different kinds of entities (DfD steel structure vs. single use wooden structure, traditional waste approach vs. resource recovery principle). Secondly, research focuses on expanding the scope of LCA. Thirdly, LCA appears to be operationalised by circularity indicators as mentioned by Cruz Rios et al.. Perhaps, future research could embed circularity indicators with LCA to assess the life cycle on a broader spectrum.

BIM-based management reporting systems

BIM-based management reporting systems are management reporting systems integrated with building information modelling (BIM). The aim of these digital reporting systems is to digitally prescribe the degree of circularity by using BIM software. Akanbi et al. (2019) developed a BIM-based whole-life-performance-estimator in order to map the whole-life salvage performance of buildings during the design stage. Therefore, they extend the availability of information about materials early in the project, and create a long-term vision for the building's materials. The authors then test the system on a case and find that buildings with demountable parts have a high rate of reusability, and that concrete buildings generate demolition waste that is mostly recyclable. However, in their conclusion, the authors merely focus on the salvageability of the buildings, rather than the model they developed. Their model could be extended by connecting it to other models like material passports to create a more thorough system for secondary building materials.

Another BIM-based management reporting system was developed by Honic et al. in 2019. In their tool, they integrated LCA principles into a material passport and connected it to BIM software. Consequently, two material passports were made. Material passport A was used for the conceptual design stage as a decision tool, whereas material passport B enabled variations in layers of building elements. If a certain insulation material would generate massive waste quantities, it can be replaced by an alternative with a bigger recycling potential. Additionally, material passport C serves as a documenting tool and material passport D provides information for recycling and an inventory of the realised building as a basis for an urban material cadaster. Thereafter, the authors investigated how policymaking, based on three pillars of institutional theory, supports the implementation of BIM-based material passports. During the development of their BIM-based material passport, however, they encounter high inconsistency in stakeholder data. Therefore, they proposed a stakeholder management framework on how to gather coherent data according to the regulative, normative and cultural-cognitive pillars of institutional theory.

BIM-based management reporting systems enable practitioners to reflect on design choices during the design phase. Practitioners are required to assess whether a certain material is the 'best choice' within the given programme of requirements. Therefore, BIM-based management reporting systems have both a prescriptive and descriptive role in the development of buildings.

Quantification of environmental impacts

Environmental impacts can be quantified to temperature fluctuations, the amount the sea levels rise and the amount of carbon in the air. However, financial resources play a significant role in the built environment. Therefore, Sanchez et al. (2019) develop a methodology to quantify and analyse the net environmental impacts and cost performance of adaptive reuse of a building after which they quantify the net environmental impacts and monetise the carbon savings, in order to compare costs and benefits. The results suggest that adaptive reuse of buildings is considered a superior alternative to new building construction, regarding sustainable development and a CE.

Main take-aways

The research considering this topic entails operationalising it through circularity indicators and means of measuring circularity in buildings. These tools or systems, portray how circularity is being exerted in the built environment and play an important role in the assessment of and progression in the circular economy in the built environment. Additionally, they can be used both prescriptive and descriptive, like described by Honic et al.. Although these systems are a sound way to measure circularity in buildings, they merely focus on the material aspect, rather than also paying attention the human factor, and what the role of other resources are in circularity such as knowledge and human resources. Future research could point out the potential of the use of management

reporting systems to reflect on processes and human resource management in the CE in the built environment. Additional research could focus on integrating circularity indicators, including human resources, stakeholder management and other (intangible) resources with BIM software to create a mainstream measurement tool which can be used universally.

3.6.Main take-aways from systematic literature review

The goal of this section is to emphasise the main take-aways from the literature review. It starts with a bit of a general overview, and narrows down to specific surprising findings and gaps.

Concerns about the environment have been expressed since the late 18th century, but the Circular Economy gained attention and momentum throughout the 1960s and 1970s (Boulding, 1966; Pearce et al. (1998)). The CE in general is perceived as a term which envelops different schools of thought (Boulding, 1966; Erkmann, 1997, Graedel, 2003; Ausubel, 1994; Braungart, 2002; Stahel, 1981; Pauli, 2016; The Biomimicry Institute, 2020; Lyle, 1994; Hawken et al., 1999). Although there are different schools of thought, the main goal remains to increase material efficiency, build and rebuild overall system health and provide a long-term solution to environmental challenges.

The academic pool of literature on circularity in the built environment is four years old as of 2020 and is getting an increasing amount of attention. In order to get an overview of the existing literature, the literature has been categorised into five key themes in chapter 4. These are circular strategies, circular business models, management reporting systems, organising systems within construction practice and resource processing. This categorisation of research within the CE in the built environment serves two purposes. On the one hand, it provides a means of categorising how research in the CE in the built environment is spread, and it provides a foundation on which literature gaps can be identified and further research can be suggested. On the other hand it shows how the five key themes are interrelated to each other.

Within the five key organising themes, there are themes related to theoretical processes and thinking, as well as others relate to practice. Theoretical processes are involved in developing circular strategies, since they provide the base for further action. Also, a lot of thinking is involved in developing circular business models. One might think that circular business models are also a way of strategising. However, circular business models are perceived as a product of a strategy. While still remaining a theoretical entity, it is an action derived from strategy. For example, if the strategy of a company focuses on building circular housing, the business model derives from that strategy.

On top of that, there are practical processes, which are the act of organising systems in construction practice and resource processing. From the five key themes, resource processing is the most practical one, since it involves the most steps implying physical

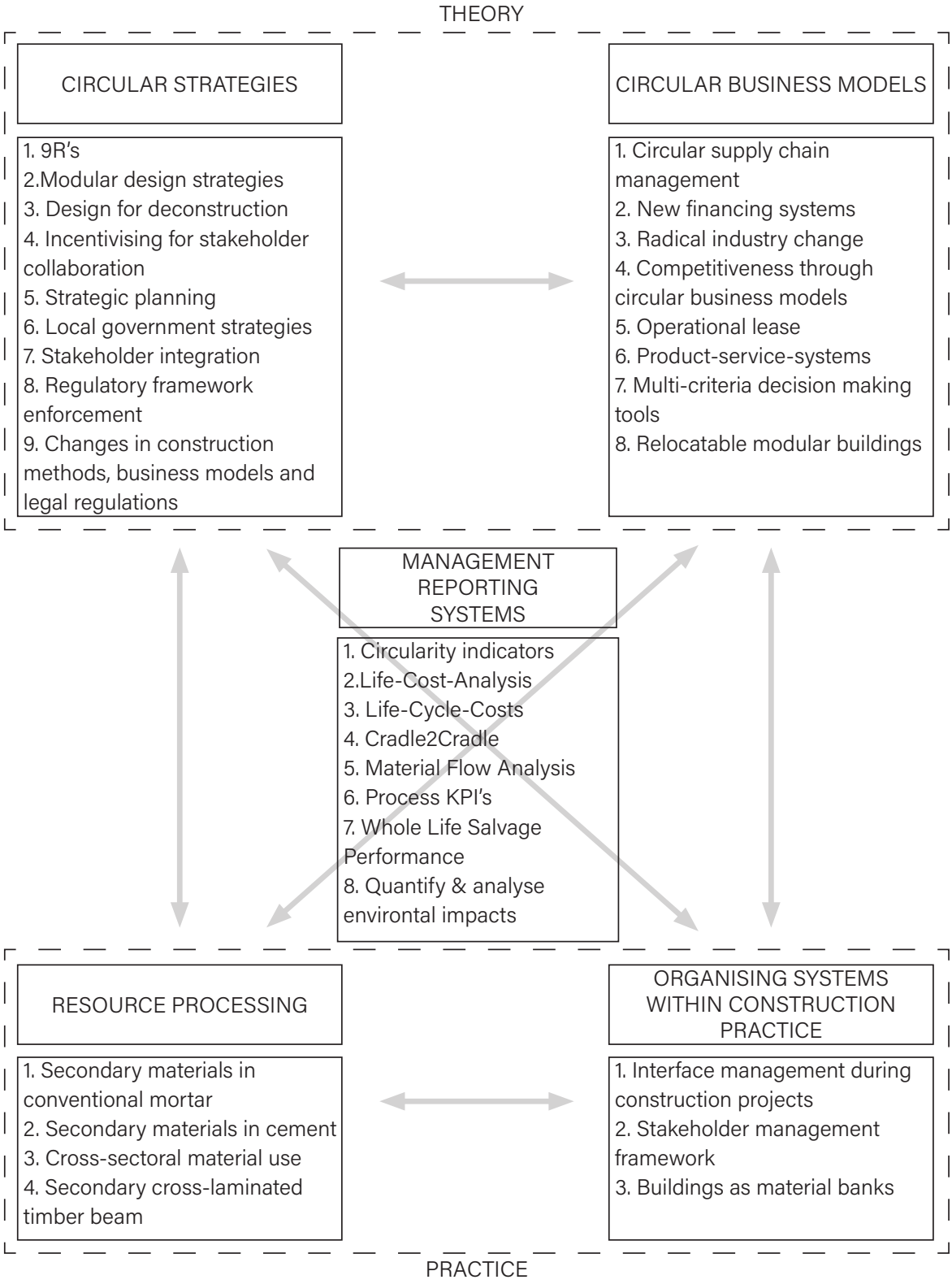

Figure 4. The Circular built environment framework (own Figure)

effort. In the literature, there seems to be a firm understanding about the processing of resources. However, the focus should defer from making polluting substances like cement and mortar less bad, and focus on substances that promote the regeneration of natural systems.

Following the act of processing resources, are organising systems within construction practice. While there is still some thinking involved in this by the development these systems (like modular construction or DfD), the act of organising systems is practically oriented. There is a link between modular design strategies and design for deconstruction, since these strategies are translated into practice by physically organising building elements in either a modular way or that they can be deconstructed again. For instance, this can be manifested in/from a strategy as follows: Company A wants to develop a building. During the creation of the brief for the building, the strategic brief entails that the building should be demountable. Therefore, to operationalise this strategy, company A decides to combine modular construction principles with DfD principles. These founding principles form the base for the design. After the strategy has been developed, it is operationalised by creating the design. This is one way of implementing organising systems in construction practice. Further, during the construction phase, the design is realised, again by implementing organising systems. In short: these organising systems are the practical translation of strategies and business models.

The last of the five key organising themes are the management reporting systems. These entities assess circularity and provide useful data for further innovations. Management reporting systems (MRP's) are virtually the bridge between circular strategies and circular business model innovation, and organising systems and resource organisation. The reason for this is that an MRP assesses how the theory is translated into practice. For example, an LCA assesses how circular strategies and circular business models are being implemented by means of organising systems and resource organisation. They assess what is done well, what is not done (well), and what should be done in terms of theory articulated in practice.

The framework on the next page represents how previous studies describe circularity in the built environment, and which key themes are at play. It is an operationalisation of the current understanding on how circularity is practiced and also clearly shows how the themes are interconnected with each other. In short: circular strategies and circular business models are processes which require a lot of thinking, in which circular business models are a product of circular strategies. The thinking is turned into action (doing) by physically processing resources and handling resources by implementing organising systems in the construction practice. Finally, management reporting systems reflect how thinking is translated to doing, and vice versa. Management reporting systems provide tools in which the circular economy can be assessed and optimised. For instance, the use

of management reporting systems shows how Eberhard et al. (2018) conducted a life cycle assessment of a Danish office building, which was designed for disassembly to measure the potential environmental impact savings. It assesses how strategies such as design for deconstruction enable carbon savings in the reorganisation of the resources at the end of the building's life cycle.

Previous studies concerning circular strategies and circular business model innovation, recommend that a close relationship between stakeholders, a radical change in the current business model and a shift from ownership-driven development to product-service-systems are enablers for the CE in the built environment multiple times. (Azcárte-Agurerre et al., 2018; Arora et al., 2019; Bertoni, 2019). Therefore, future research could elaborate on stakeholder integration, new business models and product-service systems. Additionally, literature on strategies report top-down incentivisation strategies and strategic planning (Bolger et al., 2019; Ghaffar et al., 2019; Dewick et al., 2019; Minunno et al., 2018). It would be interesting to investigate how government policies incentivise and prevent circular solutions, and if there is any flexibility in those policies.

There are also multiple authors pleading for integration of various bodies. Laurenti et al. (2018) recommend that the CE should be developed as a solution of integration of systems. Ghaffar et al. (2020) add to the circular strategy literature that there needs to be integration and collaboration between scientists, policymakers, government ministers and companies. Additionally, Górecki et al. (2019) suggest a vertical integration of companies, industrial parks, communities, countries and international bodies. In the regenerative design school of thought, the emphasis lies on the development of community support systems, capable of being restored, renewed, revitalised or regenerated by integration of natural processes, community action and human behaviour. This idea is in line with the CE trail of thought, aiming to develop the linear economy to a more integrated industrial ecosystem in which resources are optimised. Therefore, future research could look into how to integrate different systems like top-down-horizontal stakeholder integration, or radically new ways of stakeholder integration.

Keeping the focus on stakeholder integration, as Laurenti et al. (2018) suggest: we need to ask the question on how stakeholders have an influence in the front-end phase of a project and how they affect the CE implementation to the CE initiatives. Future research could point out the significance of different stakeholders in the front-end phase, since current literature lacks this perspective. The front-end phase is defined by Sarde (2016) as a process wherein project planning and scope definition is developed according to a detailed framework for project management and is considered an effective construction project management practice at the early stages of a project. Decisions that are made early in the process, cascade down into practice. This stresses the importance of the front-end in the CE in the built environment, since the wrong decisions could jeopardise a project.

Moreover, the literature seems to have a dominant focus on processes surrounding materials. Although this is a pivotal element in the implementation of the CE, there are also other resources that enable the circular economy like human resources, planning, transport, etc. as mentioned in section 2.2. 'A note on resources'.

Additionally, there is a lack of focus on the existing building stock, and how it can be optimised. The literature focuses a lot on construction and how resources can be processed, but not on resource optimisation, while this still is an important pillar in the CE. This raises the question on how resources in already realised buildings can be optimised.

The last main take-away is that these key themes are often addressed from the perspective of the contractor and the supply chain with a dominant focus on construction. Construction is where the decisions in earlier phases are exercised in practice, and it is interesting to pay attention to what exactly enables this. The construction phase effectively proves whether choices made in the early stages of a project make the project successful. However, as mentioned, the focus of the CE in the built environment is mainly concentrated around the construction phase which is part of a real estate development process. This means that the entire real estate development process is underrepresented in delivering circularity in the built environment in previous studies, and there is a lack of focus on the whole life cycle of buildings.

As mentioned above, early stages in the project effectively predetermine a project's success. A pivotal player in these stages is the real estate developer. Secondly, there is a lack of focus on the perspective of circular RE development in the review of previous studies. To address this gap, the real estate development process and the role of the real estate developer had to be understood. The next section will address this.

4. The real estate development process

The goal of this section is to describe the real estate development process according to literature, and served as a foundation for the development of the circular RE development process. Within the built environment, real estate (RE) development plays a significant role in creating the structures, features and facilities people live and work in. Essentially, the RE development process enables the realisation of the built environment through creating buildings and structures that make up the built environment. A significant player in the RE development process is the RE developer, whose role is perceived as that of a “director of a play, who has to manage the diverse and conflicting objectives of all actors on a public stage. As such a director must have the capacity and energy to pull together the performance to ensure it reaches a satisfactory solution” (Wilkinson & Reed, 2008). Therefore, the following section describes the RE development process, the phases and the key players involved, what they do and when they do it.

4.1. Defining the real estate development process

According to Wilkinson and Reed (2008) the RE development process is in line with any other industrial production process and involves the combination of various inputs in order to achieve an output or product. Inasmuch as the RE development process is concerned, the output or product is a change of land use and/or a new or altered building in a process that combines land, labour, materials and finance. Moreover, Wilkinson and Reed (2008) add that the RE development process is complex and often takes place over a considerable amount of time. Furthermore, no other process operates under such constant public attention, setting the RE development process apart from other production processes through its complexity, combination of resources, duration and public attention.

The development of real estate entails the process of creating a tangible product which generates value. This product refers to physical spaces which are conceptualised, designed, constructed and occupied (Bulloch et al., 2010). Graaskamp (1981) defines the RE development process as the creation of space delineated by man, relative to a fixed geography, intended to contain activity for a specific period of time. To add, the author also states that the RE development process consists of four dimensions of which the first three dimensions are the physical dimensions length, width and height. For example, a building has a length of 20 meters, a width of 80 meters and a height of 30 meters. The fourth dimension is the space-time characteristic which refers to possession and benefit. A significant characteristic of the space-time dimension is that any space-time unit has a corresponding monetary value. For instance, space-time units may be apartments per month, motel rooms per night, square footage per year, or tennis courts per hour. Furthermore, Graaskamp states that the creation and management of space-time units can also be described as the real estate development process, as shown in the following quote:

“The creation and management of space-time units is termed real estate development. Real estate developments range from a simple cave to the complex technology of the Park Avenue skyscraper. Like a manufactured product, a real estate project is part of a larger physical system programmed to achieve long-term objectives, but each real estate project is also a small business enterprise of its own. Thus, the development process is a continuum of construction technology, financing, marketing skills, administrative controls, and rehabilitation required to operate the real estate enterprise over many years.“ (Graaskamp, 1981, p. 1)

Graaskamp elaborates that, apart from the physical creation of a building, the RE development process also consists of activities such as involving different parties and interest groups, dealing with limited resources and the involvement of political and social processes, thus being a complex, collective process.

In addition to Graaskamp’s (1981) definition, Miles, Netherton and Schmitz (2015) define the RE development process as follows:

“Real estate development is the process of bringing built space to fruition. It starts with an idea and ends when consumers - tenants or owner-occupants - occupy the physical space but in place by the development team. Each real estate project is in essence a separate business entity employing the three factors of production - land, labour, and capital to create a product. To transform an idea into reality, these factors are coordinated by entrepreneurial management and delivered by teams. Value is created by providing space to meet the needs of society. Although the definition of real estate development remains simple, the process grows more and more complex as municipalities, financial markets, and consumer tastes evolve.“ (Miles, Netherton & Schmitz, 2015, page 31)

In conclusion, the RE development process is a complex process, characterised by change of land use and/or a new or altered building in a process that combines land, labour, materials and finance and is under constant public attention. It sets itself apart from other production processes by its tendency to encompass longer amounts of time, the product being perceived a more permanent fixture and every development being a unique endeavour. Furthermore, the process brings together various stakeholders that all play different roles throughout the different RE development process phases. Phases in the RE development process, and which phases are included in this thesis will be elaborated in the next section.

4.2.Phases in the RE development process

In his book ‘inleiding projectontwikkeling’, Nozeman (2010) provides an overview of how different authors view the phases of the RE development process. These are shown in table 2 (Nozeman, 2010).

	Van Beukering	Miles, Netherton & Schmitz	Neprom	Van Gool	Wilkinson & Reed
1	Programme (initiative, feasibility study, project definition)	Idea conception	Initiative or starting phase	Initiative	Initiation
2	Design (structural design, preliminary design, definitive design)	Idea refinement	Development phase	Contracts	Evaluation
3	Working out (specifications, pricing, preparation of the works)	Feasibility	Realisation phase	Realisation	Acquisition (legal, soil, funding)
4	Realisation (execution, delivery)	Contract negotiations	Exploitation phase	disposal	Design and costing
5	Use and management (use, management and demolition)	Handling formal commitment			Permissions
6		Construction			Commitment
7		Completion and formal opening			Execution
8		Property, asset and portfolio management			Let/ manage/ dispose

Table 2: RE development phases according to various authors (Nozeman, 2010)

Furthermore, there are three additional sources that also state their view on the RE development process. This is shown in Table 3.

The following table shows the phasing table by Nozeman (2010) complemented by the additional authors (Warmedam & Heinz, personal communication, September 14, 2018; Antink et al., 2014; van Kranenburg, 2011) .

	Warmedam and Heinz (personal communication, September 14, 2018)	Antink et al. (2014)	Van Kranenburg (2011)
1	Initiative phase	Concept/ definition phase	Brainstrom & context
2	Design phase	Design phase	Confrontation
3	Construction phase	Construction phase	Concept
4	Exploitation phase	In use phase	Project
5		End-of-life phase	Asset

Table 3: re development phases according to additional sources (own table

	Van Beukering	Miles, Netherton & Schmitz	Neprom	Van Gool	Wilkinson & Reed	Warmedam & Heinz	Antink et al.	Van Kranenburg (2011)
1	Programme (initiative, feasibility study, project definition)	Idea conception	Initiative or starting phase	Initiative	Initiation	Initiative	Concept/ definition phase	Brainstorm & context
2	Design (structural design, preliminary design, definitive design)	Idea refinement	Development phase	Contracts	Evaluation	Design	Design phase	Confrontation
3	Working out (specifications, pricing, preparation of the works)	Feasibility	Realisation phase	Realisation	Acquisition (legal, soil, funding)	Construction	Construction phase	Concept
4	Realisation (execution, delivery)	Contract negotiations	Exploitation phase	disposal	Design and costing	Exploitation	In use	Project
5	Use and management (use, management and demolition)	Handling formal commitment			Permissions		End-of-life	Asset
6		Construction			Commitment			
7		Completion and formal opening			Execution			
8		Property, asset and portfolio management			Let/ manage/ dispose			

Table 4: accumulator of re development phases according to various actors (composed table)

Virtually all authors agree that the RE development starts with an initiative phase. Although, some authors take a more detailed approach to phasing than others. The first three phases stated by Miles, Netherton & Schmitz for example can all be regarded as activities taking place in the initiative phase. Similarly, Wilkinson & Reed (2008) split the design phase in two: Design and consting, and permissions. It is interesting to see that there are quite the number of interpretations about the RE development process, and it seems that some authors take a more general approach to phasing than others. For instance NEPROM (in Nozeman, 2010) mentions the 'development phase' as a second phase. This leaves the reader guessing what happens in this phase. Whereas for instance a 'design phase' clearly indicates that the main activity is the creation of the design, it is quite unclear what the development phase is. This can be regarded as the entire RE development process if not mentioned in the context of the four phases described by NEPROM.

What is surprising is that there is no author, except for Antink et al., mentioning an end-of-life phase. This might be an indication that real estate developers do not concern themselves with the end-of-life stage of a building. Given the assumption that the end-of-life phase plays a significant role in the CE in the built environment, it raises the question why other authors do not mention this phase. It seems that other authors define the end of the RE development process when the building has become an asset or us in use or its exploitation phase.

There are five sources that share a similar view on the RE development process (NEPROM in Nozeman, 2010; Warmedam & Heinz, personal communication, September 18, 2018; Antink et al., 2014, van Gool (2007), van Beukering (in Nozeman, 2010). These sources provide the foundation for the RE development process phases regarded useful in this thesis. The key phases this thesis focuses on are the following:

1. Initiative phase
2. Design phase
3. Construction phase
4. Exploitation phase
5. End-of-life phase

This does not exclude other authors, though, since the phases that they describe are virtually incorporated within the phases used in this thesis. Table X illustrates this.

	Phases in thesis	Van Beukering	Miles, Netherton & Schmitz	Wilkinson & Reed	Van Kranenburg (2011)
1	Initiative phase	Programme (initiative, feasibility study, project definition)	Idea conception	Initiation	Brainstorm & context
			Idea refinement	Evaluation	Confrontation
			Feasibility	Acquisition (legal, soil, funding)	
			Contract negotiations		
2	Design	Design (structural design, preliminary design, definitive design)	Handling formal commitment	Design and costing	Concept
				Permissions	
3	Construction phase	Working out (specifications, pricing, preparation of the works)	Construction	Commitment	Project
		Realisation (execution, delivery)	Completion and formal opening	Execution	
4	Exploitation phase	Use and management (use, management and demolition)	Property, asset and portfolio management	Let/ manage/ dispose	Asset
5	End of life phase				

Table 5: Distillation of key phases in the re development process (own table)

Apart from the five *phases* defined in this thesis, Nozeman also provides a more detailed list of *actions* that are taken during the development process. These are written down in figure 1 (composed figure). The end of life protocol is added to Nozeman's sequence, since it is expected that circular economy principles will prove valuable during this period. For example, whereas a building would traditionally get demolished and only leftover concrete would be used for highway construction, it may prove valuable to carefully extract building materials like windows, doors and structural elements and reuse/ sell them. Furthermore, the five phases that have been defined for this thesis are written down under the term 'phases'. However, this is still a linear development process. Further elaboration about a circular RE development process and how this can be achieved is stated in chapter 11. Additionally, on the left side of the 'actions' column, it shows which stakeholders are involved during certain phases.

The next sections serve to deepen the understanding of the five main phases in the RE development process.

Initiative phase

The initiative phase starts with the decision to start thinking about developing real estate. Reasons for development might be (Nozeman, 2010):

1. An existing user seeking new accommodation
2. A local government publishes a competition for (re)development of an area, looking for original ideas
3. A real estate owner wants to sell his property
4. A developer of investor investigates the market for possible voids to fill in by developing real estate that fills that void. These could be regions where there is a lack of parking services, high-end apartments or homes for the elderly.
5. A developer develops a concept which he wants to realise, followed by the acquisition of land.

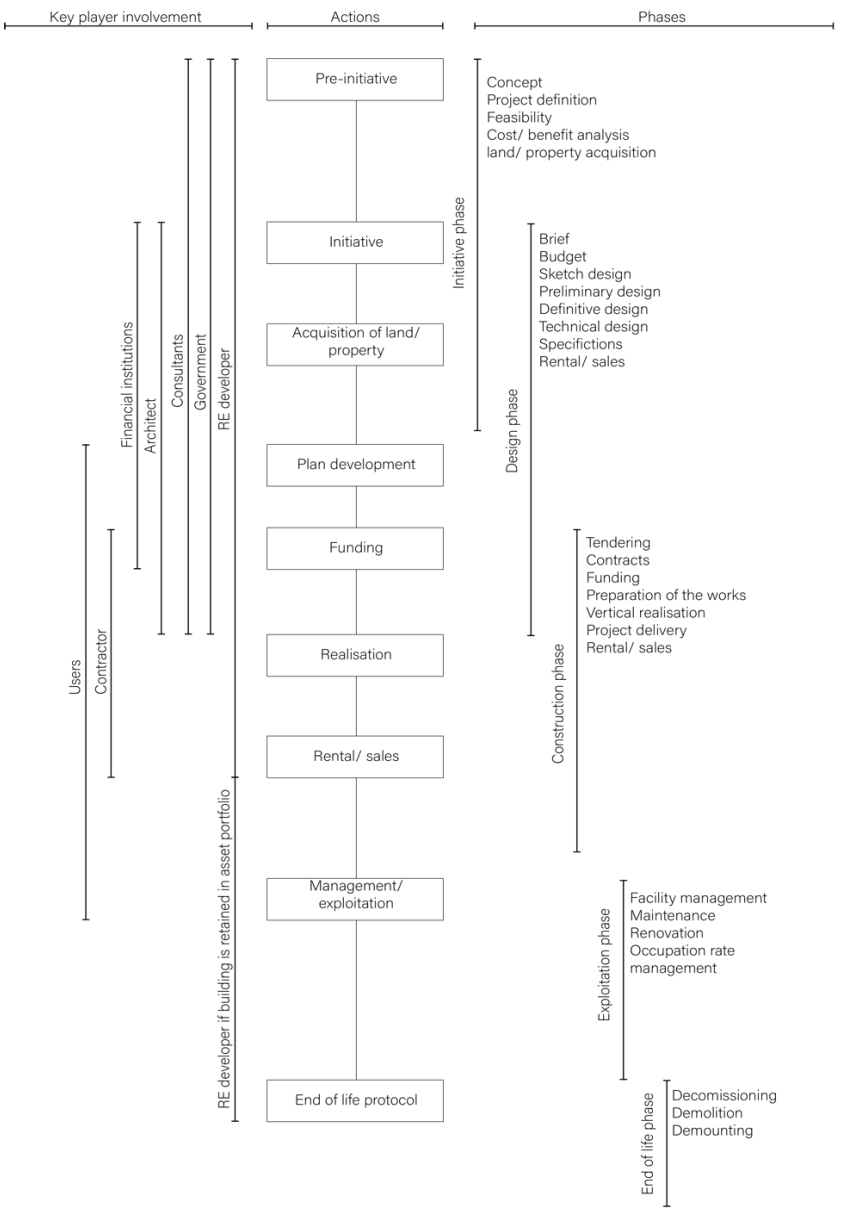

Figure 5: the real estate development process including stakeholders and actions (own figure)

The initiative phase starts with the pre-initiative phase, in which the development team is being assembled and the strategy and concept about the development become clear. The initiative phase consists of activities such as determining the scope of the development and feasibility studies. During the feasibility studies, the RE developer conducts a formal market study to estimate market absorption and capture rates. If it appears that the

development is not feasible, the concept changes, the development process gets adjusted or the development process ends. Additionally, a cost-benefit analysis is conducted, and the plans are processed with government agencies. Whereas a cost-benefit analysis in traditional the RE development process might have a dominant focus on monetary value, cost-benefit analyses in a circular RE development process could divert the focus from purely financial value, to environmental and social value.

Consultants may be consulted during the feasibility study, as well as government agencies and planners. A feasibility study is positively valued if it demonstrates legal, physical and financial feasibility for all participants (Miles, Netherton & Schmitz, 2015). Other activities include adjusting the zoning plan (if necessary), determining the budget and creating a brief of the building, otherwise known as the programme of requirements. The brief is a significant document which provides a desire of the to be developed building. A brief may include descriptions of the client, building site, spatial and technical requirements, budget and desired contract form. The initiative phase ends when the concept is feasible or, despite multiple efforts, appears not to be feasible.

Design phase

During the design phase, the physical representation of the building is given shape by the architect. Generally, there are four designs in the design phase (Beelen CS architecten, 2018). First of which is the sketch design, which serves as a rough design to give the client an idea of the physical shape of the building. The second stage, the pre-design is more detailed, it shows where the windows are placed in the façade, the functions within the building and to some extent, materialisation. The client can provide feedback on the design and indicate additional wishes, since there is still the opportunity to adjust the design. Thirdly, the definitive design shows the final shape, materialisation of the building and main dimensions. After the definitive design is finished, fourthly, the design will be prepared technically for the environmental permitting process, in which the designer needs to provide mandatory calculations like daylight and ventilation calculations in the Dutch building context. These will be assessed by the local government. Furthermore, the building designer needs to develop details of where materials meet, like the roof and outer façade. The architect mostly outsources structural calculations to a constructor. In traditional contracts, the tendering of possible contractors starts when the design is finished. This can either be done by asking a contracting company to build the building and provide a price. But it can also be done competitively, in which multiple contractors are asked to provide a price and building specifications. This is also called EMVI (Economisch Meest Voordelige Inschrijving) or Economically Most Profitable Tender. Consequently, whichever contractor provides the best balance in price and quality, gets selected by the client to realise the building.

Construction phase

The construction phase generally starts when the construction contract is signed (Nozeman, 2010). This is dependent on the contract, though. For instance, this does not apply for a Design and Build contract, where the contractor is involved early in the process, even before the design stage. Early contractor involvement (or stakeholder involvement in general) might prove pivotal in enabling the RE development process to deliver circularity in the built environment. Firstly, because previous studies state that early stakeholder involvement is a significant enabler of the CE (Azcárte-Agurerre et al., 2018; Arora et al., 2019; Bertoni, 2019).

The successes or setbacks in the construction phase mostly arise out of choices made in the initiative and design phase. In the construction phase, the building is realised by the contractor. This process includes the procurement of building materials and suppliers, preparing the building site, vertically raising the building, controlling the works and eventually, the project delivery, rent and/ or sales. The end of the realisation phase is generally the day of delivery. Miles, Netherton and Schmitz (2015) write that, during the construction phase, the RE developer switches to a formal accounting system, aiming to keep costs of the development within budget. The role of the developer now becomes more of a controller of the construction process, in which he/ she approves suggestions by the marketing professionals and development team, resolves construction disputes, signs checks, keeps works on schedule, brings operating staff as needed, etc.

Exploitation phase

The exploitation phase is the longest lasting phase. This is the phase that real estate management practices play a big role. Also, the building is used, maintained and renovated. Additionally, in this phase, the building will be assessed whether it complies with the expectations. Occasionally, the building gets sold to other investors (Nozeman, 2010). Miles, Netherton and Schmitz (2015) describe the exploitation phase as the period in which the owner of the building conducts real estate management, reconfiguration of the building, remodelling and remarketing unused space as necessary to extend both the economic life and performance of the asset. As mentioned earlier, this phase if often excluded from literature concerning circularity in the built environment. Therefore, this thesis also paid attention to what practitioners do in the exploitation phase.

End of life phase

Lastly, the End of life phase represents the phase in which the building is decommissioned, and new development is needed out of necessity, rather than desire. The reason for this can be physical, economic, functional, aesthetic, environmental, legal and social, technological or locational obsolescence (UK, Essays, 2018). After decommissioning, the building will be disintegrated by either demolition of demounting. Previous studies on circularity in the built environment indicate that decommissioned buildings can serve as

material banks for further development. However, an important pillar of the CE is to lengthen material loops. Perhaps there are more ways in which soon to-be decommissioned buildings (say 2 to 5 years) can contribute to circularity in the built environment, by lengthening its functional life (thus materials loops), preventing physical obsolescence. Here is where asset management plays a big role in enabling current buildings to remain functional as long as possible. One way of doing this might be to defer from short-term RE revenue models and focussing on maximisation of the building's functional life, rather than profits.

4.3.Key players in RE development

As mentioned earlier, the RE developer is regarded as the director of a firm, having to manage different players with differing goals, and that the three factors of production are delivered by teams. But, who are these players in these teams? Miles, Netherton and Schmitz (2015) point out the partners of RE developers, which are architects, engineers, landscape architects, land planners, urban designers, building contractors, environmental consultants, traffic and transportation consultants, biology consultants, geotechnical and soil consultants, hazardous substance consultants, air quality consultants, greenhouse gas consultants, noise consultants, market research analysts, lenders, joint venture partners, appraisers, public finance consultants, attorneys, accountants, leasing agents and sale brokers, marketing and public relations consultants, property managers, regulators and end users. Wilkinson and Reed (2008) state that main actors are landowners, developers, public sector and government agencies, planners, financial institutions, building contractors, agents, planning consultants, property economics consultants, architects, construction economists, engineers, project managers, solicitors, accountants, objectors and occupiers. It can be stated that there are numerous professions involved in the RE development context, with quite a number of consultants. Furthermore, in this thesis the actors are perceived on a more general level. This allows for a more compact research and prevents repetitiveness. Table 1 represents the key general players in the RE development process.

Generalised terms	Miles, Netherton & Schmitz	Wilkinson & Reed (2008)	Nozeman (2010)
RE developer	RE developer	Developers	RE developer emerged from construction companies Independent RE developer RE developer allied to investors RE developer emerged from financial institutions RE developer with other core business
Financial services	Lenders Joint venture partners Appraisers Accountants Leasing agents Sale brokers	Financial institutions Agents Construction economists	Investors
Regulators	Regulators	Public sector Government agencies	Local government
Contractor	Building contractor	Building contractors Project managers	Building contractor

Planners	Architect Landscape architect Land planner Urban designer Environmental consultant Traffic and transportation consultant Biology consultant Geotechnical and soil consultant Hazardous substance consultant Air Quality consultant Greenhouse gas consultants Noise consultant	Architects Planners Engineers	Architect Engineers
Consultants	Market research analysts Public finance consultant Marketing and public relations consultant	Planning consultants Property economics consultants	Consultants
Users	End users	Landowners (if owner-occupier) Solicitors Occupiers	Owner Users Local government
Facility managers	Property managers		Facility manager

Table 6: generalisation of the key re development players (own figure)

Thus, according to table 6, the following key players arise:

1. RE developer
2. Financial services
3. Regulators
4. Contractor
5. Planners
6. Consultants
7. Users
8. Facility managers

In conclusion, the RE development process is a complex process, characterised by change of land use and/or a new or altered building in a process that combines land, labour, materials and finance and is under constant public attention. It sets itself apart from other production processes by its tendency to encompass longer amounts of time, the product being perceived a more permanent fixture and every development being a unique endeavour. Furthermore, the process brings together various stakeholders that all play different roles throughout the different RE development process phases. The RE development process consists of the initiative, design, construction, exploitation and end of life phases in which 8 main bodies of actors play a role: the RE developer, financial services, regulators, contractors, planners, consultants, users and facility managers. These are key players as described in the traditional RE development process, though. This thesis therefore also asks the question about which stakeholders play a key role in the circular RE development process. It was suspected that suppliers would play a big role in the circular RE development process, since their business models focus on materials and their flow. Additionally, the timeline that is shown in this chapter is a process that has been constructed according to the literature read. This is a traditional, linear process. Therefore it can be concluded that there is a lack of an end-to-end, or circular RE development process according to the literature.

Now that the circular economy, its relation to the built environment and the RE development process have been described, the research aim and objectives are described in the following section. This section serves to precisely clarify the main aim of the research, and its five objectives. After the aim and objectives have been described, chapter 6 will reveal accompanying research questions.

5. Research aim, objectives and research questions

The literature review revealed that there is a lack of a RE development process perspective, despite its significance in a project life cycle and asset portfolio. Furthermore, there is unsatisfactory focus on the building's whole life cycle and the RE development process is described as linear in the literature. Therefore, the aim of this research is to explore the current and future role of the real estate development process in terms of delivering circularity in the built environment. The research aims to do this over the entire RE development process, including the entire building life cycle. The end-product of this thesis therefore is a circular RE development process.

5.1.Objectives

The research has five objectives.

1. To review existing literature on circularity in the built environment to develop a framework that serves as a foundation for further research.
2. To analyse how key players in the real estate development process view circularity in the built environment, and their aspirations for circularity.
3. To investigate the gap between current practice and future aspirations in the circular real estate development process.
4. To analyse what and how barriers faced in the development phase of the circular real estate development process can be overcome.
5. To develop practical guidelines in order to enable concrete action in circular real estate development to occur and develop a circular real estate development process.

Objective 1 has been part of the front-end of this thesis. Therefore, objective 1 is not included in the empirical part of this research. Yet, the theoretical knowledge obtained in objective is used as comparison with practice in chapter 9 'discussion of results'.

Objective 2 serves to create a context in which the field defines circularity, who the key players in the circular RE development process are and what their current and future views on circularity are.

5.2.Research questions

With the aim to investigate the current and future role of the RE development process in delivering circularity in the built environment, the main research question of this thesis is:

What is the current and future role of the real estate development process in terms of delivering circularity in the built environment?

In order to answer the main research question, a set of sub-questions has been developed. These subsets aim to clarify the context (objective 2), analyse current and

future practices and/ or aspirations (objective 3 & 4) and to deliver guidelines to support concrete action (subset 5).

The first set of questions arises from objective 2: To analyse how key players in the real estate development process view circularity in the built environment, and their future aspirations for circularity. Firstly, there is a need to identify which stakeholder play a significant role in the development process of circular real estate, how they see circularity in the built environment, and how this understanding is formed. Questions a, b and c provide and understanding of this.

Objective 2: To analyse how key players in the real estate development process view circularity in the built environment, and their aspirations for circularity.

a. Who are the key players in the real estate development process?
b. What do key players in the real estate development process understand with circularity?
c. How is the practitioners' understanding about circularity informed?

Furthermore, there is a need to understand the key stakeholders' views of the future of circularity in their organisations and in their work. Question d is going to answer this.

d. What are their views of the future of circularity in their organisation and in their work?

Once the key stakeholders, their understanding of circularity in the built environment, and their views of the future are identified, a comparison is made between the obtained data, and the framework that is provided as a result of the literature review.

e. What are the similarities and differences between the practitioner views and the themes found during the review of previous studies?

The second set of questions is a result of the third objective of this research: To investigate the gap between current practice and future aspirations in the circular real estate development process.

Objective 3: To investigate the gap between current practice and future aspirations in circular real estate development.

a. What are current practices exercised (if any) by key players in the circular real estate development process?
b. What are current practices that contribute to the RE development delivering circularity in the built environment?

c. What is the gap between current practices and future aspirations by key players in the circular real estate development process?

The third set of questions analyses what and how barriers faced in the development process of circular real estate can be overcome.

Objective 4: To analyse what and how barriers faced in the development process of circular real estate development can be overcome.

a. What are the barriers in the circular real estate development process, according to practitioners?

b. How can these barriers be overcome?

The last question focuses on the development of practical guidelines in order to enable concrete action for a circular real estate development process to occur and to develop a circular real estate development process.

Objective 5: To develop practical guidelines in order to enable concrete action in circular real estate development to occur.

a. What are practical guidelines that support concrete action?

b. How can the real estate development process be adjusted to implement the circular economy?

6. Methodology

This chapter focuses on how the research questions will be answered. The research method will be qualitative, since the goal of the research is to gain a deeper understanding of the perceptions of people regarding a particular phenomenon.

6.1. Methods and techniques to be used

The questions in this thesis will be answered by means of a case study and stakeholder interviews.

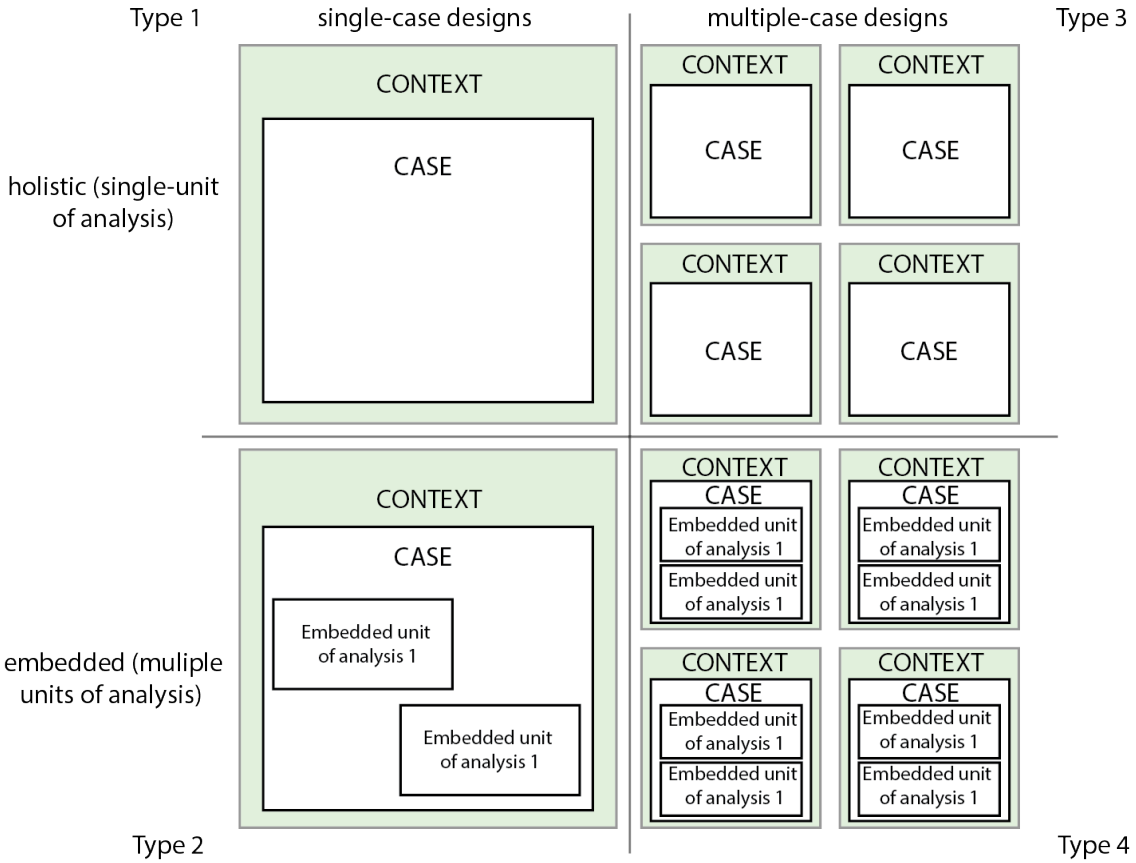

Figure 7: basic types of designs for case studies (yin, 2002)

According to Yin (2002), there are four case study designs, as shown in Figure 4. Which type of case study design one decides to do, depends on the context of the research. The matrix in figure 4 describes that a case study research consists of either single or multiple case studies, reflecting various design circumstances. Within these circumstances, there is also the option to investigate unitary of multiple units of analysis. The resulting types of case study research are single-case holistic designs (type 1), single case designs with multiple units of analysis (type 2), multiple-case holistic designs (type 3), and multiple case studies with multiple units of analysis (type 4). According to Yin (2002), there are five rationales for single-case study design.

These are:

1. the selection of a *critical* case, which is paramount to a theory, or theoretical position. The single case study can be used to confirm a theory or proposition, given the circumstances that the theory states a specific gathering of events in which the proposition is true.
2. the selection of an *extreme* or *unusual* case, deviating from usual norms or everyday occurrences.
3. the *common* case in which the goal is to focus on every-day conditions, because the results could provide insight in certain processes relating to theoretical interest.
4. the revelatory case, which is a type of case in which a situation presents itself where a researcher gains access to observe a phenomenon previously inaccessible to social science practices.
5. the *longitudinal* case that studies the same case, during different periods of time.

Rationales for a multiple-case study imply:

1. a selection of multiple cases that are perceived to be replications. An example is a multiple-case study where a set of cases with similar outcomes, when focusing on an evaluation question. As Yin puts it: “how and why a particular intervention has been implemented smoothly” (2002).
2. a comparison of a similar approach, where one case turns out a success, and the other turns out a failure.
3. a multiple case study increases the possibility of the research turning out a ‘good’ case study. The danger with single-case study research is that you have the phenomenon of ‘putting your eggs in one basket’ which limits one’s view of a certain phenomenon because the case study, for example, does not focus on different circumstances.

6.3.Cases

Since the primary interest of this research aims at the development process of circular real estate, the case studies will revolve around stakeholders present in this phase. The significant data will be collected through interviews with a circular building as the case. Within, units of analysis are aspired to be conducted. These units entail interviews with key stakeholders in the development process. Depending on how many stakeholders can be interviewed per building, the case study design will be multiple case studies with either single or multiple units of analysis. This is paramount for developing an understanding of

the practices conducted across the framework, because there is a need for a deeper understanding. Secondly, multiple case studies increase the credibility of this thesis.

Additionally, it is very well possible that there will be additional stakeholders that come up during the research. Therefore, there is an iterative approach between questions, methods and literature.

6.4.Data collection

During the case study, interviews will be conducted with key stakeholders in the development process of circular real estate to gain a deeper understanding of the current practices, future views, future aspirations and barriers. This approach focuses on multiple processes containing various stakeholders within the five key organising themes. Given the fact that there will be multiple units of analysis within different cases, this research is carried out as type 4; multiple case study designs, with multiple units of analysis. These units of analysis include stakeholder interviews. These interviews aim to provide a deeper understanding of current practices, future views, future aspirations and barriers. An example of this is a set of interviews with the developers of a circular strategy or business model, and document the processes involved, the manner of communication, tools used, etc. Figure 5 (Yin, 2002) shows the data collection process.

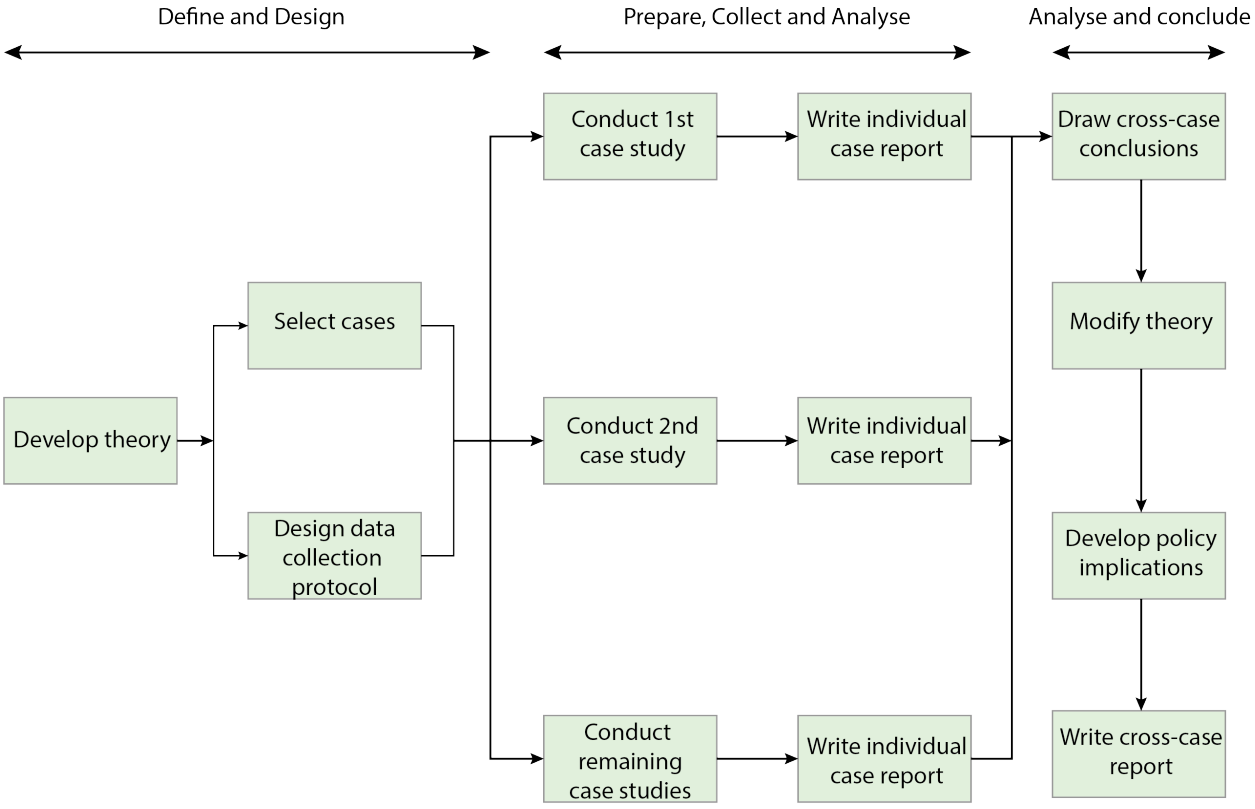

Figure 7: case study data collection process (yin, 2002)

6.5.Case selection criteria

In order to get the most valuable data, a set of requirements has been set up which serves to define key stakeholders worth gathering data from.

The following table shows selection criteria for interviews with sustainable, circularly oriented real key players in circular RE development.

Qualification criteria	**Preferred stakeholder/ case project**	**Required**
Entity	- Key stakeholders in the development process of circular real estate	- Key stakeholders in the development process of circular real estate
Circularity	- Building has won awards - Focus on regenerating natural systems, implementing the principles of the circular economy	- Focus on sustainable construction - Focus on regenerating natural systems, implementing the principles of the circular economy
Portfolio	- Company has at least one circular building in portfolio	- Company has a building in portfolio that is as circular as possible within the company's power
Disqualification criteria		
Climate risk	- Buildings rely primarily on follis fuels	
Entity	- Parties that have no affiliation with circular real estate development	
Controversy	- Company is greenwashing	

Table 7: qualification and disqualification criteria for the cases (own table

According to the selection criteria, 9 key stakeholders have been chosen to be interviewed, according to 6 renowned and/ or awarded building. The following interviews have been conducted:

nr.	Interviewee	Building	Awards/ significance	Location	Organisation
1	Development manager (developer)	Office 1	Golden Frog (most sustainable building in the Netherlands)	Driebergen-Rijsenburg	RE development organisation
2	Project leader (contractor)	R&D Centre	Global Award for Commercial Projects Global Public Award	Wageningen	Large building company
3	CEO 2 (developing contractor)	R&D Centre	Global Award for Commercial Projects Global Public Award	Wageningen	Large building company
4	Banker (investor)	Pavilion	Best building of the Netherlands 2018	Amsterdam	Large Bank
5	Architect	Pavilion	Best building of the Netherlands 2018	Amsterdam	Renowned architecture firm
6	Head of projects (client)	Office 2	1. Most sustainable building of Utrecht Circularity perceives as a standard	Utrecht	RE investor
7	Sustainability advisor	Office 3	First circular building in Europe	Duiven	Large building company
8	CEO 1 (developing contractor)	Office 3	First circular building in Europe	Duiven	Large building company
9	Consultant	School building	Circularity as educational example	Woerden	Consult & management company

Table 8: case study buildings (own table)

6.6.Data analysis

After the gathering of raw data obtained from the case studies, the data will be processed. The data from the interviews will be transcribed and analysed by means of ATLAS.ti. ATLAS.ti is an all-in-one qualitative data analysis tool that allows for qualitative data processing of large bodies of textual, graphical, audio and video data. Accordingly, the obtained data will be used to answer the research questions.

The research aim, objectives, questions and interview questions have been summarised in table 9 (own table).

The aim of this research is to examine current and future practices being to be conducted during the real estate development phase in circular real estate development.		
Objective	Research Questions	Interview questions
1. To review existing literature on circularity in the built environment to develop a framework that serves as a foundation for further research.	a. How do previous studies describe circularity in the built environment? b. What are the key organising themes?	None, this has been conducted before the research questions have been formed
2. To analyse how key players in the RE development process view circularity in the built environment, and their aspirations for circularity.	a. Who are the key players in the real estate development process? b. What do key players in the real estate development process understand with circularity? c. How is this understanding informed? d. What are their aspirations for the future of circularity in their organization and in their work? e. What are the similarities and differences between the practitioner aspirations and the themes found in the review of previous studies?	1. Which stakeholders are most important to you? 2. What do you understand with the term ‘circularity’? 3. How is your definition of circularity informed? 4. How does circular real estate development compare to traditional real estate development? 5. How do you see your role in the real estate development process adapt as we make the transition towards the circular economy? 6. How do you see the development phase change as we make the transition towards the circular economy?

3. To investigate the gap between current practice and future aspirations in circular real estate development.	a. What are current practices exercised (if any) by key players in the circular RE development process? (reflects on framework) b. What is the gap between current practices and future aspirations by key players in the circular RE development process?	1. How is circularity guaranteed in the development phase of circular real estate? 2. How do you measure circularity in a building? 3. How do you secure the availability of materials at the end-of-life stage of a building to be used again? 4. What would you do differently next time?
4. To analyse what and how barriers faced in the development phase of circular real estate development can be overcome.	a. What are the barriers in the circular real estate development process? b. How can these barriers be overcome?	1. What are common causes for difficulties during the development phase of circular real estate? 2. What barriers do you face in the development of circular real estate? 3. How could these barrier be overcome?
5. To develop practical guidelines in order to enable concrete action in circular real estate development to occur.	a. What are the practical guidelines that support concrete actions? b. How can the real estate development process be adjusted to implement the circular economy?	None, because this is a result of data analysis to develop practical guidelines that support concrete actions.

Table 9: objectives, research questions and interview questions (own figure)

7. Results

The results of the case study process are presented in this section. This section presents a chronological outline following the objectives and research questions.

7.1.Key players in the real estate development process

According to the interviews, there are 7 key players in the development of circular real estate which are listed below:

- Real estate developer
- Client
- Planners
- Contractor
- Suppliers
- Consultants
- Investors
- Regulators

In the process of RE development, the RE developer connects all other stakeholders, which could be up to thirty, and is responsible for successfully guiding the development process, and delivering the building (development manager, 2020). The RE developer has a close connection with the planners in the development of circular real estate, which is regarded as an important stakeholder in the creation of value by design. The architect (2020), in turn, stated that the contractor is the most important stakeholder due to the contractor playing an important role in enabling resource availability, which is then implemented in the design. The project leader (2020) stated that the contractor emphasises on the importance of suppliers and steering these to engage in circular practices and the significance of encouraging suppliers to think about circular solutions, because these stakeholders are closer to the secondary or raw resources in the supply chain. Additionally, regulators play a big role in enabling flexibility in laws and regulations regarding developments. The client, occasionally also the investor, has close connections with the RE developer and planners given the need for the client to approve the development and accompanying design (This depends on the contract, however. For instance, in a Design and Build contract, the client has close contact with the contractor). The Development manager pointed out that that the biggest barrier their company faces is the restrictions to build circular because of the demands that the client specifies.

“The biggest barrier that we face is the demands that are being set by various clients. Especially the demands enable of disable the circular application of materials. I think that is really a bottleneck and we see this at a lot of projects.”

- Development manager, 2020

It seems as if there are varying perceptions concerning which stakeholders and which relationships are important in delivering circularity in the built environment. This might come forward as a result of dependencies between stakeholders in the RE development process. Interestingly, practitioners did not regard users as key players during the RE development process of circular real estate.

7.2.Common terminology and discovery

The overall perception of the term ‘circularity’ by the practitioners is according to the principles of reducing the use of raw resources, and that second-hand materials can be implemented without heavy modifications. Practitioners mentioned that circularity is not only embedded within the materials itself and that the way that the material is processed enables a material to become circular. The practitioners discovered the term ‘circularity’ by their professional environment, for instance in the office, or getting involved with a circular RE development process. Others mention always having had an interest in sustainability and the reduction of raw resource use, or graduating on the topic. What practitioners emphasised was that there is a lack of awareness about circularity, and that students and practitioners should get acquainted with the principles early in order for the CE to become mainstream. Similar to more interviewees, Banker (2020) points out that circularity appears to have many definitions:

“…and so I came through (company) to sustainable, circular, and to the whole definitions. Because when we started building (pavilion) about 5 years ago. Back then, circularity also had many definitions. It now has many more definitions and we actually had no benchmark. Look, if you are in performance standard or energy label or BREEAM certificate, those are neat lists that you can tick off with clear definitions and certified documents. Well, circular doesn't have that. It is mainly experimenting.”

- Banker, 2020

When asked, the practitioners tended to give examples on how they operationalised circularity when explaining the definition. For instance, consultant (2020) points out the importance of up- and downscaling and the non-use of adhesives in the circular economy.

“Yes, as we see circularity is that you work out your building with materials that are also reusable. So, with the same principles as they are intended for. With that, we mean that we can downscale and upscale. You have a window frame that we place, that we will then use again as a frame. A second step could be that you will no longer use that frame as a frame, but that you would use it as facade material. If you have wooden beams, you can also say that we can no longer use the wooden beams for which they were intended. But if I saw it I can make facade material out of it, then you are downscaling. It is intended that you just use it for what it was intended, or that you upscaled it to something else.

Upscaling can also be, if you have a wooden frame, and in 20 years' time you will all have triple glazing, that does not fit in the wooden frame. But if we mill the wooden frame a bit in the groove, we can fit it in. Then you can upscale it as it were. So that's kind of where it is and trying to get further in your projects, that's where it should come from. That these materials are so reusable. So that they are made detachable. So, no sealant or glue joints, or anything like that."

- Consultant, 2020

Additionally, practitioners mentioned that the common terminology given by the Ellen MacArthur Foundation (2015) harbours complexity. This makes the concept of circularity harder to grasp for people that have not heard of the term yet. Therefore, many practitioners operationalise circularity by concretising actions and processes that adhere to the definition. For instance, the Sustainability manager (2020) mentions that there is a risk that circularity could be made too complex, and people tend to drop out when they hear the term. However, if you operationalise it by stating that circularity is enabling buildings to be detachable, made of renewable materials and being built from reusable materials or materials that can be reused, it becomes more graspable.

To sum up, circularity knows various definitions. Yet the common goal appears to be similar in delivering circularity in the built environment. Despite the similarity in the common goal, practitioners tend to operationalise circularity by their own or company's perceptions and no commonly used terminology on circularity exists.

7.3.Current practices

This section describes current practices being conducted by practitioners. The outline of this section follows the structure of the RE development process as described in chapter 5 'The real estate development process' and the five main organising themes provided by the CBE framework. However, the framework is a representation of previous studies, not a representation of what is being done by the practitioners. Therefore, it is expected that results also entail other approaches than described in the CBE framework. Furthermore, there are practices that encompass more than one of the five key organising themes given by the framework, this will be indicated in the text.

7.3.1.Circular strategies

During almost all development processes from the cases, there were strategies serving as a foundation for the development process. These strategies served to operationalise the concept of circularity due to its perceived ambiguity and to define the development process. These strategies always originated in the (pre-)initiative phase of the development processes. An example of circular strategies was implemented during the development process of Office 3 in which circularity was translated into 5 ambitions:

*“Then we worked it out into five ambitions: a **circular building**, which we wanted to realise. We wanted to ensure that the building provided more energy than it consumed. So the building had to provide energy, a **positive energy balance**. It must be aimed at **active collaboration**. Yes, how do you ensure that the interior of the office facilitates collaboration? Back then it was still much internal departments of course, but how do you ensure that those departments are much more connected an d that there is much more search for each other to work together? How do you ensure that the building facilitates that? If a building part is not in use, then so much energy must be used for it, but well, that is elaboration. So actively focused on collaboration. They wanted, if you are talking about relationships**, **relationship with the area**. So can we, as a player in the industrial area, make a positive contribution to those other companies around it? So collaborations have started on how can we share solar energy, how to share mobility, how can we all do things like that ... how can we take our environment into this? And how can we take care, that was the fifth, how can we get all those things to **integrate**.”*

- CEO 1 (2020)

Another example is the development process of the Pavilion where circularity was operationalised by generating design strategies such as the building being energy positive and consisting out of biomass, which is an endless resource. Further principles included the building to be fully remountable and to refuse any unnecessary materials like paint or stucco (Banker, 2020).

During the redevelopment process of Office 2, the strategy revolved around perceiving circularity as a standard. They operationalised this by, among other things, creating modular cubes that are fully demountable and can be attached and detached from each other therefore, enabling the building to be flexible according to space demands (Investor, 2020).

When keeping the entire development process in mind, it can be stated that whereas circular strategies focused on circular material use and energy efficiency, there ere no strategies involved that explicitly mentioned the longevity of the building, meaning that there appears to be a lack of focus on the exploitation phase during the initiative phase.

9 R’s

During the development of CIRCL in Amsterdam by ABN AMRO, the choice was made to ***refuse*** any unnecessary materials, and keep the building ‘pure’. Pure relates to keeping the materials as they are, and refuse the addition of paint, wall finishing or any additional materials that prove unnecessary. This way one-third of the original materials could be reduced. This strategy deferred from the initial strategy to make a sustainable pavilion, wherein a rethink of the initial strategy enabled to shed roughly one-third in weight of the building. In the same building, direct second hand resource use was implemented by ***reusing*** aluminium window frames in its basement, without being refurbished or

repainted. During the creation of Office 3, 95% of the existing building's shell was reused. During that same project, the practitioners promptly decided that wooden pallets, on which materials were brought in, could be ***rethought*** to serve as wall finishing. This had a positive economic and social impact, since the opportunity to create this wall finishing was given to people with a distance to the labour market (CEO 1, 2020). Office 3 also ***recycled*** materials like concrete. From the shell, they reused concrete in a non-constructive, aesthetic way. Another approach mentioned by practitioners is u***pcycling*** window frames by adjusting them to harbour double-layered glass, improving the energy efficiency and longevity of the window frame (Consultant, 2020). While Consultant perceived this as upcycling, it it also possible to call this ***refurbishing*** since it is a "process of taking a product, restoring it and bringing it up to date". ***Remanufacturing*** is also included in the development process in the form of using buildings as material banks. Parts of the discarded product (EoL building), such as wooden beams, window frames and roofing are placed into a new product ((re)developing building) with the same function.

Practitioners also think about the 9 R's in a future perspective during the development process. For instance, when a material or building element has reached the end of its valuable life, it can easily be detached and repurposed, refurbished of recycled. An example of this is Office 2, in which modular units are made without any use of adhesives and elements can be exchanged or ***repaired*** with ease (Investor, 2020). Another example of this is the wall finishing in the pavilion. As mentioned by Banker (2020), the wall is made up of finely chopped clothing fibres combined in a bio-based glue which can be washed off with warm water. This wall finishing is both circular in the use of secondary materials (retroactive) and future-proofed (proactive)

Practitioners appear to have a thorough understanding of the 9 R's and how to use them. Surprisingly, reduction and recovery were not mentioned during the interviews. In order to also implement 'reducing', their needs to be a production process involved (such as making modular dwelling units). This might indicate that the RE development process does not concern itself with the act of production. Instead, it possibly is regarded to be a duty of the suppliers.

Front-end strategies

The front-end phase is generally regarded as the initiative and design phase (development manager, 2020). In the front-end phase of building projects, there is greater uncertainty, and a lot can still change. Decisions made in the front-end phase of the development process cascade down towards the construction phase and finished building, and determine the intensity of maintenance of the building. Mistakes made in these early phases, could potentially take months to set right (Development manager, 2020). Therefore, practitioners implement front-end strategies ensuring that circular objectives defined in the initiative phase are adhered to throughout the development process.

Practitioners emphasise on the significance of these strategies in order to bring a project to a success. The most influential strategies mentioned by interviewees are early stakeholder collaboration including stakeholders with a similar mindset and continual reminders of circular objectives (CEO 1, 2020). These strategies provide the foundation of design strategies, as explained by Development manager (2020)

"So how I actually see it, is that the first step is in any case that you make a design, such as we did with (client), which is as demountable as possible. And that the materials you implement are reused. That is the ***basis: design for dismountability as much as possible and also record that in all kinds of descriptions so it is made dismountable.*** *And also design the materials you use in such a way that they do not have a very* ***specific shape,*** *but are quite* ***accessible*** *for a second project. That is the basis. This guarantees that the building you create can get a second life. But it also leads the other way. From, how can I use materials that already have a life? And it becomes a bit more soft there, because you can only do something with it if you have those materials available. And we did that at (client) when we were already building. That has been a completely different mindset of open communication with each other and certainly when it comes to sustainability. A kind of* ***openness*** *to each other, this is now the specification, but, if there are even more sustainable alternatives, then we should be able to replace this material for another material."*

- *Development manager, 2020*

The main drive in the design process in most development processes were honesty regarding the feasibility of certain design propositions, both from the perspective of the developer or client end and the architectural end. What is striking is that there appears to be more intense stakeholder involvement compared to traditional projects during the design process, where design strategies were continuously repeated in order to keep the common goal in sight. Because of open communication structures during the development processes, there were continuing iterative processes between the design and construction phases. For instance, because Office 1 had more generic elements implemented in the design, there was more room for flexibility regarding the prompt availability of secondary building materials.

In short, design strategies created in the initiative phase and refined during the design phase combined with open communication with various key stakeholders enable the application of both secondary materials and new materials which can be given a second life.

Design strategies

Another point of focus in design strategies are modular construction, demountability and remountability. Practitioners state that modular construction allows for flexibility in terms of adding and subtracting space from a building (Investor, 2020). Furthermore, demountable

buildings provide flexibility in materials, as these can be dismounted and used elsewhere. In order to build dismountable, there should be no use of adhesives and the material should be pure. Pure material refers to a material that should be kept in its original state, without the addition of paint or stucco. This enhances the reusability of the materials. One step further from demountability is remountability, which focuses on the materials keeping their function as window, beam, column, etc. Additionally, this means that the connections of remountable materials should be designed in a way that there is no damage during the demounting process. CEO 2 (2020) stated that built-up tension in the connections may cause materials to be damaged during the demounting process. Therefore, connections in remountable buildings need refinement.

Interviews proved that there is a thorough understanding of key circular design principles as a result of operationalising circularity in the built environment. The process for this generally entails that the brief, shared by the client is interpreted, operationalised in general strategies, which cascade towards design strategies including close collaboration between client, developer, planners, contractor, suppliers and investors. This again signifies the importance of the front-end processes of the circular real estate development process.

7.3.2.Circular business models

In terms of circular business models, there are similarities and differences concerning what current literature investigates and what practitioners currently implement. A report from ABN AMRO shows some interesting ways to implement circular approaches while providing financial stability for the business model. These are circular inputs, lifetime-extension, sharing platforms, value recovery.

Circular inputs aim to close material loops by the implementation of non-toxic, natural resources such as wood and hemp, reuse of complete building elements or highly recycled building materials. The added value of this approach originates from the exploitation phase and at the end-of-life stage. To enable this, demolishers and recyclers should redefine their perspective on buildings and regarding them as material banks. An important enabler of this process is digitalisation of resources by means of BIM. According to ABN AMRO (2017), this business model does not vary much from traditional business models. nontheless, a sound indication of costs and yields and certainty are of key importance. By implementing circular inputs, resources are rethought into creators of value before, during and after the real estate development process and, therefore, enable resources to retain their value. In market systems such as real estate, where capital is a key resource, circular inputs provide a way to incentivise long-term investments.

A business model with a dominant long-term focus is product **lifetime-extension**, which aims to lengthen the life of existing buildings during the exploitation phase by means of renovation, restoration or transformation. Extending the lifetime of a building also starts in the design phase, in which timeless architecture and flexibility are key. Furthermore,

periodical maintenance also extends the lifetime fo a building. Design strategies that enable lifetime-extension are modularity and design for deconstruction. Additionally, the report mentions the concept of LEGOlising, which entails that buildings, as well as their components can be put together and dismantled like LEGO. The financial system behind lifetime-extension is based on an investment that is expected to be earned back. A significant aspect about this business model is to recognise is that the building costs are subordinate to the cashflows that the product generates, due to its long lifetime. The time in which the product can earn itself back become important in such business models.

Increasingly more commonly practiced business models in the Dutch economy are **sharing platforms**, where use becomes more important than property. These platforms are made accessible via digitalisation through apps and the internet. In the exploitation phase, sharing platforms also open the possibility to optimise the value of a building by shared working spaces, parking spots and sports facilities.

What is widely mentioned in previous studies, interviewees and a report from ABN AMRO (2017), are **product-service-systems**. These are a favourable option in order to build in a more circular manner are product-service-systems, because they take away the client's worries about the material, and it keeps track of used resources and connect clients with suppliers for a longer term (ABN AMRO, 2017). And product-service-systems have potential to improve circularity (Development manager, 2020). Product-service-systems are also regarded as an incentive for suppliers to increase the robustness of their product, resulting is less maintenance during the use of the product. (Banker, 2020). A current example of a product-service-system is Philips, a Dutch electrical company, offering light as a service. The company has a production line that enables lightbulbs that have reached the end of their lives to be repaired and serve the same purpose again. Another example from Pavilion is that a supplier offers vertical movement as a service by means of an elevator. This company provides this service by offering elevators as a service for 15 years and sending monthly invoices. The price depends on how many times the elevator is used, because it is a pay-per-ride system.

Then, at the end-of-life stage of buildings or other products, there are business models in place that facilitate **value recovery**. With existing buildings that are not built with circular design strategies, this might prove complex and intensive. Therefore, the report by ABN AMRO (2017) recommends to add a 'deconstruction' phase to the Design-Build-Finance-Maintain-Operate (DBFMO)-model. Investing in new developments require more up-front investments, but it results in low maintenance and a higher end-value, increasingly facilitating value recovery.

Apparently, numerous business models aim to give the CE a place in the current market. However, it should be kept in mind that although these new business models may enable the CE to scale up in the built environment, neither of the mentioned business models

have been put to severe use for i.e. twenty-five years. Therefore, these business models have not proven their worth over an extended period of time.

Financial leverage

Financial leverage can be exercised by investors only issuing finance if the project fulfils a certain sustainability standard. This incentivises developers looking for financial resources to revalue what can be done differently in order to build in a more circular manner.

Supply chain management

Managing the supply chain by involving key stakeholders from the start of a circular real estate development process enables them to think of possible materials they can supply, and to seek out second-hand alternatives. A Development manager (2020) mentioned that the reason why the circular economy is not widely implemented on full scale is due to the fragmentation of the supply chain. Therefore, supply chain management practices, open communication and making suppliers aware about operationalised circularity indicators early in the real estate development process are pivotal in order to create a strongly integrated supply chain.

Buy and sell back constructions

An interesting statement made by the Sustainability manger is the following:

"We do not remain the owner of the materials. We will of course think about that. But very often the lifespan of such an object is too long to attach a value to it. What we do do, for example, is sometimes make an agreement with the supplier so they buy it back after a certain amount of time."

Sustainability manager, 2020

There already appear to be purchase agreements that allow for buying and selling back, which is an enabler to close material loops, since the supplier might have systems in place to process the elements after they are bought back.

Cross-sectoral circularity

Cross-sectoral circularity has found its way to the built environment. During the development process of Pavilion, people donated working uniforms which were cut up to fibres and used as wall finishing (banker, 2020). Therefore, a symbiosis between the clothing industry (creator of uniforms) and the built environment (creator of wall finishing) was established.

7.3.3. Management reporting systems

Management reporting systems that are being used widely are BREEAM Excellent and BREEAM Outstanding certificates. These are certificates that assesses the sustainability of a building according to nine sustainability parameters: management, health, energy, transport, water, materials, waste, land use and ecology and pollution. During the interviews, it became clear that there are no other widely used management reporting

systems. Although BREEAM is a sound certification tool, it does include circularity indicators. Therefore, circular assessment tools are being developed right now by the Dutch Green Building Council and Alba Concepts in the Netherlands. Herein, circularity is operationalised through performance indicators and real estate developments are assessed according to these.

Buildings as data banks

Data on how a building is used and its climate-system performance can be gathered by the RE developer, which can be used to adjust future design strategies, or the business model. (Development manager, 2020). Using buildings as data banks gives the opportunity to see how the building is used by the user, therefore expanding the time that a developer is engaged with the project life cycle of a building through the exploitation phase. The data collection also serves as a tool in increase facility management effectiveness because the collected data can be evaluated to improve processes within the building.

Interestingly, there is not a commonly used circular measurement tool according to circularity indicators. The process of developing such a tool might take significant amounts of time due to the current subjectiveness of how circularity in the built environment is perceived. For instance, the Development manager (2020) stated that for some instances, aesthetics contribute to a longer building lifetime because the building is not regarded as something that has to be replaced in 20 years.

7.3.4.Organisation systems in construction practice

Delays in consultation

Stakeholder alignment strategies, an open mind set during the project and a solid common goal enabled the opportunity to delay the delivery date of the project, in consultation with the client during the development process of Office 3.

This way of flexible phasing creates the opportunity to implement circular solutions during the realisation phase. An example by CEO 1 (2020): *“if you take a little bit more time during the finishing phase, it enables the opportunity to implement something that fits better to the circular trail of thought. You need to make people understand that it is worth the wait, because we had a fantastic idea about the interior of the atrium, so people can meet each other. However, it is essential that there is a realistic view on the adjustments, and all stakeholders should concur.”*

Buildings as material banks

Current practices indicate that the perception of a building is changing from the function of providing space, to also providing a bank of materials. Project leader (2020) mentioned that material value increases if it is easily accessible. This is in line with what ABN AMRO points out about value recovery. Consequently, buildings as material banks might spark a demand for documenting where the materials are located in the building, enabling value recovery. Therefore, R&D Centre was given a material passport. This passport contains

information about the origin of the materials their location in the building and its possibilities for reuse. Material passports ease maintenance on the building because the location of materials become clear, creating the opportunity to extend the building's life.

Banker (2020) also mentioned that the existing building stock (also the stock that has not been built with circular approaches) should be given a material passport when the building is near the end of its life. This enables the materials to be brought to the market in a foreseeable time.

"One is a materials pass report from (architect). I am a fan of that. Not so much to put all new construction there now. But in any case to use all buildings that will be demolished or partially dismantled within the foreseeable future. You can then bring it to the market. Then you say "Well, I have a materials passport here. Dear demolition worker, you can get this out, that, that and that, for the rest I leave it to you. Tell me what the building is worth to you instead of me paying you for the cost of breaking it down."

- Banker, personal communiction, May 1, 2020

Stakeholder management

During circular construction projects, aligning stakeholders is paramount to reach a common goal (Architect, 2020; CEO 1, 2020). Therefore, in the initiative phase, it is regarded as the task of the RE developer to gather a team of like-minded stakeholders. If you are innovating, but if you include traditionally-minded stakeholders in your team, it is going to be a tough process (Banker, 2020). Therefore, current practices emphasise on the significance of early stakeholder involvement in the initiative phase. This is done by including them in the initiative phase and clearly defining the project goals altogether to prevent ambiguity regarding the goal during the development process. Enablers for stakeholder alignment are an open mindset and collective problem solving. This project definition process includes space for individual stakeholders to present their own values and expectations.

7.3.5.Resource processing

Digitalisation of resources

The digitalisation of second-hand resources is regarded as an important step in enabling second-hand material streams to occur. Therefore, there have been organisations developing digital databases containing second-hand materials, such as the MADASTER (CEO 2, 2020). Current practices include the development of a code which can be attached to BIM software, which automatically chooses a registered second-hand building material to be implemented in the model, according to the preferences of the modeller. This enhances convenience in the CE, since it increases the availability of materials.

Use of biomass

Banker (2020) indicated that recently, the building industry has been forgetful in its use of biomass. The use of biomass, such as wood, is pivotal in decreasing the environmental impact of the built environment because it is a resource that is infinitely available, given the condition that it is harvested sustainably. Sustainable harvesting entails that resources can be extracted from the earth, but they have to be put back in, creating a cycle. Wood is a preferred material because it stores carbon. This is also in line with the ability of materials to be processed in a circular way at the end-of-life stage. This phenomenon, the use of biomass, can be linked to the business model about circular inputs.

Making social impact while processing resources

As mentioned in the circular strategies section, during the development of case 3, pallet wood from suppliers was rethought and up cycled and used as wall cladding. The pallets were demounted by people with a distance to the labour market. By giving these people the opportunity to work, the pallets served a purpose. Otherwise, they would have been burned to generate electricity. This approach serves multiple purposes: firstly, it is better for the environment, because value-destruction is prevented. In this case, value was actually added. Secondly, it gives people a chance at the labour market. This is an example of how open communication during the construction phase enabled resource processing and making social impact.

Main take aways

It seems as if there is occasional integration of processes, as was just described in the previous section. Practitioners indicate that the circular economy might be an integration between various processes. However, these processes are yet not made explicit. Surprising findings are the ability to stretch the construction phase in order to implement a circular process that adds value to the building. Furthermore, the ability of documenting the performance and location of materials adds to delivering circularity in the built environment, because it makes second hand materials more accessible.

7.4.Future views

This section describes the practitioners' perspective on the future of the real estate development process delivering circularity, and how roles are expected to change in their organisation. This is not to be confused with section 13.6. 'Future aspirations', since the focus is on what practitioners *desire* in the future. This section is parted in how the roles of stakeholders are expected to change, and how the overall development process is expected to change.

The future role of the **RE developer** is thought to be focused more on connecting a bigger variety and quantity of stakeholders, for a longer period of time. The RE developer is also expected to have to steer processes differently in the future and become an increasingly significant player in bringing like-minded stakeholders together.

“I think that there is going to be more and more a kind of dialogue with all kinds of different parties to form a kind of chain integration of clients, suppliers, contractors, et cetera in order to make agreements about how we deal with materials and products and how we are going to give them a second life instead of just talking to the contractor. It should be more like this, dealing with each other, engaging in a dialogue, integration, deeper in the chain. And let's mention where a material comes from and how are we going to use it in 20 years' time. And because we as developers are right at the center of that whole thing, we also have to talk to more parties about a long period instead of just working on that development or redevelopment”

- *Development manager, 2020*

A RE developer that came forth out of a building company mentioned that the future will not only change the role of the real estate developer, but also what the real estate developer possesses. What is often mentioned by practitioners is that buildings are build to be sold. However, a future expectation is that real estate developers could become interested in keeping their buildings in order to create a building portfolio. This eventually enables them to engage in a process referred to as ‘project coupling’ (Project Leader, 2020). This entails a process in which soon to be deconstructed buildings can serve as donor buildings for new developments within the real estate portfolio. Hence, RE portfolio management becomes an important aspect of providing a circular built environment.

The **planners** will have a better knowledge about the availability of materials and where to find them, so the materials can be implemented in the design. Additionally, the planners are thought to integrate aesthetics with technical solutions. An example for this is the connection between en wooden column and a wooden beam by bolts. This is perceived as a more industrial aesthetic by CEO 2 (2020.

“I think there might be a slightly stronger integration of aesthetics and engineering. So technical knowledge, how to assemble buildings, but especially how to take them apart again is important in circularity. And maybe a little better knowledge of where you can get your materials from. Because finding used materials is, yes, not that easy at the moment. And it is true that in my opinion that is changing quickly. When I was working on (building), I really could not find any material that we could apply in that building, or almost not. And now there are already companies there that are working on this full time. And I think that is a very good development. But I think as a planner you should be aware of this. You must know if and where you can find it. You also have to develop a bit of an open mind to be open to possibilities other than new materials. That is perhaps the most important thing: That you are open to it, that you want to see it.”

- *Architect, 2020*

In general, **contractors** are expected to be involved in the project earlier, because there is a need to talk about the availability of materials early in the development process. This is

already happening in Design & Build contracts such as happened during the development process of R&D centre. However, the quantity of the implementation of these contracts is expected to increase. The contractor is also expected to become more flexible in the materials that contractors will provide. This is expected to be enabled by creating an open communication between actors during the RE development process. Implementing open communication allows the players in the development to pitch ideas and materials that differ from the initial specified drawings. A manner of open communication was already conducted during the development process of Office 1 (development manager, 2020) in which there was an open communication between the contractor, developer and client regarding possibilities to implement circular solutions.

“Every month we have a kind of morning meeting together to put ideas that we discussed during that month together. Like, “Okay, I am now in a project that happened to be in Rotterdam.” It was a demolition building. The contractor came across wooden beams. He says: "Do you agree that those second-hand materials are used?” I say: “Well, fine, do they meet certain quality requirements?” Yes, those meet the requirements. Okay, they can get in. Likewise, I came across a wooden platform from an old apartment complex. I submitted it to (client) and said: “Are you okay with that?” They thought it was fine. But not the contractor. So it didn't come in like that. So, along the way there has of course been the basis for building as dismountable as possible. In the implementation it has been what we come across.”

- Development manager, 2020

CEO 1 agrees with this approach, and expects that this will become the norm in the future of circular real estate development.

“But if you think about the role of the contractor who gets specification drawings, he has to realise that. But now in the process came, in which a number of things were still newly implemented during that process. Yes, that contractor can do that like no other, but you must have a contractor who can and who understands it.”

CEO 1, 2020

The way that financial resources are being issued is expected to change. **Investors** are thought to become more aware of the significance of the environment and society, and develop sustainability and/ or circularity standards on which a project has to adhere in order to be financed. Another thing expected to change is what investors are going to finance. New business models like PSS and Lifetime extension create an open field for what investors are exactly going to finance. As the Banker puts it:

“so there is something spectacular for us as a bank. What are we going to finance then? A building, raw materials, the producer of materials? That's where it gets interesting.”

- Banker, 2020

Suppliers are additionally expected to adapt their products in order to decrease maintenance in PSS contracts and to increase the generality and versatility of the product in order to give them multiple applications. This also means that there might be a shift between the business models of the suppliers, raising questions such as whether they sell or lease their products.

Consultants are expected to advise on circular approaches from day 1 in the project development phase and that they are going to play a significant role in upscaling the transition. They are expected to put more emphasis on circularity, especially during the tender process. This is where the strategies of the real estate development process are developed and implemented. Therefore, advising on circular approaches in this phase could potentially set a circular course for the development process.

"The contracting business will follow with building second-hand materials. But it is exactly those investors, the architects, and their clients and especially their advisors. Like Royal Haskoning DHV, Arcadis that can also arrange that. Consultants who supervise those tenders together with architects and constructors. They have to start with that request to make it sustainable."

CEO 2, 2020

The overall **development process** is expected to become an integrated supply chain. This entails that suppliers involved in the project will be integrated into one system and work towards the same goal. Within the supply chain, it is expected that there is a continuing dialogue about the origins of materials and how they will be processed after the material has fulfilled its purpose. Moreover, it is expected that during the RE development process, there will be project coupling, as mentioned before. This entails that there are donor projects which can be coupled to new developments. Project leader (2020) thinks that there is an increasing demand for this, despite not having developed any process for it. In the future, the development process changes from giving the planners freedom to design with the materials being purchased after the design is finished, to the planners having to design with the available materials from donor projects. In terms of overall stakeholder collaboration, it is expected that stakeholders are going to be more open to other ways of project finance, other products and bio-based materials like wood, reed and loam.

7.5.Future aspirations

This section focuses on the future aspirations of the practitioners in the circular economy.

7.5.1.Circular strategies

Portfolio management strategies

Portfolio management gives the opportunity to couple projects as explained by Project Leader (2020). Although there are yet no processes in place to realise this, its demand is increasing. Stakeholders aspire to let building material remain in their portfolio, so they can be reused. One example was provided by Project Leader, in which an organisation's building portfolio entails 10 donor buildings which provide the necessary resources for a new building that will be developed within the asset portfolio. This changes the perception of a building portfolio to a perception in which buildings are seen as material banks, so they could be perceived as material bank portfolios. Portfolio management strategies then need to develop a structure that allows reverse-design strategies, in which new developments are designed with existing building elements. Secondly, then the role of the real estate developer not only encompasses the development of real estate, but also the management of resources within the asset portfolio. This results in portfolio management and the real estate development process becoming intertwined with each other.

Mind set

One of the significant aspirations for the future, mentioned by all interviewees, is that the mindset in a circular building project is paramount. This not only applies to the building sector, but also for the general way of living. Practitioners state that we should change the way we look at buildings, and not see them as a finished product, but as a process. Seeing a building as something that still requires in- and outputs could redefine the way we see the built environment. It might mean that each building could deliver outputs for another building that requires inputs, hence creating a symbiosis between real estate assets.

Additionally, having a circular mindset from day one in a project plays a significant role in enabling the project's stakeholders to align. This change of mind set can enhance how circularity in the built environment is perceived. Architect (2020) stated that this gives the opportunity to see the fun in the challenge of creating a building with resources that are already available, compared to having to excavate the earth to make building materials.

7.5.2.Circular business models

Change of focus

Practitioners indicate that the focus on financial gain is too dominant in the built environment. They aspire to convince investors and clients to not only think about the financial aspects during the RE development process, but also the environmental and social aspects. One way of doing this is to implement the business models as mentioned in the current practices. Lifetime-extension for instance forces investors to look at their

investments in the long term, rather than making a quick profit. Although profit remains an important part in the circular economy due to liquidity and solvability of companies, deferring the focus on pure financial gain to environmental and social gain eventually indirectly delivers profit. This could for instance be measured by carbon savings that are being converted to financial gain like Sanchez et al. (2019) did in their study.

The conception of new business models changes the value proposition for players in the real estate development process. Consequently, this raises the questions what the RE developer owns and leases, or whether they are going to own anything. It might occur in the future is that RE developers are going to be owning materials, rather than just spaces.

“Not every building needs an own façade, or interior. That could be a product-service-system. Not every building needs its own lighting system. Philips can already offer lighting as a service. So then you buy a main structure, stairwells and square meters. What are you going to offer, and what are you going to sell? That’s where real estate developers need to be open for.”

- Banker, 2020

Market systems

Although there are currently some market systems in place that enable circularity, the market for circular in- and outputs in its infancy. Therefore, practitioners aspire to persuade investors to invest in circular RE developments and create a more substantial market in the circular economy. Additionally, practitioners indicate a need for more demand and making second-hand materials more widely available in order to spark the market for second-hand materials. Furthermore, practitioners state that there is a need for more turnover and other financing systems in order to make the market feasible for circularity.

“you have to be able to get more sales. But as long as we continue to adhere to a great many laws and regulations, that market will remain limited and you will have very few clients who will take risks in it. Only when ***demand increases*** *will you get a market, real market forces. And then the material really becomes worth money. So that step has yet to be taken and I hope it will take place in the coming years.”*

- Project leader, 2020

The current market seems to be a bottleneck for the implementation of circular solutions in the built environment. Therefore, practitioners recommend to rethink the construction sector, with new business models that have a focus on more sustainable and circular development, social inclusion and making second-hand materials more widely available. Yet, these mechanisms appear to be in place already according to current practices (chapter 8.4). Therefore, these business models should be proven and/ or improved in order to upscale them to a national or international level.

Football-player principle

CEO 2 mentioned a new, interesting business model which is not presen in previous studies. This is referred to as the Football Principle (FP)

“And then you get ... if you build an office tower and after 20 years you turn it into a hotel, then in my opinion, and this is an important line of thought, the hotel developer should contribute a part of his profit to the developer of the office tower. I kind of call that the football principle from the football brokerage. I think circular construction and developments can get a boost if owners know that I am going to invest time and effort in this, it is still investing in this time. So let's say the building will become ten percent more expensive, at the expense of my profit. Then I'm not going to do it. Or I'll do it, but every time that building is resold, just like a football player, I get a percentage of the money.”

- *CEO 2*

The FP increases certainty about cashflow over a longer period of time, hence extending the business-model period. The FP additionally incentivised to build more robust, longer-lasting buildings and take on a greater investment at the front-end of the RE development process. Although the FP is an interesting business model, there is not yet a known business model that enables the advantages mentioned in this paragraph.

Supply chain management

There is a need for circular supply chain integration, in which all suppliers are involved in the development process from the start. This manner of supply chain management creates opportunities for the implementation of second-hand materials, since the suppliers can start thinking about second-hand material use from the start. By involving suppliers from the start, there is a common mindset to build without the use of raw resources, and the suppliers have more time compared to when they are involved from the construction phase on.

“What would be interesting, I think, is to think about a collaboration that still has sufficient incentives for all parties, so there is sufficient incentive to be competitive in that collaboration. Because what you notice now is that many parties remain on their own island. The contractor has its own budget, the developer has its own budget, which is all good, because everyone has to earn their money. But that sometimes gets in the way of cooperation. It would be quite interesting if you could be open to each other about that. In a manner of speaking, can make ***return agreements*** *with each other, which everyone can earn together. And then when you start building circularly, if you improve it, you will also benefit from it all. For example, that you turn cooperation into an incentive. Because I think that* ***collaboration in the entire chain****, is really a very important part of circularity”*

- Sustainability manager, 2020

7.5.3. Management reporting systems

Measuring circularity

Practitioners indicate a lack of a mainstream circular measurement tool. Although certificates like BREEAM are widely used, they do not harbour a circularity component. Currently, practitioners exercise circularity through their own understanding of the phenomenon. Although there is a common understanding of the key circular principles like demountability, remountability, PSS systems, robustness and less use of raw resources, they indicate a need for a mainstream, renowned measurement tool indicating the circularity score of a building. Currently, there are some instances working on the creation of such a tool, such as Alba Concepts and the Dutch Green Building Council. However, as of 2020, a circular assessment tool that is as widely used as BREEAM has yet to be published.

7.5.4. Organisation systems in construction practice

Digitalisation

Practitioners aspire to create mainstream digitalisation processes for the purpose of documenting second-hand materials in a material database, which can be coupled to BIM-software. In line with circular management reporting systems, there are initiatives trying to realise this software. An established process which allows precise allocation of second hand materials serves two purposes: It can eradicate uncertainties considering second-hand materials during the design phase of a circular RE development since second-hand availability becomes clearer. Consequently, these digitalisation processes might kickstart the market for second hand materials. Another significant advantage of digitalising resources is that it can be used to manage resources within an asset portfolio. In this reality, the RE developer might become the owner of materials.

Process adaptation

Process adaptation in circular RE developments entails the adaptation from the traditional real estate development process to a process that adheres more to the circular economy, and enhances the overall process. Future aspirations include implementing circularity in the programme of requirements, in order to predefine the development process. Additionally, flexible phasing during the development process creates opportunities for the implementation of circular solutions. This has already been done with, for instance, Office 3. Yet, practitioners aspire that this becomes the norm. This is in line with the overall desire to have a more open communication between the RE development process' stakeholders. Process adaptation is where this thesis also is focused on. Therefore, this thesis proves valuable to stakeholders aspiring to adapt the RE development process to the CE.

Stakeholder collaboration

Stakeholder collaboration is highly regarded by practitioners in order to improve the development process of circular real estate. Currently, depending on the development, there is a lack of stakeholder involvement and alignment in the initiative phase of a RE

development process, where a possible team for the development process is assembled. As mentioned, the initiative phase starts with the decision to start thinking about developing real estate during the pre-initiative phase. Practitioners aspire to involve key stakeholders from the first meeting of the RE development process, because a circular development requires a different process. For instance, Banker (2020) mentioned that suppliers should be involved in the initiative phase, in order to discuss possibilities regarding circular construction. Practitioners aspire for a joint trajectory, where the stakeholder collaboration is defined at the start. This also includes reaching a common goal for the development.

7.5.5.Resource processing

Resource availability

Currently, second-hand materials are not yet available on a wide scale. Therefore, practitioners aspire to make these second-hand resources widely available. One way to realise this is to attach material passports to buildings that are planned to be deconstructed in the near future, so material retain value and can be reused for new developments. An overlap between organising systems in construction practice, and resource processing becomes apparent. Whereas material passports as organising systems are used as a means to document and organise materials, it provides the necessary foundation on which a resource processing process can be exercised.

Additionally, second-hand materials should be implementable in the RE development process undergoing a minimum amount of alterations. The lesser a material is altered or processed, the more carbon is reduced. Ideally, elements taken form elsewhere should be implemented right away without any refurbishing or upgrading. However, other practitioners see this differently. Whereas some practitioners mention that a minimum of alterations is desirable, others state that upgrading a product could upgrade the physics. Practitioners reveal that there is a discussion going on whether second-hand materials should receive upgrades, to adhere to environmental standards set by the regulators. Differently, the government should be flexible in order to implement elements like single-pane glass frames that do not adhere to the standards, but have a very low-carbon processing process.

7.6.Barriers

This section describes the barriers that practitioners experience during the RE development process, or which prevent them from the development of circular real estate. The most prominent barriers include the lack of mainstream market systems and government incentives, how the circular economy is being perceived, and the absence of when second-hand materials become available. When studying the barriers, it became clear that some barriers are intertwined with others. An example of this is the lack of

market systems enabling the CE to be integrated with the built environment, and the lack of processes regarding secondary resource recovery.

There are several barriers which find their origin within current ***market systems***. Current market systems do not provide the necessary infrastructure that enable a circular RE development process and it seems as if a circular RE development process is dependent on market demand, rather than environmental necessity. Additionally, although the idea of material banks proves valuable in decreasing carbon emissions and pollution, it is regarded expensive. Demolition companies still regard deconstruction of a building more expensive than demolishing it due to the time it takes to carefully take a building apart compared to the demolishing process. Parties like these, together with key players in the market should be convinced about the residual value that materials embedded within buildings is still high. Yet, it seems that as of 2020, there are no mainstream processes that enable this.

A problem with companies that have deeply rooted organisational systems is that they have difficulty adapting to innovation. Organisational barriers originate from suppliers experiencing difficulties to differ from ***standardised*** products. Because suppliers are so deeply embedded within their own systems and organisation, it is hard for them to adapt to the demand rising from the circular economy. Suppliers have standardised their products according to the standardised measurements originating from the past 100 years (CEO 2, 2020). Therefore, adaptation is regarded difficult and expensive.

Following market barriers, there are also ***financial barriers*** preventing a circular RE development process. A barrier that is a bit intertwined with the CE being regarded expensive, is circular RE development being regarded expensive by the client, which has to guard its budget. Consequently, the client's demands, originating from their financial resources, are a restriction to implement circularity in buildings. This can provide challenges for a circular RE development process. Additionally, funding is also limited by investors, because currently, their interest in circularity and collaboration is low, and is shadowed by their aspiration for financial gain.

"he contractor has its own budget, the developer has its own budget. Which is all good, because everyone has to earn their money. But that sometimes gets ***in the way*** *of that cooperation"*

- *Sustainability manager (2020)*

"That it sometimes makes more sense to strip the building completely down to bare concrete and then rebuild it again. Ironically, you spend less money by doing that - because then money is just a determining factor - than when you, as a kind of Houdini, work through the building and looking for what you can still use. There are two camps in it. One sees it mainly as old junk, who prefers to have everything thrown away and renovated, because new is better. And ironically, it doesn't even cost anymore. It is just purely the

defect of money, which is in the way at that moment*. I don't have that myself, I first use as much of what is in the building as possible, I want to reuse that"*

- Investor (2020)

Currently, there is an ***unavailability*** of second-hand materials and the knowledge, systems and tools to retrieve them.

"But you cannot expect from a contractor that, if they are currently forming a contract that they will build in a year, that they have recycled materials at their disposal. So they will never agree if they say we are going to use 50% recycled wood. They do not know at all whether it is available or whether it meets all kinds of quality requirements. The same applies to the architect, who I am now making a design that will only be realised in two years' time. He can buy materials on a second-hand market and draw them in the design. But then they have to be stored somewhere for two years until they can be processed. That just doesn't make any progress either"

- Development Manager (2020)

This unavailability causes uncertainties in the initial stages of circular real estate development, since it is uncertain whether a certain material will be available or not. There is a lack of a common database in which second-hand materials are presented and usable for circular buildings. An planner could start designing a building, with certain design principles, but there is still an uncertainty whether the design will be generic enough to harbour second-hand materials that presumably only become available in the next months. Although there are ways to mitigate these uncertainties by implementing new materials out of circular inputs such as wood, there should be an emphasis on the creation of systems that categorise second-hand materials.

Second hand materials also face challenges regarding how the **lifecycle of *second-hand materials* in guaranteed**. The question on who is responsible and guarantees the performance of the materials to last for a certain amount of time often rises, without a clear answer. Currently, if a supplier delivers a new door or lighting systems, there is a certain time which the supplier guarantees the product will function without breaking. However, with second-hand materials, it is a lot harder to guarantee its functioning life. The reason behind this is that it is unclear how the material has been treated during its previous life and the internal state of the material is occasionally hard to see.

One of the most notorious and significant barriers originates from the ***lack of motivation*** in stakeholders due to the circular economy being perceived as something threatening to, for instance, the success of a RE development process. There is a lack of behavioural change that prevents the circular economy to accelerate. Circular RE development is countered by the advantages of the traditional way of linear construction, where circularity lacks convenience (Banker, 2020). Traditional RE development processes have a business

model behind scale, meaning that traditional RE developments can be large and still be profitable. Furthermore, traditional construction is cheaper and there is more knowledge embedded in traditional construction, resulting in enhanced risk assessment. Moreover, traditional construction is easier, and short-sighted, lowering the period of time for which a developer is responsible for a building project. There is a lack of cooperation in the building industry, and a focus on individual gain. Again it seems that finance is the main driver behind perceived advantages of traditional construction.

Another barrier is that companies often perceive sustainability to be important only on paper, to adhere to regulations set by the regulators like an EPC (Energy Performance Coefficient) or MPG (Environmental Performance of the Building) score. There is no widely implemented incentive or regulation attached to circularity which can perform leverage in circular RE development.

There are barriers embedded within the development ***process*** of circular real estate. The first barrier is the challenge between timeliness and the processes that enable circular solutions, such as open communication and flexibility in the length of phases. Since circular solutions currently require an open mindset among stakeholders in the process, it can prove difficult to implement new, circular ideas that emerged during the process due to contractual obligations. There often is a deadline which has to be adhered to, preventing the full potential of circular implementations during the design and construction phase. Another process barrier is that circularity is often implemented too late in the development process, also preventing the full potential of circular implementations. This causes an inability to adapt the project accordingly. Not clearly defining the term 'circularity' at the start of a project can cause discussions among stakeholders. Therefore there is a need to determine the common goal at the start of the project.

Practitioners indicate a ***lack of government intervention***, incentivising circularity. It is regarded as if regulators still have to define what circularity means in order to take action. Additionally, laws and regulations on building performance (EPC & MPG) prevent for the use of second-hand materials, because they do not adhere to the strict regulations set by regulators. There is a lack of mitigation between strict regulations for new materials, and the carbon saved by the implementation of second-hand materials.

The building industry is a ***fragmented industry***, with a strong focus on individual gain, rather than common growth. Embedded within this fragmented industry, is a fragmented supply chain where suppliers have regard for individual gain. The building sector is deeply embedded in its own organisational structures, making it hard to innovate.

There seems to be entanglement between various barriers. For instance, whereas the CE is perceived as difficult and expensive, this also translates to the market (which is based on opinions). Additionally, public opinion appears to be at the heart of the problems, together

with the lack of processes in place in order to facilitate the CE in the built environment. The dominant part of the barriers consist of soft barriers like communication, flexibility, teamwork and leadership. Therefore, there is a need to radically change the overall way that real estate is developed from the soft side. This can be done by various tools such as government incentives and disincentives, raising awareness, upscaling circular business models and digitalisation. Furthermore, the Football Principle, an adjusted value proposition for RE developers and flexibility in RE development phases can make a significant dent in the paradigm. These subjects, along with others, will be discussed in the next section.

The following table represents an overview of current barriers in the development process of circular real estate.

Category	Barrier
Market barriers	Lack of market systems
	Lack of demand
	Circularity regarded expensive
	Standardized products
Financial barriers	Client's financial resources
	Investor's lack of interest
Material barriers	Guaranteeing lifecycle
	Superiority of concrete
Availability barriers	Availability of second-hand materials
Perception barriers	Circularity as something for just on paper
	Circularity perceived a difficulty
	Advantages of traditional construction
	Lack of clear definition
Process barriers	Contractual obligations
	Lack of cooperation
	Lack of common goal
Regulatory barriers	Lack of government incentives
	Lack of government mitigation regarding second-hand materials
Sectoral barriers	Fragmented building industry
	Fragmented supply chain

Table 10: summary of barriers (own table)

7.7.Recommendations for overcoming barriers

This section explores how barriers, defined in the previous section can be overcome. Recommendations originated from combining practitioner views and recommendations with the author's knowledge gathered throughout the thesis.

When talking about the RE development process, decisions made in the very beginning of the process can have major effects in later phases. Practitioners indicated that creating awareness about the CE in the pre-initiative phase creates a **common mind set and goal**. Therefore, awareness about the circular economy should be raised even earlier, during the education of future practitioners. This can tackle tackle the traditional mindset of the construction industry. Hence, there is a need for education about circular principles, its strategies, business models, management reporting systems, organisation in construction practice and resource processing. Consequently, students and stakeholders can create a mindset in which these practices become the new normal. By educating students about circular economy principles early in their studies and giving them the opportunity to experiment with its principles, a collective mindset is created, creating a new norm for the RE development process. By creating awareness early on, and changing the overall mind set, a significant number of barriers can be raised, like how the CE is perceived expensive and difficult, the lack of a common terminology and a common goal.

Continuing on the aspect of the mind set to create a circular RE development process, the barriers regarding how circularity is perceived can be tackled by overall ***change of behaviour*** in practitioners. An example was given by CEO 2 (2020) about behavioural change in a hospital:

The declaration rate of employees in a hospital hovered around 30% because employees lacked behind with declarations. Therefore, an incentive was developed. If an employee would have done all his declarations, he or she would get free coffee. After this, the declaration rate went to 95%. In this case, the incentive was not to get free coffee, but there was a *disincentive* to not declare, because other employees in the break room would see that the person in question would lack behind on declaring. This incentive (or disincentive) is based on the social pressure.

There is a need for disincentivizing traditional construction, the use of raw materials, adhesives, egoism in the development process and value destruction, and incentives for stakeholder alignment, value creation, use of second-hand materials and the use of circular inputs. This can be achieved by **government incentives** such as subsidising circular inputs and processes and disincentivizing traditional processes by requiring additional excise duty on i.e. concrete or adhesives. Since money plays such an important role in the RE development process, this is an important tool to enable a RE development process that delivers circularity. In other words, the traditional RE development process should become regarded as expensive and unfeasible.

Regulators also plays a role in tackling the problem of second hand materials not complying with performance regulations. Regulators should be flexible regarding the performance regulations like Bouwbesluit and Rc-values since second-hand materials oftentimes do not comply with these high requirements, preventing them to be reused with their original purpose. Mitigating between the regulations regarding material performance prevents the need for new and high-performance materials and raw-resource extraction.

"If you are going to design with circular construction. To what extent do you know with which materials you will design it? Then you get in trouble with a piece of ***legislation****. At least, I soon had that with my project. If I don't know in advance, I will have to apply for an environmental permit from the municipality. And the municipality simply asks for all calculations. And I don't have one because I don't know exactly which materials I'm going to use. What I did with the municipality, as well as being of good heart, they wanted to go very far. They have said, the requirement is an EPC standard, which is 0.2 for your project.* ***But if that clashes with the circularity idea that you have, we want to let go of that standard and lower it if there is a good argument against it.*** *In other words, that legislation in the Netherlands is just not ready for.. they just don't have that guidance. But because they want to make this a pillar in Woerden, they have indicated that they wanted to contribute ideas. In that sense, we have also been able to tinker a bit with the regulations"*

- Consultant, 2020

Change in overall behaviour and acceptance of a new paradigm with the aid of government intervention can help break down barriers like circularity being regarded expensive, lack of common goal, advantages of traditional construction and an investor's lack of interest.

Staying with the topic surrounding materials, the lack of certainty regarding the availability of second hand materials can be tacked by implementing **design strategies** which are mainly focused on enabling the implementation of used materials. Although second hand materials appear to be central point of focus, there are numerous processes involved that actually enable the materials to be implemented. The question often arises whether a certain material will be available at a certain time. In order to tackle this problem, design strategies should emphasise the focus on generic design enabling the use of second-hand materials. This means that the use of very unique and specific elements during the design process should not be recommended. This is a practice that has been experimented with during the case of Office 1 and should be implemented on a wider scale.

"The first step is at least the design you make, at least as we have done at (client) as demountable as possible. Because what you apply that they are in any case reused, that is the basis. Design as much as possible dismountable and also record that in all kinds of descriptions that it must also be made dismountable. And that the materials you use

design in such a way that they do not have a very specific shape, but are quite accessible for a second project. That is the basis. This guarantees that the building you create can get a second life. But it also leads the other way. From, how can I use materials that already have a life? And there it becomes a bit more soft, because you can only do something with it if you have those materials available. And we did that at (client) when we were already building. That has been a completely different mindset, of open communication with each other and certainly when it comes to sustainability. A kind of openness towards each other, ***these are the specifications, but, if there are even more sustainable alternatives, we should be able to replace this material for another, second-hand material****"*

- Development manager, 2020

Furthermore, there is a need for realisation that second-hand materials have a small chance for fitting exactly within the dimensions of the desired building. The project team, and the designers especially, should be adaptive to work with what is available. If there is still uncertainty about the availability of second-hand materials that exactly resemble the material needed in a certain design, the project team has the possibility to introduce a temporary solution, or mitigate by using a material that does not fit exactly within the desired dimensions. For instance, Banker (2020) mentioned that part of the curtain wall in the case has been made from window frames that do not fit exactly, and therefore need an adapter. For the planner, this was unthinkable, because they live in a makeable world. However, in this new paradigm, a different design strategy could enable wide use of secondary materials. In short: Design processes that enable flexibility in use of materials can work two ways. It serves as a strategy that allows for the implementation of second-hand materials and materials to be extracted at the end of life stage. There is a need for openness, though, as the design will be guided more by materials, rather than the materials be chosen according to the design. Design strategies like these can reduce the uncertainty regarding the availability of second-hand materials.

Another strategy raising the convenience of acquiring second hand materials is **digitalisation** of processes. As mentioned before, the availability of materials is a bottleneck in the circular RE development process. By digitalising second-hand material (for instance form a material bank) and linking them to BIM-software, the uncertainty regarding the availability of a materials is reduced. Additionally, combined with the recommendation that buildings that will be demolished in the foreseeable future get a material passport, the market for second-hand materials is becoming more convenient and second-hand materials will retain value. Although the focus of digitalisation on the end-of-life phase of a building sure is an impactful idea, it seems like there is no attention given to its potential during the exploitation phase. In order to extend the lifetime of a building, for example, digitalisation can be used to see how the building performs, how its useful life can be optimised and when certain elements need preventive maintenance.

	Awareness	Behavioural change	Design strategies	Digitalisation	Front-end emphasis	Market systems	Government incentives and leverage	Stakeholder alignment
Lack of market systems								
Lack of demand								
Circularity regarded expensive								
Standardized products								
Client's financial resources								
Investor's lack of interest								
Guaranteeing lifecycle								
Superiority of concrete								
Availability of second-hand materials								
Circularity as something for just on paper								
Circularity perceived a difficulty								
Advantages of traditional construction								
Lack of clear definition								
Contractual obligations								
Lack of cooperation								
Lack of common goal								
Lack of government incentives								
Lack of government mitigation regarding second-hand materials								
Fragmented building industry								
Fragmented supply chain								

Table 11: overview of which recommendations raise certain barriers (own table)

Moving towards the pre-initiative phase, the **front-end** phase of a circular building project is paramount in determining the course for circular RE development. By clearly defining the

development mission, having a circular mindset on the first day of the development process and including circularity in the programme of requirements, a course for a circular development can be set. The programme of requirements could contain design strategies like remountable building, no use of adhesives and wide use of second-hand materials from a donor building. Additionally, the programme of requirements should require stakeholders to engage in open communication and involve them from day one of the RE development process. This enables cooperation, a clear definition and a common development goal. Additionally, open communication enables suppliers and the industry to honestly say whether something is not possible within their organisation due to the fragmented industry. Consequentially, the development team can brainstorm about other solutions. Involving more people in problem solving brings more ideas to the table. However, it also should not be too much in order to remain oversight. Therefore, stakeholder alignment workshops can determine the way that stakeholders define the collaboration.

Stakeholder alignment is done by including key stakeholders in the project from the beginning and defining the project. In the project definition, circularity and an open mindset are key elements in setting out a successful course. Stakeholder alignment also included that everyone takes responsibility for the project, because circular projects are complex projects where all stakeholders take on an important role. Therefore, by sharing responsibility, the material life should be collectively guaranteed by the stakeholders.

Secondly, stakeholder alignment should discover the possibilities of a **flexible delivery date** for the project. In the current market, there are still numerous uncertainties revolving around circular building project. But something that can be implemented right now is a flexible building process, with flexible phasing, with a flexible delivery date without repercussions. Contracts remain sharp in the built environment, and more emphasis should be put on the common goal, rather than contracts and delivery dates.

Since money still is an important enabler to get things to be done in the built environment, investors can demand circularity by exercising **financial leverage**. This entails that investors only grant finance to developments that prove circular. However, therefore the mindset of investors has to change first from being predominantly driven by financial gain, to shifting the focus towards the environment. Therefore, **circular business models** should be proven feasible, profitable and provide cashflow for a long-term period of 50+ years. A behavioural shift in the way investors see circular RE development raises the barrier about the investor's lack of interest. A shift in how buildings are perceived is paramount in enabling these barriers to be overcome. Taking the example of the building as a material bank being expensive, demolishers should not be paid to demolish the building, but owners of the to-be demolished building should receive a sum of money due

to the remaining value of the materials present in the building (Banker, 2020). This requires new business models from the demolisher's side.

Another market system that could incentivise to invest more financial resources up front and to build more robust, circular buildings is the **football principle**. As explained by CEO 2 (2020), there is a market for professional football players. If a club A sells a player to club B, it sells for a certain price. Additionally, if club B sells the same player to club C, club A receives a certain amount of money. The same can be done with buildings. For instance, an investor is willing to invest more in a more robust, energy efficient and circular building that lasts for a long time, if he gets a certain percentage every time the building is passed on to the next owner. The same concept can be done with products or materials. If a wall segment can fulfil its function for multiple buildings and every time it gets passed on, the manufacturer receives a certain percentage for the initial production costs, the business case is more feasible. The same goes for a building.

These recommendations, provided by interviewees and the author's insight have provided some means of clearing the barriers, and are also embedded within the *circular real estate development process*.

Rather interestingly, the results revolve mainly about processing the materials either during construction or at the end of life phase of a building, while mostly leaving out the exploitation phase. This is in line with the notion shared by Kyrö (2020) about the lack of RE management practices during the exploitation phase of a building. There is a severe need to emphasise this phase, as optimisation of currently existing buildings is rarely practiced as of 2020, which is also reflected in the interviews.

This chapter ends with an overview about how different recommendations from this section can aid to bring down barriers preventing the RE development process to deliver circularity. The next section will discuss the current practices, future aspirations, barriers and recommendations with the previously reviewed literature with the goal to find surprising similarities and differences. Thereafter, all knowledge gained during the development of this thesis will be assimilated in the end-product of this thesis: the circular real estate development process.

8. Discussion of findings

The discussion of findings serves to compare the findings from the case study research with previous studies, and emphasise surprising findings. This section aims to answer the questions on the similarities and differences between the practitioner views and the themes found in the research of previous studies, what current practices exercised by key players in the circular real estate development process are, and the gap between current practices and future aspirations. Moreover, the discussion provides valuable insight in how the RE development process can adapt to the CE according to findings from both practitioner views and previous studies. Additionally, findings from previous studies and data collected in this thesis will provide the foundation for the circular RE development process, presented in chapter 10.

The first remarkable difference was that the literature has a dominant focus on the construction phase and the supply chain, which differs form practitioner views. Practitioners appear to have a more holistic understanding of how circularity in the built environment can be delivered by the RE development process, and emphasise processes throughout all phases. However, the exploitation phase is largely left unattended. nonetheless, one business model with a focus on the exploitation phase is the lifetime extension model which can certainly play a part in sparking a market, and it is a sound step in the right direction. Yet, the exploitation phase should also be taken into consideration in the early phases, and extending the life of currently existing buildings may profit from a lifetime-extension maintenance strategy. Therefore, further research should focus on RE management practices and building life extension during its exploitation phase.

8.1.Circular strategies

Circular strategies seem to have a significant presence in both previous studies as well as in practitioner views, with key strategies being design, portfolio and government strategies. Additionally, circular strategies appear to have a strong presence in the initiative phase of the RE development process. This is not an unexpected finding, since RE development processes significantly benefit from strong and clear strategies developed in the initiative phase.

There is a strong overlap between current practice and the CBE framework in the application of the 9 R's. There seems to be a thorough understanding of this aspect of the CE in the built environment. While design strategies in the literature mention modular design and design for deconstruction, practice seems a bit more developed in the implementation of design strategies. Current practice adds generic design, enabling the widened availability of second-hand materials, and remountable design, enabling a building to be deconstructed and remounted elsewhere.

The main difference between strategies from previous studies and practitioner views is the focus. While practitioner strategies during the RE development process have a more holistic scope to implement strategies, such as in the initiative, design, construction and end of life phase, strategies in previous studies have a tendency to focus only on the design phase.

An interesting government strategy that has been mentioned by the Consultant (2020) is the ability of a municipality to be flexible regarding building performance regulations. This process enables the implementation of second-hand material and contributes to preventing raw resource extraction. Additionally, these strategies cascade towards business models trading in these materials, and the process of extracting them. Furthermore, this way, presumably 'worthless' materials become valuable again.

A more substantial difference originates between previous studies and future aspirations. An interesting phenomenon advocated by practitioners are strategies that facilitate resource retainment throughout the asset portfolio which indicates a radical change in how asset portfolios are going to be managed in the future. This also contributes to how the role of the RE developer may change throughout the transition towards the CE. In other words, the future value proposition of the RE developer might not only be trading space, but also materials. In this new paradigm, it also raises the question of what the RE developer owns as asset, and owns in terms of access (ownership & leasing). For instance, a RE developer could own a structure consisting of columns, floors and stair cases, for which it gains access to facades, interior finishings, installations and lighting by leasing it. This radically changes the way that the RE developer represents itself in the RE development process. Another significant contributor of delivering CE in the built environment is the recommendation that practitioners in the industry start seeing buildings as processes, rather than a finished product that wears down over time and is eventually demolished. Buildings should be regarded as processes which are made capable of being flexible during all phases involved, with more emphasis on the exploitation phase.

8.2.Circular business models

Business models find their way in the RE development process throughout all phases. As described by several interviewees, RE development strategies provide the foundation for implementing circular business models like PSS. It seems as if circular business models differ from traditional business models in the sense that they are focuses on the long-term rather than focused on a single sale. Therefore, the scope of circular business models is not only the construction phase (in which traditional construction processes entail a single sale of materials), but encompasses the entire RE development process.

Business models such as PSS appear to have found and partially secured their business model in the construction industry. The main worry indicated by practitioners, though, is that it depends on whether there is a production line between the leased product or not.

Lightbulbs and elevators are good examples of this. Speculatively, PSS faces challenges for products that have a very specific shape per unit, which might occur with facade systems or floors. Therefore, design strategies play an important role in enabling PSS.

Business models in both current practice and future aspirations differ from those in the literature, whereas literature lays a dominant focus on PSS, there appears to be a development of other business models in the field, as mentioned by ABN AMRO (2017). Similarly, the Football Principle should be researched in order to make it operational. However, a discussion is rising regarding what the RE developer or owner of the building is exactly going to own or lease, raising concerns about the feasibility of the FP since it seems to be built on the idea that the building is bought. Yet, the business model is in its infancy, and perhaps there are possibilities regarding a construction where certain building elements are bought, and others are leased.

Since there is a lack of focus on real estate management during the exploitation phase, the business model mentioned by ABN AMRO in 2017 called 'lifetime extension' is a welcome addition. However, the business model has yet to be proven to work. This is something that will probably become clear in the following 25 years. Not only does this apply to this particular business model, but to all business models mentioned in this thesis.

Furthermore, the literature also does not include the investor's ability to exercise financial leverage on issuing funds on the condition that a building is developed according to circular standards.

8.3.Management reporting systems

It appears that in previous studies, current practice and future aspirations, a circular management reporting system is being developed. There is one thing that these measurement systems have in common, which is the use of circularity indicators. The operationalisation of the CE in the built environment by circularity indicators provides a sound foundation on which a circular RE development process can reflect. Although circularity indicators provide a measurement tool for how materials are and/ or should be processed, it leaves out the underlying soft processes like a stakeholder alignment process in, for instance, the first meeting. Additionally, there also is a lack of focus on the exploitation phase in the RE development process. Therefore, the scope of circularity indicators should widen from focussing mainly on construction, to the entire RE development process including real estate management practice and design strategy performance (i.e. how much CO2 is saved with modular construction or remountable designs)

Current practice does differ from previous studies in one significant way. Where previous studies focus on circularity indicators, life cycle assessment, BIM-based management reporting systems and the quantification of the environmental impact, current practice still

relies on official certification by means of BREEAM as their official way to measure the sustainability score of the project. Although BREEAM is a tool that indicates the sustainability of a building, it lacks circularity indicators. Therefore, mentioning BREEAM to indicate circularity is questionable.

8.4.Organising systems in construction practice

Previous studies on organising systems within construction practice share similarities with current practices. Where the emphasis in practitioner views is predominantly focused on buildings as material banks as part of a business model or the asset portfolio, previous studies focus more on material passports as means of a decision tool. Practitioners would definitely benefit from the integration of material passports into BIM as mentioned by both practitioners and authors from previous studies in the sense that it enables materials to be sold, creating a market. During the research, confusion rose around material passports and material banks. Therefore, it helps to know that material banks *are* buildings *containing* a material passport, with the purpose of serving as a donor building for (re)development processes during the end of life phase.

Another remarkable finding during current practice which was absent in the literature was the ability to lengthen the construction phase. The ability to lengthen phases in the RE development process, as observed during the construction phase of Office 3, appears to be a pivotal enabler to create value in the CE. Flexibility in contracts, therefore enables phases to be flexible. The reason for this is that contracts often contain penalties if a product is not delivered on time. Therefore, being able to renegotiate the contract concerning delivery dates in order to add value to the development process takes away pressure, and makes room for ideas that adhere to the CE. The RE development process becomes more flexible through the ability to stretch phases without repercussions. Additionally, this flexibility creates an environment in which ideas can be shared and experimented with during the RE development process. This could potentially give way for circular solutions, rather than focussing on timeliness and financial gain. However, this does not necessarily entail that a construction project which is planned to last 2 years should last ten years deliberately.

Similar to previous studies, current practice and future aspiration is the significance of stakeholder collaboration during circular building projects. Stakeholders should be organised in such a way that allows for creating a stakeholder management process. The central focus of this management process is openness about financial aspects, declaring personal goals and being able to work for a bigger goal, rather than being individualistic. Practitioners might benefit from the stakeholder management framework developed by Honic et al. in 2019, or the interface management framework by Eray et al. (2019). Stakeholder collaboration frameworks should be developed in the first meeting of the development process. In this meeting, the manner of collaboration should be discussed,

since RE development teams differ from development to development. The main focus in the first meeting is that alignment between stakeholders is carried out. A key enabler for this is involving stakeholders with a similar mind set to develop circular buildings.

8.5.Resource processing

Resource processing differs radically between current practice and previous studies. While previous studies emphasise on using secondary materials in conventional (highly polluting) mortars, the use of adhesives in current practice is ill-advised. It can be stated that current practices are less toxic due to the implementation of design principles like the non-use of toxic materials.

Future aspirations differ even more from previous studies in terms of digitalisation of second hand materials and the ability to use them without any alterations. This results in contractors, RE developers and suppliers can reduce their environmental impact. Current practice and future aspirations differ in focus compared to previous studies in the sense that practitioners aspire to develop processes that eradicate the use of toxic materials, whereas previous studies create processes to make polluting materials less bad. While this is a step in the right direction, the need for systems enabling second hand availability require emphasis in order to step away from raw resource use.

Another interesting finding is the inclusion of people with a distance to the labour market to upscale materials. This process is both beneficial to the environment and the economy due to the creation of jobs and the reduction of raw resource use. Yet, the reoccurring phenomenon of the lack of focus on the exploitation phase is observed in this context as well.

8.6.Gap between current practice and future aspirations

Table 9 shows current practices and future aspirations within the five key themes.

Theme	Current practice	Future aspirations
Circular strategies	Project strategies Design strategies	Portfolio management Mind set
Circular business models	Product service-systems Financial leverage	Change of focus Market systems Sypply chain integration
Management reporting systems	No mainstream way for measuring circularity Buildings as data banks	Measuring circularity
Organising systems within construction practice	Stakeholder alignment Building as material banks Delays in consultation	Digitalisation Process management Stakeholder collaboration
Processing of resources	Social impact Use of biomass Digitalisation of resources	Resource availability Reduced resource alteration

Table 12: overview of current practice and future aspirations (own table)

Although from table 9 might not reveal the gap between current practice and future aspirations, there are some societal, organisational and financial gaps between current practices and future aspirations in circular RE development. The first gap between current practice and future aspiration is the collective mindset. Where the mindset is currently traditional across the built environment, there is a severe need to change the perspective toward circular approaches like wide use of second-hand materials. By changing the overall mindset, and seeing circular RE development as a challenge to inspire and be inspired, rather than seeing is as a difficult process, the built environment can make steps in the right direction. nonetheless, there is a need to close the gap of the mindset.

A second gap between current practices and future aspirations is a change of market systems. Where the current market does not support circular RE development, there is a need for new market systems that incentivise stakeholders to engage in circular RE development.

The third gap between current practice and future aspiration is the current lack of mainstream measurement techniques for circularity. While there are instances looking to develop such tools, there is no mainstream certification method to this point of time yet.

The fourth gap is the gap between phasing being strict and bound by penalties and flexible phasing. This gap is interesting, because there are practitioners that implement this already. However, since this thesis involved practitioners that don't implement this, it appears to be a gap still.

The fifth gap consist of the current lack of widely available second-hand materials and the future aspiration in which second-hand materials are widely available. The gap in between is the lack of a collective platform containing second-hand materials that have a code which allows them to be directly implemented in BIM software.

The discussion of results has revealed that current practices and future aspirations differ from what is described in the literature. The circular economy can be delivered by the RE development process from five of key processes and changes: The first of which is to start the RE development process with stakeholders that aim to engage in a circular RE development process. Having a mindset that is open for ideas, and being flexible is key. Furthermore, stakeholder management in the initiative phase should aim to reduce uncertainty and risk by involving key stakeholders in the first meeting. Given the fact that every development process might be different, it is pivotal that the key stakeholders determine and define the manner of involvement. Secondly, mitigation of performance indicators set by regulators could be mitigated in order to make second hand materials available. Thirdly, another important process that stimulates the creation of a circular process is the ability to stretch phases which enables ad hoc resource availability and providing incentive to pitch ideas which promote a circular development process. The fourth change is that buildings should be perceived as material banks, and should be issued a material passport. This serves two purposes: The first purpose is that during the exploitation phase, the location, performance and other properties become clear, which eases maintenance. The second purpose is that materials that have a material passport can also be sold, since the properties are known. Fifth, with new business models on the rise, the value propositions of the RE developer may change, together with other key players that might depend on circular business models. RE developers might change their value proposition to trading only space, to also trading in materials. Moreover, the question arises what exactly key players are going to own, and what to lease. The key findings of this section have provided the foundation for the circular real estate development process which is revealed in the chapter ten.

9. The Circular Real Estate Development Process

After discussing current practice, future aspirations, gaps, barriers and recommendations, a thorough understanding on the current and future role of the RE development process in delivering circularity has been developed. This chapter serves to propose a new RE development process in order to execute a RE development process in a circular manner. The general idea of the circular real estate development process is that it differs from the current linear RE development process in a few ways: The main difference between the traditional and circular RE development process is that the traditional process is linear, whereas the circular process is circular, meaning that the overall aim of the circular RE development process is to optimise the performance and lifetime of materials. To achieve this, there are multiple processes in place through different phases, which are mentioned in the following sections.

The second difference is that the circular RE development process can be applied to both an individual building and an asset portfolio, while the linear lies the focus on just one building. Thirdly, key stakeholders remain involved longer in the circular process compared to the traditional process. For instance, the RE developer stays involved throughout the building's lifecycle to operate and maintain it, provided that the client does not acquire the building after delivery. This differs from developer to developer, given the fact that there are RE developers who sell the development after construction, whereas others keep the building in the asset portfolio. Therefore, it is important to notice that the circular RE development process provides a foundation for organisations to act, but that it is adaptable according to a RE development strategy.

The process model is revealed in Figure 8 (own figure) and consists of three key elements. The first element is the inner set of loops. The inner set of loops contains three sub-loops. The outer loop represents the RE development phases (initiative, design, construction, exploitation, end of life), and eventually, this loop transitions in the 'donor building', or middle loop, in which the asset becomes a material bank for a new development process or maintenance of another building. This is where the cycle starts over again at the initiative phase. This enables multiple donor buildings to be included in the RE development process of one new building. New development can be exercised within the asset portfolio, but also outside of the asset portfolio. In case new development happens outside of the asset portfolio (i.e. development by another company with another asset portfolio), the donor building will be put on the market for second hand materials). The most inner loop represents other sectors, like the shoe or clothing industry, provoking a cross sectoral market. As can be seen, elements from the donor building can be exchanged with different sectors, and vice versa. In short, the RE development process starts with (re)development and delivers a building, which eventually becomes a donor building serving for new development processes or maintenance of existing building stock.

The second element, the outer set of circles represent the stakeholders, and at which point in time they are involved. The third element is the set of yellow beams that reveal the involvement of key stakeholders, during which phase and actions that could be undertaken. Notice that some beams go through both the development process and the donor building circle, meaning there could be a donor building involved in the development process of a new building. Whereas the inner set of circles revealed in Figure 8 (own figure) represents the real estate development process, the process can also be perceived as the flow of materials.

There are many aspects determining the outcome of this development process, given the presence of the discussion about what is owned and leased. This dramatically influences the outcome and availability of second hand materials during the RE development process. Furthermore, it is important to notice that there is not one format for RE development. This process model is a suggestion that can be applied and adapted to multiple development strategies (for instance one where the RE developer keeps the asset in the asset portfolio, whereas in other instances the asset being commissioned by/ sold to the client).

With the general outlay of the model explained, the following sections go deeper into the circular real estate development process.

Initiative phase

The initiative phase plays a significant role in determining the manner of involvement of key stakeholders, contract formation and defining and operationalising circularity. In the proposed process, the following 8 key players are represented:

- RE developers
- Clients
- Planners
- Contractors
- Regulators
- Suppliers
- Consultants
- Investors

As recommended during the discussion of results, the manner of collaboration should be developed in the first meeting. It is recommended that this meeting is attended by the key stakeholders, preferably with a similar circular mindset. The first goal of the first meeting might be to operationalise circularity in the built environment and how to adhere to it

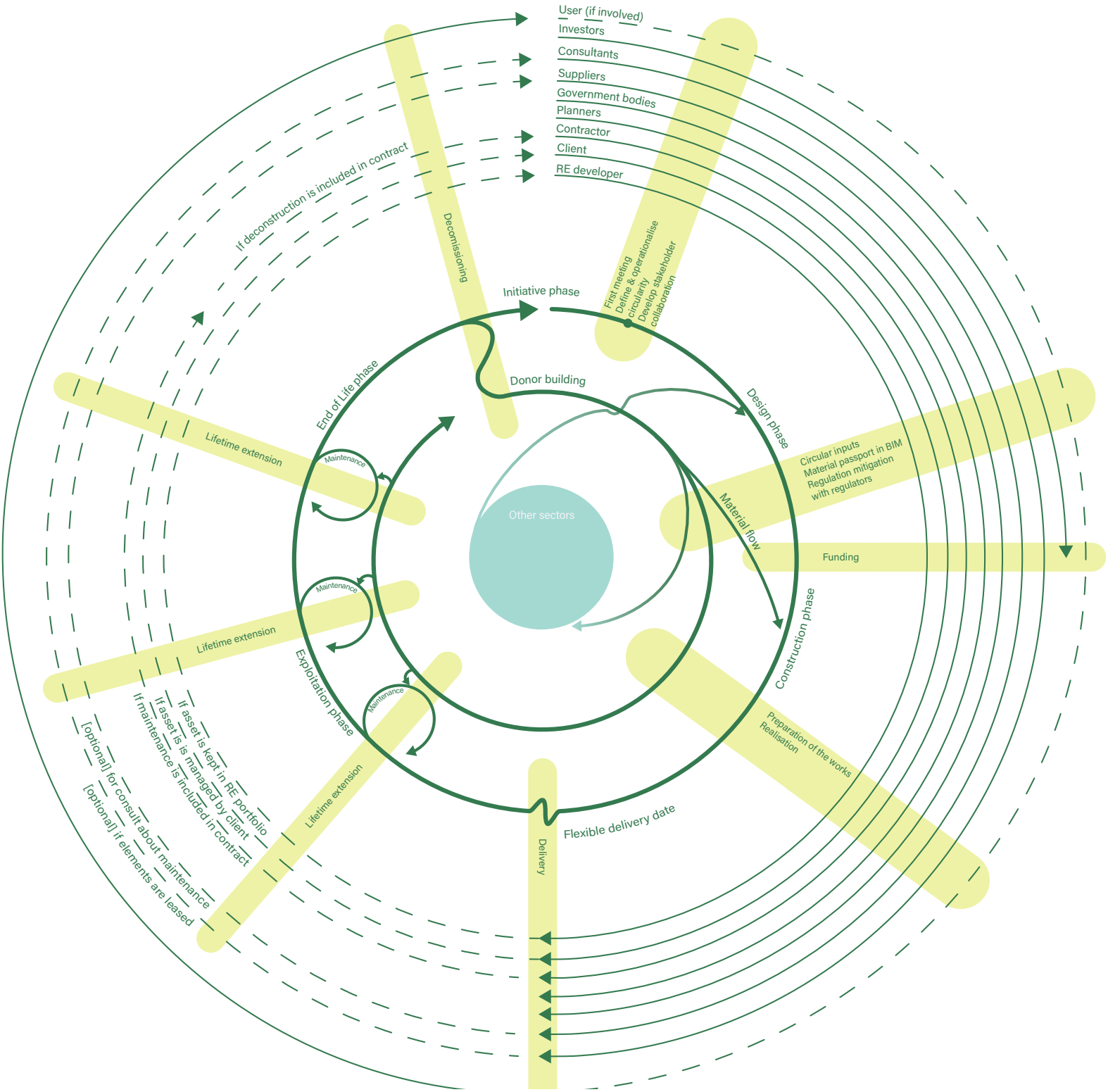

Figure 8: The circular real estate development process (own figure)

according to the key player's abilities. Therefore, honesty and an open mindset are key. Additionally, an open mindset can be incentivised by implementing contracts that allow flexibility regarding timeliness during phases. The creation of a healthy, circular RE development process combined with a healthy business case in which all stakeholders get a fair share of profit can create a successful RE development process.

In the initiative phase, every player has a different task. The duty of (circularity) *consultants* is to raise awareness about the advantages of circular construction compared to traditional construction for both the financial, social and environmental side throughout the process. An example could be that the implementation of PSS facades increases the robustness of the product and that it takes worries away for the client and/ or developer. Alternatively, for the supplier of these facades, there is a long-term business model attached which ensures long-term cashflow. A societal advantage of the circular economy in the RE development process could be the involvement of people with a distance to the labour market which enable resource upcycling.

Similarly, *investors* could incentivise the development players to thoroughly think about circular processes by issuing financial resources only if a circular design is achieved. However, this could lead to tensions within the project team, because the investor is in a position of power in this example. To prevent this, agreements could be made in the initiative phase that enable cashflow from the investor towards the development if certain operationalised goals are achieved, such as a deign process that creates a remountable design.

Other means to incentivise a circular RE development process in the initiative phase is by *regulators* indicating willingness to provide incentives for a circular RE development process and mitigation of regulations regarding performance of materials. This raises the barrier of certain second hand materials not complying with strict regulations.

The task of the *planners* in the initiative phase is to use their knowledge about circular design to influence and spread knowledge to the key players about circular design principles. During the development of the concept of the building, the planners can already discuss with the *contractor* and *suppliers* about the possible availability of materials. The earlier knowledge about the availability of second hand materials is made available, the bigger the chance that it could be implemented during the development process.

Throughout the initiative phase, and the coming phases, the *RE developer* is the spider in the web that needs to manage the stakeholders and bring the development process to a success. He or she also needs to provide feedback to the client, provided there is one involved. Being the bridge between the client and the other key players, the RE developer has a difficult task if the client does not want to have a circular RE development process. Therefore, the RE developer might be able to persuade the client to engage in a circular

RE development process if he or she has expert knowledge on the topic and can persuade the client by proving its advantages.

Design phase

During the design phase, things become interesting, and can have multiple outcomes. A reason for this is that in this phase, decisions about what is going to be owned or leased by who are made. Possibly, the *RE developer* or *client* could own the structure of the building, and lease facades, interior, installations, etc.. This promotes circularity, provided that *suppliers* have processes in place to process the materials in a circular manner at the end of life stage. Additionally, the question is raised whether the RE developer has an asset portfolio with a possible donor building. This is where processes take on a soft side and agreements about the origin of building materials are made. Furthermore, design strategies that allow for generic design also make way for ad hoc implementation of secondary materials that are found during the construction phase. Therefore, *planners* should be involved until the project delivery date, so they can see if secondary elements fit in the design, or if design changes need to be made. The *regulators* keep its significant role in this phase, since the local municipality can influence which building elements can be used or not. Mitigating strict government regulations in order to implement secondary materials can increase the level of circularity of the building during the RE development process. During the design phase, it is pivotal that the building is given a material passport, which proves immensely useful during the exploitation and end of life phase of the building.

Construction phase

During the construction phase, stakeholder collaboration and design strategies from the initiative and design phase are put into fruition. In this phase, it is still possible to change the design provided that second hand materials become available. To realise this, close communication between the contractor, RE developer and/ or client and planners is paramount. If necessary, suppliers and consultants could also be included in the decision making process. Just as during the traditional RE development process, the successes or setbacks in the construction phase mostly arise out of choices made in the initiative and design phase. The main difference between the proposed and traditional development process in the construction phase is the flexibility of the construction phase. It can be lengthened by i.e. the sudden availability of second hand materials which can used to add value to the building. A concern might rise regarding the extra time and profits, since there is a longer period that wages that has to be paid. Therefore, assessing the feasibility of lengthening the construction phase becomes important.

Exploitation phase

In this phase, the building is put to use by users. In the first few months after delivery of the building, it becomes clear whether design strategies, lease constructions, and second-hand material application as a result of a predetermined RE development strategy pay off. In any case, the exploitation phase provides the opportunity to maximise the lifetime of the

building. A tool that can enable this, is the material passport that has been issued during the design phase. The reason for this is that during the maintenance of the building in this phase, the size, performance, weight, etc. is known, which speeds up the process of maintenance. Having a strong maintenance strategy as a result of a strong design strategy could increase the building's lifetime by decades. Important enablers for this are design processes that provide easy access for maintenance or replacement such as modular and remountable design strategies.

Consultants might still play a role in advising circular facility management practices. Therefore, they are included in the exploitation phase. Yet, the intensity of their involvement becomes low. The same goes for suppliers. They still might play a role in the exploitation phase, provided that they work together with the RE developer or client to supply materials during maintenance. In case of the building already being part of an asset portfolio with a donor building in place, materials could also originate from the donor building. Alternatively, materials can be purchased from a donor building outside the asset portfolio. This depends on what is owned by the RE developer or client, and what is leased.

End of life phase

The end of life phase starts when lifetime extension by maintenance, renovation or restoration is not financially feasible anymore. Again, this is where the material passport proves its use. It is recommended that materials present in the building are put up for sale a few years before the building is supposed to be decommissioned. Then, when the day comes that the building is officially decommissioned, there are four things that can happen.

1. PSS suppliers come to collect their products. This is why they are involved throughout the entire RE development process.
2. Materials that are owned by the client or RE developer can be sold to other parties. This can be enabled by a material passport that is attached to a secondary material market place.
3. Materials that are owned by the client or RE developer are extracted to be used for another development within the asset portfolio.
4. Materials are exchanged on a cross-sectoral level.

When the end of life phase starts, the initiative phase of another development process aspiring to use a building as donor building might have already started, and that is where the loop repeats itself.

10.Limitations

The current research is limited in the amount of key stakeholders that the current research represents. In this research, the main stakeholders have been generalised to groups (i.e. ‘consultants’) in order to provide a clearer overview. However, future research could include all key stakeholders. This could be pursued during a PhD, for example.

Due to the amount of interviewees, the level of detail in this thesis might have benefited from additional interviews. Furthermore, this was the first time that the author engaged in extracting information by interviewing. Therefore, due to the inexperience of the interviewer, the data could have been more specific. In conclusion: an important recommendation is that this research provides a foundation for future deeper research in how the RE development process can deliver circularity in the built environment. There have been some surprising and exciting findings and the research has opened doors to new questions like the impact of early stakeholder involvement (such as: how early is early?), the football principle, market systems and awareness.

Additionally, although the author of this thesis aspired to describe and operationalise the RE development process and circularity in the built environment, there inevitably are things where the author did not think about. This is due to the complexity and infancy of the circular economy and the shifting perspective on what the RE development process entails. This is also referred to ‘not knowing what you do not know’. Therefore, it is not unlikely that readers might tackle certain barriers differently, or implement other changes in the circular RE development process. For that, the author is interested in engaging in a discussion, since he aspires to develop an expert-level knowledge about how the RE development process can deliver circularity in the built environment.

Another limitation about this research is that the literature review search queries had only focused on circularity in the built environment, building industry and construction industry. It could be that the gap that has been discovered (the lack of representation on how the RE development process can deliver circularity in the built environment) originates from these search queries, excluding the real estate development process.

11. Conclusion

The built environment is a major polluter of the Earth, but there are initiatives countering this. One of which is the circular economy, which primary goal is to create a paradigm in which material loops are lengthened and/ or closed by following principles of designing out of waste and pollution, keeping products and materials in use, regenerating natural systems. The research on circularity in the built environment is young, but it is gaining an increasing amount of attention. From a literature review starting with 337 studies, focusing on the processes within circularity in the built environment, a framework has been developed containing five main themes. However, the real estate development process appeared to be absent in previous studies. Therefore the aim of this research was to investigate the current and future role or the real estate development process in delivering circularity in the built environment. This section serves to answer the main research question*: What is the current and future role of the real estate development process in delivering circularity in the built environment?*

The research has served two purposes: to provide an overview of current practices, future views and aspirations and barriers in circularity in the RE development process. Additionally, the results have been discussed and recommendations have been proposed. Secondly, the research has proposed a circular real estate development process in which knowledge gained throughout this thesis is translated into recommendations that support concrete action.

To serve the first purpose, key stakeholders have been identified. These are the RE developer, the client, planners, contractors, suppliers, investors, consultants and regulators. Their understanding of circularity is similar and adhered to the definition of circularity in this thesis. Many stakeholders operationalised circularity by means of circularity indicators, which were mainly design principles. The understanding of the term was often found in a professional environment or by intrinsic motivation, but never in academic surroundings. Therefore, one recommendation is to create awareness about circularity in the built environment in academic environments.

Current practices include circular design strategies, product-service-systems, financial leverage, buildings as data and material banks, stakeholder alignment, making social impact, use of biomass and digitalisation of resources. The most surprising findings were the ability to lengthen the construction phase in consultation with the client. The significance of recommending the construction phase to be flexible in terms of the delivery date originates from the social, financial and environmental advantages that were gained during the implementation of this strategy.

Future aspirations include circular portfolio management, a change of mind set, deferring focus to mainly financial gain, change in market systems, supply chain integration, being able to measure circularity, digitalisation, process management, stakeholder collaboration,

resource availability and reduced resource alterations. The most radical change of these aspirations is circular portfolio management, in which buildings become part of the pool of materials embedded within the asset portfolio. Buildings could become materials banks that are able to exchange materials or serve as donors for new developments.

Another striking finding is that the value proposition of the real estate developer might change to trading spaces to also trading materials, since the CE surrounds this topic. The future of circularity in the RE development process might answer the question of what the RE developer it will own and lease. This means that the business model of RE developers could change as well in the future, and not only that. Suppliers and contractors also might have to adapt to changing value propositions. Especially if the market for second hand materials might become so mainstream and profitable that raw resources might become more expensive. This also provides an interesting question for financial services, since they are forced to ask the question what they are going to finance if, for instance, the value proposition changes from owning to leasing materials.

It seems that there are a considerable number of barriers challenging the built environment from developing circular real estate. However, there are some practical guidelines that support concrete action to raise these barriers. At the foundation of change lies the overall change of perspective, mind set and behaviour. By introducing circularity in the academic environment, students and young practitioners can spread awareness and knowledge about the significance of the topic. Additionally, clearly defining the project, involving like-minded parties, defining what circularity entails for the development process and defining the stakeholder collaboration and alignment in the first meeting of the development process can provide the foundation for a development process without unnecessary discussions, misunderstandings and non-cooperativity. Furthermore, second-hand materials should be perceived as valuable, rather than scrap. This prevents the destruction of value.

Digitalisation of processes has great potential in raising barriers regarding the availability of second hand materials. An interesting approach is to provide buildings that are planned to be deconstructed in one year with a material passport. Then, embedding these material passports within BIM software enables the materials to be reused and retail value.

Moreover, government intervention by means of laws, regulations and incentives can play a big role in steering the transition of the built environment towards the circular economy. Regulators can use disincentivising strategies like excise that reduce the use of raw or highly polluting materials like concrete.

During the development of the circular RE development process, four key processes and changes are at play. The first of which is to start the RE development process with stakeholders that aim to engage in a circular RE development process. Having a mindset

that is open for ideas, and being flexible is key. Furthermore, stakeholder management in the initiative phase should aim to reduce uncertainty and risk by involving key stakeholders in the first meeting. Given the fact that every development process might be different, it is pivotal that the key stakeholders determine and define the manner of involvement. Secondly, another important process that stimulates the creation of a circular process is the ability to stretch phases which enables ad hoc resource availability and providing incentive to pitch ideas which promote a circular development process. The third change is that buildings should be perceived as material banks, and should be issued a material passport. This serves two purposes: The first purpose is that during the exploitation phase, the location, performance and other properties become clear, which eases maintenance. The second purpose is that materials that have a material passport can also be sold, since the properties are known. Fourthly, with new business models on the rise, the value propositions of the RE developer may change, together with other key players that might depend on circular business models. RE developers might change their value proposition to trading only space, to also trading in materials. Moreover, the question arises what exactly key players are going to own, and what to lease.

In short: the current role of the real estate development process in delivering circularity in the built environment mainly consists of the application of strategies that enable the implementation of second hand materials and flexible phases throughout the development process. Circularity also is delivered by digitalisation processes, enabling materials to be documented, easing the process of retrieving materials. Circular business models also play an important role in delivering circularity in the built environment, since they pave the way for sparking a large-scale market for lengthening lifetimes of buildings, leasing building elements and sharing spaces.

The future role of the real estate development process in delivering circularity in the built environment is the change of focus on the individual building to the asset portfolio, enabling availability of second-hand materials. Furthermore, the real estate developer might possibly become a trader in both space and materials, and own access to materials, rather than owning them as an asset might play a significant role in delivering circularity.

Another finding that might enable financial feasibility and incentivise a higher amount of up-front investment is the football-principle. However, this thesis has not gone deep enough into this phenomenon. Yet, it is a very interesting concept. Therefore, future research could be conducted into creating a feasible business model.

Secondly, future research could focus on what the future value proposition of the RE developer could be. This could also be done from the perspective other RE development process players. Additionally, future research should emphasise the importance of the existing building stock and how real estate management practices can be optimised in order to extend the lifetime of an asset. Finally, since practitioners mentioned that the built

environment is fragmented, further research could also focus on the fragmentation of the built environment, and how the built environment could become a less fragmented industry.

12.References

1. ABN AMRO. (2017). Toekomstbestendig Vastgoed Bouwen, aan de slag met circulaire verdienmodellen.

2. Akanbi, L. A., Oyedele, L. O., Akinade, O. O., Ajayi, A. O., Davila Delgado, M., Bilal, M., & Bello, S. A. (2018). Salvaging building materials in a circular economy: A BIM-based whole-life performance estimator. Resources, Conservation and Recycling, 129, 175–186. https://doi.org/10.1016/j.resconrec.2017.10.026

3. Akinade, O., Oyedele, L., Oyedele, A., Davila Delgado, J. M., Bilal, M., Akanbi, L., … Owolabi, H. (2019). Design for deconstruction using a circular economy approach: barriers and strategies for improvement. Production Planning & Control, 1–12. https://doi.org/10.1080/09537287.2019.1695006

4. Ali, A. K., Wang, Y., & Alvarado, J. L. (2019). Facilitating industrial symbiosis to achieve circular economy using value-added by design: A case study in transforming the automobile industry sheet metal waste-flow into Voronoi facade systems. Journal of Cleaner Production, 234, 1033–1044. *https://doi.org/10.1016/j.jclepro.2019.06.202*

5. Antink, R., Garrigan, C., Bonetti, M., & Westaway, R. (2014). *Greening the Building Supply Chain*. United Nations Environment Programme. http://doi.org/ Job Number: DTI/1753/PA

6. Arora, M., Raspall, F., Cheah, L., & Silva, A. (2019). Residential building material stocks and component-level circularity: The case of Singapore. Journal of Cleaner Production, 216, 239–248. *https://doi.org/10.1016/j.jclepro.2019.01.199*

7. Azcárte-Aguerre, J. F., den Heijer, A., & Klein, T. (2018). Integrated façades as a Product-Service System – Business process innovation to accelerate integral product implementation. JOURNAL OF FACADE DESIGN & ENGINEERING, 6(1). https://doi.org/10.7480/jfde.2018.1.1840

8. Bertoni, M. (2019). Multi-Criteria Decision Making for Sustainability and Value Assessment in Early PSS Design. Sustainability, 11(7), 1952. https://doi.org/10.3390/su11071952

9. Boerop, L. (2019, September 25). Waarom staan er door stikstof 18.000 bouwprojecten op losse schroeven? 4 vragen en antwoorden. Retrieved November 12, 2019, from https://www.businessinsider.nl/stikstof-uitspraak-pas-uitleg/

10. Bolger, K., & Doyon, A. (2019). Circular cities: exploring local government strategies to facilitate a circular economy. European Planning Studies, 27(11), 2184–2205. *https://doi.org/10.1080/09654313.2019.1642854*

11. Boulding, K. E. (1966) 'The Economics of the Coming Spaceship Earth', in Jarrett, H. (ed) Environmental quality in a growing economy: Essays from the sixth RFF forum, New York, RFF Press, pp. 3–14.

12. Bulloch, B., & Sullivan, J. (2010). Information – The Key to the Real Estate Development Process. *Cornell Real Estate Review*, *8*, 78–87. Geraadpleegd van https://scholarship.sha.cornell.edu/cgi/viewcontent.cgi?article=1045&context=crer

13. Casas-Arredondo, M., Croxford, B., & Domenech, T. (2018). Material and decision flows in non-domestic building fit-outs. Journal of Cleaner Production, 204, 916–925. https://doi.org/10.1016/j.jclepro.2018.08.328

14. Cruz Rios, F., Grau, D., & Chong, W. K. (2019). Reusing exterior wall framing systems: A cradle-to-cradle comparative life cycle assessment. Waste Management, 94, 120–135. *https://doi.org/10.1016/j.wasman.2019.05.040*

15. Dewick, P., Maytorena-Sanchez, E., & Winch, G. (2019). Regulation and regenerative eco-innovation: the case of extracted materials in the UK. Ecological Economics, 160, 38–51. https://doi.org/10.1016/j.ecolecon.2019.01.034

16. Eberhardt, L. C. M., Birgisdóttir, H., & Birkved, M. (2018). Life cycle assessment of a Danish office building designed for disassembly. Building Research & Information, 47(6), 666–680. https://doi.org/10.1080/09613218.2018.1517458

17. Ellen Macarthur Foundation. (n.d.). Circular Economy Schools Of Thought. Retrieved October 8, 2019, from https://www.ellenmacarthurfoundation.org/circular-economy/concept/schools-of-thought

18. Ellen MacArthur Foundation. (2017a). 6:R3 CIRCULARITY AND NINE 'RS.' Retrieved December 21, 2019, from https://www.ellenmacarthurfoundation.org/assets/galleries/CEinaction-_Activity06-nine-Rs-6R3_from-graham-081217.pdf

19. Ellen MacArthur Foundation. (2017b). 6:R3 CIRCULARITY AND THE 9 "RS" [Table]. Retrieved from https://www.ellenmacarthurfoundation.org/assets/galleries/CEinaction-_Activity06-nine-Rs-6R3_from-graham-081217.pdf

20. Eray, E., Sanchez, B., & Haas, C. (2019). Usage of Interface Management System in Adaptive Reuse of Buildings. Buildings, 9(5), 105. *https://doi.org/10.3390/buildings9050105*

21. European Commission – DG Environment. (2014). *Development of Guidance on Extended Producer Responsibility (EPR)*. Retrieved from https://ec.europa.eu/environment/archives/waste/eu_guidance/pdf/Guidance%20on%20EPR%20-%20Final%20Report.pdf

22. Ezema, I. C. (2019). Materials. Sustainable Construction Technologies, 237–262. *https://doi.org/10.1016/b978-0-12-811749-1.00007-9*

23. Fargnoli, M., Lleshaj, A., Lombardi, M., Sciarretta, N., & Di Gravio, G. (2019). A BIM-based PSS Approach for the Management of Maintenance Operations of Building Equipment. Buildings, 9(6), 139. https://doi.org/10.3390/buildings9060139

24. Ghaffar, S. H., Burman, M., & Braimah, N. (2020). Pathways to circular construction: An integrated management of construction and demolition waste for resource recovery. Journal of Cleaner Production, 244, 118710. *https://doi.org/10.1016/j.jclepro.2019.118710*

25. Ghisellini, P., Cialani, C. and Ulgiati, S. (2016) 'A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems', Journal of Cleaner Production, vol. 114, pp. 11–32.

26. GoContractor. (2019, August 28). How Does Construction Impact the Environment? | GoContractor. Retrieved October 26, 2019, from https://gocontractor.com/blog/how-does-construction-impact-the-environment/

27. Google. (2020a). define organisation - Google zoeken. Retrieved January 6, 2020, from https://www.google.com/search?q=define+organisation&rlz=1C1GCEA_enNL751NL751&oq=define+organisation&aqs=chrome..69i57j0l7.2902j1j4&sourceid=chrome&ie=UTF-8

28. Google. (2020b). Define Peri-Urban . Retrieved 20 February 2020, from *https://www.google.com/search?q=define+peri+urban&rlz=1C5CHFA_enNL887NL887&oq=define+peri+&aqs=chrome.1.69i57j35i39j0l6.3527j1j7&sourceid=chrome&ie=UTF-8*

29. Google. (2020c). Pozzolana define - Google zoeken. Retrieved 6 February 2020, from https://www.google.com/search?q=pozzolana+define&rlz=1C5CHFA_enNL887NL887&oq=pozzolana+define&aqs=chrome..69i57j0l4.16249j1j4&sourceid=chrome&ie=UTF-8

30. Górecki, J., Núñez-Cacho, P., Corpas-Iglesias, F. A., & Molina, V. (2019). How to convince players in construction market? Strategies for effective implementation of circular economy in construction sector. Cogent Engineering, 6(1). *https://doi.org/10.1080/23311916.2019.1690760*

31. Graaskamp, J. A. (1981). *Fundamentals of Real Estate Development*. Retrieved from http://morris.marginalq.com/GREM_RE720_MoreFiles/Urban%20Econ%20Graaskamp%20ULI.PDF

32. Graedel, T. E., & Allenby, B. R. (2003). Industrial Ecology. Upper Saddle River, NJ, United States: Prentice Hall.

33. Healey, P. (1991). Models of the development process: A review. *Journal of Property Research*, *8*(3), 219–238. https://doi.org/10.1080/09599919108724039

34. Heisel, F., & Rau-Oberhuber, S. (2020). Calculation and evaluation of circularity indicators for the built environment using the case studies of UMAR and Madaster. Journal of Cleaner Production, 243, 118482. *https://doi.org/10.1016/j.jclepro.2019.118482*

35. Hendrickson, C., & Au, T. (1989). Project Management for Construction: Fundamental Concepts for Owners, Engineers, Architects, and Builders (PRENTICE-HALL INTERNATIONAL SERIES IN CIVIL ENGINEERING AND ENGINEERING MECHANICS) (Facsimile ed.). Upper Saddle River, NJ, United States: Prentice Hall.

36. Honic, M., Kovacic, I., Sibenik, G., & Rechberger, H. (2019). Data- and stakeholder management framework for the implementation of BIM-based Material Passports. Journal of Building Engineering, 23, 341–350. https://doi.org/10.1016/j.jobe.2019.01.017

37. Hossain, Md. U., & Thomas Ng, S. (2019). Influence of waste materials on buildings' life cycle environmental impacts: Adopting resource recovery principle. Resources, Conservation and Recycling, 142, 10–23. https://doi.org/10.1016/j.resconrec.2018.11.010

38. IBM. (n.d.). What is supply chain management? Retrieved April 12, 2020, from https://www.ibm.com/topics/supply-chain-management

39. Joroff, M. L., & Corporate Real Estate Project 2000. (1993). *Strategic Management of the Fifth Resource*. Washington, United States of America: Industrial Development Research Foundation.

40. Jiménez-Rivero, A., & García-Navarro, J. (2016). Indicators to Measure the Management Performance of End-of-Life Gypsum: From Deconstruction to Production of Recycled Gypsum. Waste and Biomass Valorization, 7(4), 913–927. *https://doi.org/10.1007/s12649-016-9561-x*

41. Johnson, G., & Scholes, K. (1998). *Exploring Corporate Strategy (5th Edition)* (5th ed.). Hempstead, New York: Prentice Hall.

42. Kate Raworth. (2019, August 3). What on Earth is the Doughnut?…. Retrieved May 10, 2020, from https://www.kateraworth.com/doughnut/

43. Kaufman, S. M. (2012). Quantifying sustainability: industrial ecology, materials flow and life cycle analysis. Metropolitan Sustainability, 40–54. https://doi.org/10.1533/9780857096463.1.40

44. Kyrö, R., Jylhä, T., & Peltokorpi, A. (2019). Embodying circularity through usable relocatable modular buildings. Facilities, 37(1/2), 75–90. https://doi.org/10.1108/f-12-2017-0129

45. L.D., M.-A., Sánchez M., M., M.A., R., A.L., C. V., & J.M., M.-A. (2019). Recycled Mineral Raw Materials from Quarry Waste Using Hydrocyclones. Materials, 12(13), 2047. *https://doi.org/10.3390/ma12132047*

46. Laurenti, R., Singh, J., Frostell, B., Sinha, R., & Binder, C. (2018). The Socio-Economic Embeddedness of the Circular Economy: An Integrative Framework. Sustainability, 10(7), 2129. https://doi.org/10.3390/su10072129

47. Leising, E., Quist, J., & Bocken, N. (2018). Circular Economy in the building sector: Three cases and a collaboration tool. Journal of Cleaner Production, 176, 976–989. https://doi.org/10.1016/j.jclepro.2017.12.010

48. Lozano-Lunar, A., Barbudo, A., Fernández, J. M., & Jiménez, J. R. (2019). Promotion of circular economy: steelwork dusts as secondary raw material in conventional mortars. Environmental Science and Pollution Research. https://doi.org/10.1007/s11356-019-04948-y

49. Lyubenova, T. S., Fraga, D., B., J., Castelló, C., Kozhukharov, V., & Machkova, M. S. (2018). MULTIFUNCTIONAL SMART COATINGS ON NOVEL CERAMICS AND GLASS-CERAMIC SUBSTRATES IN THE CONTEXT OF THE CIRCULAR ECONOMY. Journal of Chemical Technology and Metallurgy, 53(6), 1103–1116. Retrieved from https://www.researchgate.net/publication/328699108_Multifunctional_smart_coatings_on_novel_ceramics_and_glassceramic_substrates_in_the_context_of_the_circular_economy

50. Madaster. (n.d.). Madaster real estate owners & property administrators:: Madaster. Retrieved April 7, 2020, from https://www.madaster.com/en/business/real-estate-owners-property-administrators/madaster-real-estate-owners-property-administrators

51. Martínez-Martínez, S., Pérez-Villarejo, L., Eliche-Quesada, D., Sánchez-Soto, P. J., Christogerou, A., Kanellopoulou, D. G., & Angelopoulos, G. N. (2019). New waste-based clinkers for the preparation of low-energy cements. A step forward toward circular economy. International Journal of Applied Ceramic Technology, 17(1), 12–21. *https://doi.org/10.1111/ijac.13390*

52. Miles, M. E., Netherton, L. M., & Schmitz, A. (2015). *Real Estate Development - 5th Edition: Principles and Process* (Fifth Edition, Fifth edition). Washington, United States of America: Urban Land Institute.

53. Minunno, R., O'Grady, T., Morrison, G., Gruner, R., & Colling, M. (2018). Strategies for Applying the Circular Economy to Prefabricated Buildings. Buildings, 8(9), 125. https://doi.org/10.3390/buildings8090125

54. Nasir, M. H. A., Genovese, A., Acquaye, A. A., Koh, S. C. L., & Yamoah, F. (2017). Comparing linear and circular supply chains: A case study from the construction industry. Int. J. Production Economics, 183, 443–457. https://doi.org/10.1016/j.ijpe.2016.06.008

55. Nozeman, E. F., Fokkema, J., Vereniging van Nederlandse Projectontwikkeling Maatschappijen, Laglas, K., Scholten-Theessink, M., & Vereniging van Nederlandse Projectontwikkeling Maatschappijen. (2010). *Handboek projectontwikkeling*. Amsterdam, Netherlands: Reed Business Education.

56. Nuñez-Cacho, P., Górecki, J., Molina-Moreno, V., & Corpas-Iglesias, F. (2018). What Gets Measured, Gets Done: Development of a Circular Economy Measurement Scale for Building Industry. Sustainability, 10(7), 2340. https://doi.org/10.3390/su10072340

57. OECD. (2019). Raw materials use to double by 2060 with severe environmental consequences - OECD. Retrieved January 7, 2020, from https://www.oecd.org/environment/raw-materials-use-to-double-by-2060-with-severe-environmental-consequences.htm

58. Pavlíková, M., Zemanová, L., Záleská, M., Pokorný, J., Lojka, M., Jankovský, O., & Pavlík, Z. (2019). Ternary Blended Binder for Production of a Novel Type of Lightweight Repair Mortar. Materials, 12(6), 996. *https://doi.org/10.3390/ma12060996*

59. Pearce, D. W., & Turner, R. K. (1989). Economics of Natural Resources and the Environment. Baltimore: The John Hopkins University Press.

60. Pincetl, S. (2012). Pincetl, S. (2012). Metropolitan sustainability: Understanding and Improving the Urban Environment. Metropolitan sustainability. Metropolitan sustainabiltiiy.

61. 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

62. Porter, M. E., & Kramer, M. R. (2018). Creating Shared Value. *Managing Sustainable Business*, 323–346. https://doi.org/10.1007/978-94-024-1144-7_16

63. Rijksvastgoedbedrijf. (2015, November 11). Contract types. Retrieved June 6, 2020, from https://english.rijksvastgoedbedrijf.nl/expertise-and-services/doing-business-with-the-central-government-real-estate-agency/contract-types

64. Rocha, C., Formoso, C., & Tzortzopoulos, P. (2015). Adopting Product Modularity in House Building to Support Mass Customisation. Sustainability, 7(5), 4919–4937. https://doi.org/10.3390/su7054919

65. Robin, E., & Brill, F. (2018). The global politics of an urban age: creating “cities for all” in the age of financialisation. *Palgrave Communications*, *4*(1). https://doi.org/10.1057/s41599-017-0056-6

66. Rose, C., Bergsagel, D., Dufresne, T., Unubreme, E., Lyu, T., Duffour, P., & Stegemann, J. (2018). Cross-Laminated Secondary Timber: Experimental Testing and Modelling the Effect of Defects and Reduced Feedstock Properties. Sustainability, 10(11), 4118. https://doi.org/10.3390/su10114118

67. Saeli, M., Senff, L., Tobaldi, D. M., La Scalia, G., Seabra, M. P., & Labrincha, J. A. (2019). Innovative Recycling of Lime Slaker Grits from Paper-Pulp Industry Reused as Aggregate in Ambient Cured Biomass Fly Ash-Based Geopolymers for Sustainable Construction Material. Sustainability, 11(12), 3481. https://doi.org/10.3390/su11123481

68. Sanchez, B., Esnaashary Esfahani, M., & Haas, C. (2019). A methodology to analyze the net environmental impacts and building’s cost performance of an adaptive reuse project: a case study of the Waterloo County Courthouse renovations. Environment Systems and Decisions, 39(4), 419–438. *https://doi.org/10.1007/s10669-019-09734-2*

69. Sarde, R. R. (2016). An Overview of Front-End Planning for Construction Projects. *International Research Journal of Engineering and Technology*, *03*(07), 1297–1300.

70. TU Delft. (2020). Track: Management in the Built Environment. Retrieved January 7, 2020, from https://www.tudelft.nl/en/education/programmes/masters/architecture-urbanism-and-building-sciences/msc-architecture-urbanism-and-building-sciences/master-tracks/management-in-the-built-environment/

71. Essays, UK. (November 2018). A Study of Building Obsolescence in Standard Design. Retrieved from https://www.ukessays.com/essays/property/a-study-of-bulding-obsolescence.php?vref=1

72. United Nations. (2020). Green Economy. Retrieved May 15, 2020, from https://www.unenvironment.org/regions/asia-and-pacific/regional-initiatives/supporting-resource-efficiency/green-economy

73. Van Gool, P., Brounen, D., Jager, P., & Weisz, R. M. (2007). Onroerend goed als belegging. Houten: Noordhoff Uitgevers Groningen.

74. Voordijk, H., Meijboom, B., & de Haan, J. (2006). Modularity in supply chains: a multiple case study in the construction industry. International Journal of Operations & Production Management, 26(6), 600–618. https://doi.org/10.1108/01443570610666966

75. Wilkinson, Sara & Reed, Richard. (2008). Property Development.

76. Winch, G. M. (2009). *Managing Construction Projects*. Hoboken, NJ, United States: Wiley.

77. Zăinescu, G., Deselnicu, V., Constantinescu, R., & Ciulacu, C. (2018). Bio-Composites with Leather Fibers and Cement - Physico-Mechanical and Structural Characterization. Leather and Footwear Journal, 18(4), 327–336. https://doi.org/10.24264/lfj.18.4.8

78. Zigan, K., & Zeglat, D. (2010). Intangible resources in performance measurement systems of the hotel industry. *Facilities*, *28*(13/14), 597–610. https://doi.org/10.1108/02632771011083667

13. Appendix

13.1.Appendix 1: systematic literature review method

This section is dedicated to the strategy used to acquire the necessary literature in order to build a foundation for further research. In order to find the relevant literature for this thesis, two concepts have been defined. These concepts are “circularity” and “built environment”. Because of the broad variation of topics concerned with circular economy in the built environment, the search query was kept broad in order to get as many hits as possible in Scopus.com and webofscience.com. Later on, through the application of filters within the search engine, the amount of hits was reduced. The following steps elaborate on the selection process of scientific journal articles deemed appropriate for deeper study.

Step 1: Create search terms.

1. “circular economy” AND “construction industry”
2. “circular economy” AND “built environment”
3. “circular economy” AND “building industry”
4. “circularity” AND “construction industry”
5. “circularity” AND “Built environment”

Step 2: These terms would then be inserted into www.scopus.com and webofscience.com with the focus on title, abstract and keywords. This gave the following results on December 12th, 2019.

Search term	**Hits**
TITLE-ABS-KEY(“circular economy” AND “construction industry”)	169
TITLE-ABS-KEY(“circular economy” AND “built environment”)	98
TITLE-ABS-KEY(“circular economy” AND “building industry”)	23
TITLE-ABS-KEY(“circularity” AND “construction industry”)	16
TITLE-ABS-KEY(“circularity” AND “built environment”)	31
Total	337

Table 13: scopus and webofscience hits (own figure)

Step 3: The focus of the review was on empirical journal articles. This was done by filtering them with the search engine.

Search term	**Hits**
TITLE-ABS-KEY(“circular economy” AND “construction industry”)	64
TITLE-ABS-KEY(“circular economy” AND “built environment”)	33
TITLE-ABS-KEY(“circular economy” AND “building industry”)	18
TITLE-ABS-KEY(“circularity” AND “construction industry”)	4
TITLE-ABS-KEY(“circularity” AND “built environment”)	5
Total	124

Table 14: hits after filtering in the search engine (own table)

Step 4: The following step was to eliminate duplicates from the literature selection.

Search term	**Duplicates**	**Hits**
TITLE-ABS-KEY(“circular economy” AND “construction industry”)	0	64
TITLE-ABS-KEY(“circular economy” AND “built environment”)	8	25
TITLE-ABS-KEY(“circular economy” AND “building industry”)	11	9
TITLE-ABS-KEY(“circularity” AND “construction industry”)	2	2
TITLE-ABS-KEY(“circularity” AND “built environment”)	5	0
Total		98

Table 15: Hits after elimination of duplicates (own table)

After the elimination of duplicates, the author commenced selecting relevant papers through step 5 to 8. The papers were adjudicated according to inclusion and exclusion criteria presented in table 16.

Inclusion	Exclusion
Journal article	Literature review
Focus on the built environment	Not related to circularity
Operations research	Not related to the built environment
Empirical research	Focus on material properties
Focus on processes	Focus on material behaviour
Written in English	Other language than English (German, Italian)

Table 16: inclusion and exclusion criteria (own table)

Step 5 – scanning title, journal type and keywords – 98 journal articles

In this step, the journal articles were scanned on title, journal type and keywords. Articles that did were not relevant for the research were eliminated. After this scan, 11 out of 98 papers were deemed irrelevant. The reason for this was that the papers were not related to the built environment because they focused on water management, not related to circularity in the built environment or a literature review.

Step 6 – scanning title, author and abstract – 87 journal articles

When looking at the abstract, attention was paid to processes and treatments of materials, which indicate an organizational process. In this scan, 26 out of 87 papers were deemed irrelevant for further study, because they focused on material properties, material behaviour, were not focused on either the circular economy or the built environment, or were a literature review.

Step 7 – main results and conclusion – 61 journal articles

In this scan, 21 out of 61 papers were deemed irrelevant for further study, because the article was not written in English (two articles were German and Italian), the article would be a literature review or did not focus on circularity in the built environment.

Step 8 – reading articles thoroughly – 40 journal articles

In this scan, 5 out of 40 papers were deemed irrelevant for further study. The reason behind this was that the papers were either focused on resource properties or assesses a current situation in a certain context of the circular economy, which does not adhere to the

goal of this research. The eventual outcome of the literature study deemed 35 papers to be fit for use.