Technische Universiteit Eindhoven University of Technology

Where innovation starts

Towards a circular real estate development process model

Developing a circular real estate development process model to identify guidance rules for developers of circular real estate

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Preface

The world is facing ever increasing new challenges, such as the search for energy sources, the possibilities of endless available data and the scarcity of raw materials. In order to contribute to finding a solution for the last mentioned challenge, this research project focused on the concept of circular economy and its implementation within the real estate development process.

Working on this thesis did not only open my eyes and ears for new possibilities, but also deepened my awareness, that every single action can have large-scale effects on us as humans, but also on our planet. So, it is our task to increase this awareness and spread the word about possibilities, how to minimize negative effects. I hope, that reading this report will inspire you and provide you with some ideas and guidance on how to reach this.

The here presented thesis forms the last task for the completion of the master track Construction Management and Engineering at the Eindhoven University of Technology. It represents the steps undertaken and the results found while working on this research during the last six month. The aim of this research was to develop a process schema following the BPMN standard for the circular real estate development process for the Netherlands. I am proud to announce, that this aim is reached.

I would like to thank my first supervisor, Jan Dijkstra from TU Eindhoven for his patience and our productive meetings. Furthermore, I would like to thank my company-supervisor from Hurks Vastgoedontwikkeling, Carina Hak, for her motivating and friendly support even when she was very busy with her regular work. Besides that, I would like to thank Prof. Bauke De Vries for his willingness to take over the positions of second supervisor and chairman of my commission team. Despite his busy work schedule, he had an open ear for me and provided me with helpful comments.

In addition, I would like to thank the 21 experts, who have been willing to support me in my research. Without them sharing their knowledge with me, a lot of valuable information would have been missing.

Last, but not least, I want to thank my family, boyfriend and friends for all their support, motivating and friendly words and for the moments of distraction. They all helped me to reach this goal. My loving thoughts also go towards those, who aren't here anymore to share this moment.

But now, I want to wish you much fun reading this report and hope to inspire you towards the implementation of the concept of circular economy!

Johanna Scherer
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Management Summary English

The current economic model developed since the Industrial Revolution can be described as linear following the pattern of 'take-make-dispose' (Ellen MacArthur Foundation, 2013a; Andrews, 2015), in which raw materials are taken from the natural environment, are used to make products and are disposed at the end of the use period of this product. Continue this pattern will increase the scarcity of raw materials and waste production. Both of these two effects are further pushed by the growing population and wealth level worldwide. By 2030 a total of three billion new middle-class consumers are expected to enter the economic market (Ellen MacArthur Foundation, 2013a). These effects are especially relevant for the construction sector, as accounting for 32% of the total global energy use in 2010 (Lucon, et al., 2014). In the Netherlands, the construction sector is responsible for producing most of the waste of all industries with nearly 25 billion kg in 2010 (Statistics Netherlands, 2012) and five percent of the national greenhouse gas emissions in 2010 (Van Odijk & Van Bovene, 2014).

In order to meet these challenges the concept of circular economy was introduced in 2013 by the Ellen MacArthur Foundation. Following the principle of circular economy, the use of virgin materials needs to be reduced as far as possible while as little as possible water and energy are used for the recovery processes for materials (Ellen MacArthur Foundation, 2013b). Transferring this concept for the built environment asks for a translation towards precise principles, which can be distinguished in design principles, material-related principles and process-related principles. Besides this, buildings need to be seen as consisting of layers with different lifespans following Brand (1994), which are important for the circular approach.

Up till now, no standardized process model has been developed yet for the circular real estate development process focusing on residential real estate in the Netherlands. Previously, several aspects of the implementation of circularity within the built environment have been researched, such as defining circular buildings (Loppies, 2015), measuring circularity (Verberne, 2016), environmental impact assessment (Baartmans, 2013), circular value chain model (Van de Kaa, 2013), value creation (Kusters, 2013) and potential opportunities for Dutch commercial real estate developers (Rood, 2015). This research was conducted in the form of a qualitative research based on literature study, Delphi method and Business Process Modelling and Notation (BPMN) standard in order to develop a standardized and detailed process model for the circular real estate development process. This process model need to be practically usable by real estate developers to implement the concept of circular economy within residential real estate developments based on the traditional real estate development process.

The traditional real estate development process focusses on the development or redevelopment of residential or commercial real estate, which covers the combination of land and the building positioned on it. The real estate development process is a unique, iterative-executed process covering the main phases of initiation, development, construction and exploitation, which are filled in depending on the specific project conditions. As being highly influential on the real estate landscape and therefore also on energy and material use, as well as waste production, the tasks included in the real estate development process are of great influence on sustainability. Important stakeholders are the real estate developer, project developer, construction manager, architect, specialized engineers, builder, municipality, board of real estate company, future user and investor. During the last years, more and more

interest is generated by real estate developers related to sustainability. As such, Carlock (2015) indicated, that sustainability has been driven into mainstream through client demand and market demand. One possibility to introduce sustainability within the real estate sector in a structured manner is through the concept of circular economy.

Using the Delphi method, 21 experts of the field have been asked to evaluate nine propositions regarding the implementation of the circular economy principles within the real estate development process. It became clear, that the choice of principles is highly dependent on the clients' ambition and project conditions. Moreover, aiming for a circular building asks a different way of collaboration between all project-participating parties. Besides, suppliers, producers and the construction company are faced with more tasks and responsibilities within the process. The outcomes are summarized in a BPMN process model for the circular real estate development process, which can be used by real estate developers and other interested parties for the practical implementation of the circularity concept within real estate development.

This research is of high scientific relevance particularly due to the limited available scientific publications related to the topic of circular economy and especially regarding circular economy within the built environment. As indicated before, the concept of circular economy is of high relevance for the further social development worldwide. As predicted by the Ellen MacArthur Foundation, continuing with the current linear economic pattern of take-make-dispose, the scarcity of virgin raw materials will increase and the world will face ever increasing waste problems (Ellen MacArthur Foundation, 2013a). This effect is further triggered by expected three billion new middle-class consumers entering the economic market till 2030 (Ellen MacArthur Foundation, 2013a). This already indicates the need to introduce the concept of circular economy on a large scale.

Management samenvatting Nederlands

Het huidige economische model dat ontwikkeld is sinds de industriële revolutie, kan worden omschreven als lineair volgens het patroon van 'take-make-dispose' (Ellen MacArthur Foundation, 2013a; Andrews, 2015), waarin de grondstoffen afkomstig zijn uit de natuurlijke omgeving, en gebruikt worden om producten te maken, die uiteindelijk aan het eind van hun gebruiksperiode vernietigd worden. Mocht de wereld doorgaan met dit patroon dan zal de schaarste aan grondstoffen en de productie van afval steeds groter worden. Deze beiden effecten worden verder ondersteund door de groeiende bevolking en het welvaartsniveau wereldwijd. Er wordt verwacht dat in 2030 meer dan drie miljard nieuwe middenklasse consumenten in de economische markt stromen (Ellen MacArthur Foundation, 2013a). Deze effecten zijn vooral van belang voor de bouwsector, die verantwoordelijk is voor 32% van het totale wereldwijde energiegebruik in 2010 (Lucon, et al., 2014). In Nederland is de bouwsector verantwoordelijk voor de productie van het grootste deel van het afval van alle sectoren met bijna 25 miljard kg in 2010 (Statistics Netherlands, 2012) en vijf procent van de nationale uitstoot van kooldioxide in 2010 (Van Odijk & Van Bovene, 2014).

Om deze uitdagingen aan te gaan werd in 2013 het concept van circulaire economie geïntroduceerd door de Ellen MacArthur Foundation. Volgens het principe van circulaire economie moet het gebruik van nieuwe grondstoffen zoveel mogelijk beperkt worden terwijl zo weinig mogelijk water en energie verbruikt zullen worden bij de bewerking van deze grondstoffen en producten (Ellen MacArthur Foundation, 2013b). Om dit concept te kunnen vertalen voor de gebouwde omgeving moeten concrete principes bepaald worden, die te onderscheiden zijn in ontwerp principes, materiaal-gerelateerde principes en proces-gerelateerde principes. Daarnaast moeten gebouwen worden gezien als bestaande uit lagen met verschillende levensduur volgens Brand (1994). Deze indeling is belangrijk voor de benadering volgens het concept van circulaire economie.

Tot nu toe is er geen gestandaardiseerd proces model ontwikkeld voor het circulaire vastgoedontwikkelproces gericht op woonvastgoed in Nederland. Eerder zijn verschillende onderzoeken uitgevoerd betreffende het definiëren van circulaire gebouwen (Loppies, 2015), het meten van circulariteit (Verberne, 2016), het beoordelen van milieueffecten (Baartmans, 2013), een circulaire ketenmodel (Van de Kaa, 2013), waarde creatie door het toepassen van circulariteit binnen de vastgoedontwikkeling (Kusters, 2013) en het bepalen van mogelijke kansen voor Nederlandse commerciële vastgoedontwikkelaars door het toepassen van circulaire principes (Rood, 2015). Dit onderzoek is uitgevoerd in de vorm van een kwalitatief onderzoek op basis van literatuurstudie, Delphi-methode en de Business Process Modelling and Notation (BPMN) standaard met het oog op een gestandaardiseerd en gedetailleerd procesmodel voor het circulaire vastgoedontwikkelproces. Dit procesmodel moet praktisch bruikbaar zijn voor vastgoedontwikkelaars om het concept van circulaire economie te kunnen implementeren in woonvastgoedontwikkelingen gebaseerd op het traditionele vastgoedontwikkelproces.

Het traditionele vastgoedontwikkelproces richt zich op de ontwikkeling of herontwikkeling van woningen en commercieel vastgoed, dat gedefinieerd wordt door de combinatie van de grond en het gebouw daarop. Het vastgoedontwikkelproces is een uniek, iteratief uitgevoerd proces, dat bestaat uit de fasen van initiatie, ontwikkeling, bouw en exploitatie, die afhankelijk van de specifieke omstandigheden van het project zijn ingevuld. Omdat de

vastgoedontwikkeling taken zeer invloedrijk zijn op de energie- en materiaalgebruik, alsmede de productie van afval, moeten deze taken vanuit het oogpunt van duurzaamheid bekeken worden. Belangrijke stakeholders zijn de vastgoedontwikkelaar, projectontwikkelaar, de bouwmanager, architect, gespecialiseerde ingenieurs, bouwer, de gemeente, de raad van bestuur van het vastgoedbedrijf, de toekomstige gebruiker en investeerder. Gedurende de afgelopen jaren wordt er meer en meer aandacht besteed aan duurzaamheid, ook binnen de vastgoedwereld. Door Carlock (2015) is aangegeven, dat duurzaamheid gedreven wordt door de vraag van klanten en de markt. Een mogelijkheid om duurzaamheid op een gestructureerde manier te introduceren binnen de vastgoedsector is door middel van het concept van de circulaire economie.

Met behulp van de Delphi-methode hebben 21 experts op het vakgebied negen stellingen geëvalueerd, die betrekking hebben op de uitvoering van de circulaire economie principes binnen het vastgoedontwikkelproces. Het werd duidelijk, dat de keuze van principes sterk afhankelijk is van de ambitie en de projectvoorwaarden geformuleerd door de klant. Bovendien vraagt een streven naar circulair bouwen om een andere vorm van samenwerking tussen alle project partijen. Leveranciers, fabrikanten en het bouwbedrijf worden eerder betrokken in het proces en worden geconfronteerd met meer taken en verantwoordelijkheden binnen het proces. De resultaten van dit onderzoek zijn samengevat in een BPMN procesmodel voor het circulaire vastgoedontwikkelproces, dat door vastgoedontwikkelaars en andere geïnteresseerden gebruikt kan worden voor de praktische uitvoering van het circulaire begrip binnen de vastgoedontwikkeling.

Dit onderzoek is van hoge wetenschappelijke relevantie temeer vanwege de beperkte beschikbare wetenschappelijke publicaties in verband met het onderwerp van de circulaire economie en in het bijzonder met betrekking tot circulaire economie binnen de gebouwde omgeving. Zoals eerder vermeld, het begrip circulaire economie is van groot belang voor de verdere sociale ontwikkeling wereldwijd. Zoals voorspeld door de Ellen MacArthur Foundation, zal door de voortzetting van het huidige lineaire economische patroon van ‘take-make-dispose’ de schaarste van zuivere grondstoffen en de afvalproblemen steeds toenemen (Ellen MacArthur Foundation, 2013a). Dit effect wordt verder veroorzaakt door de verwachting dat tot 2030 drie miljard nieuwe middenklasse consumenten tot de economische markt zullen toetreden(Ellen MacArthur Foundation, 2013a). Dit geeft al de noodzaak aan om het concept van circulaire economie op grote schaal te introduceren.

Abstract

Environmental issues such as global warming, waste occurrence and scarcity of raw materials are facing more and more attention worldwide. To face these problems, the Ellen MacArthur Foundation published the concept of circular economy in 2013, which asks for an economic system in which materials are kept as long as possible within the economic circle in order to prevent waste production and to reduce the need for virgin materials. Focusing on the construction industry as being one of the biggest energy consumers and waste producers, great opportunities for improvements towards sustainability can be found. To support the practical implementation of the theoretical concept of circular economy, this study aims for the development of a process model for the circular real estate development process following the standard of Business Process Modelling and Notation (BPMN). To reach this, first nine propositions have been formulated based on literature reviews regarding the concept of circular economy and the traditional real estate development process. Secondly, these propositions have been evaluated based on expert knowledge of 21 field experts by performing two rounds of Delphi method including personal interviews and an online-survey. Based on this analysis, it is found, that an early implementation of the concept of circularity in the initiative phase together with a clear definition of the ambition, the relevant circularity principles and necessary development partners are of high importance. Due to the need of specified knowledge, an early participation not only of the traditional team members, but also of the suppliers, producers and construction companies responsible for construction and maintenance need to be arranged in alliance with a clear documentation throughout the whole lifecycle of the building and its elements. Based on these findings, the process model has been developed in order to provide practical guidance for professional real estate developers for the development of circular real estate. This research provides the first approach of presenting a standardized and yet detailed process model useable for the practical implementation of the concept of circular economy. With this, this research is of high scientific and social relevance and forms a good starting point for further research.

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1. Introduction

In this introduction the research background is presented leading towards the research question and related sub-questions. Furthermore, the research design is presented, which is used to answer the research question including the methodology. Finally, the expected results are stated and a reading guide is provided.

1.1 Problem definition

The current economic model developed since the Industrial Revolution can be described as linear following the pattern of 'take-make-dispose' (Ellen MacArthur Foundation, 2013a; Andrews, 2015). As such, raw materials are taken from the final resources available in our natural environment. Those materials are used to make new products, which get disposed after a certain period of use duration. This means, that a cumulating amount of raw materials are taken from nature, whereas the total available quantity is limited leading to material scarcity on the long term. Likewise, the linear economic system focusses mainly on the production and consumption of new products while dismissing the possibilities to reuse existing products. In this way, a growing garbage problem occurs (Bonciu, 2014).

Both of these two effects are further increased by the growing population and wealth level worldwide. As indicated by the United Nations, the world population is projected to increase towards 8.5 billion people in 2030 and towards 9.7 billion people in 2050 (United nations, 2015). By 2050, 66% of the world's population is expected to live in urban areas compare to 54% in 2014. Due to this, a total increase of 2.5 billion people is expected to live on earth by 2050 (United Nations, 2014). Furthermore, by 2030 a total of three billion new middle-class consumers are expected to enter the economic market (Ellen MacArthur Foundation, 2013a). This does not only reflect the growing number of population, but also the growing demand for consumer goods and with this demand for raw materials, as well as an increase in waste production.

These effects do not only effect the economic market of consumer goods, but also the construction sector. As part of it, buildings account for 32% of the total global energy use in 2010 worldwide (Lucon, et al., 2014). Due to increased access to a higher living standard, population growth and the trend towards urbanization, energy use and related emissions are expected to double or even triple by 2050 (Lucon, et al., 2014). In the Netherlands, the construction sector is responsible for producing most of the waste of all industries with nearly 25 billion kg in 2010 (Statistics Netherlands, 2012) and 79% of all mineral waste in the Netherlands (Statistics Netherlands, 2012). Likewise, the construction industry is highly dependent on fossil fuels (96%) and raw materials such as iron, aluminum, copper, sand, clay, wood or limestone worth 260 million tons in 2010 (Van Odijk & Van Bovene, 2014). Furthermore, for material harvesting of the Dutch construction and demolition field 57 thousand million kWh were used in 2010, which equals 4.5 percent of the primary energy use of the whole country. Five percent of the national greenhouse gas emissions have been caused by this industry in 2010 (Van Odijk & Van Bovene, 2014). In order to meet these shortcomings for a sustainable development, the principles of circular economy need to be considered consequently especially for the construction sector.

The concept of circular economy was introduced in 2013 by the Ellen MacArthur Foundation. Following the principle of circular economy, the use of virgin materials needs to be reduced

as far as possible while as little as possible water and energy are used for their recycling processes (Ellen MacArthur Foundation, 2013b). This reduction should be reached by keeping the raw materials and products created out of it as long as possible within the economic circle. In this way, the consumption of virgin raw materials can be reduced, just as the production of unusable waste. Even though the circular economy model focusses on saving as much as possible, the model does not assumes a closed system as a perpetuum mobile. Especially energy will be used also during the recycling phase (Bonciu, 2014).

The need for a concept to reach a sustainable development was already indicated in the 1980s by the Brundtlandt Comission (United Nations, Brundtland comission, 1987) and the Dutch National Environmental Policy Plan in 1988 (Bressers & Rosenbaum, 2003). However, first concepts are already developed since the 1970s with the Performance Economy, the Lifecycle concept, Natural Capitalism, Biomimicry, Blue Economy, Cradle-to-Cradle and other concepts. Some of them are indicated as being influential for the concept of circular economy and still remain important in the current situation.

In order to really integrate the concept of circular economy, a new way of thinking and valuing need to be introduced. This is especially relevant for the built environment, as its main products face much longer overall lifecycles compare to consumer goods. Due to this, decisions made today face consequences at a point in time several decades later. Besides that, buildings are a combination of parts, which face varying maximum lifespans, as indicated by Steward Brand (1994). Therefore, the different layers of buildings belong to different economic lifecycles which complicates the transition of the economic system from linear to circular for the built environment.

1.2 Research question

To provide practical guidance on how to meet this challenge, this research focusses on the creation of a process schema for the development of circular real estate. Activities of the property development such as extracting materials, manufacturing products, building structures and maintaining them, as well as replacing disposing waste affect sustainability highly (Kibert, 2007) and offers likewise great opportunities for actively supporting a sustainable development (Razali & Mohd Adnan, 2015).

The process map developed following the BPMN standard (Business Process Modelling and Notation) will enable real estate developers to implement the necessary circularity principles within their work. Furthermore, recommendations will be provided for professional parties of the built environment working on the transition towards a circular built environment. As indicated by Van Odijk and Van Bovene (2014), great influence on the decisions in favor of circularity can be executed during the design of an building, as well as during other steps of the real estate development process, which influence the design, the construction process, future use and maintenance opportunities. Within the built environment the concept of sustainability focusses on creating a situation, which can be describes as follows: The real estate development of today allows future generations to enjoy today's developments without facing disadvantages of it (Razali & Mohd Adnan, 2015). That is, what this study tries to reach by answering the following research question.

How does the real estate development process need to be adjusted to meet the principles of circular economy?

To answer this research question the following sub questions need to be answered:

1. What is a circular economy and how is it characterized within the construction sector?
2. Which principles of circular economy exist and are relevant for the real estate industry?
3. How does a traditional real estate development process look alike for the Dutch market?
4. How does an ideal circular real estate development process look like?
5. Which recommendations can be concluded from the comparison of a traditional and a circular process model?

1.2.1 Research objectives and limitations

It is the aim of this research project to develop each a traditional and a circular process model for the real estate development process within the Netherlands. This is done in order to compare the models and develop valuable guidance for real estate developers focusing on the development of a circular real estate.

The development of real estate can be done in many differ ways including a wide variety of stakeholders. For this research the following limitations have been assumed. This research is focusing on the perspective of the real estate developer. The most important tasks for him and his peer-mates of the development team, as well as the municipality, his directional board and the future owner are considered. The focus of the study is clearly assigned towards the process of developing and does not consider legal, financial or technical requirements in depth.

It is assumed, that the municipality will offer land, which is ready to be built on, so only the real estate itself needs to be developed. Furthermore, it is assumed, that an investor is known already at the beginning of the process, which will take over the property and will rent out the included apartments to private tenants. The real estate therefore is developed as a residential building.

1.3 Research design

This research is executed in the form of a qualitative research including some minor quantitative elements based on literature study, Delphi method and Business Process Modelling and Notation (BPMN) standard. Due to the relative novelty of the topic of circular economy, also within the construction sector, this open and quality-oriented approach was chosen. The novelty of this concept leads towards a limited number of field experts, which hinders the execution of a valid quantitative research. However, as part of the Delphi method, the executed interviews and online-survey are analyzed statistically as a form of quantitative research.

Overall, this research is executed following three different phases. First, an explorative in-depth literature review is executed regarding the topics of circular economy within the construction filed and the traditional real estate development process. Based on the outcomes of this literature review, the Delphi Method is used in an adopted approach consisting of two rounds of experts interviews. For the first round of personally executed interviews with field experts nine propositions are formulated. Those propositions are related

to the possible implementation of the circularity principles within the traditional real estate development process. The experts are asked to indicate their level of agreement per proposition and give a motivation for their evaluation. Based on this the group evaluation per proposition is analyzed along with the most important reasons for agreement or disagreement. In the third part, these propositions are adapted according to the indicated reasons to reach more alignment between the propositions and the overall expert opinion. The evaluation of these adapted propositions in the form of an online-survey is analyzed to develop a process schema for the circular real estate development process following the BPMN standard. Furthermore, recommendations are formulated for real estate developers focusing on a circular development process. The following research model shown in Figure 1 represents the relations between the different steps.

Figure 1: Research model

1.4 Expected results

The expected results are first to understand and express a useful definition of the term of circular economy within the real estate development context. Furthermore, it is expected to develop two BPMN models, which represent the traditional real estate development process and the circular real estate development process respectively.
Based on these models the differences within the processes will be quantified using statistical tests such as tests for normal distribution of the data, a test for homogeneity of the variance or a test for independence of the collected data. It is expected that differences between the models will be quantified to be able to formulate advice for professional real estate developers, how the optimal development process would look like when a circular building should be developed.

1.5 Reading guide

This research focusses on the development of a circular real estate development model and valuable guidance for real estate developers of the Netherlands to successfully develop circular real estate. To meet this research objective, the following four chapters describe valuable background information and the process towards the answer for this research question.

Chapter 2 represents a broad overview over the concept of circular economy including different definitions from literature and the historical development of this concept. Furthermore, the most important principles of circular economy derived from literature are presented. With this, this chapter finds answers to the first two research questions defined earlier.

Chapter 3 focusses on answering the third research question. Based on literature and expert knowledge, the traditional real estate development process is described including the main stakeholders and their tasks, as well as important decision moments.

Chapter 4 focusses on answering the fourth and fifth research question focusing on the implementation of circularity principles within the traditional real estate development process. By executing two rounds of the Delphi method experts of the field are asked to evaluate statements regarding the transition of the process towards a circular process model based on literature. Those answers are used to adopt the BPMN process model

Chapter 5 answers the questions of the scientific and societal relevance of this study, gives a critical review on it and shows opportunities for future research.

2. Background circular economy

This research focusses on the question, how the traditional real estate development process can become more circular in order to support a sustainable development within the built environment. To find an answer for this question, it is essential to understand the term of circular economy, which is presented throughout this chapter. The circular economy school-of-thoughts is based on many different developments throughout the past. Different definitions for circular economy can be found, as are presented in the following section 2.1. After that, section 2.2 describes the historical development of this school-of-thoughts before section 2.3 indicates the most important principles of the circular economy.

2.1 Definition of circular economy

The circular economy can be described as a holistic approach, which is defined in several ways (Verberne, 2016). Amongst others, the Aldersgate Group presented a definition in 2012 (Wallace & Raingold, 2012) focusing on the biological and technical material cycle. The European Commission presented another definition in 2014 (EUROPEAN COMMISSION , 2014), which focusses mainly on the aspect of waste prevention. However, the Ellen MacArthur Foundation published a definition in 2013 (Ellen MacArthur Foundation, 2013a), which focusses on the term as an overall, industrial system. Following this, the definition used by Loppies (2015) in his master thesis outlines the same focus of economic system thinking (Loppies, 2015), as well as Rood (2015) in her master thesis, as shown in Table 1.

Table 1: Definitions of the term circular economy

Source	Definition
Focus on material cycles (Wallace & Raingold, 2012, p. 5)	"The circular economy is a generic term for an industrial economy that, by design or intention, is restorative and eliminates waste. Material flows are of two types; biological nutrients, designed to re-enter the biosphere safely, and technical nutrients (non-biological materials), which are designed to circulate at high quality, with their economic value preserved or enhanced. "
Performance of products (Joustra, de Jong, & Engelaer, 2013, p. 3)	"The Circular Economy is an economy that enables producers to show the value and quality of the performance of their products to the customer. Products are designed for performance and also for re-use of all materials in different phases of sharing parts up to recycling of (almost pristine) resources."
The industrial system (Ellen MacArthur Foundation, 2013a, p. 7)	"A circular economy is an industrial system that is restorative or regenerative by intention and design (…). It replaces the 'end-of-life' concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models."
Prevent waste creation (EUROPEAN COMMISSION , 2014, p. 1)	"A circular economy preserves the value added in products for as long as possible and virtually eliminates waste. It retains the resources within the economy when a product has reached the end of its life, so that they remain in productive use and create further value."

Economic system thinking (Loppies, 2015, p. 6)	"The circular economy is an economic and industrial system, regenerative by design that aims to maximize the reuse of products and materials and minimizes or eradicates waste by 'system thinking'."
Economic circle concept (Rood, 2015)	"The circular economy is an economic and industrial system that is restorative by intention and design in terms of ecology and economy, where the value of natural resources is maximized and depreciation of resources is minimized throughout the whole system."

The concept of circular economy forms the opposite to the so-called 'linear economy', which describes the traditional economical system, that exists since the industrial revolution of the 19th century consisting of a take-make-waste pattern (Ellen MacArthur Foundation, 2013a). This pattern means that virgin materials are taken out of the natural environment, before they are used to make new products. Those products are used and finally disposed as waste. As can be seen, this system automatically leads to a reduction of the finite raw materials and an increasing amount of waste. These effects are further supported by the increasing world population and average wealth level (Ellen MacArthur Foundation, 2013a).

In order to understand the background of the circular economy concept, the historical development of this concept including influential schools-of-thoughts need to be considered.

2.2 Influences and historical development of the idea of circular economy

The following sections describe the influential developments and schools of thoughts throughout the 19th, 20th and 21st century, which had impact on the concept of circular economy.

The 19th century

The theory of circular economy is not completely new, but it is a result of a longtime development. During the industrial revolution peaking in 1840 in Western Europe, the steam machine was used widespread, which allowed increased production and more reliable logistics (McDonough & Braungart, 2002). Furthermore, those developments have led to large movements of population towards the cities. At the same time, the awareness for related health problems within the cities had increased (Bouwens, Mooij, Lafta, Lafta, & Van Uitert, 2016). The industrial revolution is characterized by McDonough and Braungart (2002) as exposing billions of pounds of toxic material into the natural environment every year, producing highly dangerous materials, resulting in gigantic amounts of waste, exposes valuable materials to irretrievable conditions, characterizes productivity by the number of working people and prosperity by extracting natural resources and exposing them by burying or burning them (McDonough & Braungart, 2002).

The 20th century

Throughout the 20th century the population grew four times worldwide. The economic output showed an increase of 22 times and the fossil fuel consumption was 14 times as much as during the 19th century (OECD, 2012). Already during the early 1970s environmental awareness became a major policy issue. In 1989, 58% of the population recognized environment as a key social problem (OECD, 2003). Within 10 years detailed policy programs

and legislation were developed. A large step in environmental awareness was made with introducing the Dutch National Environmental Policy Plan in 1988, which formed the first example for an integrated national environmental plan worldwide (Bressers & Rosenbaum, 2003). Since 1989 the overall interest in the environment and the willingness to take action decreased due to environmental progress and increased wealth associated with higher consumption and mobility (OECD, 2003).

During the 1970s the oil crisis occurred in Europe. Therewith, the scarcity of natural materials became visible for the average population and a social development started to save energy. Educational institutes started teaching about energy efficiency as an environmental topic considered by architects and designers (McDonough & Braungart, 2002). Likewise, the interest in solar power increased due to high gas prices (McDonough & Braungart, 2002).

In 1976, Walther Stahel, an industrial analyst and architect published his research report 'The Potential for Substituting Manpower for Energy' to the European Commission. In this report, he sketched his idea of economy in loops, which is today called 'circular economy'. He also described the influence of such an economy for the creation of jobs, the economic competitiveness, saving resources and preventing waste (Ellen MacArthur Foundation, 2015). Indicated as the functional service economy, the idea already was formulated of trading services instead of products. Nowadays, his concept is broadly described as 'performance economy' (Ellen MacArthur Foundation, 2015; Stahel, 2010). As basis for the circular economy, the principle of performance based contracting was taken over from Stahel. This idea implies, that the owner in a traditional economy becomes the user of a product within the circular economy, who pays a fee for the use of the product. Therefore, the producer keeps ownership of the products, which allows him to manage the resource- and material flows based on feedback-loops. Likewise, the consumer becomes a user of this performance (Joustra, de Jong, & Engelaer, 2013).

An important aspect of circular economy theory is to think about products in lifecycles including all phases from extraction out of the natural environment ('cradle'), manufacturing and use until disposal ('grave'). This concept of life cycle perspective was developed in order to create a sustainable development, which can be formulated as appreciating the quality of life by focusing on healthy environments for people to live in by improving the environmental, social and economic conditions for present and future generations as claimed by the Brundtland report (Ortiz, Castells, & Sonnemann, 2009; United Nations, Brundtland comission, 1987).

In order to evaluate the environmental impact of processes, goods and services, the lifecycle assessment was developed. This method was introduced into the building sector in 1990 (Ortiz, Castells, & Sonnemann, 2009; Taborianski & Prado, 2004; Fava, 2006). Being able to indicate the impact on the environment is the first step to take measures and decrease this effect.

Based on this social trend of focusing more on the environmental impact, a new awareness was created and forms of recycling were developed. Furthermore, energy- and material saving techniques, and materials were developed in order to improve the quality of life while supporting environmental protection.

The 21th century

Hawken, Lovins and Lovins (2000) published a book presenting the idea of 'Natural Capitalism', which looks at the water, air, soil and all living as the natural assets of the world. They assume, that there is an overlap between the environmental interests and the business interests in a global economy due to interrelations between capital made by humans and the natural capital (Ellen MacArthur Foundation, 2015; Hawken, Lovins, & Lovins, 2000). Their concept is based on four principles: "(i) Radically increase the productivity of natural resources, … (ii) Shift to biologically inspired production models and materials, … (iii) Move to a "service-and-flow" business model …[and] (iv) Reinvest in natural capital" (Ellen MacArthur Foundation, 2015).

Starting with the Brundtland report published in 1987 (United Nations, Brundtland comission, 1987) up till now, all concepts focused on eco-efficiency, which means to behave in a less bad manner regarding environmental effects. With the publication of cradle-to-cradle in 2002, the first approach for eco-effectiveness was created. Eco-effectiveness means to do something totally different based on a cyclic approach (McDonough & Braungart, 2002; Verberne, 2016). The design philosophy of cradle-to-cradle is developed by architect William McDonough and chemist Michael Braungart. They recognized the destructive effect of the current industry for the natural world including the extraction of raw materials, manufacture and disposal process. As current environmental problems they recognized the global warming, deforestation, waste and pollution. They were the first to introduce the idea of 'waste is food', which was taken over by the Ellen MacArthur Foundation in 2013 (McDonough & Braungart, 2002; Ellen MacArthur Foundation, 2013a; Joustra, de Jong, & Engelaer, 2013). Likewise, the concept of cradle-to-cradle already introduced the idea of material cycles, distinguishing between a technical and biological cycle as it is drawn in the fundamental diagram for the circular economy, presented in Figure 3. This concept is developed to optimally design systems, processes and products from the perspective of its whole lifecycle. To lengthen such a lifecycle the designer need to consider material health, possibilities to recycle, used form of energy (preferably renewable), water efficiency and quality, as well as social responsibility (McDonough & Braungart, 2002; Verberne, 2016).

In the same year (2002), another influential school-of-thoughts was published with the book 'Biomimicry: Innovation Inspired by Nature', written by Janine M. Benyus. It describes the principle of 'biomimicry', which tries to learn from the nature in order to solve the problems of humanity. Therefore, this concept can be summarized as nature-inspired innovations and is based on three key principles with 'nature as mentor', 'nature as measure' and 'nature as model'. With this, nature is valued for what can be learned from it, is used as standard to judge innovations' sustainability and nature is seen as a case model to learn from (Benyus, 2002; Ellen MacArthur Foundation, 2015).

In 2004, the concept of 'Blue Economy' was initiated by Gunter Pauli in the form of a report towards the Club of Rome, in which he presented specific case studies of current innovations. The blue economy movement is an open-source idea focusing on the use of available resources in "cascading systems" (Ellen MacArthur Foundation, 2015), in which the remaining rests of one product become the basis to create a new cash flow (Ellen MacArthur Foundation, 2015; Pauli, 2016).

In 2010, the Ellen MacArthur Foundation was founded with the goal “to inspire a generation to rethink, redesign and build a positive future.” (Ellen MacArthur Foundation, 2013a). To reach this, the foundation developed the theory of circular economy of which they believe that it can be an useful framework for redesigning the system levels. Furthermore, they see the theory as an opportunity to support creativity and innovation. They are focusing on developing a restorative economy in which materials are used more efficient (Ellen MacArthur Foundation, 2013a).

Architect Thomas Rau was the first one to introduce the principles of circular economy within the Dutch construction industry. Using these principles, the municipality office of Brummen was developed and built as a material storage in 2013. Furthermore, stated as being the first circular building in Europe, Rau architects developed and built the new headquarter of Liander in Duiven in 2015. The building is developed under the use of 80 percent second life materials and reaching energy positivity for the whole complex (RAU architects, 2016). In addition, Thomas Rau gives interviews and holds presentations throughout the country and already created with this great publicity for the theory of circular economy and its necessity in order to protect the environment (Wiering, 2015).

From 2015, the Dutch government started the initiative ‘Green Deal Circulaire Gebouwen’ (EN: Green Deal circular buildings), which was built on a cooperation of 59 participants from governmental units, knowledge institutes and public companies. In the first phase of the project starting in January 2015, those building characteristics should be identified, which are essential for the circularity of buildings. Furthermore, a building passport should be developed. During the second phase from march 2015 till beginning of 2016, several pilots are executed to support the theoretical work of the first phase. Furthermore, it is determined how the building characteristics and the circular value will be presented within the building passport. The third phase starting in the beginning of 2016 has the aim to identify reference values to be used as benchmarks for the circularity of buildings. The aim of this Green Deal project is to develop knowledge about how to use the principles of circular economy for buildings and how to make their level of circularity measurable (Rijksoverheid, 2015).

Besides that, the government of the Netherlands tries to create incentives for circular developments within the built environment. The ‘Rijksdienst voor Ondernemend Nederland’ published recently an overview of subsidy possibilities for building circular. As such, private or public investors can make use of tax advantages. Besides, investors for environmentally friendly techniques can apply for other tax-related financial incentives, called MIA (Dutch: Milieu-investeringsaftrek) and Vamil (Dutch: Willekeurige afschrijving milieu-investeringen). Furthermore, innovation loans can be applied for developing new products, processes or services with a strong business case. Likewise, financial support in the form of a scholarship can be reached from the KIEM-VANG regulation, which supports the collaboration of chain partners from practice, education and public organizations (SiA, 2016; RVO, 2016).

Figure 2 shows the historical development, which led to the concept of circular economy.

Figure 2: History of circular economy development, figure following (Bouwens, Mooij, Lafta, Lafta, & Van Uitert, 2016)

As indicated before, the concept of circular economy is developing for a long time already, always influenced by the conditions and the knowledge of the prevailing time. As indicated by Joustra et al. (2013), no fundamental change can be found up till now, but rather a hybrid system evolving, which combines "the good elements of the old system to compensate the failures of the new system." (Joustra, de Jong, & Engelaer, 2013, p. 10). Learning from the failures of the past and the new system, a better adopted system can be developed and implemented.

2.3 Important principles of circular economy

The concept of circular economy is based on several principles, which are influenced by the school-of-thoughts cradle-to-cradle stated by McDonough and Braungart, the concept of building layers proposed by Brand (1994), design aspects for decomposable building structures developed by Durmisevic and Brouwer (2002), as well as the concept of 'design for disassembly' (Guy & Ciarimboli, 2005) and 'design for adaptability' (Moffatt & Russell, 2001). Those concepts influence the principles for design, material choice and process-related principles, as they are presented in the following sections.

2.3.1 Basic principles of circular economy

The design principles of the circular economy theory are based on previous concepts such as cradle-to-cradle and the circular economy concept itself proposed by the Ellen MacArthur Foundation. An overview is given hereafter.

2.3.1.1 Cradle-to-cradle principles

The cradle-to-cradle concept developed by McDonough and Braungart (2002) shows great influence on the concept of circular economy (Joustra, de Jong, & Engelaer, 2013). This theory is based on three principles (Van der Westerlo, Halman, & Durmisevic; McDonough & Braungart, 2002):

1. Waste equals food: everything is seen as a nutrient for something else
2. Use of solar energy: only renewable energy is used since it can be renewed when used
3. Celebrate diversity: make use of the different species, cultural and innovation diversity

2.3.1.2 Circularity principles proposed by Ellen MacArthur Foundation

Following the Ellen MacArthur Foundation, the concept of circular economy is based on five basic principles (Ellen MacArthur Foundation, 2013a):

1. Design out waste: All components of a product are designed to fit within the biological or technical cycle by disassemble and refurbishment in order to eliminate waste. Components of the biological cycle are compostable and non-toxic. Components of the technical cycle are reusable with high quality and minimal energy usage (Ellen MacArthur Foundation, 2013a).
2. Building reliance through diversity: Uniform systems face fragility through the single focus on throughput maximization. To meet this challenge, systems need to be constructed following the natural one combining diversity, complexity and uniformity to adapt to the environmental conditions (McDonough & Braungart, 2002; Ellen MacArthur Foundation, 2013a).
3. Rely on energy from renewable sources: To create circularity, circular energy sources need to be used throughout the whole economic lifecycle of any product. Therefore, energy and material should be taxed instead of labor, as stated by Walter Stahel (Stahel, 2010; Ellen MacArthur Foundation, 2013a).
4. Thinking in systems: Every product is part of a system or even forms a system in itself. That means, that it is influenced over time, influences other parts or systems and may change throughout its lifespan. Being able to think in systems is crucial to understand the influences and relationships within its social context and towards its environment and infrastructure. Such systems need to be seen as iterative, non-linear processes, in which one small decision can have an unexpected, multiplied result. Therefore, it is crucial to consider the system as a whole and do not focus on single parts (Ellen MacArthur Foundation, 2013a).
5. Waste is food: Biological, non-toxic nutrients are reintroduced into the biological cycle to become valuable raw materials. Likewise, other rest-products, or waste following the linear system are reintegrated into the technical cycle to recover its original quality through maintenance, reuse/ redistribution, refurbishment/ remanufacturing or recycling or even reach a higher quality level through the so-called upcycling (Ellen MacArthur Foundation, 2013a).

A summarizing figure of the cycling processes can be found in Figure 3.

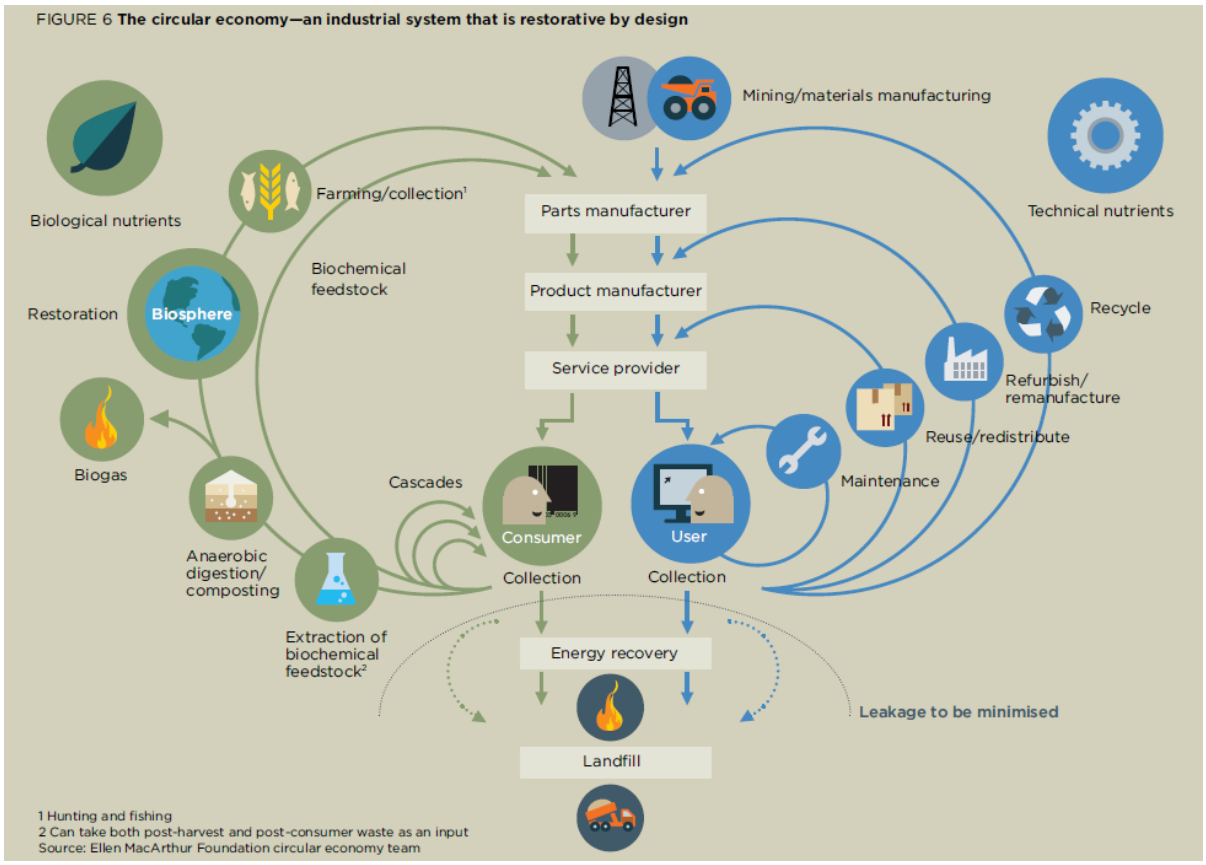

Figure 3: Circular economy with biological and technical cycle following Ellen MacArthur Foundation (2013)

Figure 3 shows the overall concept of the circular economy, representing the different economic cycles for the biological nutrients in green on the left side and for technical nutrients in blue on the right side. Overall, it is the aim to prefer smaller cycles against longer cycles to create a small negative environmental impact and increase the positive benefits (UKCG, 2014). An example can be maintenance for the technical cycle and cascading of biological nutrients. If this does not yield a sufficient result, the nutrients are maintained following the wider cycles such as reuse, refurbishment or recycling. Within the biological cycle, it is the overall aim to keep a high quality of soil by composting or digestion of used raw materials (Joustra, de Jong, & Engelaer, 2013). In opposite to the circular economy, the traditional, linear economic system is represented by the vertical middle line consisting of mining and manufacturing materials towards parts and products, providing a service, using the product, recovering energy by burning the waste and placing the very last parts as landfill (Verberne, 2016).

In addition to that, Joustra et al. (2013) appends the following principle:

6. Share values: 'Symbiosis' describes the economic concept of making business, creating products and creating profit. Within the circular economy, cooperative entrepreneurship and performance are used to create shared values, which help to maintain long term business collaborations (Joustra, de Jong, & Engelaer, 2013).

Following Loppies (2015), there are two basic principles for the circular economy stated from a technical point of view. First, the 'circular material usage', which means that only non-toxic materials should be used, which are well reusable or renewable following the basics of circularity. Second, a circular design should be used, which includes, that products and / or

components are designed and produced so that they can be easily disassembled to be reapplied for something new (Loppies, 2015).

The following sections describe, which design principles, principles for material selection and process-related principles can be used to achieve this.

2.3.1.3 Design principles

This concept of thinking in lifespans closely fits with the concept of building layers proposed by Brand (1994). Whereas the idea of thinking of a building in its whole is still dominating nowadays (Beurskens & Bakx, 2015), a building underlies large adjustments throughout its lifecycle. This is due to changes in user needs, but also due to changes in its environmental conditions (Verberne, 2016). Because of that, Brand (1994) developed a model, in which the building is split up in different layers according to their service lifespans. These layers differ widely in their lifespan, which makes it necessary to replace some parts of the building while other parts are still in perfect condition to be used continuously. In opposite with other use goods, which show the same lifespan for the whole good, this is an important characteristic of buildings, which need to be kept in mind when formulating the circularity principles.

Brand distinguishes the following elements (see Figure 4):

1. Site: the geographical location legally defined (infinite)
2. Structure: foundation and load-bearing elements (30-300 years)
3. Skin: exterior surface (20 years)
4. Services: all kind of installations (HVAC, electrical, …) (7-15 years)
5. Space plan: interior layout including floors, walls, ceilings and doors (3-30 years)
6. Stuff: all kind of furniture including tables, chairs, pictures, lamps etc. (<1 year)

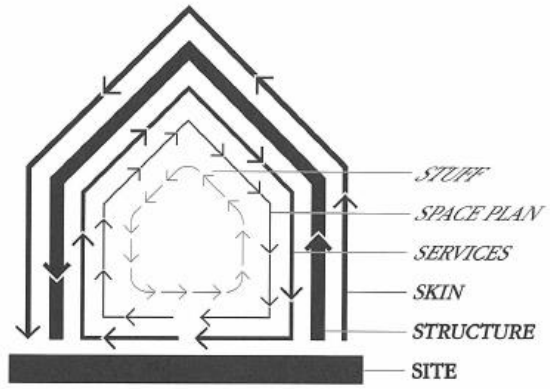

Figure 4: Building layers following (Brand, 1994, p. 13)

Due to this, it is one of the most important aspects of circularity within the construction sector, that building parts need to be considered separated in different circles. To reach this, loose connections between the layers are necessary in order to be decomposable, reusable and can be recycled without great material losses due to fixed connections (Geldermans & Jacobson, 2015). Due to its special characteristic of combining parts with different lifespans, certain design principles need to be used. As part of this, buildings need to be designed to support disassembly, redeployment, reusability and adaptability (Rood, 2015). Stated by Durmisevic and Brouwer (2002), three different levels of transformation can be described for buildings:

- Spatial transformation: use spatial adaptability to ensure continuity in the exploitation of the space
- Structural transformation: replaceability, reuse and recover of building components are used to provide continuity in the exploitation of the building and its components
- Elements and material transformation: use of recycling measures for building materials to provide continuity in the exploitation of the materials

Durmisevic and Brouwer (2002) summarized these findings as shown in Figure 5.

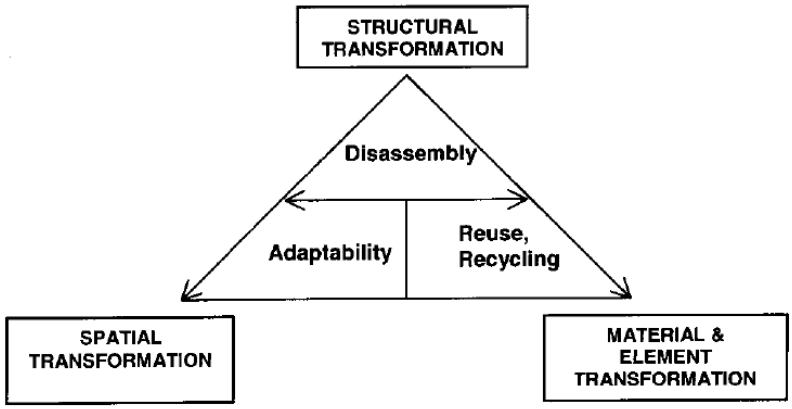

Figure 5: Three levels of design for disassembly by (Durmisevic & Brouwer, 2002, p. 3)

Those three levels can be structures hierarchically including the building level, system level and component level as presented in Figure 6. Following Durmisevic and Brouwer (2002), the levels differ in functional and technical lifespan for the building material depending on the layer. The technical lifespan refers to the time that a building meets the technical requirements of its users, whereas the functional lifespan determines the timespan that the building meets the requirements of its users (De Vree, 2007). Three layers are defined as following (Durmisevic & Brouwer, 2002, p. 7):

- "Building level represents the composition of systems which are carriers of main building functions (load-bearing, enclosure, partitioning, servicing)
- System level represents the composition of components which are carriers of the system functions (bearing, finishing, insulation, reflecting, distributing etc)
- Component level represents the layered or frame assembly of component functions which are allocated through the elements and materials at the lowest level of building assembly."

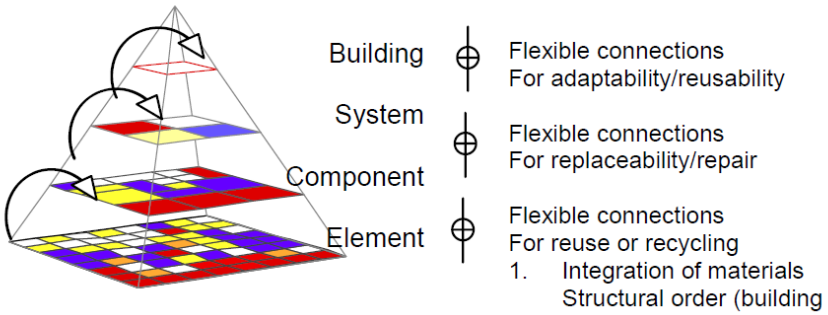

Figure 6: Hierarchy of material levels following (Durmisevic & Brouwer, 2002, p. 7)

Those system-related concepts are closely interwoven with the idea of disassembly and adaptability, forming the basis for many design principles. As such, the 'design for disassembly' proposed by Guy & Ciarimboli (2005) means, that buildings need to be designed in such a way that they facilitate future changes and possible dismantlement of parts or the whole system. Such a dismantlement would be used to recover the whole system, components and materials including the "assemblies, components, materials, construction techniques, and information and management systems" (Guy & Ciarimboli, 2005, p. 3). An overview of the most important principles of design for disassembly is presented hereafter (Guy & Ciarimboli, 2005, p. 6):

1. "Document materials and methods for deconstruction: As-built drawings, labeling of connections and materials, and a "deconstruction plan" in the specifications all contribute to efficient disassembly and deconstruction.
2. Select materials using the precautionary principle: Materials that are chosen with consideration for future impacts and that have high quality will retain value and/or be more feasible for reuse and recycling.
3. Design connections that are accessible: Visually, physically, and ergonomically accessible connections will increase efficiency and avoid requirements for expensive equipment or extensive environmental health and safety protections for workers.
4. Minimize or eliminate chemical connections: Binders, sealers and glues on, or in materials, make them difficult to separate and recycle, and increase the potential for negative human and ecological health impacts from their use.
5. Use bolted, screwed and nailed connections: Using standard and limited palettes of connectors will decrease tool needs, and time and effort to switch between them.
6. Separate mechanical, electrical and plumbing (MEP) systems: Disentangling MEP systems from the assemblies that host them makes it easier to separate components and materials for repair, replacement, reuse and recycling.
7. Design to the worker and labor of separation: Human-scale components or conversely attuning to ease of removal by standard mechanical equipment will decrease labor intensity and increase the ability to incorporate a variety of skill levels.
8. Simplicity of structure and form: Simple open-span structural systems, simple forms, and standard dimensional grids will allow for ease of construction and deconstruction in increments.
9. Interchangeability: Using materials and systems that exhibit principles of modularity, independence, and standardization will facilitate reuse.
10. Safe deconstruction: Allowing for movement and safety of workers, equipment and site access, and ease of materials flow will make renovation and disassembly more economical and reduce risk."

Besides that, the design for adaptability forms another important concept influencing the principles of circular economy. As presented by Moffatt and Russell (2001), this concept focusses on the idea of enlarging the use period of a product by accommodating changing circumstances. As can be see, the 'design for disassembly' focusses more on the reuse of components, whereas the 'design for adaptability' focuses on maintaining the building designed to be easily adoptable for future needs without essential changes. The 'design of adaptability' is based on eight key design principles as stated by (Moffatt & Russell, 2001, p. 10):

1. "Durability: repair, maintenance and replacement periods, especially for the structure and shell
2. Versatility: the shape of the space lends itself to alternative use
3. Access to services: Dropped ceilings, raised floors, central cores that provide easy access to pipes, ducts, wires and equipment
4. Redundancy: structural elements can bear larger loads that were originally imposed
5. Simplicity: the absence of complex systems vital for the continued operation of the building
6. Upgradability: systems and components that accommodate increased of the building
7. Independence: features that permit removal or upgrade without affecting the performance of connected systems
8. Building information: records of drawings, specifications and design limits that assist in future economic analysis of renovation and expansion"

The principles of the 'design for adaptability' are closely related to the building levels defined by Brand (1994), as has been identified by Beurskens and Bakx (2015) in the following Figure 7.

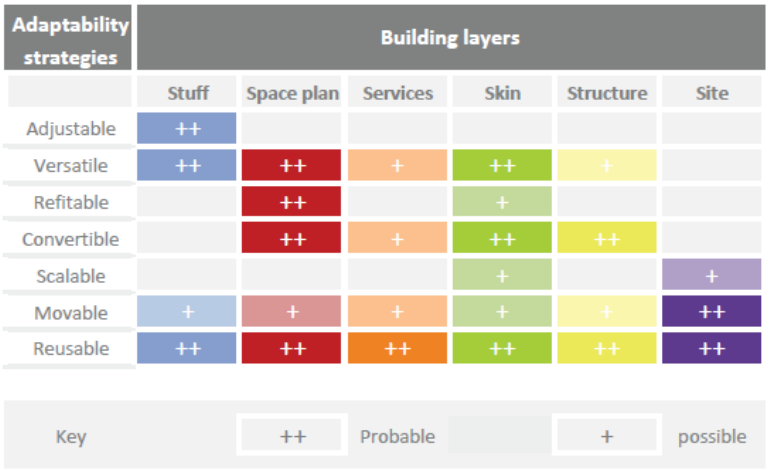

Figure 7: Relationships between adaptability types and building systems following (Beurskens & Bakx, 2015)

Based on the before mentioned concepts and additional literature, Table 2 is prepared, which represents the most important design principles for circularity in the built environment.

Table 2: Overview circular design principles, adopted from (Rood, 2015, pp. 9, appendix 2)

Circular design principle	Description in literature	Source
Design for reuse	Easy to reuse	(Joustra, de Jong, & Engelaer, 2013)
	Design for multiple use by designing multifunctional and flexible	(UKCG, 2014)
	Reuse instead of deconstruction during 'last' phase of life cycle	(Rood, 2015)
Design for disassembly	Use elements fit for disassembly	(Van Odijk & Van Bovene, 2014)
	Products are easily reassemble and material flows are easily separated	(MVO Nederland, 2016; Kimmel & Dam, 2013)

	Design for disassemble	(Ellen MacArthur Foundation, 2013a), (Loppies, 2015)
	Design for deconstruction to lengthen lifecycle through increase of adaptability	(UKCG, 2014)
	Design to the worker and labour of separation	(Guy & Ciarimboli, 2005)
	Safe deconstruction	(Guy & Ciarimboli, 2005)
Prevent fixed connections	avoiding permanent connections such as glue, chemical or mechanical connections	(Loppies, 2015)**,** (Van Odijk & Van Bovene, 2014)
	Design accessible connections	(Guy & Ciarimboli, 2005)
	Access to services	(Moffatt & Russell, 2001)
	Eliminate chemical connections	(Guy & Ciarimboli, 2005)
	Use bolted, screwed and nailed connections	(Guy & Ciarimboli, 2005)
	Separate mechanical, electrical and plumbing (MEP) systems	(Guy & Ciarimboli, 2005)
Inter-changeability of components	Interchangeability using modular, independent and standardized materials and systems	(Guy & Ciarimboli, 2005)
	Use of standard sizes	(Van Odijk & Van Bovene, 2014), (Loppies, 2015))
	Modular building	(Rood, 2015); (Schoolderman, et al., 2014); (Ellen MacArthur Foundation, 2013a); (Loppies, 2015)
	Use of prefabricated components to enable modularity	(Van Odijk & Van Bovene, 2014);
Adaptability	Adaptable	(Ellen MacArthur Foundation, 2013a)
	Simplicity of structure and form	(Guy & Ciarimboli, 2005); (Moffatt & Russell, 2001)
	Versatility (enable alternative use through shape of space)	(Moffatt & Russell, 2001)
	Upgradability	(Moffatt & Russell, 2001)
	Independence of features to enable removal and upgrade without affecting system performance	(Moffatt & Russell, 2001)
	Easy to adapt to future needs	(Schoolderman, et al., 2014); (Van Odijk & Van Bovene, 2014)
	Flexibility for changing needs	(Kusters, 2013), (Loppies, 2015); (UKCG, 2014); (Verberne, 2016)
	Redundancy	(Moffatt & Russell, 2001)
Design to lengthen lifecycle	Build to lengthen life cycle	(Rood, 2015); (Bonciu, 2014); (Van Odijk & Van Bovene, 2014)
	Durability	(Moffatt & Russell, 2001)

	Ensuring the functionality long-life and safety of products	(Van Odijk & Van Bovene, 2014)
	Separate structural elements and coverings	(Van Odijk & Van Bovene, 2014); (Rood, 2015)
	Integrate installation in construction structure	(Van Odijk & Van Bovene, 2014)
	Separate parts with different lifespan	(Loppies, 2015)
Design for maintenance and repair	Improve building performance	(Van Odijk & Van Bovene, 2014)
	Ease for maintenance and repairs	(Bonciu, 2014)
Reduce material mass	Diminish material mass	(Van Odijk & Van Bovene, 2014)
Minimize waste	Optimization in production processes to minimize waste	(Rood, 2015); (Van Odijk & Van Bovene, 2014), (Loppies, 2015)
	Design for disassembly to reduce waste at end of lifespan	(Van Odijk & Van Bovene, 2014)
Minimize energy use	Use better insulation to reduce energy use during use phase	(Van Odijk & Van Bovene, 2014)

2.3.2 Principles for material choice

Following Rood (2015), the second group of circularity principles is focussed on the choice of material. Table 3 represents her findings accomplished by additional sources and principles from literature.

Table 3: Circular materials principles, adopted from (Rood, 2015, pp. 9, appendix 2)

Circular material principle	Description in literature	Source
No non-biodegradable materials	Prevent the use of toxic materials	(Van Odijk & Van Bovene, 2014); (Loppies, 2015)
	Prefer biodegradable materials	(Van Odijk & Van Bovene, 2014); (Ellen MacArthur Foundation, 2013a)
	Close biological cycle by biodegrading materials after extraction of valuable components	(MVO Nederland, 2016)
Lengthening lifecycle of materials	Lengthening life cycle of materials by protecting it from external influences	(Van Odijk & Van Bovene, 2014); (Bonciu, 2014)
	Materials must be able to be reclaimed	(Loppies, 2015)
	Design for pure material flows	(Loppies, 2015)
	Prevent quality loss: The subparts and raw materials of use products are reused without a loss in quality	(MVO Nederland, 2016)
Cycle-fitting materials	Value prevention: The value prevention is maximized by looking	(MVO Nederland, 2016)

	first at product reuse, then at reuse of parts and finally at reuse of raw materials.	
	Only use of materials which fit within loops of Figure 3	(Loppies, 2015)
	Use of pure materials	(Ellen MacArthur Foundation, 2013a); (Loppies, 2015)
Use materials that improve performance	Use materials that improve building performance	(Van Odijk & Van Bovene, 2014); (Ellen MacArthur Foundation, 2013a)
	Focus on qualitatively high products to increase value	(MVO Nederland, 2016)
	Select materials using the precautionary principle	(Guy & Ciarimboli, 2005)
Use of recycled materials	Use of recycled materials instead of virgin materials	(Van Odijk & Van Bovene, 2014); (Ellen MacArthur Foundation, 2013a), (Loppies, 2015)
	Improve value of materials recycling and recovery	(UKCG, 2014)
Use of locally available materials	Use of locally available materials to reduce negative effects of transport	(Van Odijk & Van Bovene, 2014)

2.3.3 Process-related principles

Following Rood (2015), a large number of circularity principles can be found from literature, which are used to influence construction processes towards the idea of circular economy. The table underneath is oriented on her summary filled up with additional findings from literature. All of the principles are presented in Table 4 underneath.

Table 4: Process-related circularity principles, adopted from (Rood, 2015, pp. 9, appendix 2)

Circular process-related principle	Description in literature	Source
Collaboration with chain partners	Collaboration with chain partners	(Kimmel & Dam, 2013)
	Value-creation through cross-sectional chain cooperation and collaboration to create multi-layer values (economic value of all companies of the chain, ecological and social value)	(MVO Nederland, 2016)
	Principals and designers need to formulate clear goals and involve actively	(Van Odijk & Van Bovene, 2014)
	Users are guiding the chain as independent parties	(Kimmel & Dam, 2013)
	Integrated value and chain supply: safeguarding circularity by creating	(Loppies, 2015)

	new relations between manufacturers, users and products to secure the possibility for recovery of used materials	
	Shared value: create value through performance and cooperative entrepreneurship aiming at creation of long-term business perspectives	(Rood, 2015); (Joustra, de Jong, & Engelaer, 2013)
	New forms of contracts such as product service systems	(Loppies, 2015)
	Securing long-term vision for circularity	(Joustra, de Jong, & Engelaer, 2013); (Loppies, 2015)
	Innovation	(Kimmel & Dam, 2013); (Joustra, de Jong, & Engelaer, 2013); (Schoolderman, et al., 2014)
	Innovate together	(Kimmel & Dam, 2013)
	Responsibilities at the right parties/people	(Loppies, 2015); (Kimmel & Dam, 2013); (Joustra, de Jong, & Engelaer, 2013)
Adjusted business cases	Adjusted business cases	(Kimmel & Dam, 2013)
	New revenue models	(Joustra, de Jong, & Engelaer, 2013)
Information exchange	Use of software platforms (like BIM) to collect and share important information to optimize design and construction processes	(Van Odijk & Van Bovene, 2014)
	Exchange of resource related information	(Damen, 2012)
Resource passport	Resource passport in form of database to record what materials are used where and how they can be extracted (e.g. BIM)	(Loppies, 2015); (UKCG, 2014); (Damen, 2012)
	Building Information	(Moffatt & Russell, 2001)
	Document materials and methods for deconstruction	(Guy & Ciarimboli, 2005)
Reverse logistics	Reverse logistics (logistic system of taking back materials or products at end of life)	(Loppies, 2015); (Kimmel & Dam, 2013); (Joustra, de Jong, & Engelaer, 2013)
	Feedback-loop for producer	(Joustra, de Jong, & Engelaer, 2013), (Schoolderman, et al., 2014)
	Developing system for end-of-life of resources and products	(Damen, 2012)
	Develop take-back system	(McDonough & Braungart, 2002)
	Development of network for material exchange and collection	(Damen, 2012)

Change tax system	Taxing resources instead of labor to support labor-intensive recycling	(Van Odijk & Van Bovene, 2014)
Consider effects later in process	Use prefabricated components to reduce loss of material and waste	(Van Odijk & Van Bovene, 2014)
Product as a service	Service/performance leasing instead of ownership, product service systems	(UKCG, 2014); (Schoolderman, et al., 2014))
	Function oriented business model	(UKCG, 2014)
	Customer is user of the performance of product	(Joustra, de Jong, & Engelaer, 2013); (Schoolderman, et al., 2014)
	Manufacturer responsible for production, distribution, maintenance and service as keeping ownership during use-phase aiming at delivery of product with optimum performance for the end user	(Joustra, de Jong, & Engelaer, 2013)
	End users use product instead of ownership, producers keep ownership and clients pay for the use of it	(MVO Nederland, 2016); (Kimmel & Dam, 2013)
	producer rebuys the product at the end of its lifecycle	(MVO Nederland, 2016); (Kimmel & Dam, 2013)
Prevent harmful emissions	During the production, use and handling of the product, no harmful emissions are set free	(MVO Nederland, 2016)
Purely renewable energy-use	Use only renewable energies with lowest environmental footprint	(Verberne, 2016)
	Enable the use of pure renewable energy systems	(Ellen MacArthur Foundation, 2013a)

2.4 Conclusion

The circular economy represents a holistic concept, which can be defined in several ways. Focusing on the definition of the Ellen MacArthur foundation, the circular economy is defined as “an industrial system that is restorative or regenerative by intention and design (…). It replaces the ‘end-of-life’ concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models.” (Ellen MacArthur Foundation, 2015, p. 7).

This concept is not developed newly, but is based on a longterm development starting in the 1970s as a contradictionary model to face the problems of the current linear model. The linear model can be described as take-make-dispose and led towards an increased material scarcity and waste problems worldwide. Influencial schools-of-thoughts of the circular economy concept are amongst others, the performance economy, lifecycle assesment, natural capitalism, cradle-to-cradle, biomimicry and blue economy. Finally, in 2010 the Ellen MacArthur foundation started to summarize the ideas of such influential schools-of-thoughts

and finally published in 2013 the before mentioned definition along with its most referenced diagram, presented as Figure 3 on page 28 including the biological and technical cycle with all its cascading opportunities.

The whole concept of circular economy is based on some fundamental principles, as well specific principles related to the built environment. Based on the cradle-to-cradle concept, the fundamental principles of 'waste equals food', 'use of solar energy'and 'celebrating diversity' are identified. Furthermore, the Ellen MacArthur Foundation formulated the five principles of 'design out waste', 'building relinace through diversity', 'rely on energy from renewable sources', 'thinking in systems' and 'waste is food'. This is accomplished by a sixth principle of 'shared value' introduced by Joustra, De Jong and Engelaer (2013).

Translating the concept of the circular economy for the built environment requires some additional principles due to the specific characteristic of buildings. In opposite to the broadly accepted viewpoint of thinking of a building in its whole, Brand (1994) and Durmisevic & Brouwer (2006) stated different building and material layers including the building level, system level and component level, as well as the site, structure, skin, service, space plan and stuff. All of these layers differ in their technical, functional, aestetic and economic lifetime, which makes it necessary to separately review those levels.

Based on this knowledge, three different types of principles can be found for the development of real estate aiming at the implementation of the circular economy concept. These include design-related principles, material-choice-related principles and process-related principles. The design-related principles include 'design for reuse', 'design for disassembly', 'prevent fixed connections', 'interchangeability of components', 'adaptability', 'design to lengthen life cycle', 'design for maintenance and repair', 'Reduce material mass', 'Minimize waste' and 'Minimize energy use'. The material-choice-related principles include 'no non-biodegradable materials', 'lengthening lifecycle of materials', 'cycle-fitting materials', 'use of materials improving performance', 'use of recycles materials' and 'use of locally available materials'. Finally, the most-stated process-related principles refers to the 'collaboration with chain partners' including chain supply and creating a shared value. Other principles influencing the collaboration are the 'adjusted business cases' and 'information exchange', which can be done material-related through the implementation of 'material passports'. Another important aspect of the development process is the implementation of a 'reverse logistics' to enable the closing of the material lifecycle. A change in the tax system, considering effects later during the process, as well as switching towards seeing 'products as s service', preventing harmful emissions and purely use renewable energy are important principles during the process to reach circularity.

Overall it can be seen that the concept of circular economy is well developed, however its practical implementation within the construction industry and especially within the real estate development process still asks for additional research. As indicated before, some practical experiences have been developed throughout the last years, as well as an evaluation method for the level of circularity of buildings (Ellen MacArthur Foundation & Granta, 2015). However, this research is less relevant for this study. By contrast, it is now important to develop a process model on a practically useful way that can be used to implement the principles of circularity.

3. Towards a circular real estate development process

Abstract: The traditional real estate development process focusses on the development or redevelopment of residential or commercial real estate, which covers the combination of land and the building positioned on it. The real estate development process is a unique, parallel process covering the main phases of initiation, development, construction and exploitation, which are filled in depending on the specific project conditions. As being highly influential on the real estate landscape and therefore also on energy and material use, as well as waste production, the tasks included in the real estate development process are of great influence on sustainability. This research indicates the steps within a traditional real estate development process, along with the most important stakeholders. Besides, taking into account previous research, the implementation of sustainability aspects and the circularity concept within the real estate development process are determined in order to provide essential information for the development of a circular real estate development process model.

Keywords: Circular economy, building circular, real estate development, development process, circular process model

3.1 Introduction

The traditional real estate development process can be described in several manners and including different phases and stakeholders. Depending on the project condition, the process need to be adjusted, tasks need to be added or left out. Also, the process of developing real estate can focus on several targets, such as redeveloping real estate, developing new real estate or earning money. Throughout the last years, new trends of developing sustainable real estate occurred. In order to be able to develop a circular real estate development model, the traditional model need to be understood in detail. Furthermore, previous research regarding process models for real estate development focusing on sustainability and circular economy need to be reviewed in order to determine existing knowledge. The literature review presented here focusses on the Dutch real estate market. This literature review is meant to introduce into the topic of real estate development processes and sustainability developments as a basis for further research.

3.2 Real Estate Development Process

The real estate development process describes the process of developing real estate executed by a private or professional real estate developer and other participating parties. Within the following sections, the terms of real estate, real estate market and real estate development will be clarified. After that different types of real estate development process models are described and one model is determined as the traditional model for this study. In the following, the different phases of the traditional real estate development process are described along with the most important, involved parties.

3.2.1 Real estate

Real estate can be defined as the combination of land and the building, which is built on this land including the infrastructure placed within the building (Nozeman, 2010). Due to this characteristic of being firmly connected with the ground, the value of the real estate has a strong influence on the value of its surrounding built environment, on the land, the environment and the real estate itself (Nozeman, 2010). Real estate can be seen not only as a

place to live, work or trade goods, but as an economic good, as part of a loan or as a source for the national tax system, which vary widely from other economic goods with shorter lifespans (Mooya, 2016; Nozeman, 2010).

Overall, real estate and its development can be described as heterogeneous and unique (see section 3.2.4). Its value is dependent on the motive for acquisition, governmental interventions and inelasticity of demand and supply quantified in price changes. Besides, the costs for acquisition, the durability and indivisibility, as well as the transaction costs characterize the real estate (Mooya, 2016). In the Netherlands, real estate is classified as a residential or commercial property. Commercial properties include office buildings, retail units and industrial properties. The classification influences the value of the real estate (Nozeman, 2010).

3.2.2 Real estate market

The real estate market is traditionally described as the "mechanisms by which buyers and sellers of various types of property are brought together to determine price at which such property could be exchanged" (Mooya, 2016, p. 99). In a broader sense, the real estate market covers all involved stakeholders, who are related to the use, trade and development of property (Mooya, 2016). The real estate market can be distinguished between new development and redevelopment, between residential or commercial real estate and social property, but also between non-profit segment and profit segment or between the three fields of rental market, asset market and development market (Mooya, 2016; Nozeman, 2010). As being responsible for the creation of new real estate and as such supplying new space as an investment object or for use purposes (Mooya, 2016), this research focusses on the development market.

3.2.2.1 Expected developments

A close correlation can be found between the spatial developments within a country and the real estate development, both regarding commercial as residential real estate development (Schoenmaker & Van der Vlist, 2015). Based on this relation, real estate development can deliver a valuable contribution to job creation, as well as supporting a viable economy with a sustainable and energy-efficient built environment (Schoenmaker & Van der Vlist, 2015). Indicated by Schoenmaker and Van der Vlist (2015), the Randstad area within the Netherlands showed for the period of 1990 till 2012 fifty percent higher investments in residential real estate development compare to commercial real estate development based on investment costs. With the Randstad accounting for one quarter of the national development in residential and commercial real estate this presents a significant market trend (Schoenmaker & Van der Vlist, 2015).

Overall, the market report for real estate in the Netherlands indicates a growing demand for real estate with a decreased space demand per person for the year 2016. Furthermore, a trend can be seen towards the use of facilities instead of its ownership, as well as an increased interest in and use of 'smart solutions' (Donkers, Velleman, Van der Hosrt, & Bronckers, 2016). Using smart solutions in the form of technically supported processes makes products qualitatively more valuable and more flexible, which means an increase in quality (Donkers, Velleman, Van der Hosrt, & Bronckers, 2016). Market trends show, that the definition of real estate development is changing from delivering a housing solution towards a total solution for

the whole life span of the building offering different possibilities for use through a high degree of flexibility (Donkers, Velleman, Van der Hosrt, & Bronckers, 2016).

Real estate development is always dependent on demographic trends. For the Netherlands, the tendencies till 2020 show a decrease in the growth of the population overall and an increase in the aging of the population. A steady demand for residential rented flats is found and expected to continue throughout the years to come. Due to this, the market report for the Netherlands suggests to invest in new constructions for the rental, residential market (Donkers, Velleman, Van der Hosrt, & Bronckers, 2016), as it is chosen for this study.

3.2.3 Real estate development

The real estate development process has been described as a linear process in the past. However, since the 1970s, the process needs to be described as a parallel process representing the iterative process of real estate development (Das, Sah, Sharma, Singh, & Gulappo, 2013). Even though the same tasks need to be executed, a higher degree of complexity is recognized due to more stakeholders, faster changing market circumstances, an earlier participation of the future owner or user and changed laws and regulations. Therefore, a parallel process is executed, as shown in Figure 8 (Nozeman, 2010).

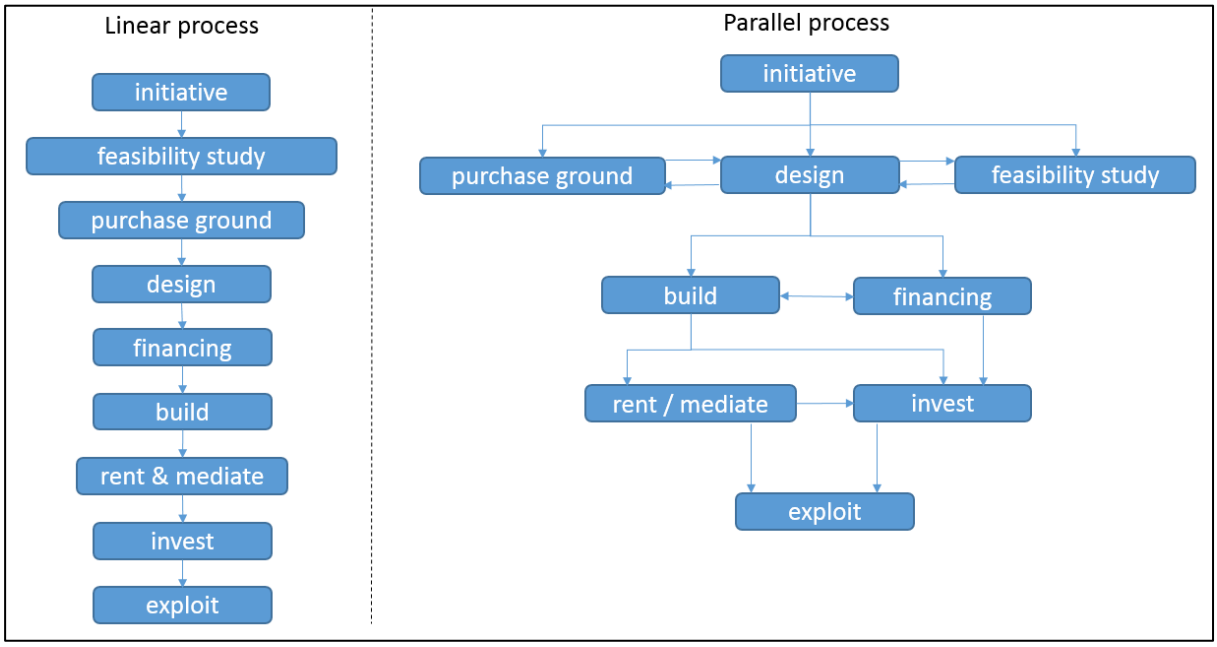

Figure 8: Tasks of development process as linear or as parallel process following (Nozeman, 2010, p. 33)

Real estate development can be configured to provide, develop or redevelop a real estate or can become necessary due to changes within the society, population growth, availability of new technologies and technical solutions or economic developments (Nozeman, 2010). Being highly dependent on the project conditions of every new development, real estate development can be seen as multi-disciplinary, very complex and unique (Keeris, 2008; Nozeman, 2010). Therefore, the process needs to be adopted to the local conditions for every new project. The process is highly dependent on several factors such as location, size, complexity, budget, time, involved actors, organizational forms, legal entities, financial arrangements, economic evaluation, contractual procedures, building design, construction techniques and different objects for each project (Das, Sah, Sharma, Singh, & Gulappo, 2013;

Ratcliffe, Stubbs, & Shepherd, 2004). However, the decisions made in the earliest phase, are very influential on all subsequent tasks (Nozeman, 2010).

Even though the process of real estate development needs to be adjusted for every project, the included tasks as described in section 3.2.3 are nearly always covered. However, all included tasks can be clustered into different states or phases within the process from development towards exploitation. The used clusters can vary regarding their content, temporary order and concerned parties (Nozeman, 2010). All of those included tasks represent a number of subtasks, which are interrelated, rather than one linear sequence of processes (Ratcliffe, Stubbs, & Shepherd, 2004).

The management of projects follows the key values of time, cost, quality and asset value (Ratcliffe, Stubbs, & Shepherd, 2004). However, sustainability aspects start to be of increasing importance within the property development process (Razali & Mohd Adnan, 2015). Indicated by Stenberg (2006), environmental issues were not included in the daily interest of companies in 2006 (Stenberg, 2006). Due to the increased awareness for sustainability aspects and the high impact of the built environment on sustainability, this has started to change in 2015 (Razali & Mohd Adnan, 2015). As indicated by Rekola, Mäkeläinen and Häkkinen (2012), the call for sustainable buildings asks not only for the change in key values, but also for changes in the development process regarding responsibilities and influences of the chief designer especially throughout the design phase (Rekola, Mäkeläinen, & Häkkinen, 2012).

Following Stroink (2005), the Dutch real estate management is highly focused on the separation of different development steps. Especially the responsibility for different stages within the development process are clearly separated (Stroink, 2005). A Dutch development focusses more on the future user in the form of prototype customers compare to a development within the US market (Stroink, 2005).

3.2.4 Different types of real estate development process models

Since the mid-50s several describing models have been developed for the property development process. Those can be summarized as ‘Equilibrium Models’, ‘Event Models’, ‘Agency Models’ and ‘Structure Models’ (Healey, 1991). The first type of models are guided by economic numbers and effective demand. The second type focusses on managing one stage after another and is often combined with real estate management. Agency models describe the process from an institutional or behavioral perspective focusing on the involved actors and their relations. The last group of models zooms in on the political and economic forces, which influence the relations within the development process and dynamic drivers (Healey, 1991).

Based on the principles of BPMN (see 4.2.1 Business Process Modelling and Notation on page 65) an event model will be developed for both the traditional as the circular real estate development process. However, that will not be purely an event-oriented model, but will also include the involved actors as part of the agency model type. Focusing on event-based models, several ways of describing the steps within the real estate development process can be found from literature. In the following table, a non-terminal overview is given for such models.

Table 5: Overview real estate development process models

phase	(Cadman & Topping, 1995)	(Miles, Malizia, Weiss, Berens, & Travis, 1991)	(Ratcliffe, Stubbs, & Shepherd, 2004)	Invalid source specified.	(Stroink, 2005)	(Nozeman, 2010)	(Soebiantono, 2012)
1	Evaluation	Inception of an idea	Concept and initial consideration	Entitlement stage	Entitlement stage (zoning plan)	Initiative phase	Development of vision
2	Preparation	Refinement of an idea		Pre-development stage	Pre-development stage (business plan, concept, marketing plan, financial plan etc.)		Stakeholder-analysis
3		Feasibility	Site appraisal and feasibility study				Organization of process
4							Concretize ambitions regarding sustainability aspects
5			Detailed design and evaluation	Development stage	Development stage (building permit, building plans, execution of construction)	Development phase	Formulate abstract design- and development
6	Implementation	Contract negotiation	Contract and construction	Investment stage	Investment stage (asset management)	Realization phase	Choose sustainability label
7		Formal commitment					Determine decision-making structure and process
8		Construction					Formulate requirements for leadership
9		Completion and formal opening					Select and contract project team members
10							Develop innovation
11							Optimize future proof of real estate
12							Measure and evaluate the plan (periodical)
13							Develop sustainability vision greater than real estate
14							Inform stakeholders
15	Disposal	Asset and property management	Marketing, management and disposal			Exploitation phase / management	

3.2.5 Steps within the real estate development process

Table 5 shows an overview of real estate development process models. From this table, it can be concluded, that the combination of Ratcliffe et al. (2004) and Nozeman (2010) covers all the relevant phases of the real estate development process indicated by the several models. Ratcliffe et al (2004) developed his model based on Cadman and Topping (1995) and Miles et al (1991) for the European market, while Nozeman (2010) presented his model specified for the Netherlands based on the four models of Van Beukering, Miles, Van Gool and Wilkinson/Reed (Ratcliffe, Stubbs, & Shepherd, 2004; Nozeman, 2010).

Following Table 5 the overall process for the traditional real estate development process covers the following four phases:

1. Initiation and concept,
2. Development and detailed design,
3. Contract and construction,
4. Exploitation and management.

This process is used traditionally by real estate developers within the Netherlands. Those phases are described in the following sections presenting the included tasks.

3.2.5.1 *Initiation and* concept

Following the defined traditional real estate development model, the process starts with initiation and concept. During this phase, the objectives of the development are determined and ideas for the development are generated (Ratcliffe, Stubbs, & Shepherd, 2004). For professional developers, the overall objective is mostly related to profit maximization or the image of the developer (Ratcliffe, Stubbs, & Shepherd, 2004). However, only developing a structured, innovative and attractive concept, which is aligned with the market will be chosen by the client for further development and execution.

Initiation

The initiation starts with one party initiating the process, which could be a current user of real estate, a municipality, a current owner willing to sell his property, a developer or investor (Nozeman, 2010). Municipalities often start the development process by proving their available land for developing a certain type of property in order to realize the municipal goals without taking the risks of developing by themselves. The initiator determines a tender procedure and the requirements for the tender document, which will be created by the developers. Contacted by this party, it is the first task of the developer to develop a concept for the provided piece of land based on the information given by the initiator and an executed market research (Nozeman, 2010).

Development concept

To develop a concept, the project specifications are studied and a market research is executed. After that, the concept is developed by identifying the important stakeholder, including the input of external parties such as the municipality and executing the site appraisal. In order to create a positive environment for the execution of the project, the planning authorities will be consulted along with other statutory agencies (Ratcliffe, Stubbs, & Shepherd, 2004). Documents such as the land-use plan and town regulations or cadastral specifications are considered.

Market research
As part of this research, landowners, potential users and possible development partners are contacted to identify their needs and interests and collect first information regarding the project (Nozeman, 2010). Furthermore, the market is analyzed whether a proposed concept could fit regarding the current market conditions for this type of real estate, regarding the expected demand, the possible economic advantages, the requirements to be satisfied, the differentiation from competing parties and legal conditions (Nozeman, 2010). The market research is executed to identify the most important components related to the market itself, but also to physical, legal and administrative constraints (Ratcliffe, Stubbs, & Shepherd, 2004). All of these information are collected in the so-called research exposé (Nozeman, 2010). This is an internal document, which is made in order to reach the approval of the company's board to invest time and resources in the tender project. Within this document, the research is presented along with a time-planning and estimated budget (Nozeman, 2010). It is essential to include critical decision points throughout the project planning to guarantee its feasibility (Ratcliffe, Stubbs, & Shepherd, 2004).

Rent and sale
The marketing activities start already during the initiation phase to create financial security for the investments before the construction starts. An early start of the marketing activities helps the developer to determine the focus group and its wishes and needs. The selling value will increase due to the higher level of adoption with the clients wishes. Different forms of early agreement, sale or rent contracts can be agreed upon. Mostly, a stepwise payment is contracted in alliance with important process milestones (Nozeman, 2010).

Team building starts
Depending on the size of the given project and the available know-how, additional partners are asked to participate within the project team, such as an architect, engineer or investor. At the beginning of the process, the contacted parties decide upon their participation in the tender process. After agreement is reached, often a declaration of intention is made, which determines, that the included parties will research a globally formulated field in more detail, exchanges information and collaborate with the aim to reach feasibility of the project and to be selected for the project. Often, the intention is formulated, that the parties are willing to continue their collaboration after being selected (Nozeman, 2010). Based on the declaration of intention, all parties work on the tender document, which is submitted to the initiator of the project for evaluation and selection of the best development team. Before submitting it, a feasibility study is executed.

Feasibility study
In order to evaluate the feasibility of the developed tender concept, several checks are executed regarding the administrative-political aspects, societal consequences, financial effects and technical achievability (Nozeman, 2010). Especially financial consequences are of high interest. Based on all of these feasibility studies it is evaluated whether the proposed concept is feasible to be submitted for the tender. Finally, the whole package of information including the developed tender concept and executed feasibility study are summarized in the research exposé, which is presented to the board of the development company (Nozeman, 2010). After the approval, the concept is submitted as a tender proposal towards the initiator. The process only continues, if the proposed concept is selected by the tender-initiator.

The success of the initiative phase depends on several factors, such as a well thought-through plan of concept, which is flexible enough to react on changing market conditions and committed enough to really fit with the indicated needs. Furthermore, the commitment of important stakeholders is of great influence, as well as a good internal and external organization with clear aims. Last, but not least, a project can be only successful, if it is developed and executed at the right point in time (Nozeman, 2010).

3.2.5.2 Development and detailed design

The development phase starts after the proposed concept is selected by the initiator. During this phase the concept is further developed towards an executable plan, including financial-technical, juridical, technical, market related and societal-political aspects (Nozeman, 2010). To reach this, several steps are executed such as finalizing the team building process, formulating the programme of requirements, developing and evaluating the design, as well as the bill of quantities (Nozeman, 2010).

Development exposé

The development phase starts by creating a development exposé by the real estate developer, which indicates the preliminary program, the planning of following steps, estimated costs and profits, way of financing and risk management. This internal document is provided for the board of the development company in order to inform and reach approval for the further steps (Nozeman, 2010). It also is important for the collaboration with project team partners since it indicates the financial and legal conditions, as well as responsibilities and duties.

Programme of requirements

Based on the initial concept, feasibility study and the approved development exposé, the proposed concept is detailed towards a defined program and finally the design as the center of the development process. With this a constructible design is created, which needs to satisfy the clients' wishes, the users' demands and all other external requirements (Nozeman, 2010). To reach this, first a programme of requirements (PoR) is determined, which is often based on a standard program provided by the client or future user.

A programme of requirements is oriented on the wishes and requirements of the client or future user and clarifies, what is finally delivered. To prevent that the program becomes obsolete, it needs to be reviewed and updated regarding current market developments (Nozeman, 2010). The PoR needs to clarify the specifications for the future activities, reachability, security, flexibility, but also regarding cultural, economic and legal aspects (Van der Voordt, 2000). Mostly all those factors are determined in a quantitative form to measure their fulfillment after the construction. The programme of requirements has an essential influence on the final design result, but shows small influence of financial effects (Nozeman, 2010; Antunes & Gonzalez, 2015).

Team building

The development team can consist of well-known partners from large or small companies or new partners (Ratcliffe, Stubbs, & Shepherd, 2004). Between all partners collaboration contracts. While collaboration contracts with advisors determine the tasks to be executed or results to be reached in exchange for a fixed compensation, collaboration contracts with authorities focus on the aim of collaboration, the considered field, the duration, mutual obligations and the way of cooperation. Contracts with real estate owners focus mainly on

taking over the ownership for real estate (Nozeman, 2010). Examples for contract forms can be design and build, serial tender, management fee contract or negotiation tender (Ratcliffe, Stubbs, & Shepherd, 2004). During the development phase also a good relationship should be created with important involved parties, such as the statutory undertakers, local authorities and other interested parties (Ratcliffe, Stubbs, & Shepherd, 2004).

The developer forms the development team together with the architect, engineer, quantity surveyor, advisors, partners of the communication department and marketing professionals. It is the overall task of the development team to create the design. Within the team, the developer takes responsibility for the process, planning and results. However, more parties are involved and influence the progress and decisions.

Design process
The design process starts after the programme of requirements is determined and the team building process is mostly finished. First, a sketch design is drawn, which forms the basis for the preliminary design and the final design. To create those design steps, the team members need to collaborate with each other and use each other's specific knowledge. It is important to regularly discuss the design and evaluate it based on the PoR and legal restrictions (Nozeman, 2010) since discovering a problem later during the development process can have larger consequences, both functionally as financially. It is the task of the client or his representative in the form of the developer to keep control over this issue (Nozeman, 2010).

Sketch design
Based on the PoR, the sketch design is made, which gives a good indication whether the PoR is realistic or might need to be adopted. The sketch design includes the building typology, access, parking solution, framing regarding square meter and cubic meter (Nozeman, 2010).

Preliminary design
After evaluating and adopting the PoR and the sketch design to reach alignment between them, the preliminary design is made. The preliminary design includes information regarding the selection of construction, spatial layout, technical spaces, basic decisions regarding building physics and fire protection, overall sizing of included parts and principles of basic details. Furthermore, a quick scan is executed regarding the alignment with construction law (Nozeman, 2010). The preliminary detailed drawing can be used to specify the budget determined together with the planning (Ratcliffe, Stubbs, & Shepherd, 2004).

Final design
After reaching alignment with the adopted PoR, the budget for construction is determined and it is evaluated whether the proposed design fits within the budget. If agreement is reached, the final design is worked out, which includes exact dimensions of the shafts and technical spaces, of the floor plan and of cross sections. The detailed planning needs to be finalized and the evaluation regarding the building regulations is executed. Finally, all elements are dimensioned accurately. If the final design does not fit with the PoR, one of the two need to be adopted. To limit the risks within this iterative adoption process, all concerned team members need to take part in the evaluation and adoption (Nozeman, 2010).

Bill of quantities

Calculating the bill of quantities needs to be executed carefully based on the material- and installation-technical specifications. The drawings and calculations for the bill of quantities become part of the contract agreed upon with the builder. Depending on the kind of contract and the contractual conditions, the builder determines the price and hires additional subcontractors. Alternatively, the client selects the builder based on several selection criteria, of which a low price is the most common one (Nozeman, 2010). Furthermore, the planning application will be submitted (Ratcliffe, Stubbs, & Shepherd, 2004).

Financial influence

Besides this decreasing level of uncertainty and increasing level of risk exposition, the design phase is essential regarding financial aspects. While the probability for cost reduction is maximal at the beginning of the project, this decreases throughout the design phase. Likewise, the accumulated investment increases throughout the development process (see Figure 9) (Antunes & Gonzalez, 2015). In order to estimate the financial requirements and determine the finance structures including suitable sources, floor layouts and cross sections of the whole project will be created (Ratcliffe, Stubbs, & Shepherd, 2004).

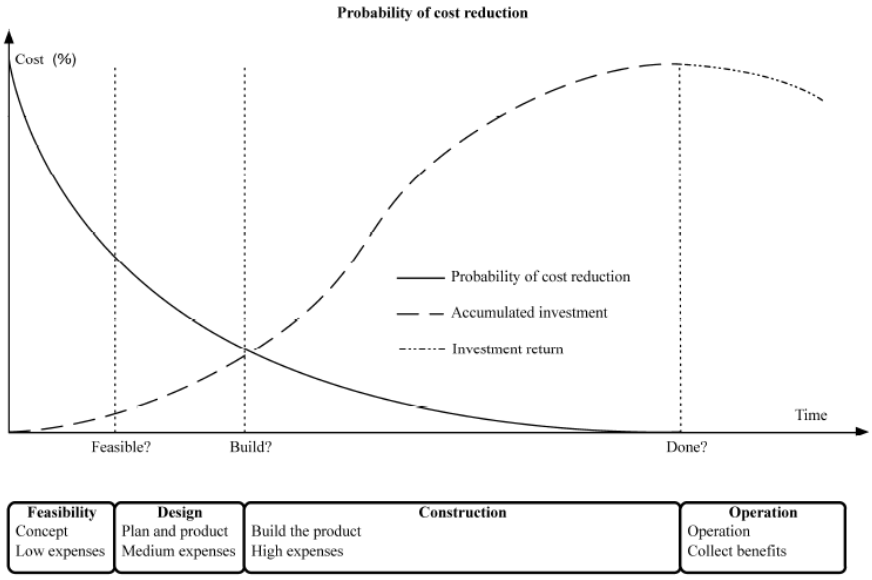

Figure 9: Influences on costs throughout the development process (source: (Antunes & Gonzalez, 2015))

However, the design phase is likewise indicated as being essential for the level of sustainability of the construction. During this phase, most of the materials and construction methods are determined. Furthermore, future users are appointed as target group (Rekola, Mäkeläinen, & Häkkinen, 2012). All of these aspects influence the environmental impact, which should be as little as possible while still reaching the required level of performance in order to create a sustainable construction as defined in ISO 15932 (Rekola, Mäkeläinen, & Häkkinen, 2012).

Risk management

The risk management is an essential task of the professional developer, which describes the conscious decision in taking and managing risks. The risks to manage vary fundamentally from phase to phase and between different projects. An active risk management can be used to control the ratio between rate of return and risks, unexpected struggles and to plan the cash flow. Risk management becomes more and more essential due to changed legal regulations

(such as Basel II), changed organizational structures, new ways of contracting and collaboration (Nozeman, 2010). As part of the risk management, it is essential to adopt the planning throughout the process. Changes following from new information or new decisions need to be integrated in the project planning. Openness between all project participants is critical to create flexibility, which makes it easier to react on changes (Ratcliffe, Stubbs, & Shepherd, 2004). In order to limit some of the development risks, it is important to maintain a close collaboration with the future user. After each step within the development phase and when important decisions need to be made, the client is contacted to get informed and give feedback. After his approval, the information are presented to the board of the development agency to ask for an extension of the budget.

End of development phase

The end of the development phase is indicated differently within the sector of real estate (Nozeman, 2010). Here it is assumed, that the construction phase starts with receiving the building permit and preparing the execution

3.2.5.3 Contract and construction

The contracting and construction phase includes the sub processes of work preparation, execution and handover. The construction phase starts with signing the execution contract, which indicates the real estate product characterized by time, money and quality and presents the realization process by means of the organization and information. The construction phase stops with the transfer of the real estate (Nozeman, 2010).

The construction phase can be characterized as the phase during which the ideas and concepts of the earlier phases become tangible assets. As shown in Figure 10, the possibility to influence the result is highest during the initiation phase and decreases until the construction. However, the financial and other effects of made decisions are small during the initiation and become more and more important throughout the process (Nozeman, 2010). This means, that wrong decisions at the beginning of the process can have large effects at a later phase.

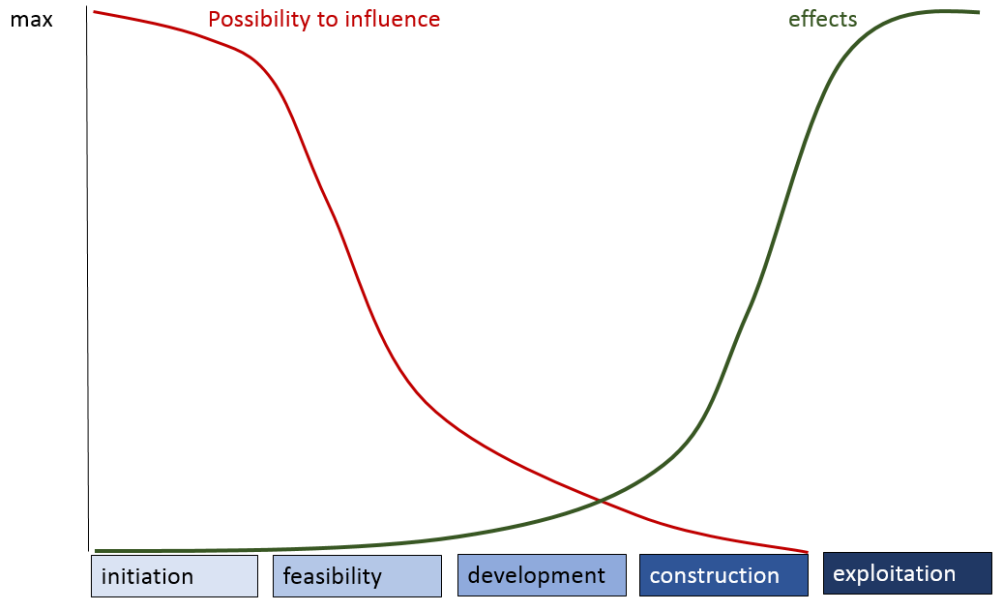

Figure 10: Influence and financial effects throughout the development process oriented on (Nozeman, 2010, S. 80)

Work preparation

The phase of work preparation is used to detail the contractual drawing up to the level to enable production and to buy the most important parts as preparing the execution of the work (Nozeman, 2010). To do so, the subcontractors and the builder works out several plans in close collaboration with the construction manager, who takes over the operational tasks from the developer (Nozeman, 2010). It is the task of the builder to sign contracts with subcontractors, who will execute the work. The planning is made in order to prepare and execute the work and evaluate and manage the project progress related to time, money, quality, organization, information and safety. Such planning documents include amongst others, the contract- and overall planning, purchase planning, inspection planning, organogram, building site equipment, drawing schema, meeting schema, plan for safety and health during the execution (Nozeman, 2010). During this stage, appointments are agreed upon and contract documents are approved (Ratcliffe, Stubbs, & Shepherd, 2004). Furthermore, usually an overview is made regarding possible risks and its management (Nozeman, 2010).

It is important to establish a structure for the communication between the parties, accounting, administration, purchasing, meetings and approval reports. It has been recognized, that establishing a strict structure with regular meetings at the beginning and allowing for relaxation during the process works best (Ratcliffe, Stubbs, & Shepherd, 2004).

Execution exposé

The execution exposé is the internal document, which is made by the developer and forms the basis for all execution actions. Following the traditional form of contracting, the invitation for tendering can be executed and the builder can be selected after the exposé is approved by the board of the development company. After the work is granted to one builder or contractor, the execution starts. Overall, the execution exposé forms an update for the development exposé (see section 3.2.5.2 on page 46) (Nozeman, 2010).

Execution

During the execution, the construction manager is responsible for coordinating and executing the work in order to deliver the contractually proposed object. He evaluates whether the execution of the construction follows the determined planning. However, all contractual conditions are supervised by the real estate developer to anticipate problems and possible solutions (Ratcliffe, Stubbs, & Shepherd, 2004).

Different actors are important participants throughout the construction phase. Besides the client, the architect, the builder and the advisors are important. The client, the architect or the construction manager guide the process, whereas the architect is responsible for the quality of the product specifications and the builder and subcontractors for the final execution. Advisors are asked for their opinion when important decisions need to be made. The exact responsibilities, competences and tasks per actor depend highly on the organization form and type of contract (Nozeman, 2010). Besides traditional contracts, contracting with a consultant following The New Rules 2011, the Building Contract following the UAC 2012, the Design Team or Integrated Contracts following UAC-IC 2005 are known amongst others (Chao-Duivis, Koning, & Ubink, 2013).

Handover
The handover represents the point in time, when the execution of the work is finalized and the ownership for the real estate can be taken over by the client (Nozeman, 2010). It is the task of the construction manager to inform the developer about the construction in order to enable him to prepare the handover with the client. As being the first contact person for the client, this is a task of the developer and not of the construction manager. He will check the final construction regarding its accordance with the planning and construction procedures and prepare the construction for the approval of his client (Ratcliffe, Stubbs, & Shepherd, 2004; Nozeman, 2010). This needs to be done before executing the handover. If necessary, remaining work to be done is recorded in the process statement. After the client or his representative agree with the delivered product, the builder transfers the asked guaranties and the dossier for handover. This dossier contains the as-built drawings and user manual, which contains essential information for the management, maintenance and final demolition of the real estate (Nozeman, 2010).

Rent or sale
Depending on the project situation, it is essential to determine potential customers and sign contracts with them for buying or renting parts of or the whole new real estate. Normally, this is executed already during the development phase and needs to be finished far before the construction starts to create financial security for the developer (Nozeman, 2010).

3.2.5.4 Exploitation and management
Since every development is aimed at selling the construction to one or more clients, it is important to develop a marketing strategy right from the start of the project. In this way, it is possible to determine the demand of the clients and adjust the project accordingly. Furthermore, it is important to determine, when the marketing campaign will start, how it is executed and by which party. This could be supported by market research, advertising or public relations under a certain promotion budget (Ratcliffe, Stubbs, & Shepherd, 2004). Besides that, it is important to decide upon, whether the final object will be sold or rent out and under which conditions. Both obligations and incentives of the different contractual constructs need to be reviewed and selected (Ratcliffe, Stubbs, & Shepherd, 2004).

Whereas the real estate is constructed within the construction period and ownership is (nearly always) taken over by the new investor or owner, the exploitation phase is still interesting to examine for the developer. At the one hand, the developer is still the first contact for a client to be contacted, if defects or problems are detected. Furthermore, accompanying the client at least partly during the exploitation phase will show the developer, whether the proposed objectives are reached and the project can be considered as an success. Identifying the drawbacks and critical decisions for success helps the developer to reflect the development and (possibly) improve the procedure for a next development project (Nozeman, 2010). Furthermore, the development will be important as an valuable reference for the developer to be appointed as experience for future projects. Besides that, every new project helps the developer to strengthen his position against competitors regarding price-quality ratio, efficiency and charisma.

3.2.6 Participants within the real estate development process

During the real estate development process several groups are participating. They can be summarized as space consumption group, space production group and public infrastructure group (Graaskamp, 1981). The space consumer group consists of the individual space users, collective users and future users, who are interested to rent or buy real estate to meet their needs, such as the investor and his tenants. The space production group consists of all individuals, who contribute to the expertise, which is necessary to transform the available space in worthy space. This group includes all parties of the development team. The public infrastructure group summarizes all companies, which provide real and concrete services or abstract services for the individual space user. Those services include real services such as road infrastructure and sewers, but also abstract services such as education and governmental regulations (Graaskamp, 1981). In the next sections individual stakeholders of the real estate development process are presented.

3.2.6.1 Development team

The development team consists of different specialists, whereas their way of collaboration has a major impact on the efficiency and quality of the developed project. It is the aim of every property development to reach a harmonized way of working together to eliminate delays and misunderstanding (Ratcliffe, Stubbs, & Shepherd, 2004). An overall structure of collaboration within the development process is presented in Figure 11.

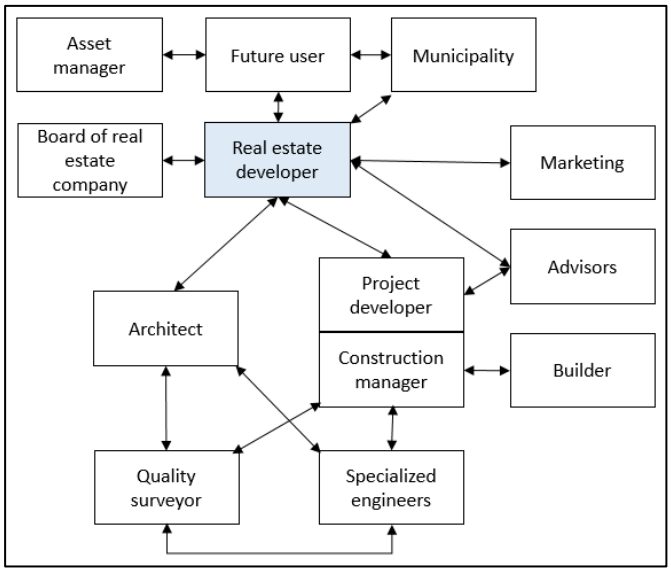

Figure 11: Overall structure of collaboration within the development process (source: (Walker, 2015, p. 259)

Real estate developer

As part of the development team, the position of the developer is fulfilled by professionals with a background in estate agency, building, engineering, architecture, law, finance or business management. They show different levels of involvement within the process from mostly delegating the tasks to others up to full commitment and management responsibility within every stage of the process. A developer can be characterized as somebody, who identifies the demand for a certain property and is committed to take the risks in order to gain a profit. The tasks of a developer cover the promotion and negotiation with committed approval authorities and other stakeholders, the market analysis and marketing for potential purchasers and tenants, as well as securing the financial capital, employment and managing

the team of professionals (Ratcliffe, Stubbs, & Shepherd, 2004; Miles, Malizia, Weiss, Berens, & Travis, 1991).

The party, who develops the real estate shows a large variation from professional, governmental agencies up to individual, local individuals. They vary largely both regarding their efficiency and aim of development. Property development companies describe all companies from large to small, which are engaged in the development of properties. Many different forms of organization, operational range, types of projects, way of teaming up for a project and specialization can be found, such as financial institutions, construction companies, public sector agencies, large land owners and business concerns (Ratcliffe, Stubbs, & Shepherd, 2004; Nozeman, 2010). Besides this, the group of specialized real estate developers has emerged, which is purely interested in the development of new real estate or the redevelopment of existing real estate. When mentioning the 'real estate developer' during the previous sections, the last type of developing agency is referred to.

Project developer
Another important party can be the project developer, who takes over the project management from the developer. This includes the coordination of the team members and tasks within an overall planning. An important part of the function is to monitor the progress of the project regarding the given time- and cost limits in order to make changes whenever critical developments take place. This function became important since the 1980s and can be fulfilled by an internal expert of the development company or an external party. Since every project is unique, the tasks to be included for the project manager vary as well. The responsibility of the project manager continues from the first developed ideas until the disposal of the constructed property (Ratcliffe, Stubbs, & Shepherd, 2004; CIOB, 1992).

Construction manager
In comparison to this, the construction manager takes over the responsibility of these phases of the development process, which are related to the construction of the building. Those tasks require both managerial as technical knowledge and are often outsourced to professionals when the overall project developer faces a lack of experience, knowledge or time to execute all tasks. The function of construction manager is often executed by architects, engineers, construction professional, building surveyors or quantity surveyors. Besides their technical background a broad experience in the field of property is required. The main task of the construction manager is to ensure the delivery of the property within the given time and cost limitations, as well as required specifications (Ratcliffe, Stubbs, & Shepherd, 2004).

Architect
The task of the architect within the property development process is to translate the concept of the developer into an attractive solution, which is workable for the technical execution (Ratcliffe, Stubbs, & Shepherd, 2004). The tasks of an architect are crucial for the development process including the design, planning approval and management of construction contracts (Parnell, 1991; Ratcliffe, Stubbs, & Shepherd, 2004).

Specialized engineers
Different specialized engineers take part of the development team consisting of the structural engineer, the geotechnical engineer, the mechanical and electrical engineer, as well as the

environmental engineer. They work together with the architect closely in order to ensure the structural and mechanical functionality of the building. The structural engineer is responsible for the design of structure frame of the building in close consideration with the architect at the beginning of the design phase. He needs to consider all interfering forces including a safety margin, high flexibility to realize different use possibilities and construction costs (Ratcliffe, Stubbs, & Shepherd, 2004).

The geotechnical engineer is responsible for evaluating the soil conditions of the proposed location including the bearing and drainage conditions as basis for the calculations of the structural engineer. The mechanical engineer and electrical engineer take responsibility for all facilities of a building such as water supply, heating, lighting, air conditioning, fire protection, communication and if necessary lift services.

The life cycle assessment for every part of this system and its whole is crucial to manage both the construction as the maintenance costs for a building. Based on the fact, that around 60% of the total building costs account for those systems and strong regulations are made for energy consumption and CO2 production, a detailed evaluation of the system for improvement is essential (Ratcliffe, Stubbs, & Shepherd, 2004). Based on this, the increasing importance of an environmental engineer for the evaluation of environmental impact of existing buildings is understandable (Ratcliffe, Stubbs, & Shepherd, 2004).

Quantity surveyor

The quantity surveyor executes the task of analyzing and controlling all costs related to the project and is therefore recommended to be involved already during the early design decisions and financial appraisal. Throughout the development process, the quantity surveyor or building economist takes responsibility for cost-advising his team partners and cost checking. Due to the financial aim of profit maximization of most development projects, cost-effectiveness is of increasing importance. To reach this, techniques such as lifecycle costing, cost-in-use and value engineering are used (Ratcliffe, Stubbs, & Shepherd, 2004).

Builder

The builder is included in the development team during the procurement phase. He has the practical knowledge, how constructions need to be executed and can therefore deliver important information for the design and construction engineering of the property (Ratcliffe, Stubbs, & Shepherd, 2004).

Specialized team members

Other specialized members of the development team can include the valuer, the solicitor, accountants, town planning consultants, planning supervisors, landscape architects and facility managers. Even though, the steps of the development process seem clear just as the functions of the different parties, the process consists of many different sub-processes, which are interwoven and influencing each other (Ratcliffe, Stubbs, & Shepherd, 2004). They are all impacted by social trends and changes, such as the ecological awareness of the last years.

3.2.6.2 Additional stakeholders

Besides the development team, more stakeholders are important for the development of real estate. This includes for example the municipality, the board of the real estate company and

the future user of the developed real estate. These three parties can be called the evaluation team as they monitor and evaluate the process. More stakeholders could be mentioned such as the neighborhood influenced by the project or specific interest groups, such as an environment protection group. The most important external stakeholders are described briefly in the following as being relevant for the presented model.

Municipality
Both the real estate developer as the municipality are collaborating closely during the development process. While the real estate developer develops the property, the municipality is responsible for the spatial development and executing building permits (Schoenmaker & Van der Vlist, 2015).

Board of real estate company
As mentioned earlier, it is the task of the developer to create at least a research exposé, a development exposé and an execution exposé including the most important information, documentation, planning and evaluation of the finalized phase in order to inform the board of the real estate development company. By doing so, the board members receive insight in the progress of the project and can decide upon those information, whether the project can be finished successfully. Only after approving such an exposé including also information regarding the next phase, the allowance to continue the project and a budget for it are provided. In this sense, such moments of evaluation form an important Go-/No-go-moment for the developer within the development process (Nozeman, 2010).

Future user
The future user is essential for the development of real estate since he is able to specify his demands, wishes and needs as the basis for the development. The real estate needs to be developed so that it satisfies exactly those requirements. A constant cooperation and information exchange with the future user is highly important for the success of the development process (Nozeman, 2010).

Investor
A housing investor often also appears as a housing agency. The housing investor is a party owning the real estate and renting out the real estate units positioned within their real estate portfolio. Some of the housing agencies are also taking over the position of real estate developer. However, as stated by Kuij (2014), Dreimüller (2008) questions whether such agencies pursue the necessary knowledge and experience to do so (Van der Kuij, 2014; Dreimüller, 2008). In many cases, the housing agency hires a so-called asset manager, who is responsible for the management and maintenance of the object after the handover took place. As such, this party often is involved throughout the development process as a representative for the housing agency taking influence on the design so that management and maintenance can be optimized.

3.3 Developments towards sustainability

In the period from 1987 to 1997, a rapid development of real estate research is identified by Hoesli & MacGregor (1997). They found that emerging from the Northern European countries, such as the Netherlands, the research of commercial real estate expanded also to the Southern and Eastern European countries focusing on topics such as real estate indices, tenure

choice decisions and subsidy impacts on real estate markets (Hoesli & MacGregor, 1997). Parallel to this development, another direction of research was developed within the United States of Amerika. In comparison with the American research, the European focus was rather less oriented on financial aspects and more interested in urban economics, planning and land development (Hoesli & MacGregor, 1997).

Besides this, more and more interest is developed for real estate development related to sustainability. As such, Carlock (2015) indicated, that sustainability has been driven into mainstream through client demand and market demand. Besides this overall market trends, research has been performed regarding the fields of sustainability within real estate. As stated by Soebiantono (2012), the sustainability of real estate can be determined based on fifteen different fields: energy, water, materials, transport, health, land use & ecology, management, waste, pollution, sustainability of the location, environment, user quality, future value, development process innovation and region (Soebiantono, 2012). Till 2013 the worldwide green building market grew to US$ 260 and sustainability can be named as one of the best marketing tools (Carlock, 2015). In total, client demand accounted for 35% and market demand for 33% of the top reasons to develop sustainable buildings (Carlock, 2015). Therefore, strong demands occur for sustainable buildings and new possibilities need to be developed to introduce the topic within the real estate development process.

One possibility to introduce sustainability within the real estate sector in a structured manner is through the concept of circular economy. The circular economy describes a holistic approach, which draws a changed model for economic flows of materials within all sectors of the current economy. Instead of the traditional linear model of creating a product, using it and throwing it away after a certain lifetime, the circular model focusses on keeping materials within the economic cycle. In an ideal situation, those cycles would be everlasting and never ending. The greatest trigger for changing the economic system towards a circular economy is resource scarcity and therefore rising prices of resources (UKCG, 2014).

As indicated by Schoolderman et al (2014), a change towards the circular economy could have mayor impacts regarding different fields of daily life. This includes an environmental impact with a total reduction of use of fossil energy and a total reduction in the production of waste. Furthermore, an economic impact can be found with an increasing number of job opportunities and a reduced capital blocking by paying for use instead of property ownership. As a third field, the circular economy would influence the social structures by decreasing the number of health issues and improving the education system (Schoolderman, et al., 2014; Loppies, 2015).

Besides that, within the field of construction the costs for landfill, the legislation and the reduction of costs, as well as energy savings and environmental protection trigger an introduction of the circular economy concept within the construction industry as indicated by respondents of an UK survey, executed amongst almost 300 contractors, suppliers, developers and clients (UKCG, 2014). Especially the clients and developers indicated a great potential for the circular economy to offer an solution to the future challenges in resource efficiency and to provide competitive advantages for buying and selling products. Furthermore, the circular economy concept is indicated to change the way materials are sourced for the construction industry significantly (UKCG, 2014). Likewise, barriers are indicated for the implementation of

the circular economy concept within the construction sector, including political issues, supply chain issues, financial issues, change in business culture and technical issues (UKCG, 2014).

To overcome these barriers and reach the implementation of the circular economy concept, mostly practical research has been executed by practitioners and graduation students throughout the last years. Mostly, qualitative research has been executed regarding the overall process or specific aspects of real estate. As part of this, Loppies (2015) executed an explorative, qualitative research regarding the definition of circular buildings using literature study, case studies in the form of dossier analysis and interviews, as well as brainstorming sessions with experts (Loppies, 2015). Jeroen Verberne (2015) finished his master thesis in 2015 researching the building circularity indicators using literature review and expert interviews, as well as case studies and an expert panel (Verberne, 2016). Besides these detail oriented researches, several studies have been executed in order to develop circular process models.

As such, Baartmans (2013) developed an illustrative process model for the concept of sustainable construction based on literature review, expert interviews and case studies (see Figure 12). Focusing on aluminum facades, a specific evaluation tool for the environmental impact of different scenarios is developed, such as recycling, reuse and reduction. It is indicated, that the sustainability impact is highly dependent on the product, which is addressed, and the process that is executed. However, this research did not include the concept of circular economy yet.

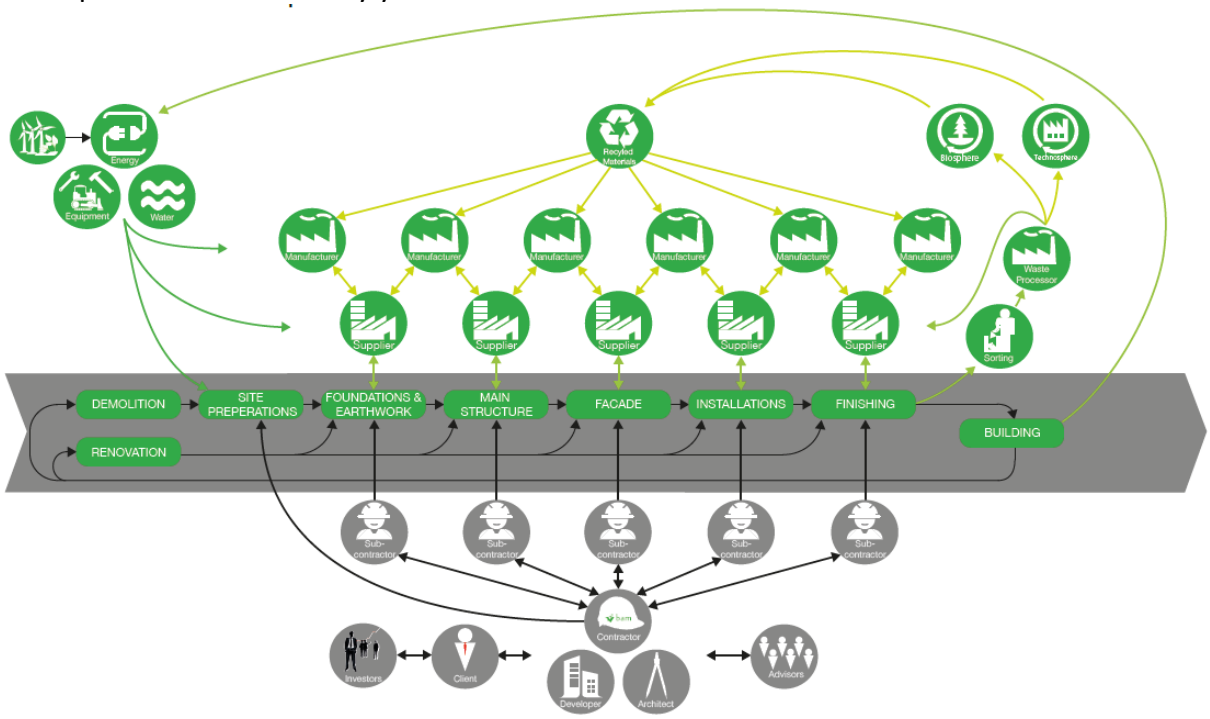

Figure 12: Process model for sustainable construction (source: (Baartmans, 2013, p. 8 in Appendix 2))

In 2013, Bram van de Kaa conducted a research regarding the possibilities to implement the concept of circular economy within the real estate sector. Performing a qualitative research with case studies and individual, direct, oral interviews, an overall-model was developed and detailed for the construction phase (see Figure 13). Besides, another model is developed for the circular value chain within real estate including six different stakeholders (see Figure 14).

Based on this study, it is investigated, how far the transition towards circular real estate economy is executed, which is indicated as very limited up till 2013. Besides, Van de Kaa (2013) indicates, that suppliers need to be involved in the early phases of the process to support the transition. Furthermore, circularity need to be maintained after the realization of the real estate to minimize material destruction (Van de Kaa, 2013).

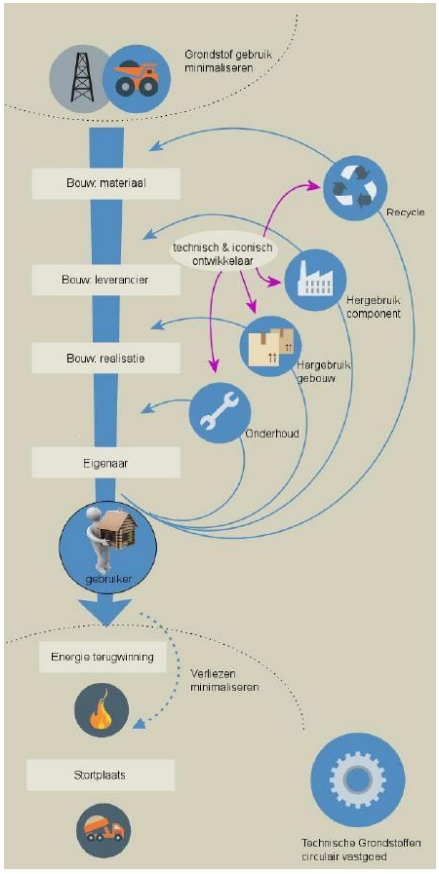

Figure 13: Model for circular real estate economy (in Dutch, source: (Van de Kaa, Vastgoed en de circulaire economie: een toekomstverkenning, 2013, p. 48))

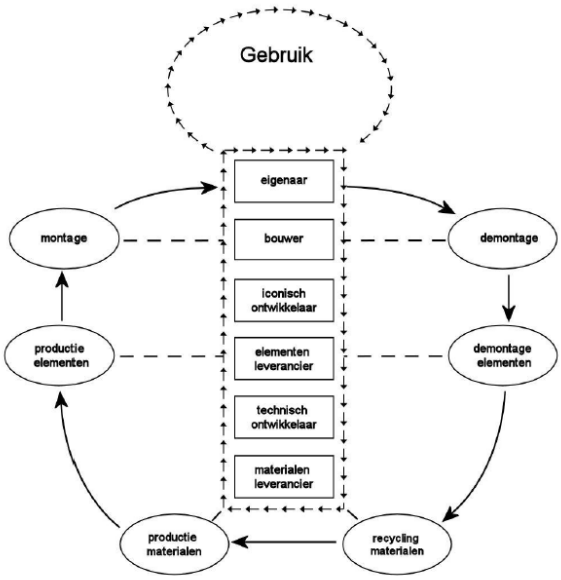

Figure 14: Circular real estate value chain (source: (Van de Kaa, Vastgoed en de circulaire economie: een toekomstverkenning, 2013, p. 45)

Also as of 2013, Sander Kusters carried out a master research regarding the way how value creation within the real estate development process can be directed by the key values of the circular model represented by performance oriented contracts. Focusing on commercial real estate and developers, investors and users as main actors, an explorative research is executed regarding the characteristics to create value with the implementation of the circular economy concept based on case studies (Kusters, 2013). As implemented in the process model in Figure 15, performance-oriented contracts show great influence on the overall process and especially on the linkage of owner and end user with the suppliers. Kusters suggests a professional service provider to manage this relation.

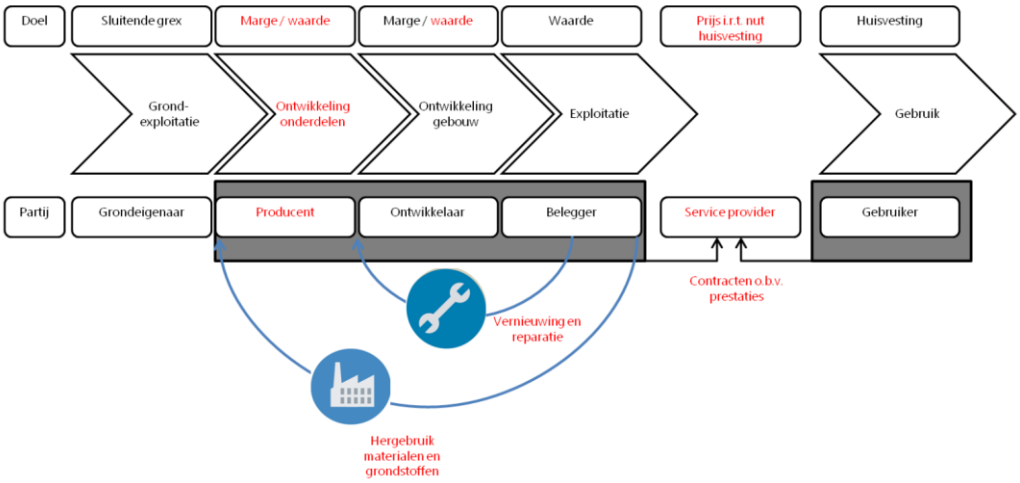

Figure 15: Circular model within the real estate development process (in Dutch, source: (Kusters, 2013, p. 51))

Likewise, in 2015 Nena Rood performed an explorative, qualitative research regarding the potential opportunities for Dutch commercial real estate developers within the circular economy. In order to conduct this research, a literature study, exploratory conversations with experts, participated in context-related symposia and seminars, as well as individual and semi-structured, in-depth interviews with experts were executed (Rood, 2015). Based on this, it was found, that knowledge regarding the implementation of circularity need to be shared to improve circular buildings. This refers to financial, organizational, demolition and recycling knowledge. Besides, architects should design following the rules of circular economy and a second hand market should be opened for regained materials. Also, the role of the contractor could range from owner of products till building manager, which is represented in Figure 16.

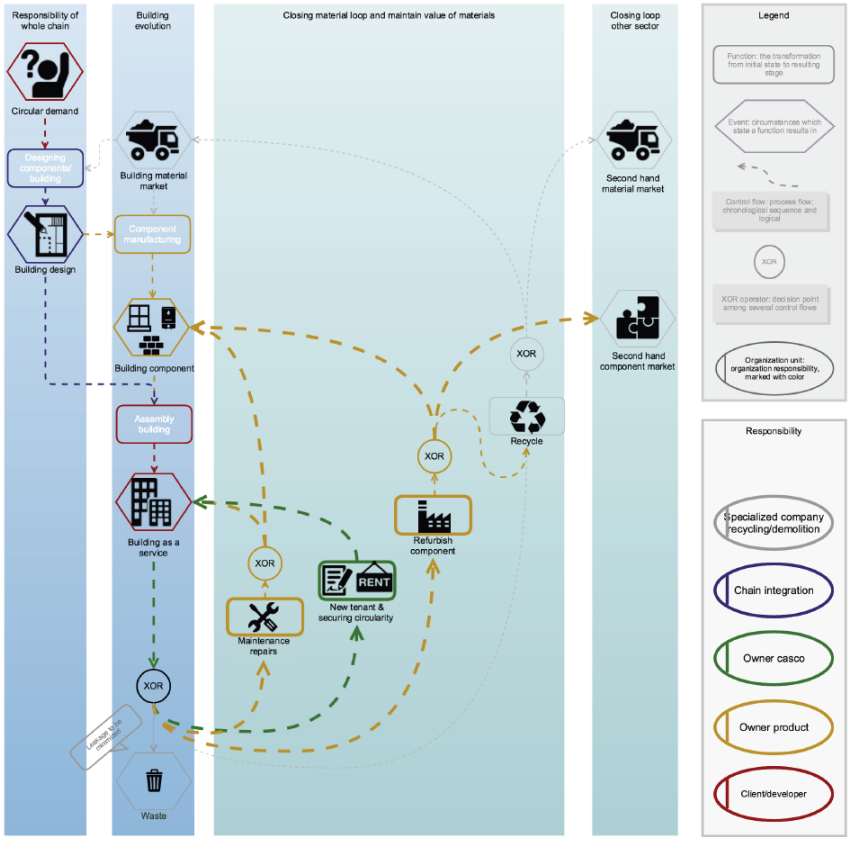

Figure 16: Circular Real estate development (source: (Rood, 2015, p. 115))

3.4 Discussion

As shown in this chapter, the traditional real estate development process need to be described as unique and highly dependent on the project conditions. Consisting of the same overall-tasks, the four phases of initiation and concept, development and detailed design, contract and construction, as well as exploitation and management can be defined. Just as the included tasks, the participating stakeholders vary highly per project, as well as contractual conditions.

Focusing on the development of real estate driven by financial incentives traditionally, more and more interest occurs in sustainable developments. As such, several process models are developed for the circular real estate process focusing on measuring the sustainability impact of different scenarios, the transition status, value creation through performance-oriented contracts and material processes combined with responsibilities for commercial real estate. Overall, it can be seen, that several aspects of a circular real estate development process have been evaluated in the past. However, no detailed, standardized process model has been developed yet. Such a model would be useable for the practical implementation of circular economy principles within the real estate development process by practitioners. Likewise, a scientifically developed model would contribute to the practically-oriented, limited available research.

In order to achieve a sustainable construction process model, a comprehensive understanding of the ongoing processes is necessary, as well as intensive collaboration between the participating parties (Rekola, Mäkeläinen, & Häkkinen, 2012). Based on the detailed knowledge regarding the traditional real estate development process and the concept of circular economy, a standardized process model can be developed in the form of a BPMN model. Business Process Modelling and Notation (BPMN) is indicated to be an efficient method to represent processes and enables the analysis and process optimization (Zeitner & Peyinghaus, 2013). Used by the independent industry association for façade elements VMRG, the BPMN standard has been used to translate feasibility studies for circular business models into computer-readable process models, which can be used for simulations, serious gaming, process optimization and chain integration (VMRG, 2016; Chinosi & Trombetta, 2012). As such, the BPMN standard also seems suitable for the development of a standardized process model for the circular real estate development.

4. Model

Abstract: Based on the current linear economic system, the world is already facing the destruction of the available raw materials and an increase of the amount of non-reusable waste worldwide. To meet these challenges, the Ellen Mac Arthur Foundation introduced the concept of circular economy with its first report in 2013 worldwide. This concept aims on keeping all raw materials and the products made out of it as long as possible and ideally endless within the economic system in order to prevent taking virgin raw materials from the earth and creating non-reusable waste. As being responsible for remarkable percentages of the countries' energy production and waste creation, the construction industry and especially the real estate development need to implement the concept of circular economy. To develop an approach for a circular real estate development process schema, the traditional process is made visual using the Business Process Modelling and Notation (BPMN) standard. Using the Delphi method, 21 experts of the field were asked to evaluate nine propositions regarding the implementation of the circular economy principles within the real estate development process. It became clear, that the choice of principles is highly dependent on the clients' ambition and project conditions. Moreover, aiming for a circular building asks a different form of collaboration between all participating project parties. Besides, suppliers, producers and the construction company are faced with more tasks and responsibilities within the process. The outcomes are summarized in a BPMN process schema for the circular real estate development process.

Keywords: circular economy, real estate development process, Business Process Modelling and Notation, BPMN, adapted Delphi Method

4.1 Introduction

Since the 1980s' the worldwide awareness is increasing for the negative effects of the current, linear economic system on the natural environment (United Nations, Brundtland comission, 1987). This current economic system is based on a 'take-make-dispose' pattern for raw materials and created products (Ellen MacArthur Foundation, 2013a). Due to its linear character it is leading towards the destruction of the final amount of raw materials and increasing the amount of un-reusable waste worldwide. This will not only lead to scarcity in raw materials, but also towards an increasing waste problem, facing large effects on the natural environment (planet), the welfare of the citizen (people) and showing a negative effect on economic growth and social welfare (profit/prosperity). Those challenges are further emerging by the population growth worldwide and the increase in economic standards leading to increased demands for raw materials and negative effects on the natural environment (Bonciu, 2014). Facing the aspect of the earth being the only natural environment for human living to exist to current knowledge, asks for drastically changes of the economic system and human behavior to safe this precious living environment.

To meet these challenges, the Ellen Mac Arthur Foundation introduced the concept of circular economy with its first report in 2013 worldwide. This idea is defined as "A circular economy is an industrial system that is restorative or regenerative by intention and design (…). It replaces the 'end-of-life' concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business

models." (Ellen MacArthur Foundation, 2013a, p. 7). This concept aims on keeping all raw materials and the products made out of it as long as possible and ideally endless within the economic system in order to prevent taking virgin raw materials from the earth and creating non-reusable waste. Instead of this, 'waste' is seen as another form of resource, which need to be reintegrated within the economic system to close the biological and technical material loops. Nonetheless, this concept needs to be seen as a broad, generally applicable concept, which needs to be fitted for the characteristics and requirements of the different industries and types of products.

As being responsible for 37% of the waste production, 4.5% of the total energy consumption and 5% of the total greenhouse gas emissions within the Netherlands (Van Odijk & Van Bovene, 2014), the construction sector urges for the implementation of the concept in order to reach viable effects and make first, important steps towards the prevention of the natural environment. As being the basis for every newly developed or redeveloped building, the real estate development process is crucial for this. As indicated by the IPCC report (2014) a doubling or even tripling of the energy usage and related emissions might need to be expected till 2050 due to growing prosperity and population, if the development continues as expected (Lucon, et al., 2014). This indicates the urgency to take action and change the system of the construction industry and especially the real estate development process.

Based on this societal urgency, this research investigates, how the principles of circular economy can be implemented within the real estate development process in order to make the process by itself more circular, but also to develop a process model and valuable guidance for real estate developers focusing on the development of circular buildings. It is aimed to provide this process map along with valuable guidance to support the parties participating in the real estate development process to find their role within the new economic system of circular economy. This will be especially valuable for the transition of the traditional form of real estate development towards a completely new way of developing following the concept of circular economy. Providing this process map will not only help the real estate developer to formulate his requirements against development team partners, but also to formulate common ground to work together on a more sustainable way of developing real estate. Important tasks and decision moments will be presented following the BPMN 2.0 standard developed by OMG (2013), so that this process can be understood easily, both by managers, practitioners and the scientific community. The process model is meant to be used as a communication tool and for guidance to reach the transition towards the circular economy.

Both, the process of real estate development as the concept of circular economy can be defined in different ways. Those depend on the project situation and the understanding of the term 'circular economy'. Therefore, it is essential to first formulate one clear definition of the two terms as basis for this research.

The traditional real estate development process is defined with four phases, as follows: 1) initiation and concept, 2) development including detailed design and evaluation, 3) contract and construction, as well as 4) exploitation and management. As the most important stakeholders for this process are considered the real estate developer, plan developer and project manager, architect, different engineers, construction company, quality

surveyor, marketing professional, as well as the direction of the real estate development company, the investor as future owner of the property and the municipality.

The process map is created for the specific situation of creating new real estate on land ready to be built on and provided by the municipality, where no existing building is available as a material donor. The real estate will be a large housing unit with several apartments meant to be taken over by an investor and rented out to the private tenants. The research focusses on the main stakeholders, tasks, the collaboration between them and important documents. Financial and legal aspects are only considered rudimentary.

Likewise, the concept of circular economy is defined following the definition of the Ellen MacArthur Foundation (2013), as stated before. Furthermore, central principles of circular economy are clustered into design principles, principles for material choice and process-related principles focusing on the built environment.

Since the concept has been introduced into the market, a large research took place, both for scientific justification, but even more for practical use of the concept of circular economy. As such, mostly non-scientific publications can be found, along with an increasing number of student theses working on the implementation of the concept (Verberne, 2016; Rood, 2015; Beurskens & Bakx, 2015). As part of this, different definitions of circular economy and its main principles have been formulated and several approaches took place to integrate the concept within different industrial sectors and for different types of products. Due to their shorter lifecycle, the implementation of the concept for use products, such as washing machines, jeans and mobile phone is far more developed than for the long-life-oriented construction industry. However, especially the integration within the built environment is of great importance to minimize the effects of the current linear economy on the natural environment.

In order to develop the described circular real estate process model, an extensive literature review is executed regarding the different forms of traditional real estate development processes, the concept of circular economy and its main principles within the construction industry. Based on this, a process model of the traditional development process is made following the standard of Business Process Modelling and Notation (BPMN), which is evaluated with two practitioners. Besides that, a long list of circularity principles based on literature is summarized, which is presented to experts of the field asking them for feedback regarding the completeness of the list. Furthermore, nine propositions are formulated regarding the implementation of circularity principles within the real estate development process. Following the adapted Delphi Method, those propositions are judged by experts' opinions and evaluated by the researcher. During a second round, the adapted propositions are judged again by the same experts. Those propositions and the collected feedback is used to construct the circular real estate development process model following the BPMN standard. Besides, clear advice will be formulated for real estate developers to reach a circularity-influenced process and building.

In the following, first, the research methodology of this research will be discussed. Then, the methodological approach used to answer the research question will be discussed, including the Business Process Modelling and Notation (BPMN) standard combined with the Delphi

method. After that, the results of the first round of interviews is presented along with the second round, before this chapter is finalized by a broad discussion of the results.

4.2 Research methodology

This research includes first an in-depth literature review regarding both the traditional real estate development process, as the concept of circular economy. Based on this literature review about the traditional real estate development process, a Business Process Modelling and Notation (BPMN) diagram is constructed, which represents the most important stakeholders, their tasks and collaboration within the development process in a standardized manner. The literature regarding the concept of circular economy is used to create three tables representing the most important principles of circular economy separated in design principles, material choice principles and process-related principles. Besides that, the knowledge collected through the literature review is used to formulate a first set of nine propositions regarding the implementation of circular economy principles within the real estate development process following the Delphi Method. Those propositions are presented to 21 experts of the field of circular economy and real estate development with different backgrounds, such as advisor, developer, architect, investor or contractor. Following the Delphi Method, they are asked separately for their opinion regarding the presented propositions. In the next step, their feedback is evaluated and the propositions are adapted for a second round of interviews in order to allow the experts to reconsider their answers. Based on the outcomes of the first and second round of Delphi interviews, a circular BPMN process diagram is created and guidance is formulated for professional real estate developers. The described process is presented in Figure 17 and will be illustrated in the following sections.

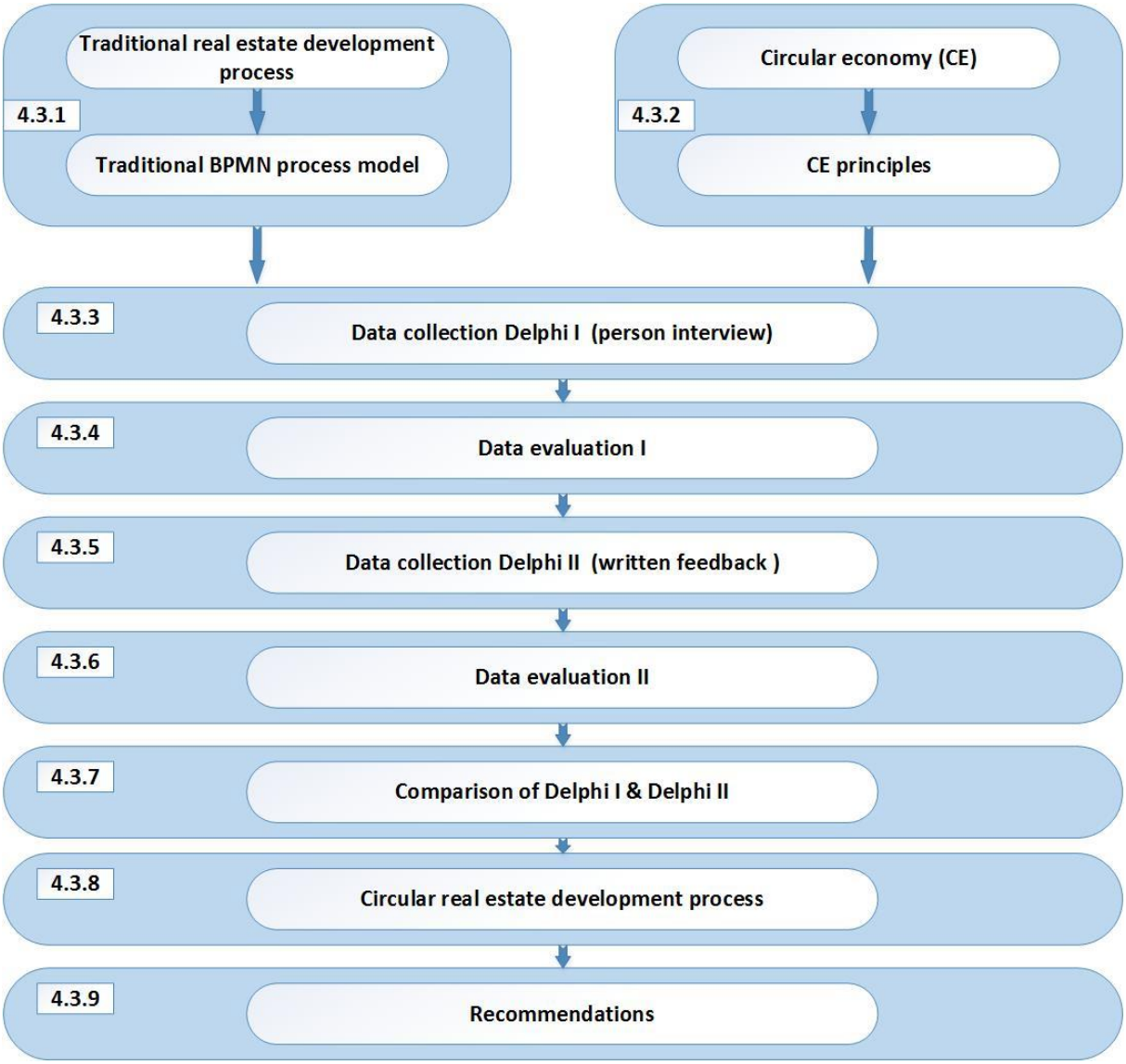

Figure 17: Research methodology

4.2.1 Business Process Modelling and Notation

The Business Process Modeling and Notation (BPMN) is a graphical method to present a business process including important stakeholders and their tasks along with responsibilities, interactions and outcomes. Significant icons are developed and need to be used to develop a process following this modelling notation norm. This standardized norm enables users around the world to understand the presented model within a short period of time. BPMN schemas however do show some limitations. They do not present state transition, functional decomposition, organizational hierarchies and data modelling. However, BPMN schemas are comparable to UML activity diagrams and flowcharts and are suitable both for the technical as the practical environment (IDM Technical Team, 2007).

The aim of developing both the traditional, as the circular process model within this modeling notation is to be able to compare the presented models on an equal basis. Furthermore, BPMN models are valued both in the scientific environment as are understandable for practitioners. Therefore, it will be easier to present the traditional model to respondents of

the questionnaire in order to create agreement about the traditional real estate development process.

In order to represent the business models both for the traditional real estate development process, as for the circular development process the notation standard of BPMN will be used. This is an easy-to-understand modelling standard both for experts as for non-experts, which aims at providing a wide range of information to a diverse audience (OMG, 2013). Up till now, BPMN models have been used widely within the field of computer science and information technology (Wong & Gibbons, 2011; López-Campos, Crespo Márquez, & Gómez Fernández, 2013; Solís-Martínez, Pascual Espada, Pelayo G-Bustelo, & Cueva Lovelle, 2014). Besides this, BPMN is used within the medical sector (Scheuerlein, et al., 2012). A first approach to use BPMN within the construction industry can be found by Kim et al. (2010), who used the BPMN methodology to represent the usual process for urban and environmental maintenance projects in order to improve the communication with stakeholders and create deeper understanding of the ongoing process (Kim, Choi, Son, & Ryu, 2010). In addition, a first approach can be found to use the BPMN methodology to model the design management of a sustainable building process (Rekola, Mäkeläinen, & Häkkinen, 2012). Within this study, the BPMN methodology was used as a tool to clarify the process and enable the formulation of observations and conclusions (Rekola, Mäkeläinen, & Häkkinen, 2012).

Following these examples, the BPMN methodology is used within this study to represent the traditional real estate development process in a detailed and yet comprehensive manner, which is understandable by all parties involved within the process. This methodology shows the advantages of being an international standard, intuitively understandable by all included parties, both by technical as business users, and can be constructed following a clear set of rules for notation (OMG, 2013; Rekola, Mäkeläinen, & Häkkinen, 2012). In the following sections a short description of the BPMN method and its construction rules is given.

4.2.1.1 Definition of BPMN

Business Process Model and Notation, often referred to with its acronym BPMN, is an established standard for business process modelling in economy and industry. It is used to describe and graphically represent complex processes including a wide range of information (Scheuerlein, et al., 2012; OMG, 2013). This modelling standard is suitable for all business users including the whole range from business analysts up till technical developers and process performers. Its purpose is to link designing a business process with its implementation in the daily business life (OMG, 2013). Furthermore, BPMN diagrams are used to get insights into the internal processes of companies to be enabled to communicate those insights towards collaboration partners and to justify internal needs within cooperation. Even though this modelling language shows data flows with associated information, the standard can't be used for operationally simulating, monitoring or deploying of business processes (OMG, 2013).

The first version of this modelling language has been developed by BPMI (Business Process Management Initiative Notation working group) since the beginning of the 2000-century and has finally been published in 2004. The current version 2.0 was further developed by the Object Management Group (OMG) (Fettke, 2008; OMG, 2013). The aim of the development of this modelling language was to worldwide standardize the representation of business

models. The activity diagrams of Unified Modelling language (UML) and the aim-oriented process chains had great influence on the developed BPMN standard. The graphical representation of a BPMN model is called a Business Process Diagram (BPD) (Fettke, 2008). Such BPDs can be used to represent organizational models and resources, functional breakdowns, data and information models, strategies and business rule models (OMG, 2013). As such, the models show who is doing what at what time (Sourdeau & Hegemann, 2010).

4.2.1.2 The graphical representation

It is the aim of a BPMN diagram to represent complex business processes in the form of simple and understandable business process models (OMG, 2013). To reach this simplification, a set of notation categories is determine(OMG, 2013)d, which can be found along with a short description in 'Appendix B - Methodology: BPMN standard' starting on page 141 The graphical representation in the form of BPDs consists of different elements, which can be summarized as swimming pools and swim lanes, activities, events, gateways, connecting objects and data objects.

The swimming pool describes a closed process, which typically takes place within an organization. Swim lanes are used to group the activities within different functional groups of a company. A message flow connects activities of different pools, whereas sequence flows connect activities within one pool including different lanes (Fettke, 2008).

Elements, which are used to describe business processes, include activities, events, and gateways. Activities describe tasks, which needs to be executed by the business. Events can represent the beginning or the end of a process, but also other important moments within the process. Gateway elements show moments of decisions, when a process may converge or diverge (Fettke, 2008).

Relations between such elements (activities, events, gateways) are represented by connecting objects. They include sequence flows, message flows and associations. A sequence flow describes the time related order of activities. A message flow shows the communication channel between activities of different process participants, who exchange messages. Associations are used to include additional information (Fettke, 2008).

Artefacts are used to describe context specific exceptions related to the business process. Those include data objects, groups and annotations. Data objects present the data necessary for or generated during the execution of an activity. Groups are used to summarize different concepts in one business process diagram for analysis and documentation purposes. Annotations allow adding additional information to certain concepts (Fettke, 2008).

To create a valuable BPMN diagram, the information need to be documented and modelled first, before the process is analyzed and simulated, validated and finally communicated (Sourdeau & Hegemann, 2010). More information regarding the construction rules of BPMN models can be found in the description of this standard, published by the Object Management Group (OMG, 2013).

4.2.2 Delphi Method

The Delphi Method can be described as a systematic procedure to obtain a reliable consensus based on the opinions of experts selected for an expert panel (Sourani & Sohail, 2015). The method was developed by the RAND Corporation during the 50s and 60s of the 20th century so that expert opinions could be collected and synthesized effectively (Gordon & Pease, 2006). The Delphi Method is used for future research related to decision making, planning and policy research (Gordon & Pease, 2006). Often, the method is used for situations in which agreed knowledge is lacking or considerable uncertainty is identified (Sourani & Sohail, 2015). Furthermore, Sourani and Sohail (2015) identified the method of being suitable to obtain information, which are expensive or even unavailable, to handle complex problems and to combine fragmented knowledge of different perspectives to reach a collective understanding. Besides that, the method can be used to create a real world model including different points of view when established quantitative evidence is available only limited (Sourani & Sohail, 2015).

The Delphi Method is characterized with anonymity since respondents of the questionnaire are contacted separated from each other and their names are not known to other respondents of the research (Martino, 1983; Robinson, 1991; Sourani & Sohail, 2015). In this way influential factors, such as status, dominance of powerful group members or group pressure are eliminated (Mullen, 2003; Sourani & Sohail, 2015). Besides that, the Delphi Method can be used to indicate the group opinion in the form of statistical group response by showing the variation within the group response statistically (Sourani & Sohail, 2015).

4.2.2.1 Qualitative research method

Even though there are possibilities for quantitative research within the Delphi Method, it is mostly described as an qualitative research method (Sourani & Sohail, 2015). Due to its dual character, this method shows some advantages compared with a questionnaire survey. As this, complex problems are better understandable and the interaction with respondents is closer (Mullen, 2003).

4.2.2.2 Use in the field of construction

The method of Delphi Method has been used in limited manners in construction-related research up till now (Sourani & Sohail, 2015). Some research indicated the little use for construction law (Chong & Zin, 2010) and for construction engineering and management research (Hallowell & Gambatese, 2010). However, examples have been found, in which the Delphi method was used for bridge condition rating, effects improvement, theory and design applications, as well as development of residential areas (Yeung, Chan, & Chan, 2009). Fields, which could be suitable to use this research method within the field of construction management, could cover amongst others risk management, contractor selection, procurement system selection and sustainability (Sourani & Sohail, 2015).

4.2.2.3 Expert selection

The participants of the research are experts, which are selected based on their expertise and knowledge related to the research question (Gordon & Pease, 2006; Martino, 1983). This is done due to the fact, that this method is especially developed for fields of research, which are not common knowledge and their research requires therefore expert knowledge

(Sourani & Sohail, 2015). For a successfully executed research a minimum number of eight respondents is mentioned in literature (Martino, 1983; Hallowell & Gambatese, 2010).

Besides the willingness and availability of experts, their knowledge or level of expertness is crucial for including them in the study (Martino, 1983). This expertise can be characterized by the number of publications within the field of study, professional eminence, membership in related professional organizations, recommendations and peer judgement, presentations given at national conventions, honors of professional societies or selection as expert by media, the number of years of relevant experience, a self-rating of available expertise, patent holding or being a faculty member of related educational institutes (Sourani & Sohail, 2015; Martino, 1983; Shon & Swatman, 1998; Khosrow-Pour & Herman, 2001; Cabanis, 2002; Rogers & Lopez, 2002; Mullen, 2003; Scholl, König, Meyer, & Heisig, 2004; Henchion & McIntyre, 2005; Hallowell & Gambatese, 2010). Besides these experience-related criteria, experts are mostly chosen from different relevant backgrounds and positions so that all important aspects of the topic are present (Scholl, König, Meyer, & Heisig, 2004; Henchion & McIntyre, 2005). Another option is to create a pool of experts and select participants randomly for the research (Sourani & Sohail, 2015).

4.2.2.4 Method procedure

The Delphi Method is executed in several rounds, in which experts of the research field are asked to state their opinion regarding certain propositions and validate those propositions based on the group outcomes in the later rounds. There are no clear arguments, how many rounds should be executed, examples between two rounds and seven are found in literature (Yeung, Chan, & Chan, 2009). However, some studies indicate, that an overall goal should be formulated and to stop the iterative process when this goal is met (Sourani & Sohail, 2015). Such a goal can be reaching consensus, which can be calculated as a percentage of respondents agreeing with a certain answer or expressed as a standard deviation value, which indicates the range of differing from the mean value(in (Sourani & Sohail, 2015): (Robinson, 1991; Mullen, 2003)). Furthermore, as few as possible rounds should be executed to prevent fatigue by respondents and secure the willingness of respondents to participate in all rounds (Gunhan & Arditi, 2005; Yeung, Chan, & Chan, 2009).

4.2.2.5 Round one

During the first round of the research, the experts are confronted with a questionnaire regarding the research topic (Sourani & Sohail, 2015). While some literature refers to the need to use open-ended questions in the first round to identify important, relevant issues for the study, some accompany the open questions with a list of issues based on literature to choose from or to inspire the respondents. Again, others use close-ended questions with categorized answer possibilities using for example the categorized Likert-type scale already in the first round (Sourani & Sohail, 2015; Mullen, 2003).

The Likert scale is used to evaluate in how far a respondent agrees with a certain proposition (Theuns, 2000). Mostly four till five response-alternatives are used, which range for example from ‘not important’ till ‘extremely important’ or from ‘highly agreed’ till ‘disagreed strongly’ (Theuns, 2000; Sourani & Sohail, 2015).

4.2.2.6 Consecutive rounds

The answers of the first round of questionnaire are collected and analyzed. In the second round the respondents are confronted again with a questionnaire including the newly gathered information of the groups' collective opinion from the first questionnaire. Based on this, the asked experts are enabled to reconsider their opinions of the first round. This iterative process continues for every expert separately until the set goal is reached (Sourani & Sohail, 2015). . The advantage of this is, that an useful opinion is more likely to be reached instead of a fast agreement. Furthermore, this method is made self-evaluating throughout the different rounds (Sourani & Sohail, 2015; Yeung, Chan, & Chan, 2009). The collection of the necessary input of experts for this method is done mostly through questionnaires. However examples for the use of structured and semi-structured interviews can be found as well in literature (Sourani & Sohail, 2015).

4.2.2.7 Adapted approach for this research

For this study, a slightly adapted approach of the Delphi Method is chosen due to the limitations in the available timeframe and number of experts available. For this research, two consecutive rounds of feedback-collection are executed contacting the same experts. The experts are purposely selected based on their role within the real estate development process and their experience and knowledge about circular economy. During the first round, all experts are confronted individually with nine propositions regarding the implementation of the circularity principles within the real estate development process. They indicate their level of agreement with the proposition and give a short explanation for their judgement. These interviews are executed as semi-structured interviews personally or via phone. Based on the evaluation of the first round, the propositions are adapted to fit better with the overall expert opinion found throughout the first round. In a second round, all experts are confronted with the adapted propositions and asked to indicate again, in how far they agree with the proposition. During both rounds, a 5-point-Likert scale is used reaching from total agreement till total disagreement and including a neutral option. Those outcomes are analyzed statistically by calculating the mean value and standard deviation according to Sourani and Sohail (2015). In the second round, the experts are confronted with a comparison of their own indicated evaluation and the evaluation of all respondents including the mentioned reasons. In this way, it can be analyzed, whether experts adopt their opinion based on the overall opinion. Likewise, different opinions based on the profession of the experts can be distinguished.

4.2.3 Expert Interviews

As indicated before, the interviews of the first round are executed in the form of semi-structured interviews. This qualitative research method is chosen in order to collect all relevant information during a one-by-one personal meeting based on a pre-defined interview guide. In comparison with structured interviews this method gives more freedom to the researcher to ask follow-up questions, which are not included in the interview guide, but seem to be relevant for the researcher (Cohen & Crabtree, 2006). This is important for this study since available information regarding a circular real estate development process known upfront are limited, so a less structured form of interviews should be chosen (Baarda, de Goede, & Teunissen, 2005). As an interview guide, nine propositions are worked out. Besides this, a general part with person-related questions is added, as well as the open question regarding the completeness of the list of circularity principles. The interview guide, which was

sent upfront the interview, can be found in 'Interview guide Delphi I' starting on page 152. In order to focus on the content of the interview, all interviews are recorded under the agreement of the interviewee.

For the second round of the Delphi method an online-survey is chosen in order to limit the time-afford necessary per respondent to prevent fatigue by respondents and secure the willingness of respondents to participate in the second round (Gunhan & Arditi, 2005; Yeung, Chan, & Chan, 2009).

4.3 Research process results

In the following sections, the various steps as shown in Figure 17 will be described and results of the steps will be presented.

4.3.1 Traditional real estate development process

The traditional real estate development process as presented by Nozeman (2009) and Ratcliffe, Stubbs and Shepherd (2004) consists of four phases with the initiative phase, development phase, construction phase and the exploitation phase. The different phases of the real estate development process are presented in section 3.2.5. The process itself is iterative by nature and includes many different stakeholders with many different interests. Based on the project conditions, a large variation of process models can be drawn. Within this study, the following boundary conditions are assumed:

- The development process is done from the perspective of the professional developer.
- The research is focused on housing in the free rental sector with real estate containing of several apartments.
- The development is initiated by the municipality, which provides developed land.
- The future owner (investor of professional housing agency) is already known at the beginning of the project.
- The development process focusses on the cooperation between the parties, excluding financial and legal process components.
- A traditional form of contracting is assumed.

4.3.1.1 BPMN

The research method of Business Process Modelling and Notation (BPMN) is used both to present the traditional as the circular real estate development process in the form of a process map including the most important functions, tasks, documents and relations. Following the description of the traditional real estate development process presented in 'Chapter 3: Real Estate Development Process' and the standards for creating a BPMN schema, as being summarized in BPMN standard on page 141, the first BPMN model was constructed. In order to evaluate the literature-based model it was presented to professionals from 'Hurks Vastgoedontwikkeling'. Furthermore, it is chosen to focus on the main activities within the process schema. Additional information regarding the presented tasks and relations can be found in the description of the traditional real estate development in 'Chapter 3: Real Estate Development Process' starting on page 39. The BPMN schema includes an indication of the overall phases on top of the diagram. The colors used for such phases are used also for the tasks within the process schema. The overview schema is presented in Figure 18. More detailed schemas of the sub-processes can be found in Appendix A - Real estate development process starting on page 135.

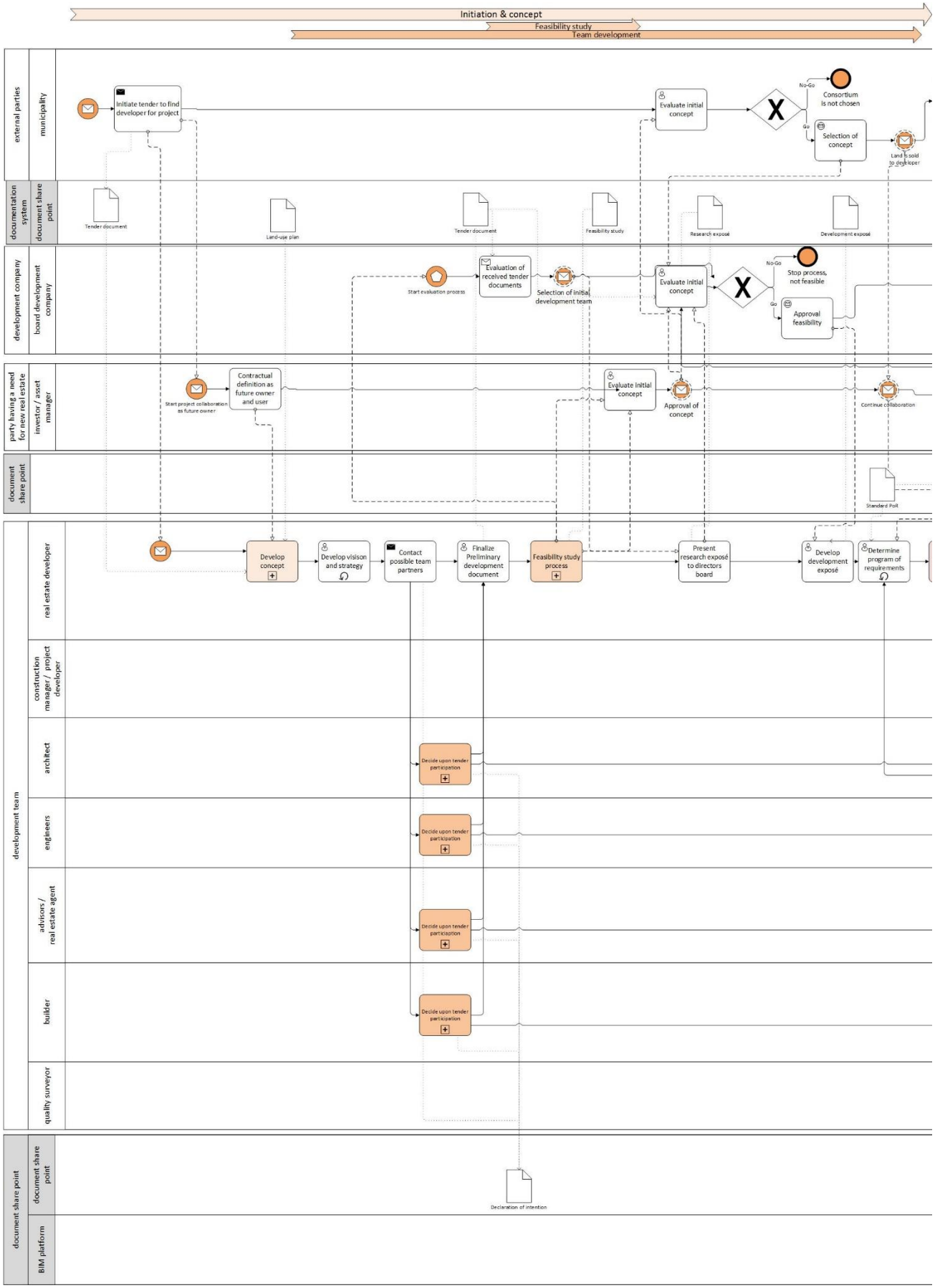

Figure 18: BPMN schema traditional real estate development process –first part

The original of this schema can be found on the attached CD as 'traditional BPMN'.

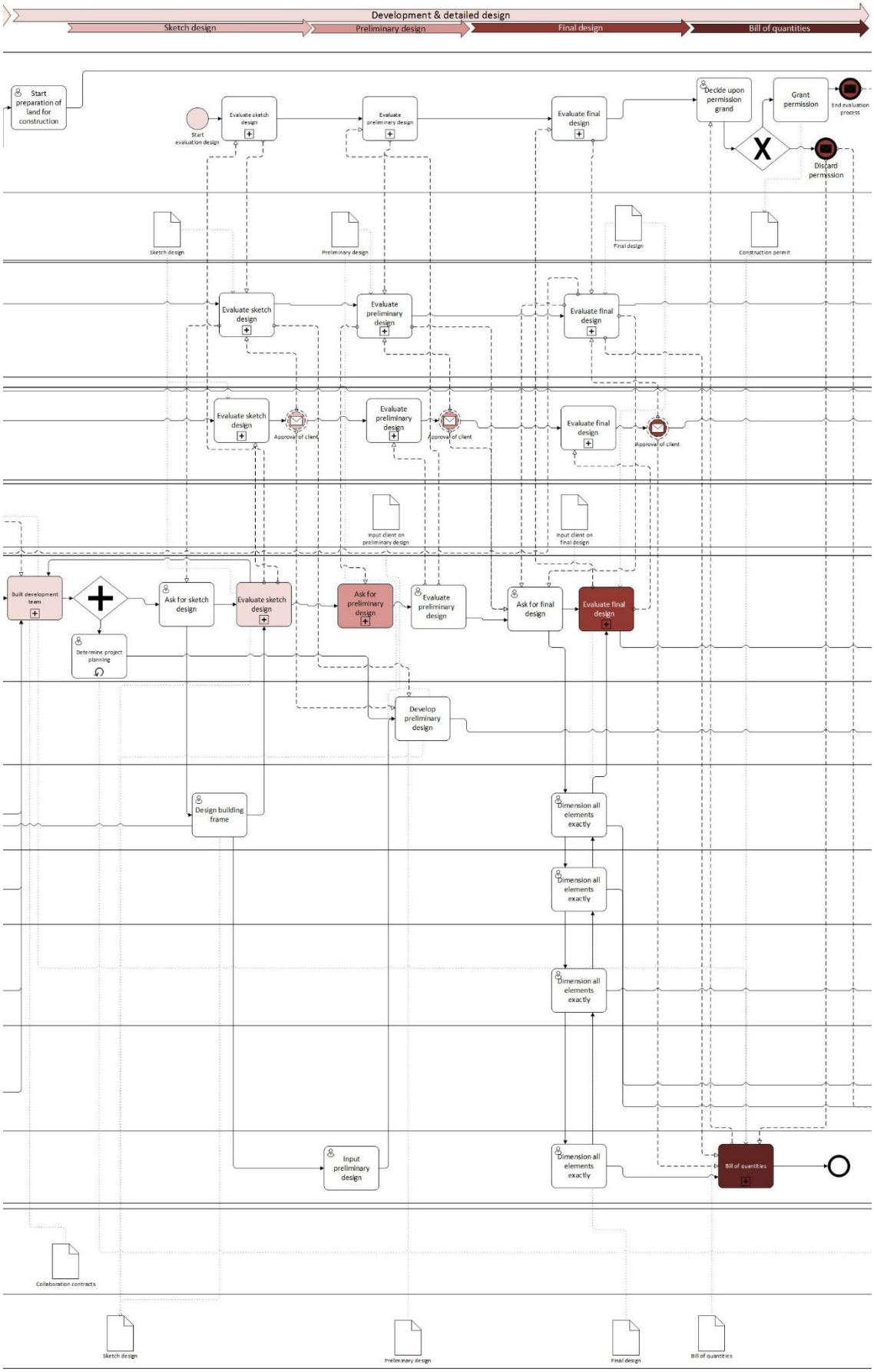

Figure 18: BPMN schema traditional real estate development process –middle part

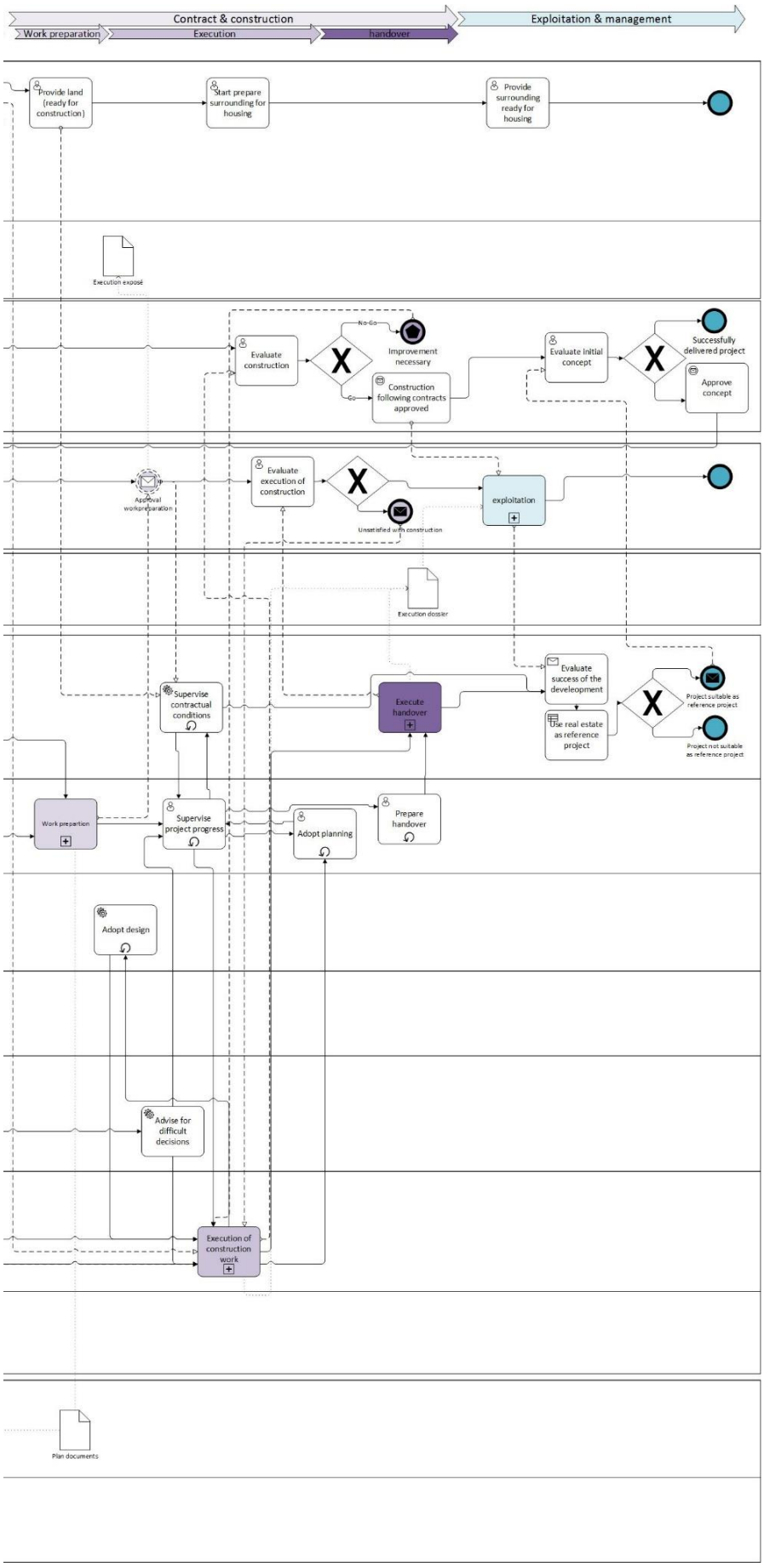

Figure 18: BPMN schema traditional real estate development process –last part

4.3.2 Circular economy

The concept of circular economy is a holistic approach, which is defined differently by various experts. For this study the definition of the Ellen MacArthur Foundation is considered: “A circular economy is an industrial system that is restorative or regenerative by intention and design (…). It replaces the ‘end-of-life’ concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models.” (Ellen MacArthur Foundation, 2013a, p. 7). Based on a broad literature review, a long list of circularity principles is collected, which is clustered into design-principles, principles related to the material choice and process-related principles. The three tables presenting those principles considered for the further research are summarized in Table 2, Table 3 and Table 4.

4.3.3 Data collection Delphi I

Based on the knowledge gathered during the literature study about the traditional real estate development process and the concept of circular economy, nine propositions are developed to be presented to field experts following the methodology of Delphi.

4.3.3.1 Questionnaire

The first round of the Delphi method is executed by personal semi-structured interviews with experts of the field of circular economy and real estate development with different professional backgrounds. All interviews took place in July and August 2016 as one-by-one interviews or based on an interview by phone. All experts were selected based on their personal experience and reputation in the field of construction following circularity and contacted personally to ask for their support of this research. An overview of all participating experts is presented in Table 23 on page 143.

To prepare for the interview, all experts received a short summary of main starting points, the traditional real estate development process and the definition of circular economy used for this study. Furthermore, upfront the interview they already received the interview guide including general questions regarding their person and personal experience in the field of real estate development and circular economy, as well as the question to evaluate the proposed list of circularity principles regarding completeness. Furthermore, the interview guide included the nine proposed statements.

Before sending the documents and executing the interviews, the documents and included propositions were presented to two practitioners to evaluate the understandability of the document and to guarantee, that the interview can be held within one hour if wished by the expert. A summary of the executed interviews can be found in ‘Appendix B - Methodology in Interview evaluation’ starting on page 143. All documentation was given in Dutch, as nearly all experts speak Dutch as their native language. Also, all interviews took place in Dutch.

The original documents of the given introduction, as well as the original questionnaire formulated in Dutch can be found in ‘Appendix B - Methodology’. The following nine propositions are presented to the experts during the mentioned interviews:

1. The most important stakeholder to reach a circular real estate development process is the real estate developer. The real estate developer is in contact with all other stakeholders and therefore needs to introduce the circular principles at first and needs to asks others to do so as well.
2. During the initiation phase, development phase and construction it is most important that the building fits with the design principles of 'design for disassembly' and 'adaptability', that materials are chosen, which fit within the cycles and that a strong communication takes place within the development team. Then, the client or future owner does not need to be concerned during the development, since every wish is suitable in the developed concept.
3. It is important to introduce the design principles already during the initiation phase within the concept development, even if there is no collaboration with other stakeholders yet and even if this leads towards higher costs for construction.
4. Process-related principles are especially relevant for the composition of a development team and during the execution of construction. During all other phases, such as design development, bill of quantities, exploitation and end-of-life, such principles are less important.
5. The programme of requirements is one of the most important documents in the real estate development process. Therefore, it is essential that design principles (such as 'design for disassembly', adaptability, no fixed connections of material), but also principles for the choice of material are adapted in the form of performance requirements.
6. During the phase of design development, mainly the design principles of 'design for reuse' and 'design for disassembly' are important, just as the process-related principles of 'collaboration with chain partners' and 'exchange of information'. Other design and process-related principles are by far less important, just as the choice for certain materials.
7. During the work preparation and work execution, process-related principled need to be used to support the communication. Furthermore, it is important that work performers understand the design principles and that fitting materials are chosen following the circular principles for material choice during the work preparation. Their influence during the initiation phase and design development needs to be increased.
8. It is important, that users or owners understand all principles of circular buildings in order to continue their validity from the development during the exploitation phase. This refers to replacing parts, updating the material passport and the economic and sustainable treatment of raw materials and waste.
9. In comparison with the traditional process, there need to be an additional phase of end-of-life for the circular real estate development process. During this phase mainly 'reverse logistics' and 'products as service' are important.

For all of these propositions the experts are asked whether they agree or don't agree with the proposition on a five-point-scale. Furthermore, they are asked to give a short motivation of their response. Due to this, the interviews can be called semi-structured, since the researcher used the given propositions and additional general questions to structure the interview in the form of an interview guide. Likewise, this form of interviewing allows the researcher to ask further to deepen the understanding of the experts' opinion (Verberne, 2016).

4.3.4 Data evaluation I

The answers of the interviews are evaluated in two manners. First, the descriptive statistics provide an overview of the type of respondents, demographic distribution and their experiences of real estate development and circular economy. Secondly, the question regarding circularity principles and their feedback regarding the proposed propositions are evaluated in order to reach more alignment through adaption of the propositions for the second round of Delphi.

4.3.4.1 Descriptive statistics

In total 21 interviews were held, of which 15 were conducted personally and six via phone. 18 interviewees were male (85.7% of all respondents) and 3 respondents were female. 14.3% of all respondents were younger than or exactly 30 years old, 47.6% were between 31 and 40 years old, 33.3% were between 41 and 50 years old and only 1 respondent or 4.8% were older than 50 years. Whereas, the topic of circular economy is introduced just recently, it seems to catch the attention of a large group of professionals from different groups of age. However, the group of respondents does not reflect the demographics of the Dutch population.

Furthermore, the group consisted of four developers, five consultants and/or researcher, two employees of municipalities, two architects, three engineers, three professionals from construction companies and two investors. This means, that more or less equal groups of respondents are included with backgrounds positioned in the main areas of the traditional real estate development process.

Overall, 23.8% of the respondents indicated less than 5 years of experience within real estate development, 38.1% indicated 5-10 years, 4.8% indicated 11-15 years of experience, 14.3% indicated 16-20 years of experience and 19% indicated more than 20 years of experience. With more than 70% of the respondents indicating at least 5 years of experience in real estate development, the reference group can be called experienced.

Regarding the question, whether the experts have experience in the field of circular economy, 19 agreed, only 2 respondents said, that they had no experience. However, both of them indicated, that they are experienced in sustainability within their field of profession and that they have knowledge about the concept of circular economy. Due to this, it was decided, that all responses, also the ones of those two respondents are considered for the evaluation. Furthermore, it need to be mentioned, that the range of experience indicated by the other 19 respondents was very widespread. While some have been working on it theoretically, others participated in the first circularity projects in the Netherlands, which follow at least partly the principles of circular economy. Others are also known for their publications about the topic or as speakers attending conferences about circular economy or participating in circular economy initiatives.

Therefore, it can be assumed, that the group of respondents represents all different functions indicated as being important during the traditional real estate development process. Furthermore, they can be described as being experienced both in real estate development, as with the concept of circular economy and can therefore contribute to this study on an expert level.

As mentioned before, a minimum number of 8 respondents should be interviewed for a successfully executed Delphi method (Martino, 1983; Hallowell & Gambatese, 2010). For this study, it was chosen to contact more potential respondents in order to be able to interview at least 2 experts per function. With focusing on the 7 functions developers, consultants and/or researchers, employees of municipalities, architects, engineers, professionals from construction companies and investors a minimum number of 14 respondents was aimed for. Since it has to be expected, that some respondents of the first round might not respond any more for the second round, additional experts were included in the study, which led finally to 21 interviews for the first round.

4.3.4.2 Circularity principles

Following the feedback during the expert interviews, several comments were given regarding the completeness and structure of the list of circularity principles. In total 19 experts indicated possibilities to optimize the list of principles based on their personal opinion. Some experts only indicated a few additional principles, whereas some indicated changes in the form of clustering the principles and representing them.

In order to change the structure on how the principles are presented, different approaches have been mentioned. Some indicated, that principles should be summarized more. Others said, that design and material choice principles should be combined in one list. Others suggested to structure the principles following the circles indicated by the so-called butterfly diagram published by the Ellen MacArthur Foundation (see Figure 3). The adapted overview based on these comments is shown in Table 6 and Table 7.

Table 6: Building-related circularity principles

	Building-related circularity principle
Maintenance	Design for maintenance and repair
	Design to lengthen lifecycle
	Minimize energy use
	Use of materials of high quality
	Use of biologically degradable materials
Reuse / redistribution	Design for reuse
	Prevent fixed connections
	Use of standardized, modular elements
	Design to enable top-up
Refurbish / remanufacture	Design for disassembly
	Reduce used material mass
Recycle	Reduce energy use
	Use of recycled materials
	Reverse logistics

Table 7: Process-related circularity principles

	Process-related principle
Framework conditions	Human-centric development
	Use only renewable energy
	Use of locally available materials
	Prevent harmful emissions
	Change of tax-system towards work instead of material
Collaboration	Long-term collaboration with chain partners
	Information exchange and maintenance via BIM model & material passport incl. engineering knowledge
	Circular business case based on TCO concepts
	Product as service

Another approach was to see circularity of buildings as part of a 'circular city'. Due to that, six overall-topics for circularity are defined, namely 1) energy, 2) water, 3) society, 4) material, 5) mobility and 6) biodiversity (Delva Landscape Architects; Metabolic; Studioninedots; stimuleringsfonds creative industrie, 2016). Based on these six topics, the circularity principles can be clustered to reach not only a circular building, but also a circular city. Since this study focusses on the circularity of the real estate development process, this approach is not followed-up further on.

Besides this, the suggestion was given to cluster the principles for circular economy following the input-categories of labor, material, energy and information (see Table 8). Those principles are relevant at different points within the traditional real estate development process. A graphical representation of the relevant timeframe is shown in Figure 19. Figure 19 indicates the starting point of relevance of the principles based on the traditional development process, along with the relevance-duration of the principle.

Table 8: Circularity principles following the input-category

Circular design principles	**Measures to realize principles**
Flexibility (reduce labor input)	Design for reuse
	Design for disassembly
	Prevent fixed connections
	Interchangeability of components
	Adaptability
	Design to lengthen lifecycle
	Design for maintenance and reparation
Material incl. water	Reduce material mass
	Use of biodegradable materials
	Cradle2cradle materials
	Prevent materials not fitting within the biological/technical circles
	Use of recycled materials
	Use of locally-available materials
	Prevent dangerous emissions
	Reduce waste
	Reverse logistics

Energy	Prevent energy use
	Use purely renewable energy
Information	Collaborate with chain partners
	Information exchange
	BIM model
	Resource passport
	Circular business cases
	Product as service

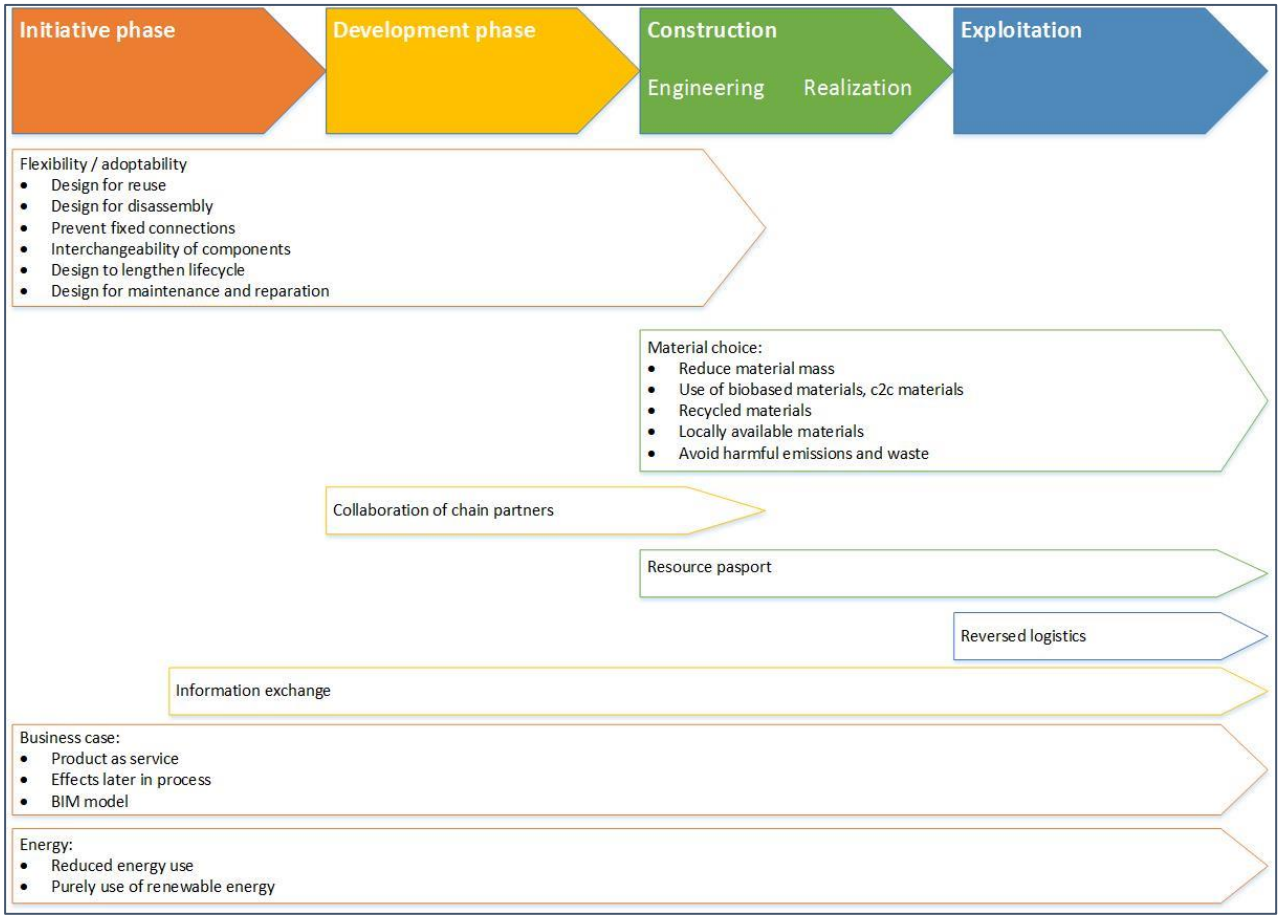

Figure 19: Circularity principles throughout the development process

4.3.4.3 Statistical evaluation

In order to evaluate the collected expert opinions regarding the nine propositions, the distribution of answers is analyzed. Further, the Likert scale is transformed as indicated in Table 9.

Table 9: Transformation table Likert scale

Translated answer	Likert value
Totally disagree	-2
Disagree	-1
Neutral	0
Agree	1
Totally agree	2

All responses are transformed to Likert values, which are used to calculate the mean value and the standard deviation. Furthermore, the explanations given for the expert's evaluation is coded into several reasons per proposition. Those coded reasons are used to analyze the relation between expert function and answers, as well as reasons and Likert value per proposition. A summary of the outcomes is presented in the next sections.

Codebook

In order to analyze the given motivation of their evaluation of the propositions, the answers are summarized in key notes. Based on these, general reasons for agreement or disagreement and restrictions to them are summarized and coded in the form of a codebook. A summary of all codes can be found in 'Appendix B - Methodology' on page 158.

Reasons, which are mentioned at least by 10 respondents are considered highly frequented mentioned. Reasons, which are mentioned at least 6 times, are considered as average frequent and still relevant. Reasons, which are mentioned less often, are considered not relevant for the total feedback. Since many respondents mentioned more than one reason for their feedback, the percentage of appearance for one reason compare to all mentioned reasons is calculated as well. Here, reasons covering at least 20% of all mentioned reasons are considered highly important, reasons covering at least 10% are considered important and all others are considered negligible.

Proposition 1

The most important stakeholder to reach a circular real estate development process is the real estate developer. The real estate developer is in contact with all other stakeholders and therefore needs to introduce the circular principles at first and needs to asks others to do so as well.

As shown in Figure 20, the largest part of the respondents agreed with the proposition, that the real estate developer is the most important stakeholder within the real estate development process. However, only a small group of about 10% agreed totally with the proposition. Many other respondents indicated a restriction to their agreement. Overall, the mean value for this proposition accounts to 0.36, which means an overall tendency towards agreement since the value is greater than 0. The standard deviation is 1.153 and the variance 1.329. This indicates, that quite a wide spectrum of answers was given, as shown in Figure 20.

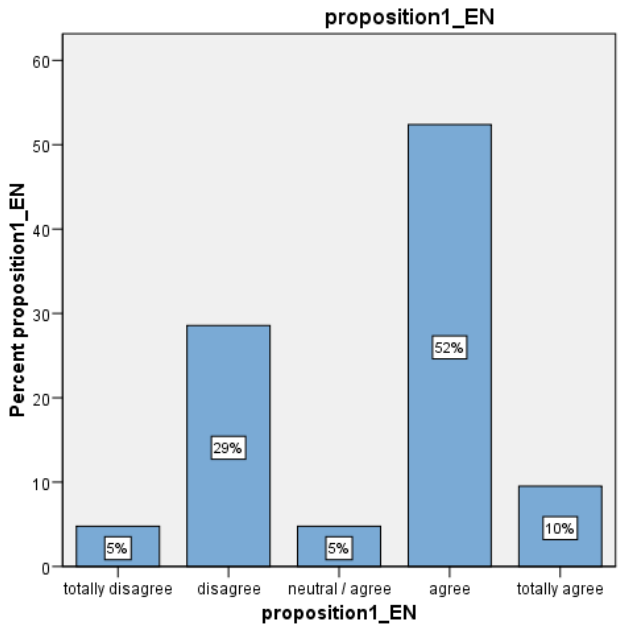

Figure 20: Evaluation distribution proposition1

The most important reasons mentioned overall have been:

1. Reason1.1: the real estate developer is important, but he need to collaborate with other parties (mentioned 10 times, 21% of all mentioned reasons)
2. Reason1.3: the client is the most important stakeholder, as carrying the risks for the development (mentioned 7 times, 15% of all mentioned reasons)
3. Reason1.6: the real estate developer is central for the organization of the process as he keeps the overview over the finance and construction execution (mentioned 7 times, 15% of all mentioned reasons)
4. Reason1.5: the real estate developer need to have knowledge and a preference for circularity principles (mentioned 6 times, 13% of all mentioned reasons)

As shown in Table 10, reasons 1.1 was most mentioned by respondents agreeing with the proposition. The same accounts for reason 1.3 and reason 1.5. However, all of these reasons have been mentioned also by respondents, who indicated disagreement with the proposition. Only reason 1.6 was purely mentioned by respondents agreeing with the proposition.
Therefore, no clear tendency can be given, whether those reasons indicate agreement or disagreement.

Table 10: Cross table: reasons-expert feedback (proposition1)

	Totally disagree	Disagree	Neutral/agree	Agree	Totally agree
Reason1.1	0	1	1	8	0
Reason1.3	0	3	0	2	2
Reason1.5	0	2	0	4	0
Reason1.6	0	0	0	7	0

Based on this feedback, a new proposition is formulated:

The most important stakeholder for any development process is the client as carrying the risk for the development. In the case of real estate development, the client can be the real estate developer, who guides the process together with other parties. The client need to have knowledge and a preference for circularity in order to be the first to introduce the circular principles and needs to ask others to do so as well.

Proposition 2

During the initiation phase, development phase and construction it is most important that the building fits with the design principles of 'design for disassembly' and 'adaptability', that materials are chosen, which fit within the cycles and that a strong communication takes place within the development team. Then, the client or future owner does not need to be concerned during the development, since every wish is suitable in the developed concept.

As shown in Figure 21, this proposition triggered a rather negative feedback with far more answers of disagreement with over 80% of all responses. The average Likert score is -0.76, which expresses the same tendency as mentioned before. The standard deviation accounts for 0.831 and the variance for 0.69, which is relatively small. That means, that respondents are closer to alignment here compare to proposition 1.

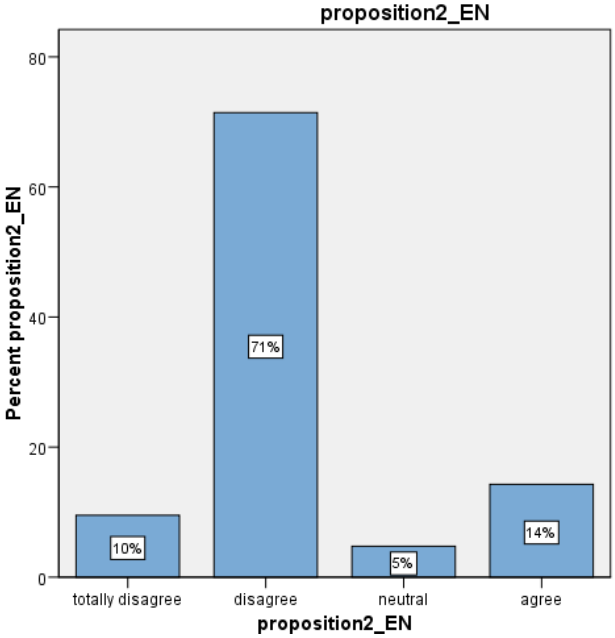

Figure 21: Evaluation distribution proposition2

The most important reasons mentioned as feedback by expert interviews are (see Table 11):

1. Reason2.1: the client and his wishes need to be considered in any case (mentioned by 16 experts accounting for 34% of all mentioned reasons)
2. Reason2.2: those principles are important to be considered (mentioned by 11 experts, accounting for 23% of all mentioned reasons)
3. Reason2.9: the client need to be considered at the beginning and his wishes need to be remembered throughout the development (mentioned by 6 experts accounting for 13% of all mentioned reasons)
4. Reason2.4: it is important to think about the modularity of the building early in the process(mentioned by 5 experts and accounting for 11% of all mentioned reasons)

Table 11: Cross table: reasons-expert feedback (proposition2)

	Totally disagree	Disagree	Neutral	Agree
Reason2.1	2	11	1	2
Reason2.2	2	5	1	3
Reason2.4	1	3	0	1
Reason2.9	0	5	0	1

Based on the evaluation of expert opinions, the proposition is transformed towards:

During the initiation phase, development phase and construction it is important that the building fits with the design principles of 'design for disassembly', 'adaptability' and 'modularity', and that materials are chosen, which fit within the biological or technical cycles. Besides, a strong communication is necessary within the development team. The wishes of the client and his priorities need to become clearly defined already at the beginning of the process, during the initiative phase. He needs to be participating throughout the whole process, but during development, realization and exploitation phase his role is rather of an evaluating nature.

Proposition 3

It is important to introduce the design principles already during the initiation phase within the concept development, even if there is no collaboration with other stakeholders yet and even if this leads towards higher costs for construction.

As shown in Figure 22, the largest part of all respondents indicated agreement or even total agreement with the proposition with about 80% of all respondents. Only about 14 % indicated disagreement. Based on this, the mean Likert value accounts to 1.05, the variance to 1.048 and the standard deviation to 1.024. This means, that there is a clear tendency towards agreement with a mean value greater than zero. Likewise, a great variation is found between the answers given and little alignment.

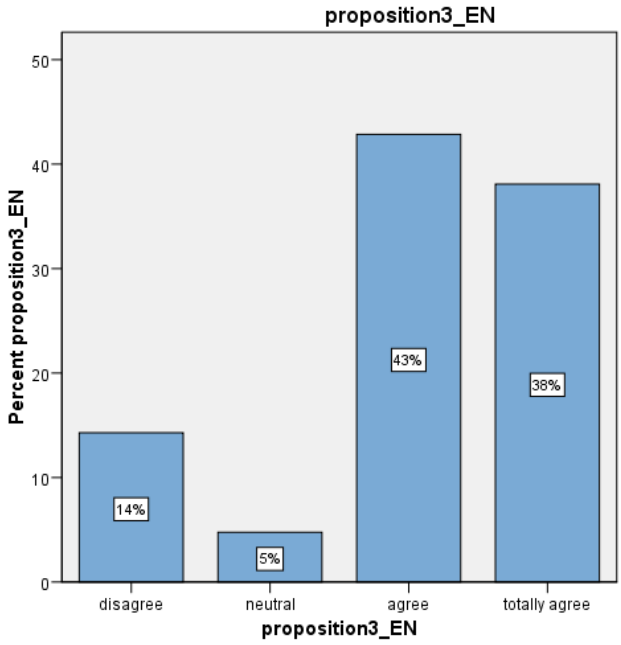

Figure 22: Evaluation distribution proposition3

As indicated by the experts, the following three reasons where mentioned most often:

1. Reason3.1: concept need to be introduced early on to take all chances (mentioned by 20 experts out of 21, 31% mentioned based on all mentioned reasons)
2. Reason3.2: the ambition need to be defined at the beginning of the process together with the client and the fitting principles need to be defined (mentioned by 17 experts, indicates 27% of all mentioned reasons)
3. Reason3.5: building circular can lead towards higher costs for construction, which can be earned back through lower costs during the exploitation phase (mentioned by 8 experts, indicating for 13% of all mentioned reasons)

As shown in Table 12, no clear relation can be found between the mentioned reasons and the evaluation of the proposition.

Table 12: Cross table reasons-expert feedback (proposition3)

	Disagree	Neutral	Agree	Totally agree
Reason3.1	2	1	9	8
Reason3.2	2	1	8	6
Reason3.5	2	0	3	3

Based on the expert feedback, the following new proposition is formulated:

It is important to introduce the design principles already during the initiative phase within the concept development, even if there is no collaboration with other stakeholders yet. To do so, the most important principles need to be defined together with the client. To develop real estate following the rules of circularity can lead towards higher costs for the construction depending on the project conditions. Those higher construction costs need to meet with lower costs mainly during the exploitation phase, so that total investment costs are lower than for traditionally built real estate.

Proposition 4

Process-related principles are especially relevant for the composition of a development team and during the execution of construction. During all other phases, such as design development, bill of quantities, exploitation and end-of-life, such principles are less important.

This proposition showed the most alignment in expert opinions. All experts indicated disagreement (57%) or even total disagreement (43%) throughout all functional backgrounds, as shown in Figure 23. With a mean value of -1.43 and a very small standard deviation of 0.507 and variance of 0.257, a high degree of alignment is measured between all expert opinions.

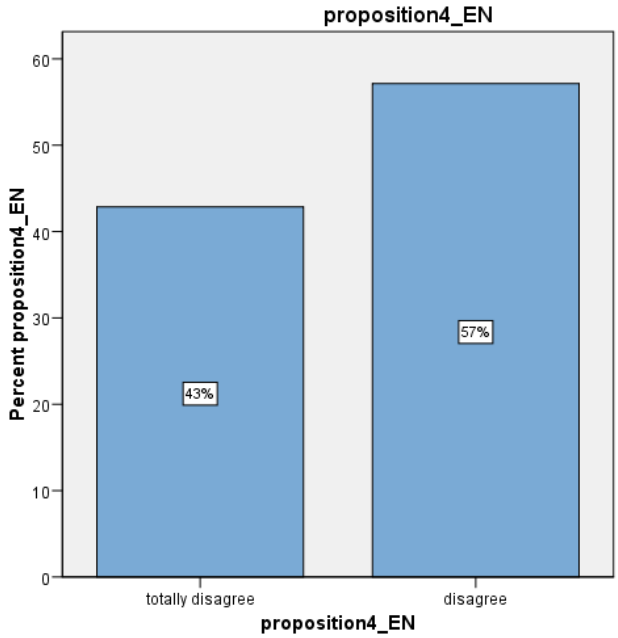

Figure 23: Evaluation distribution proposition4

In total 8 different reasons for disagreement were mentioned, of which the following three should be mentioned:

1. Reason4.4: those principles are relevant for all phases (mentioned by 13 experts accounting for 35% of all mentioned reasons)
2. Reason4.6: the selection of principles depends on the project conditions and need to be chosen at the beginning of the process (mentioned by 8 experts accounting for 22% of all mentioned reasons)
3. Reason4.1: those principles are of high importance for the exploitation phase (mentioned by 6 experts accounting for 16% of all reasons)
4. Reason4.2: those principles are of high importance for the end-of-life (5 experts, 14% of the mentioned reasons)

Here, it need to be indicated, that five times, experts mentioned reason 4.1 and 4.2 together. Furthermore, no clear relation can be found between the mentioned reasons and the evaluation of the proposition, as shown in Table 13.

Table 13: Cross table: reasons-expert feedback (proposition4)

	Totally disagree	Disagree
Reason4.1	2	4
Reason4.2	2	3
Reason4.4	7	6
Reason4.6	2	6

Based on the given feedback, the following adapted proposition is formulated:

Process related principles are important for the whole process of development and all phases need to be seen as one process. The selection of circularity principles is dependent on the project conditions and need to be agreed upon at the beginning of the process.

Proposition 5

The programme of requirements is one of the most important documents in the real estate development process. Therefore, it is essential that design principles (such as 'design for disassembly', adaptability, no fixed connections of material), but also principles for the choice of material are adapted in the form of performance requirements.

As shown in Figure 24, this proposition 5 shows about 62% of agreement, 24% of total agreement and only 14% of disagreement. Therefore, the mean value accounts to 0.95, with a variance of 0.848 and standard deviation of 0.921. This indicates a light tendency towards agreement with quiet a variation of answers.

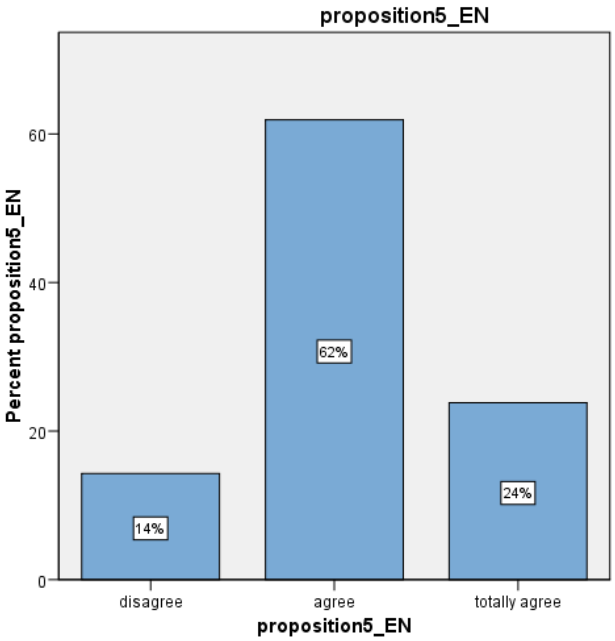

Figure 24: Evaluation distribution proposition5

Based on the 10 mentioned reasons, two showed a high frequency with more than 10 times mentioned:

1. Reason5.4: the programme of requirements is an important document (mentioned by 16 experts, accounting for about 30% of all mentioned reasons)
2. Reason5.3: the programme of requirements need to be open for new innovations (mentioned by 12 experts, accounting for 22% of all mentioned reasons)

Furthermore, two reasons have been mentioned each by 7 experts, accounting for 13% of all mentioned reasons:

3. Reason5.1: performance-based procurement enables more innovations
4. Reason5.8: it need to be clear, what the wishes are and what the hard requirements are within the programme of requirements

Reason5.1 was only mentioned in the case of agreement with the proposition. All other reasons were mentioned likewise for overall agreement and disagreement, as shown in Table 14.

Table 14: Cross table reasons-expert feedback (proposition5)

	Totally disagree	Agree	Totally agree
Reason5.1	0	4	3
Reason5.3	1	8	3
Reason5.4	2	9	5
Reason5.8	1	3	3

Based on this analysis, the proposition is adapted towards:

The programme of requirements is one of the most important documents in the real estate development process. Within this document, wishes and requirements need to be formulated performance-oriented in order to stay open for future innovations. Other important documents are a circular business case, a vision or ambition document and the contract.

Proposition 6

D*uring the phase of design development, mainly the design principles of 'design for reuse' and 'design for disassembly' are important, just as the process-related principles of 'collaboration with chain partners' and 'exchange of information'. Other design and process-related principles are by far less important, just as the choice for certain materials.*

As shown in Figure 25, a large variation of responses has been given by the 21 experts. About 24% indicated total disagreement, 38% disagreement, 24% neutrality, 10% agreement and only 5% total agreement. Due to that, it can be already concluded, that more disagreement than agreement has been indicated, leading to a mean value of -0.67. The variance accounts for 1.233 and standard deviation for 1.111. Not only based of these numbers, but also based on Figure 25, a great variation between the expert opinions and with this little alignment can be indicated.

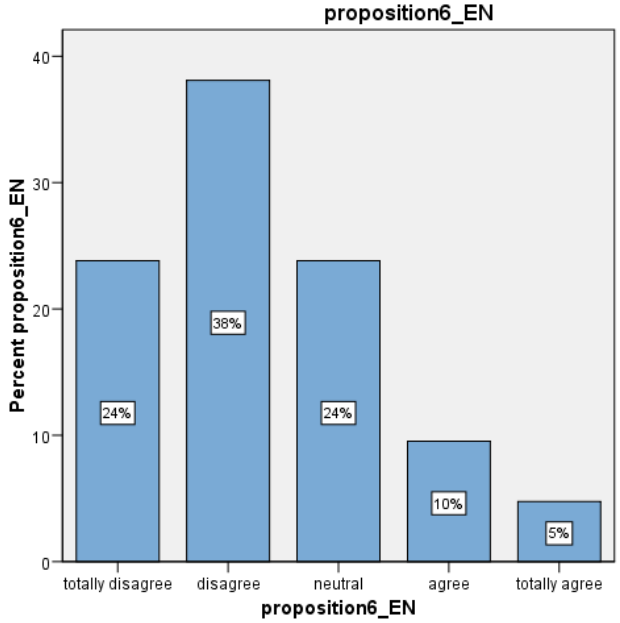

Figure 25: Evaluation distribution proposition6

In opposite to this wide range of general evaluations, only 7 reasons were indicated for their evaluation, of which two show high importance and one show still notably importance.

1. Reason6.1: those reasons are not the only important principles (mentioned by 18 experts accounting for 41% of all mentioned reasons)
2. Reason6.4: material choice is important as well (mentioned by 11 experts accounting for 25% of all mentioned reasons)
3. Reason6.3: process-related principles are important as well (indicated by 5 experts, accounting for 11% of all mentioned reasons)

As shown in Table 15, all of these three reasons were mentioned in relation with all states of evaluation from total disagreement till total agreement. The reasons for total agreement are not covered within those three most important reasons.

Table 15: Cross table: reasons-expert feedback (proposition6)

	Totally disagree	Disagree	Neutral	Agree	Totally agree
Reason6.1	4	8	5	1	0
Reason6.3	2	1	1	1	0
Reason6.4	2	6	2	1	0

Based on this evaluation, proposition 6 is changed towards:

During the initiative phase and development, all circularity principles need to be kept in mind. Depending on the project conditions and focused on the future user, the most important principles need to be chosen and adapted in order to satisfy the needs of future users.

Proposition 7

During the work preparation and work execution, process-related principled need to be used to support the communication. Furthermore, it is important that work performers understand the design principles and that fitting materials are chosen following the circular principles for material choice during the work preparation. Their influence during the initiation phase and design development needs to be increased.

Proposition 7 was indicated with total disagreement by 5%, with disagreement by 24%, with neutrality by 10%, with agreement by 33% and by total disagreement by about 29% of all experts as shown in Figure 26. Due to that, slightly more agreement than disagreement was indicated for this proposition with a mean value of 0.57. With a variance of 1.657 and a standard deviation of 1.287, a large variation and little alignment is found within all responses.

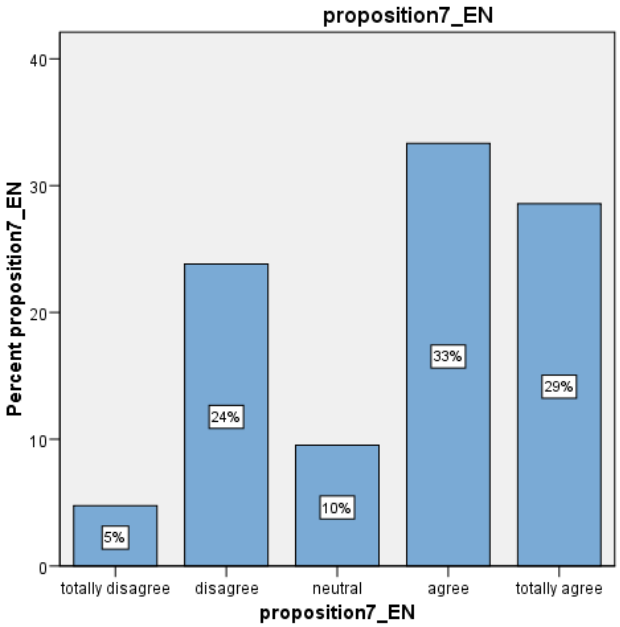

Figure 26: Evaluation distribution proposition7

Just as varied as the overall evaluation is also the variation of the reasons with 7 reasons mentioned. One of them should be indicated as important:

1. Reason7.1: the executor need to be actively included in the team early on (mentioned by 12 experts, accounting for 39% of all mentioned reasons)

Other, less important but still noticeable reasons have been:

2. Reason7.6: standardized concepts need to be developed. Here the executors should attend to support the concept development. (mentioned by 6 experts, accounting for 19% of all reasons)
3. Reason7.3: not the work executor, but the project manager from the construction company (mentioned by 5 experts accounting for 16% of all mentioned reasons)

Based on these three reasons, the cross table presented in Table 16 indicate that reason 7.1 is only mentioned for overall neutrality or agreement, whereas reason 7.3 and reason 7.6 are mentioned for the whole range of evaluation.

Table 16: Cross table reasons-expert feedback (proposition7)

	Totally disagree	Disagree	Neutral	Agree	Totally agree
Reason7.1	0	0	1	7	4
Reason7.3	1	2	0	1	1
Reason7.6	0	3	1	2	0

Based on this, the following adapted proposition has been formulated:

Employees of the builder show a lot of knowledge regarding the execution of construction tasks. In order to guarantee, that all possibilities for innovations are used and to prevent counteraction against the developed concept, they need to be included already during the development phase. If a standardized concept is developed, an employee of the contractor need to participate. This can be the executor or project manager depending on his knowledge.

Proposition 8

It is important, that users or owners understand all principles of circular buildings in order to continue their validity from the development phase towards the exploitation phase. This refers to replacing parts, updating the material passport and the economic and sustainable treatment of raw materials and waste.

As shown in Figure 27, the largest part of all respondents indicated agreement with this proposition (about 62%) or total agreement (14%). Only 19% indicated disagreement and 5% neutrality. This leads towards a mean value of 0.71, variance of 0.914 and standard deviation of 0.956. Compare to proposition 7 for example, this indicates more alignment between the expert opinions.

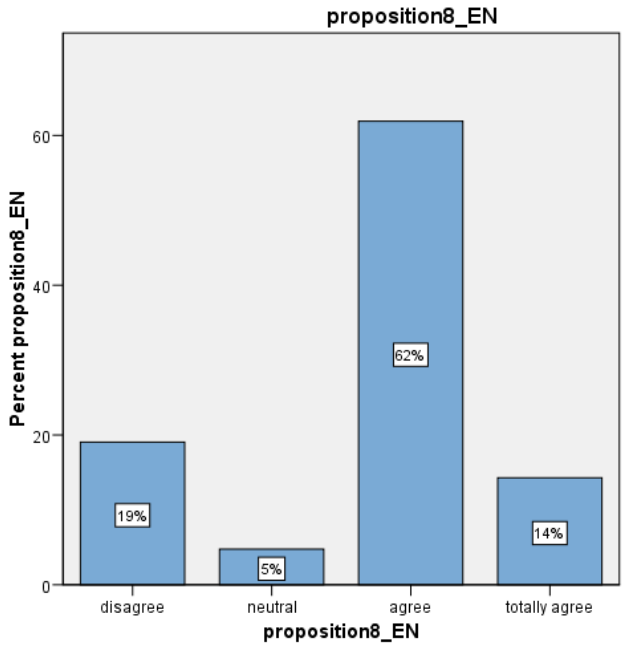

Figure 27: Evaluation distribution proposition8

Three of the 8 mentioned reasons can be indicated as important:

1. Reason8.1: tenants do not need to be confronted with too technical details, but mainly with principles, which are relevant for their living environment so that it stays nice to live there (mentioned by 17 experts accounting for 32% of all mentioned reasons)
2. Reason8.3: the owner of the building is responsible to communicate the most important principles towards the tenants and need to actively supervise changes in the building and assist the tenant in executing changes (mentioned by 11 experts accounting for 21% of all mentioned reasons)
3. Reason8.5: a professional party, such as a facility manager / asset manager need to maintain the circularity of the building

Besides these reasons, also reason8.7 should be considered for the evaluation of the experts feedback with

4. Reason8.7: the tenant and owner need to maintain the principles based on their personal interest for it, not due to an obligation (mentioned by 6 experts accounting for 11% of all mentioned reasons)

As shown in Table 17 all reasons have been mentioned in combinations with the whole range of agreement till disagreement.

Table 17: Cross table reasons-expert feedback (proposition8)

	Disagree	Neutral	Agree	Totally agree
Reason8.1	4	1	10	2
Reason8.3	2	0	8	1
Reason8.5	2	0	7	2
Reason8.7	1	0	5	0

Based on this, the adapted proposition is formulated as:

It is important, that likewise users as owners understand the principles of circular buildings, which are of relevance for them. Therefore, a user need to know mainly principles related to his direct living environment, whereas the owner focusses on the value conservation of his building. Depending on the knowledge of the owner regarding circularity a professional party should be hired for maintenance and repair in order to guarantee the circular characteristics of the building.

Proposition 9

In comparison with the traditional process, there need to be an additional phase of 'end-of-life' for the circular real estate development process. During this phase mainly ' reverse logistics' and 'products as service' are important.

Overall, a higher tendency towards agreement ca be found for this proposition against about 38% of the experts indicating disagreement. About 29% of the experts indicated total agreement, 24% agreement, 5% neutrality till agreement and only 5% neutrality. Based on this, a mean value of 0.45, a variance value of 1.648 and a standard deviation of 1.284 can be found. This indicates, that the overall opinion is close to neutral with a slight tendency towards agreement (mean value 0.45), whereas the variation of expert opinion is very large (see Figure 28).

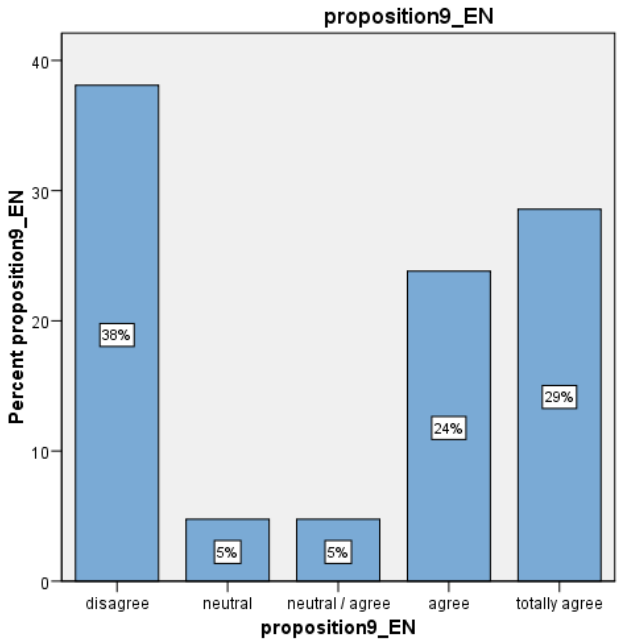

Figure 28: Evaluation distribution proposition9

Six different reasons have been indicated by experts to argue in favor of their evaluation of the proposition. Amongst them, 2 reasons need to be considered highly important:

1. Reason9.1: this final phase of the cycle is important, but future developments are difficult to predict (existence of project partners, responsibility for last phase) (mentioned by 17 experts accounting for 44% of all mentioned reasons)
2. Reason9.6: it's important to ensure, that elements and materials can be separated at the end of use (mentioned by 16 experts accounting for 41% of all mentioned reasons)

Besides this, one more reason should be considered as important:

3. Reason9.2: end-of-life is not a separate phase, but is part of the circle (mentioned by 10 experts accounting for 26% of all indicated reasons)

As shown in Table 18 no relation can be found between the indicated reason and the overall expert opinion regarding the proposition.

Table 18: Cross table reasons-expert feedback proposition9

	Disagree	Neutral	Neutral / agree	Agree	Totally agree
Reason9.1	5	0	1	5	6
Reason9.2	6	1	0	2	1
Reason9.6	6	1	1	3	5

Based on this feedback, the original proposition is changed towards:

In order to close the lifecycle for real estate, it is important that the end-of-use of building elements are considered as well. However, developments are difficult to predict, especially for elements with long lifespans. The question "what will happen at the end-of-use of elements or the building as a whole" need to be considered already during the development phase within the design. In the design, loose connections, flexibility, adaptability and modularity need to be considered. Within this, it is important to include maintenance parties and owners of elements early in the process.

Comparison professional background – proposition evaluation

Based on the evaluation of the presented nine propositions and the experts' professional background a short evaluation took place in order to analyze, whether a relation can be found. As shown in Table 19, sometimes very strong relations have been found (dark blue), sometimes only weak relations have been found (light blue) and sometimes, no relation could be found (grey). As such, a strong relation was indicated, when all experts of this professional background indicated exactly the same evaluation. A weak relation was indicated when the experts with this background indicated the same overall evaluation, which could be overall agreeing or disagreeing. A grey marking was indicated, when agreeing and disagreeing evaluations where given.

Table 19: Comparison professional function - evaluation proposition

relation	architect	construction company	consultant	developer	engineer	investor	municipality
Proposition1							
Proposition2							
Proposition3							
Proposition4							
Proposition5							
Proposition6							
Proposition7							
Proposition8							
Proposition9							

No relation between functional background and evaluation of proposition
Overall same evaluation with same background
Exactly same evaluation with same background

Conclusion statistical evaluation

Only proposition4 showed a very high level of alignment for all expert opinions with a variance of 0.257. However, this was a high level of alignment, that experts did not agree with the proposed proposition. That means, that an adaption of the proposition might most probably lead towards a more varied picture, since people did not agree with the proposition because of different reasons. For all other propositions, statements of agreement and disagreement were given likewise with more or less clear tendencies. However, it has been seen, that experts indicated the same reasons in the case of agreement or disagreement due to different perceptions on how to fill in the questionnaire. Some indicated agreement, but mentioned a concession, while others indicated in the same situation disagreement since they did not fully agree with the proposition stated. This behavior can explain quiet a range of the variation of the answers. The second round of interviews and its evaluation based on adapted propositions will show whether more alignment was reached.

Based on this evaluation, it can be concluded, that the professional background of the interviewed experts showed little effect on the stated opinion and the argumentation for it (see Table 19). However, it need to be remembered, that only very small groups of two till five

people were contacted per professional function. Therefore, these data cannot be seen as representative or generally applicable for the seven function groups included in this survey. Just as there is a great variation in the professional background of the experts, they do show different opinions regarding circularity. As such, some indicate, that circularity need to be introduced on the meta-level of a neighborhood or whole city, whereas others focus on the circularity of the building itself. Some show a clear preference for material streams, whereas some choose a broader approach also including water, biodiversity and society. Even though such great variation is found between the 21 experts interviewed, they give valuable insight in a circular real estate development process based on their different functional backgrounds, former experiences and knowledge.

4.3.4.4 General feedback

In addition to these proposition-specific feedback, general feedback is collected from the experts. Covering the topics of general definition, development focus, building circular, collaboration and information exchange, contracting, finances and development process, a very short summary can be found hereafter. A more elaborated summary of the experts' comments can be found in 'Appendix B - Methodology: Comparison professional background – proposition evaluation' starting on page 166.

General definition

Circularity is a holistic approach, which is filled in differently by every expert. As such the concept of circular economy can be described as a process optimization on project level or on the system level as changing material locations. The circular economy concept asks for a new mind-set.

Development focus (purpose)

The purpose of a circular development can follow different purposes, which include value creation, solving the waste issue, prevent toxicity, develop human-centric under the use of biobased materials, develop based on a circular city concept or purely as circular real estate. Finally it need to be decided, how circularity and sustainability are approached. Overall, it need to be said, that broad variation of interpretations of circularity focusses exist. Therefore, it is important to choose the focus for the project and its conditions early in the process.

Building circular

Building circularly is greatly based on the separation of building elements based on their technical lifespans following the concept of Brand (1994) or on system level following the concept of Durmisevic and Brouwer (2002). Depending on the layer within the building, different parties are relevant to create and continue circularity. The future of building circular lays in building in a standardized and modular manner.

Collaboration / information exchange

It is important to form a development team early on in the process, based on the ambition of the client, the willingness of every single party to be open for innovative solutions and the trust in their partners to share also sensible information. Likewise, a good process structure and regular feedback sessions, also with the client are important. In order to exchange building-related information, a dynamic BIM model can be useful, especially for new

constructions. Besides material-related information, the BIM model should also include engineering information.

Contracting
Contracting is an important aspect to implement circularity principles since it indicates, which parties take responsibilities for certain risks. Here, the possibility for circular business cases based on lease contracts need to be remembered. Depending on the form of contract, the collaboration of chain partners will be distinguished as well.

Finances
Finances are important to create attractiveness of the circularity concept based on new revenue models, the investment needs throughout the process, the total-cost-of-ownership approach and as part of the total business case for the project.

Development process
During the initiative phase it is indicated to be important, that the ambition is formulated early on by the client and his development team. Furthermore, it is important to take the necessary time to make well-thought-through decisions. During the development phase, the ambition formulated during the initiative phase need to become concrete. Predefined principles need to be used. Likewise, an open mind for new solutions and alternatives should be maintained. During the construction phase, the planning made during the development phase need to be executed based on the circularity principles agreed upon within the development team. During the exploitation phase, steps of maintenance, reuse, remanufacture and recycling appear due to the different life- and use-spans per element. Therefore, clear responsibilities need to be defined per element for maintaining the circular character. This includes a professional maintenance party, the tenant, the owner of the building, but also suppliers, producers and construction companies.

4.3.5 Data collection Delphi II

In order to perform the second round of data collection, all given feedback of the first round is collected, analyzed and coded in order to reformulate the propositions used during the first round of interviews. In order to simplify the response of the second questionnaire, an online tool was used to create the questionnaire, in which every experts only needs to indicate his level of agreement with the statement. Additional information regarding the motivation of the answer do not need to be given, which enables respondents to answer the whole questionnaire within 5 till 10 minutes. Since every respondent already took the time for a personal first interview, this efficient way was chosen for the second round. Pictures of the slides of the online-survey can be found in ‘Appendix B - Methodology: Questionnaire Delphi II’ starting on page 178. The questionnaire was formulated in Dutch.

In order to inform every expert, a personal e-mail was sent including a short evaluation of the first interviews (see ‘Appendix B - Methodology: Questionnaire Delphi II – informative document’ starting on page 173), the experts’ evaluation of the first list of propositions and his personal information to be presented within this report. Besides this, the link for the online-survey was sent.

The nine adapted propositions are (translated from Dutch to English):

1. The most important stakeholder for any development process is the client as carrying the risk for the development. In the case of real estate development, the client can be the real estate developer, who guides the process together with other parties. The client need to have knowledge and a preference for circularity in order to be the first to introduce the circular principles and needs to ask others to do so as well.
2. During the initiation phase, development phase and construction it is important that the building fits with the design principles of 'design for disassembly', 'adaptability' and 'modularity', and that materials are chosen, which fit within the biological or technical cycles. Besides, a strong communication is necessary within the development team. The wishes of the client and his priorities need to become clearly defined already at the beginning of the process, during the initiative phase. He needs to be participating throughout the whole process, but during development, realization and exploitation phase is role is rather of an evaluating nature.
3. It is important to introduce the design principles already during the initiative phase within the concept development, even if there is no collaboration with other stakeholders yet. To do so, the most important principles need to be defined together with the client. To develop real estate following the rules of circularity can lead towards higher costs for the construction depending on the project conditions. Those higher construction costs need to meet with lower costs mainly during the exploitation phase, so that total investment costs are lower than for traditionally built real estate.
4. Process related principles are important for the whole process of development and all phases need to be seen as one process. The selection of circularity principles is dependent on the project conditions and need to be agreed upon at the beginning of the process.
5. The programme of requirements is one of the most important documents in the real estate development process. Within this document, wishes and requirements need to be formulated performance-oriented in order to stay open for future innovations. Other important documents are a circular business case, a vision or ambition document and the contract.
6. During the initiative phase and development, all circularity principles need to be kept in mind. Depending on the project conditions and focused on the future user, the most important principles need to be chosen and adapted in order to satisfy the needs of future users.
7. Employees of the builder show a lot of knowledge regarding the execution of construction tasks. In order to guarantee, that all possibilities for innovations are used and to prevent counteraction against the developed concept, they need to be included already during the development phase. If a standardized concept is developed, an employee of the contractor need to participate. This can be the executor or project manager depending on his knowledge.
8. It is important, that likewise users as owners understand the principles of circular buildings, which are of relevance for them. Therefore, a user need to know mainly principles related to his direct living environment, whereas the owner focusses on the value conservation of his building. Depending on the knowledge of the owner regarding circularity a professional party should be hired for maintenance and repair in order to guarantee the circular characteristics of the building.
9. In order to close the lifecycle for real estate, it is important that the end-of-use of building elements are considered as well. However, developments are difficult to predict,

especially for elements with long lifespans. The question “what will happen at the end-of-use of elements or the building as a whole” need to be considered already during the development phase within the design. In the design, loose connections, flexibility, adaptability and modularity need to be considered. Within this, it is important to include maintenance parties and owners of elements early in the process.

4.3.6 Data evaluation II

All 21 experts contacted during the first round of Delphi were asked to fill out the online questionnaire. In total 19 experts started to fill out the questionnaire, of which 1 did not complete it. This respondent indicated his opinion for the first statement only. His answer is taken into account as a percentage of all answered responses. Missing cases are excluded for the evaluation per question individually.

In total, the group of respondents consisted of 2 architects, 3 employees of construction companies, 4 consultants plus 1 consultant, who started answering the questionnaire, 3 developers, 3 engineers, 2 investors and 1 employee of municipality. Due to this, it need to be remembered, that the following outcomes cannot be seen as representative for these function groups, but indicate the personal opinions of the participating experts and the overall opinion of the group.

As shown in Table 20, less grey fields can be found compare to Table 19, which indicates, that overall more relation is found between the professional background and the evaluation of the proposition. The clear indication of strong relation for the municipality is explainable by the fact, that this category is only represented by one respondent. So, this need to be ignored. A greater level of alignment is found between the two investors and the two architects.

Table 20: Comparison professional function - evaluation proposition

relation	architect	construction company	consultant	developer	engineer	investor	municipality
Prop1_new							
Prop2_new							
Prop3_new							
Prop4_new							
Prop5_new							
Prop6_new							
Prop7_new							
Prop8_new							
Prop9_new							

No relation between functional background and evaluation of proposition
Overall same evaluation with same background
Exactly same evaluation with same background

Proposition 1

The most important stakeholder for any development process is the client as carrying the risk for the development. In the case of real estate development, the client can be the real estate developer, who guides the process together with other parties. The client need to have knowledge and a preference for circularity in order to be the first to introduce the circular principles and needs to ask others to do so as well.

As shown in Figure 29,in total 63% of all 19 respondents indicated agreement, 3% total agreement 26% and 11% disagreement. This leads to a mean value of 1.05 with a standard deviation of 0.848 and a variance of 0.719. This shows a clear tendency towards agreement with the statement.

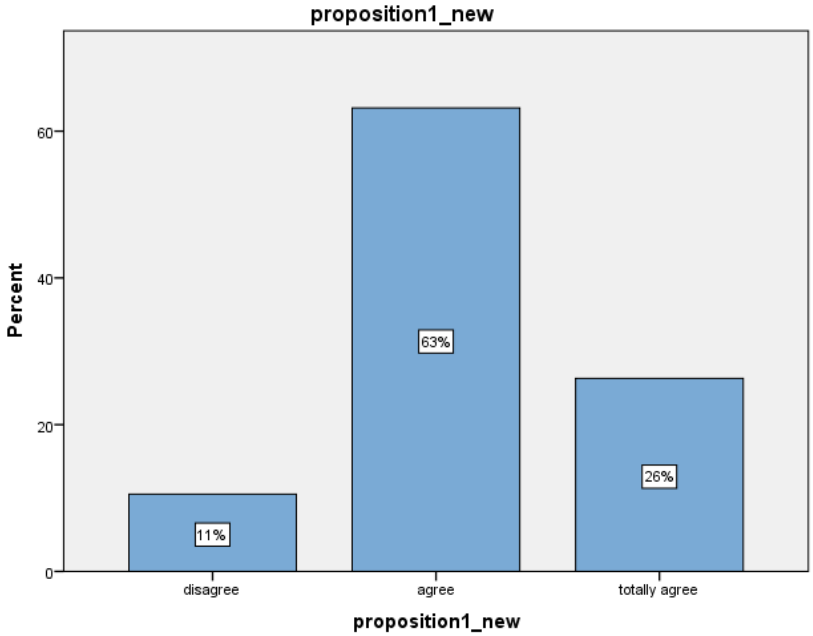

Figure 29: Evaluation distribution proposition1_new

Proposition2

During the initiation phase, development phase and construction it is important that the building fits with the design principles of 'design for disassembly', 'adaptability' and 'modularity', and that materials are chosen, which fit within the biological or technical cycles. Besides, a strong communication is necessary within the development team. The wishes of the client and his priorities need to become clearly defined already at the beginning of the process, during the initiative phase. He needs to be participating throughout the whole process, but during development, realization and exploitation phase is role is rather of an evaluating nature.

As shown in Figure 30, 78% of all 18 responding experts agree with the statement and 17% indicate even total agreement. Only 6% indicated disagreement, which leads towards a man value of 1.06, a standard deviation of 0.639 and an variance of 0.408, which indicates a high level of alignment.

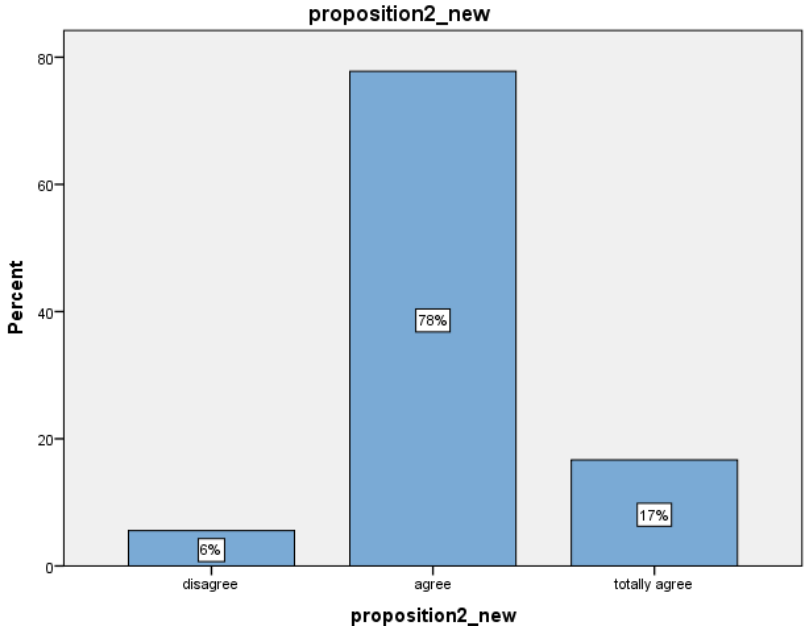

Figure 30: Evaluation distribution proposition2_new

Proposition3

It is important to introduce the design principles already during the initiative phase within the concept development, even if there is no collaboration with other stakeholders yet. To do so, the most important principles need to be defined together with the client. To develop real estate following the rules of circularity can lead towards higher costs for the construction depending on the project conditions. Those higher construction costs need to meet with lower costs mainly during the exploitation phase, so that total investment costs are lower than for traditionally built real estate.

As shown in Figure 31, a total of 89% of the 18 respondents indicate overall agreement with the statement, of which 33% even indicate total agreement. However, 2 respondents or 11% indicated disagreement. Due to that, the overall mean value for this statement accounts for 1.11 with a standard deviation of 0.900 and a variance of 0.810.

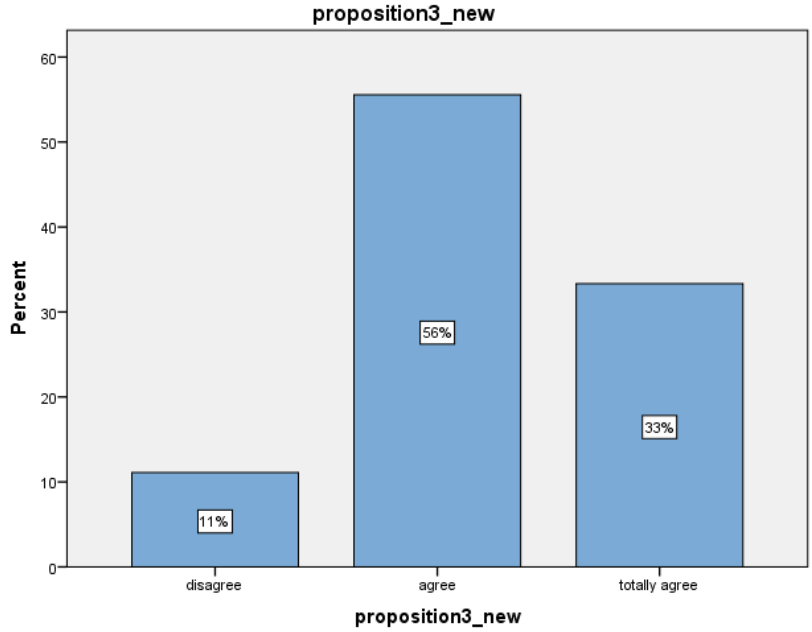

Figure 31: Evaluation distribution proposition3_new

Proposition4

Process related principles are important for the whole process of development and all phases need to be seen as one process. The selection of circularity principles is dependent on the project conditions and need to be agreed upon at the beginning of the process.

As shown in Figure 32, three respondents or 17% of the 18 respondents indicated likewise neutrality as total agreement. 61% indicated agreement with the statement, which leads towards a mean value of 1.06. The standard deviation accounts for 0.639 and the variance for 0.408, which indicate a rather high level of alignment.

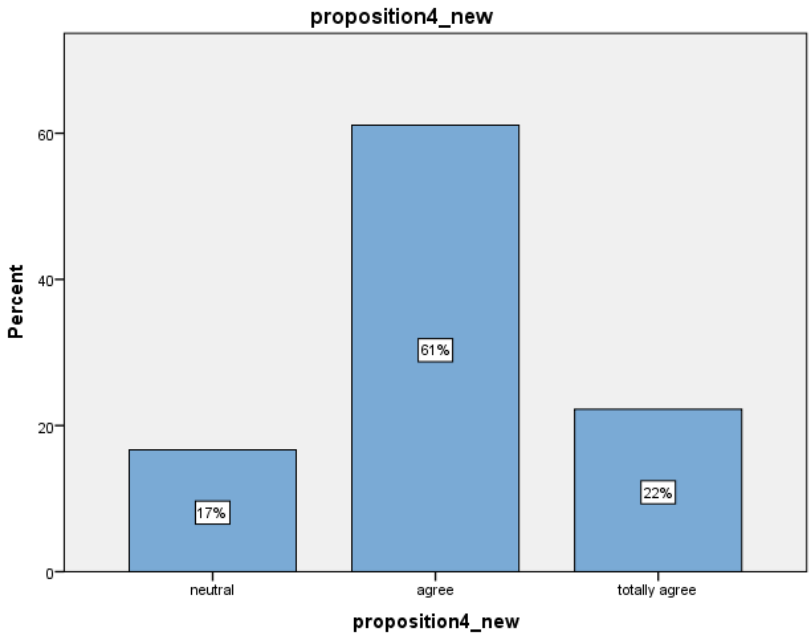

Figure 32: Evaluation distribution proposition4_new

Proposition5

The programme of requirements is one of the most important documents in the real estate development process. Within this document, wishes and requirements need to be formulated performance-oriented in order to stay open for future innovations. Other important documents are a circular business case, a vision or ambition document and the contract.

As shown in Figure 33, a total of 44% of all 18 respondents agreed with the statement and even 44% of all respondents indicated even total agreement. Only 2 respondents or 11% indicated a neutral opinion leading towards a mean value of 1.33 with an standard deviation of 0.686 and a variance of 0.471.

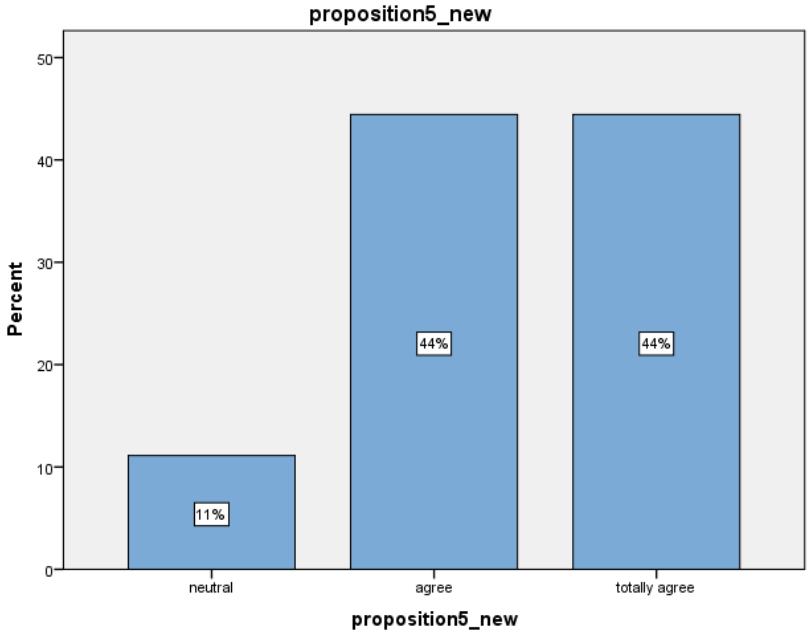

Figure 33: Evaluation distribution proposition5_new

Proposition6

During the initiative phase and development, all circularity principles need to be kept in mind. Depending on the project conditions and focused on the future user, the most important principles need to be chosen and adapted in order to satisfy the needs of future users.

As shown in Figure 34, a great majority of 72% of all 18 respondents indicated agreement with the statement. Additionally 22% even indicated total agreement and only 6% indicated neutrality. Due to that, a mean value of 1.17 is reached with a standard deviation of 0.514 and a variance of 0.265. This indicated a high level of alignment.

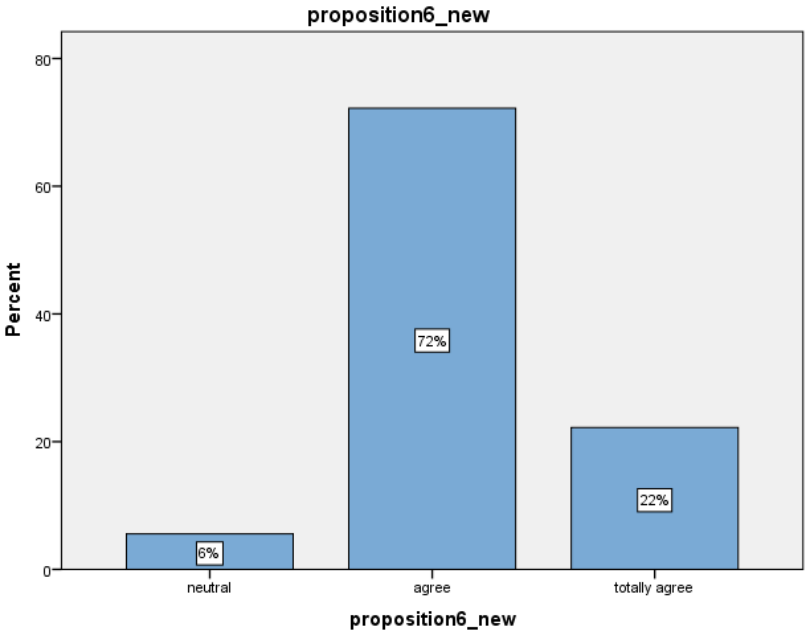

Figure 34: Evaluation distribution proposition6_new

Proposition7

Employees of the builder show a lot of knowledge regarding the execution of construction tasks. In order to guarantee, that all possibilities for innovations are used and to prevent counteraction against the developed concept, they need to be included already during the development phase. If a standardized concept is developed, an employee of the contractor need to participate. This can be the executor or project manager depending on his knowledge.

As shown in Figure 35, more than 70% agreed with the statement with 44% indicating agreement and 33% indicating even total agreement. A small group of 17% indicated neutrality and only one respondent or 6% indicated disagreement. With a mean value of 1.06, a standard deviation of 0.873 and a variance of 0.761 is reached for this proposition. This indicates little alignment between the respondents' answers.

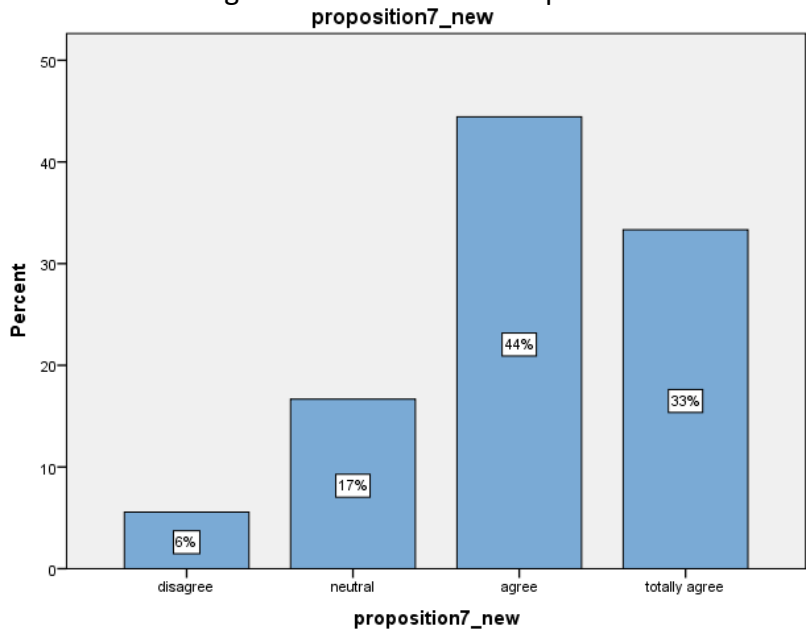

Figure 35: Evaluation distribution proposition7_new

Proposition8

It is important, that likewise users as owners understand the principles of circular buildings, which are of relevance for them. Therefore, a user need to know mainly principles related to his direct living environment, whereas the owner focusses on the value conservation of his building. Depending on the knowledge of the owner regarding circularity a professional party should be hired for maintenance and repair in order to guarantee the circular characteristics of the building.

As shown in Figure 36, only one respondent of the 18 indicated disagreement, just as two respondents indicated neutrality (11%). A great part of 50% indicated agreement and 33% even total agreement. An mean value of 1.11 is reached together with a standard deviation of 0.832 and a variance of 0.693. These numbers indicate rather little alignment.

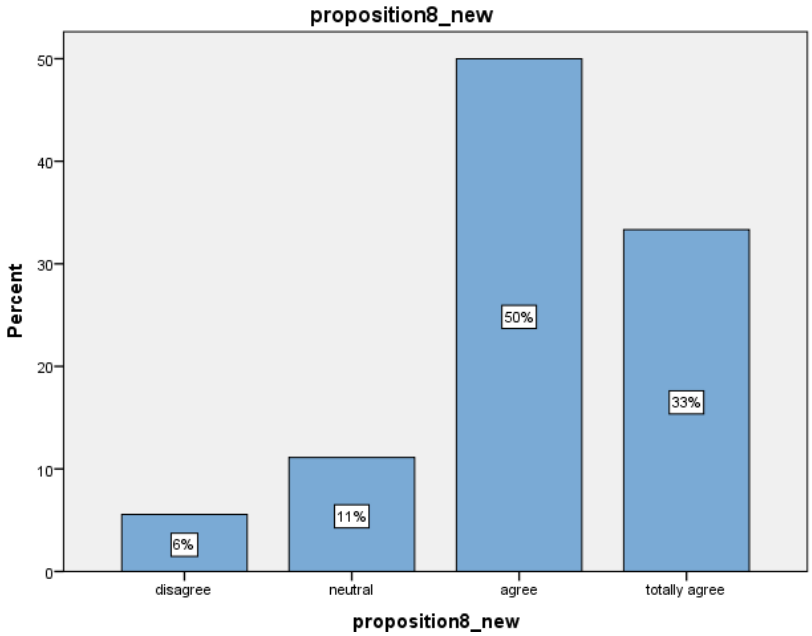

Figure 36: Evaluation distribution proposition8_new

Proposition9

In order to close the lifecycle for real estate, it is important that the end-of-use of building elements are considered as well. However, developments are difficult to predict, especially for elements with long lifespans. The question "what will happen at the end-of-use of elements or the building as a whole" need to be considered already during the development phase within the design. In the design, loose connections, flexibility, adaptability and modularity need to be considered. Within this, it is important to include maintenance parties and owners of elements early in the process.

As shown in Figure 37, out of the 18 respondents 11% indicated neutrality, while 61% indicated agreement and 28% even total agreement. This leads towards a mean value of 1.17 with a standard deviation of 0.618 and a variance of 0.382.

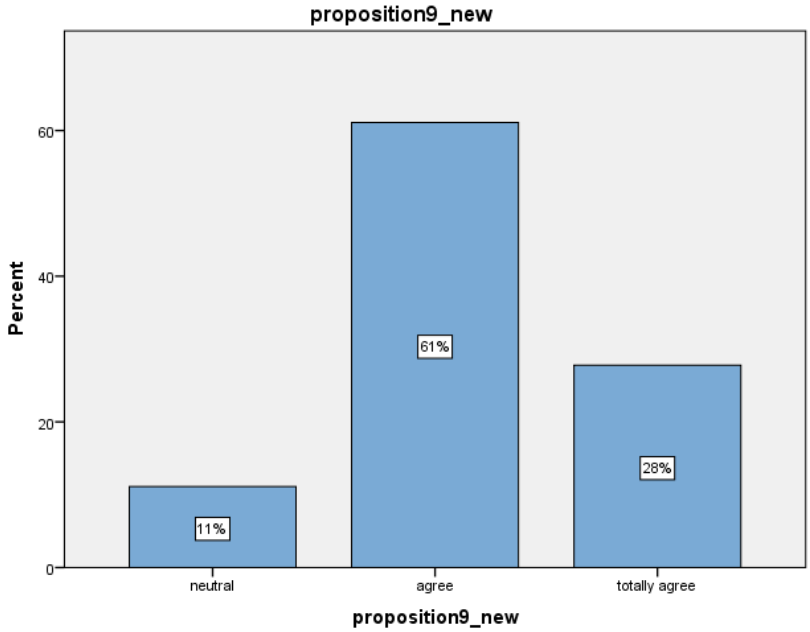

Figure 37: Evaluation distribution proposition9_new

Due to that, it can be seen, that overall more agreement has been reached for the adopted propositions. In the next section, a comparison between the outcomes of the first and second round of Delphi is given.

4.3.7 Comparison of evaluation of Delphi I and Delphi II

In order to compare the outcomes of the first round of Delphi and the second round, a comparing figure is created per proposition indicating the changes per respondent (case number 1 till 21 below). The outcomes of the first questionnaire are represented by the 0-line. A line on the 0-line indicates no change in evaluation. A block going upwards from the 0-line indicates, that the expert expressed more agreement than in the first round. A block going downwards in the negative area indicates the opposite, namely a greater disagreement compare to the first round.

In addition to this analysis on respondent level, the significance of the change of the whole group is calculated using the Related-Samples Wilcoxon Signed Ranks Test. This test is suitable for the comparison of two data sets, which are generated by the same group of respondents and need to be called 'related' (Field, 2005), which is the case for this study.

Proposition1

As shown in Figure 38, most of the respondents indicated great improvement of the proposition in their point of view. In total 8 respondents indicated in the second questionnaire an evaluation, which was one, two or even three steps more in the direction of agreement than during the first interview. Only 2 respondents indicated a less positive reaction than during the first round. In total 9 respondents indicated the same answer.

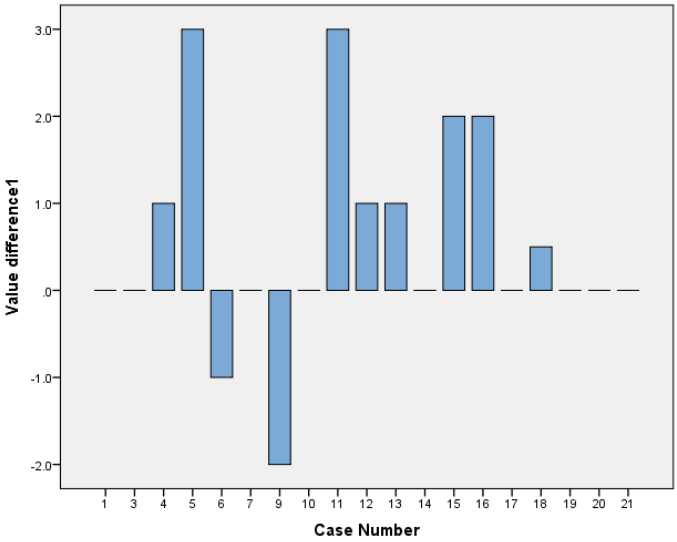

Figure 38: Comparison proposition1

The Wilcoxon test (N = 19, z = -1.750, p = 0.080 < 0.1) shows a significant improvement of the proposition towards alignment at a 0.1 significance level. Because of that, the adapted proposition need to be considered for a circular process schema.

Proposition2

As shown in Figure 39, based on the 18 selected responses only 3 indicated the same response as for the original proposition. Two respondents even indicated an improvement of three steps, which means that their opinion must have changed from disagreement towards agreement. Two other respondent indicated only 1 step towards total agreement, while 11 indicated 2 steps towards total agreement.

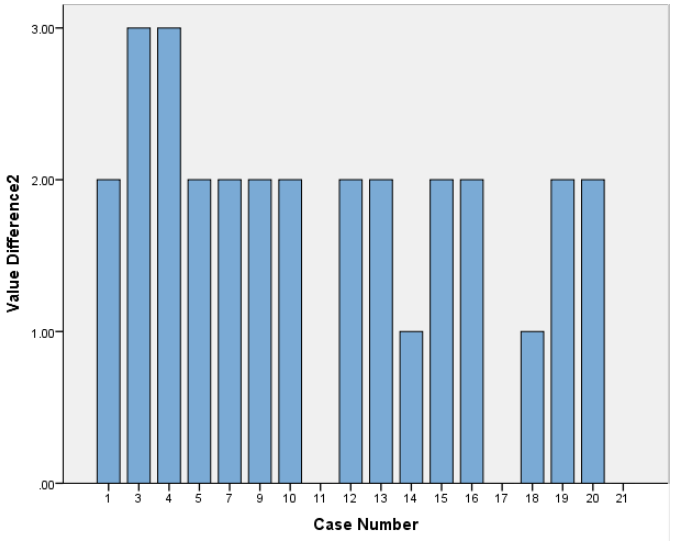

Figure 39: Comparison proposition2

Based on the Wilcoxon test (N = 18, z = -3.571, p = 0.000 < 0.05), the adapted proposition indicates a significant improvement towards alignment at a 0.05 significance level. This means, that the adapted proposition is considered further on.

Proposition3

As shown in Figure 40, 6 respondents indicated no change in opinion, whereas 6 respondents showed a change towards agreement and 6 respondents indicated a change towards disagreement. This is especially strong for respondent 17. Overall, this indicates, that the adapted proposition does not fit better with the experts opinion.

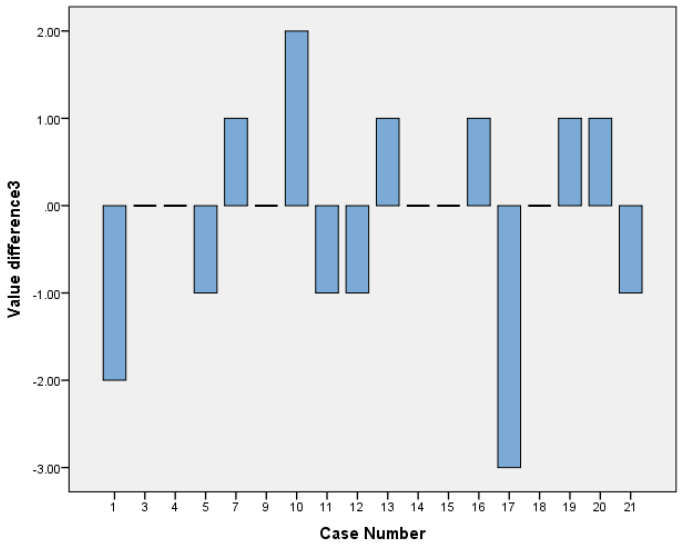

Figure 40: Comparison proposition3

The same effect is shown by the Wilcoxon test, which indicates with N = 18, z = -0.288 and p = 0.773 > 0.1 that the adaptation of the statement did not lead towards a significant improvement of the proposition. Even though a slight change towards agreement can be found in the comparison of the evaluation of the original and adopted proposition3, no significant change can be found. Besides this, including only those respondents for the evaluation of the original proposition, which participated in both rounds, led towards better statistical values for the original proposition. Due to that, the original proposition need to be considered for constructing a circular process schema.

Proposition4

As shown in Figure 41, all of the 18 respondents indicated a higher degree of agreement with the adopted proposition compare to the original proposition. An increase by 1 step was indicated by 2 experts, an increase by 2 steps was indicated by 8 experts, an increase by 3 steps was indicated by 6 steps and 2 experts even indicated an improvement of 4 steps from totally disagreement towards total agreement. This strong change was again indicated by expert 18.

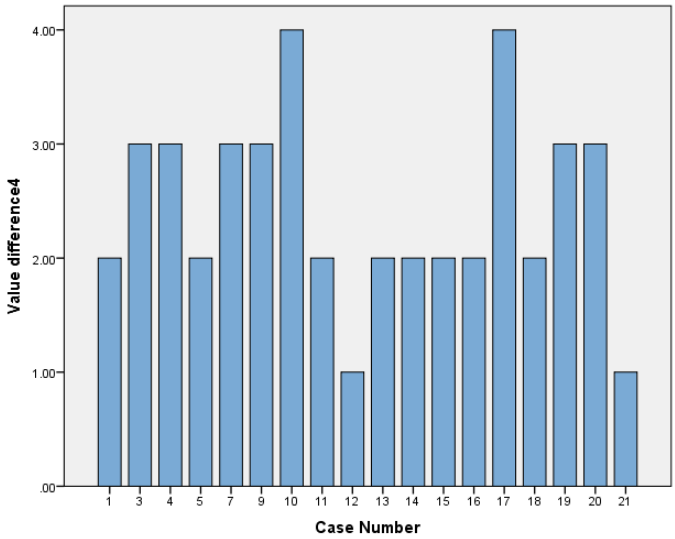

Figure 41: Comparison proposition4

This positive impression based on the comparison is also confirmed by the outcomes of the Wilcoxon test. With N = 18, z = -3.778 and p = 0.000 < 0.05 the proposition fits significantly better with the experts opinions on a 0.05 significance level. Therefore, the adapted proposition4 is considered.

Proposition5

As shown in Figure 42, a number of 12 out of the 18 respondents indicated the same level of agreement as for the first proposition. Only 2 respondents indicated a lower level and 4 a higher level of agreement. This indicates, that the proposition was not changed strong enough to trigger more changes in the level of agreement.

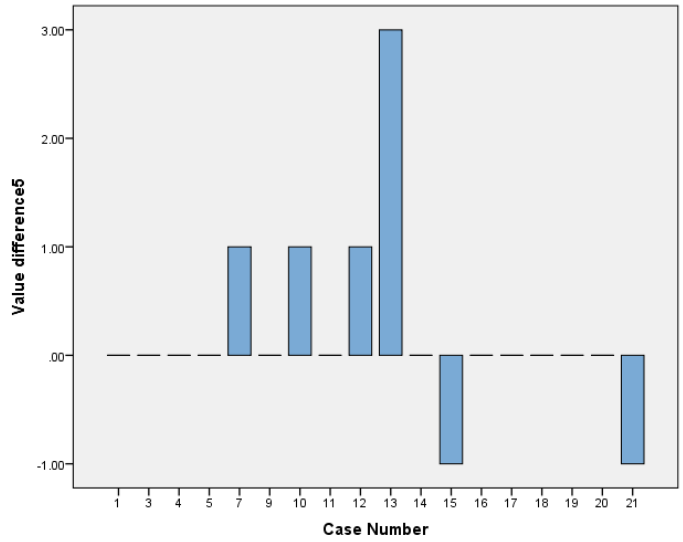

Figure 42: Comparison proposition5

The Wilcoxon test (N = 18, z = -1.000, p = 0.317 > 0.1) indicates no significantly improvement in the degree of alignment between the experts' indication. However, the comparison of the evaluation of the original and adopted proposition5 show a slight change towards agreement. Even though this change is not significant, the adopted proposition5 will be considered in the following based on the indicated change towards agreement.

Proposition6

As show in Figure 43,besides 1 all respondents indicated an increase in agreement with the adapted proposition. An increase of 1 step was indicated by 7 respondents, of 2 steps by 5 experts, of 3 steps by 4 experts and 1 respondent even indicated a change of 4 steps. This means, that the adaptation of the proposition is closer to the experts opinion.

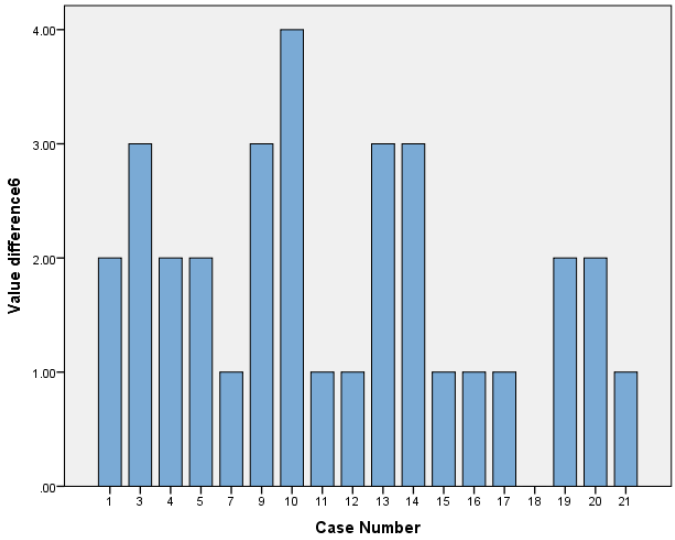

Figure 43: Comparison proposition6

Following the Wilcoxon test (N = 18, z = -3.666, p = 0.000 < 0.05) the adapted proposition shows a significant improvement towards alignment at a 0.05 significance level. Because of that, the adapted proposition need to be considered for a circular process schema.

Proposition7

As shown in Figure 44, in total 3 respondents indicated a decrease in agreement, whereas 6 respondents indicated the same evaluation as for the original proposition and 9 respondents indicated an increase in agreement. Especially, the increase by 4 steps from total disagreement towards total agreement of respondent 17 is remarkable.

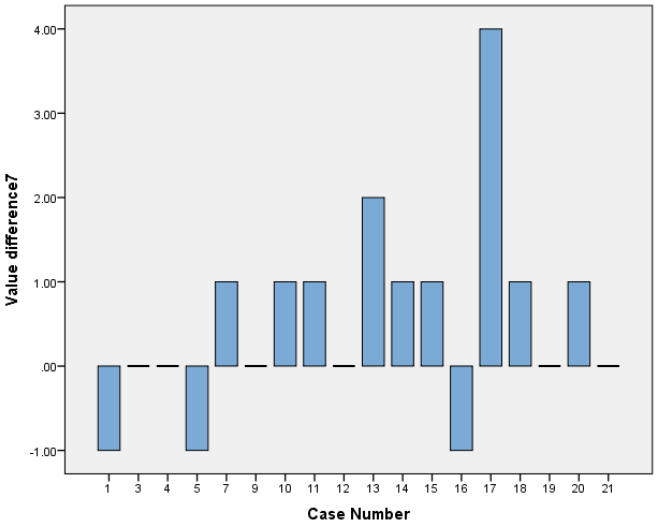

Figure 44: Comparison proposition7

The Wilcoxon test (N = 18, z = -1.889, p = 0.059 < 0.1) shows a significant improvement towards alignment at a 0.1 significance level. Due to that, the adapted statement should be considered for a circular real estate development process schema.

Proposition8

As shown in Figure 45, the same indication as during the first round was given by 9 respondents, whereas only 3 indicated a less agreeing evaluation and 6 indicated more agreement with the adapted proposition.

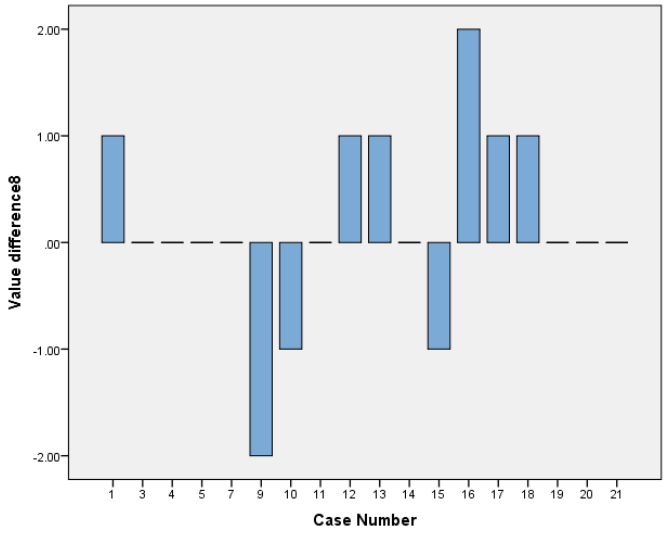

Figure 45: Comparison proposition8

This means, that the adapted proposition does not cover better the experts panel opinion, which is approved by the outcomes of the Wilcoxon test (N = 18, z = -0.749, p = 0.454 > 0.1). However, the comparison of the evaluation of the original and adopted proposition8 show a slight change towards agreement. Even though this change is not significant, the adopted proposition8 will be considered in the following based on the indicated change towards agreement.

Proposition9

As shown in Figure 46, only 4 respondents indicated less agreement with the adapted proposition, whereas 5 respondents indicated the same level of agreement and 9 indicated an increase.

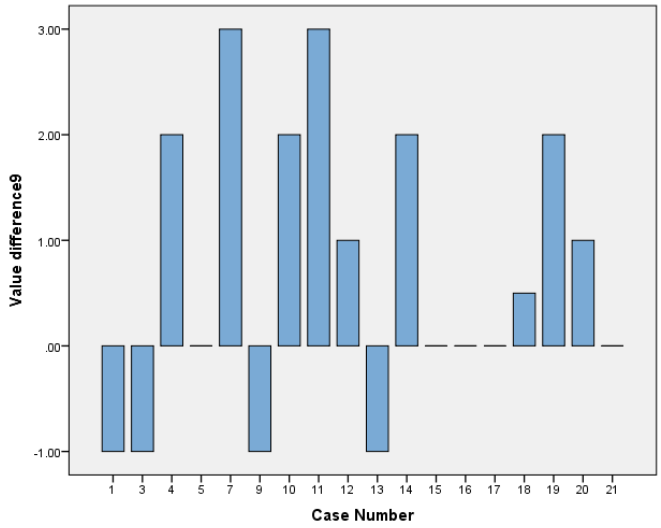

Figure 46: Comparison proposition9

Due to this comparison of the original and the adapted proposition together with the outcome of the Wilcoxon test, the adaptation of the proposition significantly fits better with the experts' opinion. With N = 18, z = -1.949 and p = 0.051 < 0.1, a higher degree of alignment is reached significantly on a 0.1 significance level. Due to that, the adapted proposition9 need to be considered for a circular process schema.

4.3.7.1 Discussion

Based on the before mentioned evaluations, the following nine propositions of Table 21 need to be considered in order to create a BPMN schema for a circular real estate development process following the expert opinions:

Table 21: Final propositions

1new	The most important stakeholder for any development process is the client as carrying the risk for the development. In the case of real estate development, the client can be the real estate developer, who guides the process together with other parties. The client need to have knowledge and a preference for circularity in order to be the first to introduce the circular principles and needs to ask others to do so as well.
2new	During the initiation phase, development phase and construction it is important that the building fits with the design principles of 'design for disassembly', 'adaptability' and 'modularity', and that materials are chosen, which fit within the biological or technical cycle. Besides, a strong communication is necessary within the development team. The wishes of the client and his priorities need to become clearly defined already at the beginning of the process, during the initiative phase. He needs to be participating throughout the whole process, but during development, realization and exploitation phase his role is rather of an evaluating nature.
3old	It is important to introduce the design principles already during the initiation phase within the concept development, even if there is no collaboration with other stakeholders yet and even if this leads towards higher costs for construction.
4new	Process related principles are important for the whole process of development and all phases need to be seen as one process. The selection of circularity principles is

	dependent on the project conditions and need to be agreed upon at the beginning of the process.
5new	The programme of requirements is one of the most important documents in the real estate development process. Within this document, wishes and requirements need to be formulated performance-oriented in order to stay open for future innovations. Other important documents are a circular business case, a vision or ambition document and the contract.
6new	During the initiative phase and development, all circularity principles need to be kept in mind. Depending on the project conditions and focused on the future user, the most important principles need to be chosen and adapted in order to satisfy the needs of future users.
7new	Employees of the builder show a lot of knowledge regarding the execution of construction tasks. In order to guarantee, that all possibilities for innovations are used and to prevent counteraction against the developed concept, they need to be included already during the development phase. If a standardized concept is developed, an employee of the contractor need to participate. This can be the executor or project manager depending on his knowledge.
8new	It is important, that likewise users as owners understand the principles of circular buildings, which are of relevance for them. Therefore, a user need to know mainly principles related to his direct living environment, whereas the owner focusses on the value conservation of his building. Depending on the knowledge of the owner regarding circularity a professional party should be hired for maintenance and repair in order to guarantee the circular characteristics of the building.
9new	In order to close the lifecycle for real estate, it is important that the end-of-use of building elements are considered as well. However, developments are difficult to predict, especially for elements with long lifespans. The question “what will happen at the end-of-use of elements or the building as a whole” need to be considered already during the development phase within the design. In the design, loose connections, flexibility, adaptability and modularity need to be considered. Within this, it is important to include maintenance parties and owners of elements early in the process.

Overall, these propositions need to be considered for the creation of a process schema of the circular real estate development process. However, it need to be remembered, that this opinion is based on a small group of experts reflecting different levels of expertise and professional backgrounds.

Overall, it should be mentioned, that in many cases, where the Delphi method is implemented, several rounds are executed in order to reach a certain level of alignment. In this study, alignment was reached on a 0.05 significance level for three propositions and on a 0.1 significance level for three propositions already during the second round. This means, that the adaptation of the original propositions was well done.

Besides this, it became clear, that implementing the concept of circular economy within the process of developing real estate is important throughout the whole process. However, the initiation phase forms the bases of all further developments and therefore, it is crucial for the implementation of the concept. Besides that, implementing the circular economy concept

strongly influences the further collaboration between the project partners. Those outcomes are implemented in the BPMN process schema of a circular real estate development process, as presented in the following sections.

4.3.8 Circular real estate development process

The process schema in the form of a BPMN diagram for the development of circular real estate is based both on the literature review and the constructed BPMN schema for the traditional real estate development process, as is based on the expert opinions collected through the use of the Delphi method and its evaluation presented the previous sections. The process schema is intended to be used as a practical guide for real estate developers in order to organize the development process so that circularity can be guaranteed. To reach this, the process schema consists of different layers.

The first layer provides an overview over the most important stakeholders, tasks and their dependencies. Tasks, which are represented by a small box including a plus-symbol represents a collapsed sub-tasks. By clicking on the plus-symbol in the original file, a new schema opens, which shows the tasks and relations included in the task of the overview page. This second schema forms the second layer of the process diagram. In case, the second layer schema includes a collapsed sub-process, a diagram on the third level is connected to the symbol.

4.3.8.1 Circular real estate development process diagram

As is shown in Figure 47, the process diagram covers the four phases of initiative phase, development phase, construction phase and implementation phase. As important stakeholders, the municipality, the client, the construction company as the producer and supplier need to be mentioned. Depending on the project conditions, the client can be an investor or private owner, but could be the real estate developer as well.

For this schema, it is assumed, that likewise as for the traditional model, the land is provided by the municipality, which is ready to be built on. Furthermore, an investor is assumed to be defined as the future owner of the real estate already at the beginning of the process. Besides, a professional real estate developer initiates and manages the development of the real estate, which will consist of several apartments for the rental market. Likewise as for the traditional process schema, this model does not focus on the representation of legal and financial aspects of the process.

Based on the performed analysis, the following seven lessons learned are integrated within the circular process schema for the real estate development process (see 'Appendix B - Methodology: Circular BPMN model' starting on page 185):

- The risk-carrying client is the most important stakeholder to trigger the implementation of the circularity concept.
- A clear definition of circularity need to be formulated based on the clients' understanding. Based on this, the appropriate principles are selected.
- All of the selected principles need to be kept in mind by all related parties throughout the whole lifecycle of the real estate and its elements.
- To reach the previous lesson, the programme of requirements need to be formulated in a performance-oriented manner.
- Employees of construction companies need to join the process already during the development phase.
- Owners and users of the real estate need to support the continuation of the circularity principles throughout the whole lifecycle. Throughout the exploitation phase, a professional maintenance service provider can support this and should attend early on during the process.
- At the beginning of the process, the end-of-use of building elements should already be considered. Therefore, circular business cases should be implemented during the development phase.

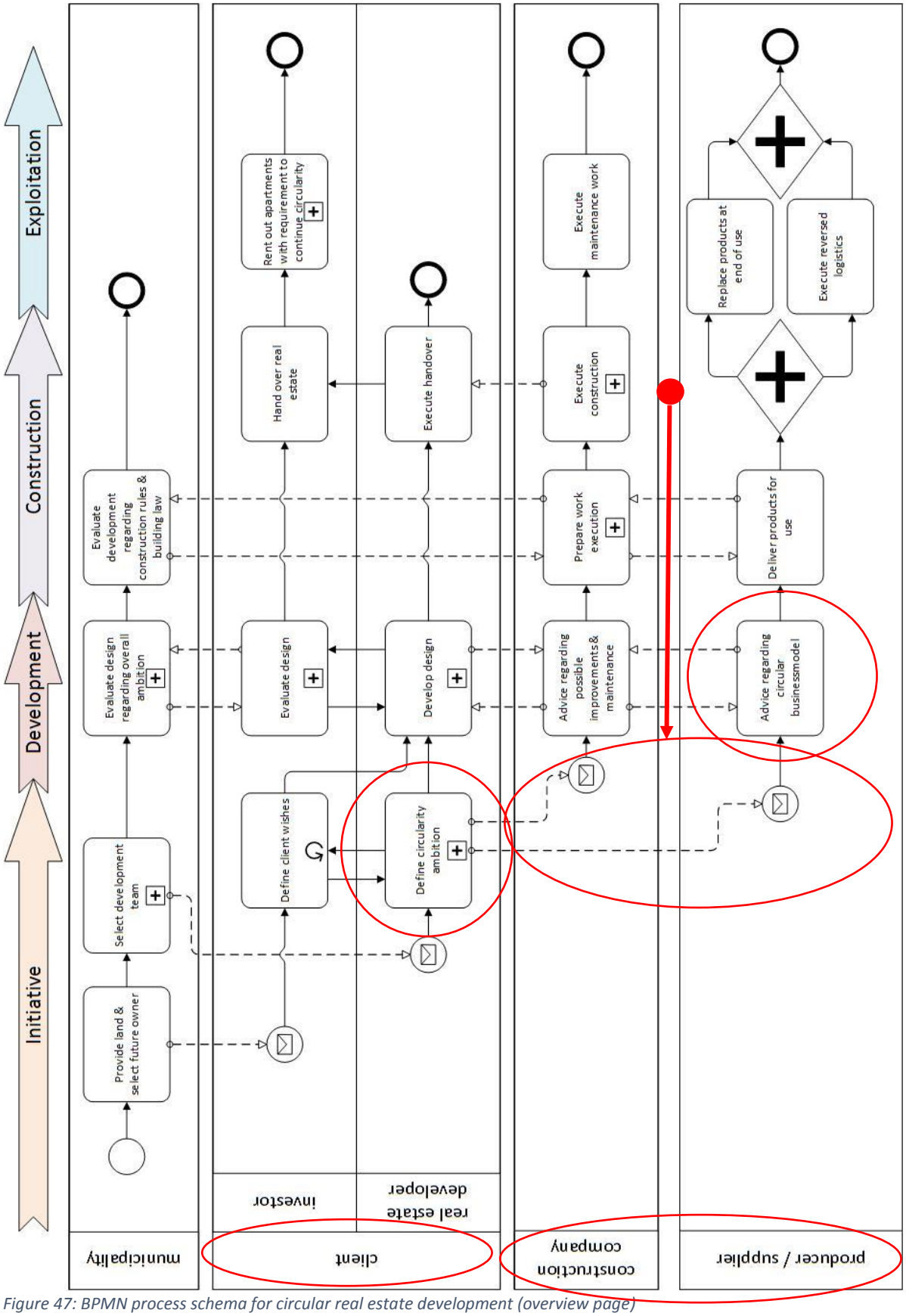

Figure 47: BPMN process schema for circular real estate development (overview page)

4.3.8.2 Initiative phase

As presented in Figure 47, the process starts by providing land by the municipality and selecting the future owner in the form of an investor. During the initiative phase, the development team is selected, a circularity ambition is defined and finally evaluated.

Select development team

Following this, the selection of the development team is executed by the municipality, which is based on the overall tender requirements and available expertise of possible partners as presented in Figure 65 on page 186. The selection of the development team starts with the start of the tender procedure initiated by the municipality by formulating the overall ambition for the project in a performance-oriented way. This means, that it is described, what the municipality wants to have realized and not how it is reached.

These information are defined within the tender requirements document, which can be text-document or a pdf-document including at least the paragraphs of location, future owner as collaboration partner, function of real estate, focus group, finances (e.g. square meter price of land) and building-related requirements (e.g. maximum heights, width and length, percentage build-on of whole ground) for information of the developers. Besides that, performance-oriented requirements regarding the functionality and sustainability ambition need to be defined, as well as the planning requirements. An important aspect of the tender document is the description, what is expected from the development team to present as tender. Here, it need to be defined, if the development of a broad vision is satisfying or if a thought-through concept including first sketch designs need to be presented.

With the help of this document, the tender is put into the market and the real estate developer thinks about a first concept. Based on the first concept, additional expertise might be necessary, so the developer searches for tender partners with the required motivation and knowledge, which can be found in architects, engineers, advisors and construction companies. The contacted parties decide upon their tender participation. If they agree to participate, they will sign a collaboration contract including the official names of the contract parties, their official address and contact details, as well as a detailed description of responsibilities and rights. After agreeing with the tender participation, all partners provide the necessary information for the tender document, which is collected by the real estate developer and presented to the municipality. This tender document includes answers for all questions and requirements presented in the tender requirement document. Based on these information, the municipality selects the tender team meeting best with the municipalities' expectations.

Define circularity ambition

Parallel with the selection of the development team, the investor defines the client wishes and other requirements for the developed real estate. In this case, it means, that the investor considers his potential tenant group and their preferences and describes those requirements performance-oriented within the programme of performance. This includes information regarding the type of tenant and his functional requirements, such as the availability of green space privately usable or publicly accessible. Besides, it need to be defined, which functions need to be included per apartment, such as sleeping, cooking, living, working, hygiene, but could also include sporting, professional office working, gardening, washing etc. This document is exchanged with the real estate developer as head of the development team to

enable them to define the circularity ambition for this project. A close collaboration and iterative character of this sub-process is essential, as shown in Figure 66 on page 187. Based on the information provided in the 'programme of performance' the real estate developer starts to translate the wishes and requirements into a circular solution. To do so, he can use the circularity checklist, that is provided in 'Circularity checklist' on page 188. This document provides an overview of decision possibilities regarding the concept of circularity within the built environment. It can help to clarify, what the exact ambition of the client is and how to reach a satisfying solution. Within this document, the understanding of the circularity concept is defined and the chosen circularity principles are indicated.

Evaluate circular ambition
The developed ambition is evaluated by the development team or a circularity advisor depending on the expertise of the development team members, as shown in Figure 68 on page 190. To do so, first the technical feasibility of the ambition is evaluated with the help of engineering specialists in an iterative process until the feasibility is reached. The advisor can ask for technical improvement or agree with the technical solution. When improvement is necessary, the engineering specialist will be asked to present alternative and/ or optimized solutions until the circularity advisor approves the technical feasibility. Then the financial feasibility is evaluated. To do so, the construction company is asked to find suitable products and determine the costs for it. This is done in collaboration with producers and suppliers, who can offer the products following a traditional or circular business model. A circular business model could include, that the products are leased and that it will be paid for the use while the ownership remains with the producer. As for the technical feasibility, the collaboration with the construction company iterates until the financial feasibility is approved by the circularity advisor. Finally, the legal feasibility is evaluated, which is especially relevant for circular business models and the legal obligations and rights based on this concept.

As shown in Figure 68, the evaluation of the circularity ambition is used to formulate the final circularity ambition by the real estate developer. He or she will present this ambition to the investor, who will review the circular ambition and will decide whether he agrees with the ambition or whether he asks for improvement. If the investor is not satisfied, the real estate developer will be asked to improve the circularity ambition, which is done in the same process as before.

4.3.8.3 Development phase
After the initiative phase, the development of the design starts again in close collaboration with the investor and the municipality as the judging instance. An early implementation of the construction company, suppliers and producers is essential for a circular development.

Develop design – sketch design
The development of the design includes the sketch design, preliminary design and the final design, followed by the bill of quantities under the lead of the real estate developer (see Figure 69 on page 191). To reach this, the real estate developer initiates the sketch design, which is worked out by the architect following the circularity ambition. The sketch design is presented in the form of drawings representing the building frame. This sketch design is presented by the real estate developer towards the investor, municipality and board of the real estate development company for evaluation, as shown in Figure 70 on page 192. As part of this, first

the investor evaluates, whether the sketch design fits with this ambition and expectations. After approval, the board of the real estate development company evaluates the design regarding time- and cost-related feasibility. After their approval, the sketch design is also evaluated by the municipality regarding building laws and regulations. If the design is not approved by one of the instances and improvement is needed, this will be communicated towards the real estate developer. He will ensure the improvement in collaboration with the development team until total approval is reached.

Develop design – Preliminary design

After the sketch design is approved, the preliminary design is developed (see Figure 69 on page 191).To reach this, the architect constructs the space plan and cross sections before the engineers create a plan for electricity, heating and cooling, as well as a mechanical plan. This plan is evaluated regarding practicability by the construction company and regarding its circular ambition by the circularity advisor. Furthermore, a maintenance professional evaluates the design regarding the suitability for maintenance work. If they do not agree with the preliminary design, improvement is created in an iterative process within the development team. The internally approved design is presented to the investor, board of real estate developer and the municipality likewise the sketch design (see Figure 70 on page 192).

Develop design – Final design

After the preliminary design is approved, the development of the final design starts initiated by the real estate developer (see Figure 69 on page 191). As part of this, the architect dimensions all building elements exactly in collaboration with the engineer and the construction company. Again, the final design is presented to the investor, the board of the real estate development company and the municipality for evaluation (see Figure 70 on page 192). Finally, the real estate developer calculates the bill of quantities based on the final design, which indicates the type of material and the amount planned to be used for the designed real estate.

Evaluate design

The design is developed following the chosen circularity ambition and circularity principles. Besides this, the design need to fit with the ambition and requirements of the investor, the financial and risk-related regulations of the board of the real estate development company and finally the legal regulations evaluated by the municipality, as indicated in Figure 70 on page 192.

Early participation

The construction company participates already during the development of the design in order to advice regarding the possibilities and alternatives for the later construction, as well as regarding the maintenance tasks. Likewise, a participation of an employee of the construction company also guarantees, that this party is informed of and included in making important decisions. The participating employee of the construction company is collaborating with possible suppliers and producers of fitting products in order to advice the development team profoundly. Within this, the possibilities for the implementation of a circular business model should be considered already.

4.3.8.4 Construction phase

During the construction phase, first the work preparation takes place, which is evaluated by the municipality regarding construction rules and building law. The final contracts are made with suppliers and producers regarding the traditional purchase of products or via circular business models in the form of lease contracts, which are already implemented during the work execution.

Prepare work execution

In order to prepare the construction, the project manager of the construction company first translates the design into an executable planning (Figure 71 on page 193), which includes responsibilities, manpower, timeframe and dependencies of tasks. Based on these detailed information the circularity rules are determined for the work execution. The document including the circularity rules contains clear requirements, how certain tasks need to be executed. As such, it might intend which materials need to be used for which task. Furthermore, the connecting elements by dry connections might be notified as well. Here, all important rules are determined in a clearly structured manner indicating, what is not allowed to do and how it can be done instead. The list should not be too long and need to be discussed with the executors to guarantee its application throughout construction.

Based on this, the project manager determines the project planning and the list of material quantities. Based on this, the executor determines the manpower within the work planning his and his colleagues, as well as the materialization. Based on all these information, the project manager closes delivery contracts with the producer and supplier, with which the work executor was in contact before to find the best suitable materials. The delivery contract indicates which materials are bought in which quantity and which quality fitting with circularity requirements. Besides that, the exact date and manner of delivery are determined. Furthermore, it becomes clear from the contract, whether a traditional way of purchase was chosen or whether it is a lease contract or a pay-for-use contract. Besides that, the quality surveyor determines the cost estimation based on the information provided by the project manager (Figure 71 on page 193).

Execute construction

After the work preparation is executed and evaluated by the municipality, the construction itself takes place. The executor starts the physical execution and executes the work following the planning. This is evaluated by the project manager regarding the planning and by the real estate developer regarding the conformity with the circularity principles and the proposed design. Based on the executed work, the municipality evaluates the conformity with the construction permit and construction laws. The construction permit was applied for based on the final design. It states, the real estate building conditions along with drawings and measurements. If all fits with the building laws and regulations for the location, the building permit is given by the governmental institution.

Based on the evaluations or other circumstances, the work might not follow the planning exactly. Then, the planning need to be adopted by the project manager, who continues evaluating the work progress regarding time, costs and quality. However, if the evaluation of the work by the real estate developer indicates that it is executed following the circularity rules, he will agree with the further execution. In both ways, the work execution will be

finalized by the executor, which enables the real estate developer to prepare for the hand-over (see Figure 72 on page 194).

4.3.8.5 Exploitation phase

After the handover, the exploitation phase starts, which includes the end-of-life or end-of use for subparts of the real estate due to differences in the technical lifecycle and use duration.

Rent out apartments

The investor rents out the apartments under the condition of maintaining circularity (see Figure 73 on page 195). To do so, the investor defines the circularity conditions for the real estate leading towards tenant requirements and circularity requirements for maintenance work. Based on this, a circularity obligation is defined and signed by the tenant together with the rent contract. This obligation is a legally valid addition of the rent contract indicating, which rules need to be followed by the tenant to maintain the circular character of the building. This can reach from very small obligations of a duty to indicate wished changes in the apartment towards self-execution of changes in a certain manner. The level of obligation should be also dependent on the level of interest in circularity of the tenant since pressuring commitment can lead towards resistance.

Circular business cases

Parallel with this, the suppliers and producers agree upon circular business cases for their products with the investor, if wished. This includes the possibility to pay for use or lease contracts of products. Besides this, the maintenance professional, which could be the construction company or another party determines the tasks to maintain circularity of the real estate. To do so, a BIM model on LOD level 500 is used, which represents the modulation of all elements exactly how it is built including the exact measures, location, quantity and quality, as well as the amount per element. Along with this, non-geometrical information are given for every element based on material choice, quality, maintenance requirements, producer, contractual obligations and engineering decisions related to the element. Throughout the development of the design, the BIM model need to be built up following the standard of the later model maintainer, who already participated during this stage within the process.

BIM model

The BIM model does not only deliver useful information for the maintenance professional, but is filled by new information of the investor monitoring the continuation of circularity. Besides this, the included information are provided for the execution of the maintenance work and to advice tenants regarding wished changes. To do so, the tenants will contact the investor and execute the changes following the rules of circularity by themselves or ask professionals to do so. Within this, they are advised by the maintenance professional.

During the exploitation phase, possibly agreed lease contracts need to be executed, which often include a phrase, that products are exchanged, if better-quality products are available. As part of this, the supplier would take back the old product to reuse its elements. Those conditions are determined in the lease contract, along with the maximum contract duration, as well as obligations and rights of the contracting parties. At the end of use of the elements, those need to be taken back by the supplier based on pay-for-use contracts.

From the perspective of the investor as owner of the real estate, one decision need to be made during the exploitation phase. Or he can choose to keep the real estate and rent it out until the end-of-use is reached for the long-life elements, such as the structure-skeleton. Then it would be his task to give back the building elements, of which the investor is not the owner based on circular business cases. Likewise, owned building elements would be sold to create another real estate out of it. The alternative for this decision would be to sell the building under the condition, that the new owner continues the circularity measures as thought of at the beginning of the process.

4.3.9 Recommendations

In comparison with the traditional process model, a few points are remarkable for the circular development process of real estate. These are important in general, but especially for real estate developers.

Early implementation
As such, it is important to implement the circularity concept early on in the process since the chances for a successful realization are greatest then. Furthermore, an early implementation is crucial since it has influence on the form of collaboration and responsibilities of the project participants. An early implementation supports the effect of outweighing possible higher construction costs for circular buildings during the exploitation phase.

Clear definition
After defining the ambition to develop following the rules of circular economy, a clear definition of this term need to be agreed upon. The circular economy and the building circular are broad terms, which are understood differently by different people. Therefore, a clear definition of the term combined with the determination of the used circularity principles is crucial for the further development. In order to focus on the aimed ambition, a performance-oriented programme of requirements need to be formulated.

Client-oriented
As being the most important stakeholder for the realization of a circular building, the risk-carrying client need to be central during the development process. It is important to formulate the circularity ambition following his knowledge and preferences and organize regular feedback from the client to implement it.

Early participation
In order to gain from the whole potential of the chain, both suppliers, producers as construction companies need to be implemented early on in the process, just like the future owner. Those parties are responsible for the continuation of the circular character of the real estate from the development through construction till exploitation and end-of-use. Therefore, their wishes and doubts need to be considered as their potential for improving ideas.

Engage professional support
In order to guarantee the successful implementation and maintenance of the circular character of the real estate, specialized knowledge is necessary. To reach this, circularity consultants can be hired during the development and users and/or owners should be supported by professional maintenance parties, which understand the difficulties in

continuing a circular character. Likewise, the integration of circular business cases requires for specialized knowledge.

Process as a whole
Besides this, all project participants need to see the process as a whole and not phase by phase as it happened in the past. As such, the chosen ambition and circularity principles need to be considered by all participants throughout the whole process. Here, it is important to establish a well-functioning foundation at the beginning of the process to build on throughout the lifecycle of the real estate and its components.

Documentation
Due to the fact, that all important principles need to be continuously considered throughout the process and lifecycle of the real estate and that many different people are related to the real estate throughout this time, documentation is essential. This means, that not only the building construction and the used materials should be documented, for example in a material passport in a BIM model, but also that reasons for important decisions are documented likewise. This information are important to continue the circular character of the building throughout the decennia's and it need to be available for people of different levels of expertise. At least for the current transition situation, one responsible organization should take over this task, which is first the real estate developer and then the investor.

4.4 Discussion

The aim of this study is to develop a process schema for the real estate development process, which follows the concept of circular economy. This process schema need to be suitable for real estate developers as a guidance when starting a new real estate development project, which focusses on building circular.

As indicated, the concept of circular economy is a holistic concept, which is filled in differently per expert depending on personal preferences, expertise and profession. Due to this, first an extensive literature study was executed, which ended in three tables summarizing the most important principles for building circularly (see Table 2, Table 3, Table 4 starting on page 32). Within this, the principles where clustered in design principles, principles for material choice and process-related principles.

Based on the first round of personal interviews with 21 experts, many comments were given regarding this overview of principles. Most importantly, the list was indicated as being too long and unstructured. Therefore, three approaches where worked out in detail. At first, Table 6 and Table 7 summarized the principles on a higher level and clustered the building-related principles in Table 6 following the circles of the well-known 'butterfly' diagram of the Ellen MacArthur foundation (see Figure 3). Besides that, the process-related principles where summarized in Table 7. As a second approach, the principles where clustered depending on the type of material input, as presented in Table 8. Thirdly, Figure 19 combines the most important principles with the four phases of the real estate development process. All of these three approaches show advantages and disadvantages. All of them provide less information than the original approach consisting of three tables, but are more suitable to create a quick overview. This means, that the original approach is more suitable for unexperienced readers, whereas the three adapted approaches give a fast overview for experienced readers. Whereas

the third approach is specific for the real estate development process, the other two new approaches are suitable also for other building-related cases. Overall, it need to be remembered, that none of the approaches claims completeness and suitability for every situation. However, they can provide overview and guidance for how to implement the concept of circular economy within the built environment.

As a second important step, the traditional real estate development process was determined in the form of a BPMN process map based on literature and the experience of practitioners. Clustered in the four main phases of initiative, development, construction and exploitation phase, the tasks of the most important stakeholders are presented (see Figure 18). Just as the concept of circular economy, the real estate development process is based on a few overall principles, which need to be adopted to the location and other project conditions. As such, a list of pre-conditions was determined for this study. Clearly, it need to be indicated, that a different process model could be just as suitable for the indicated project conditions. In order to find one basis to work with furthermore, the model created in the standardized fashion of BPMN was evaluated by two practitioners. More validation could have been possible, but that was not performed since it was not the main focus of this study.

On the contrary, developing a circular process model for the real estate development process was aimed on. Due to this, it was decided to consider the knowledge created from the previous steps to formulate nine propositions to be evaluated by field experts following the Delphi method. In the first round 21 experts with different professional backgrounds were interviewed personally regarding their agreement or disagreement with the nine propositions. This allowed the researcher to ask follow-up questions or clarify misunderstandings regarding the propositions. However, this personal form of interaction may have led also to some degree of influence on the responses since at least some of the experts asked for the researchers' opinion. Also due to a lack of experience, some follow-up questions may have been asked in a biased form. The effect of how questions were asked have not been evaluated in this study and have been assumed negligible. Also, the groups per professional background, such as architect, engineer or advisor have been too small to be representative for all experts of this field. So, no clear relation can be formulated between the professional background and the evaluation of the proposition. However, after adopting the propositions, the relations were stronger than for the first round (see in comparison Table 19 and Table 20).

After evaluating the first round of interviews, the propositions were adopted to reach more alignment between all expert opinions. Due to the widespread level of experience, professional background and personal interpretation of circularity, it was not expected, that perfect alignment could be reachable already during the second round of interviews. This was especially unexpected since many projects using the Delphi method execute more than two rounds before reaching alignment. However, as proposed by Sourani and Sohail (2015), the process can be stopped, when an overall goal is reached. Since this study aimed on reaching deep insights in how a circular real estate development process looks like, it was reasonable to stop the process after the second round of interviews. In order to improve the outcomes of the second interview, the question of motivation of the indicated evaluation could have been added. Due to the limited timeframe for this graduation project and in order to reduce the effort for every respondent, and with this the possible reluctance against responding, the questionnaire was created as short as possible.

Based on this research, a new and clearly understandable process schema is developed for the circular real estate development process in form of a standardized BPMN model (see Figure 64 till Figure 73). Overall, it need to be remembered, that this model is based on the experts' opinions, which might reflect strong circularity ambitions. When implementing this model in reality changes might need to be done due to a lower ambition of the investor or future tenants.

In comparison with the traditional model some clear differences can be found. As such, the whole lifecycle of the real estate including the development need to be seen as one. Therefore, the relevant circularity principles need to be maintained by all participants. This asks for a different way of collaboration, trust and information exchange between the participants. Likewise, supplier, producer, construction company and maintenance responsible parties need to be participating already during the development phase. Furthermore, especially the integration of circular business models can lead to differences in responsibilities, rights and duties. Their consequences need to be closely examined before signing the contract.

This BPMN model is suitable, both for experienced and unexperienced real estate developers to maintain a circular development. Depending on the project conditions, the model can be adapted and should be used as guidance, not as a fixed standard. Adoption based on the project conditions need to be done. However, it is easily understandable and can be used on the overall level or including the in-depth-layers provided. Those can be even more detailed when used for a specific project.

5. Conclusion

This research focused on the main research question of how to adjust the traditional real estate development process in order to meet the principles of circular economy. On its way towards the answer of this question, many differ steps have been executed including two times in-depth literature studies, two rounds of interviews, three rounds of data evaluation including many iterative steps and finally the development of two process schemas following the standard of BPMN. Content-wise, expectations had to be adjusted and openness of the researcher was asked in order to find the best possible solution. In this way, it was possible to answer the five sub-questions formulated in order to answer the overall research question. After answering those five questions, the scientific and societal relevance of this research are stated along with recommendations for improvement and further research.

1. What is a circular economy and how is it characterized within the construction sector?

The circular economy is an holistic approach for an economic concept, in which all raw materials and the products made out of it need to be kept as long as possible within the economic cycle in order to meet the worldwide problems of waste creation and scarcity of virgin raw materials. Within the construction industry, the implementation of the concept is affected by the differences in lifespans per building layer and building component. To reach a circular construction economy, first steps are made, such as the development of circular materials, circular design and construction principles and circular business models relevant for the collaboration. However, implementing the concept until its perfection still needs attention, innovation and new developments.

2. Which principles of circular economy exist and are relevant for the real estate industry?

The principles of circular economy relevant for the construction industry can be clustered in design principles and material choice principles, which can be further summarized in building related principles (see Table 6) belonging towards the different circles of maintenance, reuse and redistribution, refurbishment and remanufacturing, as well as recycling. Besides this, process-related principles (see Table 7) are of high importance as being influential for the collaboration of the chain partners, the economic success of the implementation and the connection towards other industries.

3. How does a traditional real estate development process look alike for the Dutch market?

In overall lines, every real estate development process consists of four phases: initiative, development, construction or realization and exploitation. During these phases, the real estate is developed from its first idea till using the property, independently from the type of building. However, the project conditions including type of property, location, focus group and main function are highly influential on the selection of the members of the development team and the tasks executed throughout the process. Therefore, every process is individual and can’t be repeated for another real estate. A process schema developed for the case situation of this study is presented in Figure 18.

4. How does an ideal circular real estate development process look like?

Based on the executed interviews, it is found, that an ideal circular real estate development process also consists of the four phases of initiative, development, construction and exploitation. In comparison with the traditional process, it is of great importance, that the whole lifecycle of the property and its components is considered at any decision made

throughout the process. Besides this, the origin of the materials and components need to be kept in mind, as well as its destination after its use time in this real estate. Besides this, reaching a circular development process, the mindset of all collaborating partners need to change towards more openness and trust to exchange information and support each others' work to reach the best possible result. Depending on the clients' ambition, the proper definition of circularity need to be considered and the fitting circularity principles need to be chosen and considered throughout the whole lifecycle.

5. **Which recommendations can be concluded from the comparison of a traditional and a circular process model?**

In order to reach a circular development process leading towards a circular building, the concept need to be implemented as early as possible to find partners with fitting mindsets and knowledge. Furthermore, a clear definition of the term, the dependent ambition and the circularity principles following from that need to be defined and documented. Every important party of the whole process need to participate early on. This does not only include the client, developer, architect, engineer and advisor, but also suppliers, producers, construction companies and maintenance professionals. This need to be done in order to reach one smooth process continuing during the whole lifecycle of this real estate and beyond. To guarantee the circular character of the real estate throughout its whole lifecycle a clear documentation is necessary to pass on important information for future owners, users or other parties getting involved with the building.

5.1 Scientific relevance

This research is of high scientific relevance already due to the limited available scientific publications related to the topic of circular economy and especially regarding circular economy within the built environment. Besides this, the topic of real estate development is approached rather practically than scientifically. Therefore, a scientifically executed research aiming on these two practically oriented fields is of high importance for further research and the scientific substantiation of these fields.

Besides this, this research summarized and structured available literature regarding circular economy and the real estate development process. As such, it combined two different fields of research, which faced only limited points of connection in past research. The research available from other graduate reports have been used as basis for this research. As such, this research continued the executed analyzes and provided additional insights. As executed by Rood (2015) the experts' opinion of three main contractors, three subcontractors from the building installation sector and three subcontractors from the façade sector have been used to find an overall process for the circular real estate development process. This research included a broader filed of experts including architects, engineers, developers, consultants, employees of construction companies and of municipalities to broaden this picture. Besides, more knowledge and experience have been built up since Nena Rood executed her research. Therefore, new insights have been added now.

Along with this overall scientific relevance, this research offers new possibilities to represent an adopted process model following a new school-of-thoughts. To reach this, the international standard of Business Process Modelling and Notation (BPMN) was used, which is done for the first time in the field of real estate due to the authors' knowledge. Using this standard enables

researchers to indicate tasks, responsibilities, influences and products throughout a process in a standardized and clearly understandable manner. Therefore, the proposed development model is suitable both for researchers to conduct further research as for practitioners to use the schema and built up additional experiences.

As such, this process model is also relevant for the project management field as offering a first possibility to adopt the concept of circular economy within the project management processes. Using the developed schema and the provided recommendations of this research, project managers are enabled to steer the process efficiently.

5.2 Societal relevance

As indicated before, the concept of circular economy is of high relevance for the further social development worldwide. As predicted by the Ellen MacArthur Foundation, continuing with the current linear economic pattern of take-make-dispose, the scarcity of virgin raw materials will increase and the world will face ever increasing waste problems (Ellen MacArthur Foundation, 2013a). This effect is further triggered by expected three billion new middle-class consumers entering the economic market till 2030 (Ellen MacArthur Foundation, 2013a). This already indicates the need to introduce the concept of circular economy on a large scale.

Besides this, it need to be remembered that the construction industry worldwide, but also in the Netherlands is one of the biggest energy and material users of this country accounting for large parts of the waste production with being responsible for 79% of all mineral waste in the Netherlands (Statistics Netherlands, 2012). The Dutch construction and demolition field used 57 thousand million kWh for material harvesting in 2010, which equals 4.5 percent of the primary energy use of the whole country. Five percent of the national greenhouse gas emissions have been caused by this industry in 2010 (Van Odijk & Van Bovene, 2014). Due to that, implementing the concept of circular economy within the construction industry is of high importance.

To make first steps in this direction, the developed process schema along with the formulated recommendations can be used for a direct implementation of the concept within the real estate development process. Following Kilbert (2007), the steps included in this process affect sustainability largely and offers likewise great opportunities for actively supporting a sustainable development (Razali & Mohd Adnan, 2015). The process model will be necessary to supervise the successful implementation of the concept of circular economy and the prevention of a fallback to the original model (Zeitner & Peyinghaus, 2013).

5.3 Recommendations

This research provides a process schema developed for the situation of residential real estate, developed by a professional real estate developer to be taken over by an investor. For further research, it can be analyzed whether this approach is suitable for other project conditions such as for commercial real estate, for smaller units, for private investors or owners association. Furthermore, it can be analyzed, how the process model need to look like if the land is not provided as ready-to-be-built and if this has a substantial influence on the process and its main points of attention. Also, a comparable schema could be developed for the situation, in which the circular building is seen as part of a circular city.

Besides this, it need to be remembered, that the developed schema is based on literature and expert opinions. This expertise is based on previous experiences related to the experts' functional background, sustainability and building circular. Up till now, no large-scale projects have been realized, in which the circularity principles have been used for residential real estate. This means, that experiences have been translated for these case conditions but are not made under exactly those conditions. Therefore, it is necessary to validate the proposed model once large-scale residential real estate is developed and in-use in order to reflect on the suitability of this process schema.

Based on this reflection, the proposed model can be adopted and a more detailed model can be worked out. Besides this, a distinction could be made under which circumstances, which model is best to be used. This could also be done through the translation of the process model within suitable software, such as Relatics or Building Information Modelling (BIM). In this way, the financial, quality- or time-related effects of changes within the process could be closely monitored based on a real-world project. Information could be stored directly for future related parties. Besides this, implementing the process model in suitable software could enable the development of a software-based standard to be used for future projects.

Besides this, in future research this model can be enlarged by implementing the financial and legal processes, which are mostly ignored for this study. Along the implementation of these tasks, the financial and legal effects of certain decisions and the overall implementation of the circularity concept can be quantified following a more quantitative research approach. This might be also highly interesting for the field of project management in order to monitor the project progress and success.

Based on this, research could be executed, whether future users or owners are willing to accept additional costs or additional effort necessary to realize a circular real estate development process and a circular building. This research could be used, how much more costs they would be willing to invest compare to a traditional building. Likewise, the research could focus on which kind of additional effort would be acceptable for future users of different levels of interest in circularity. The same accounts for investors.

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Appendix A - Real estate development process

The original schemas can be found on the attached CD as ‘traditional BPMN’.

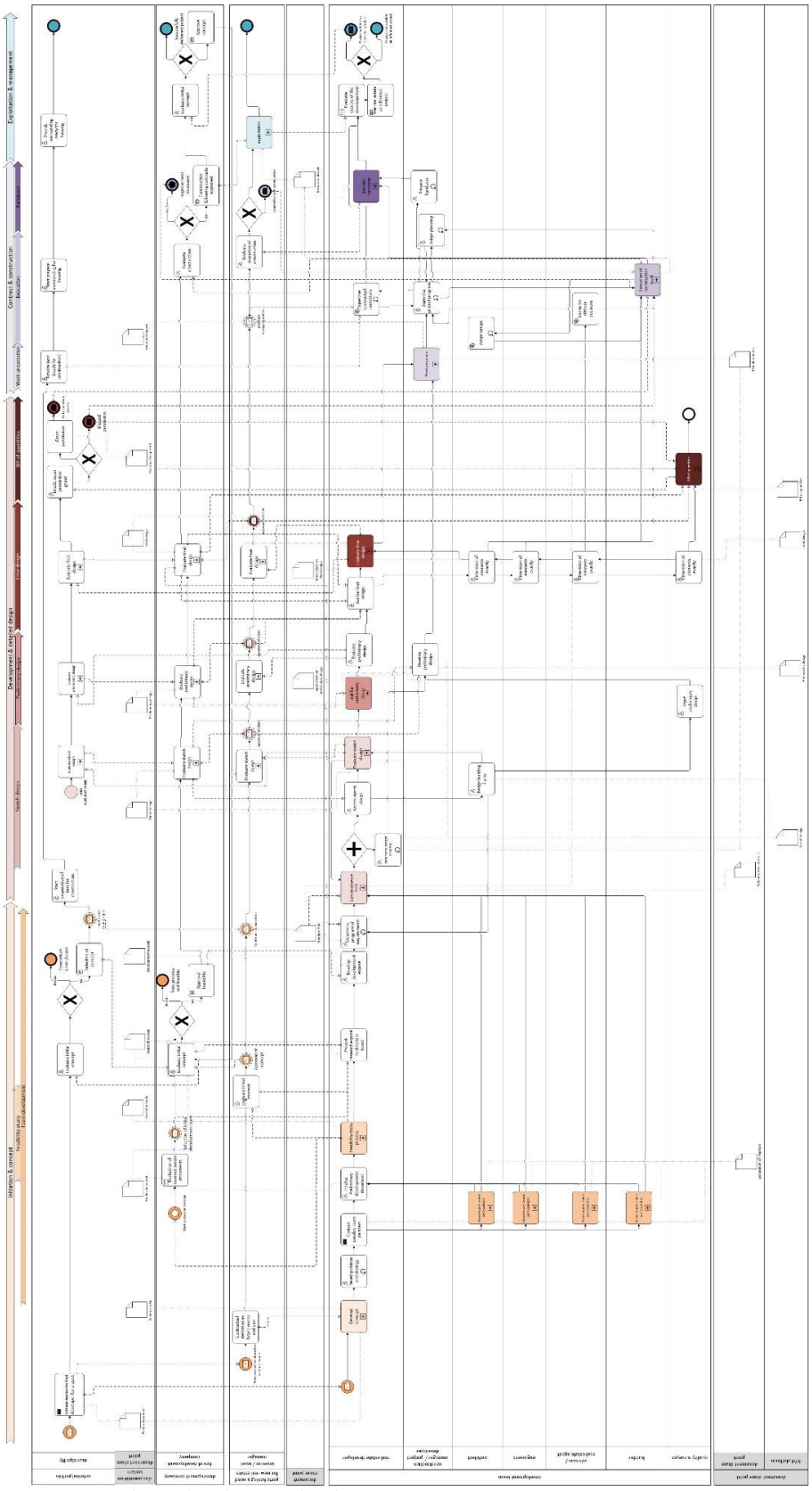


Figure 48: Traditional real estate development process - overview page

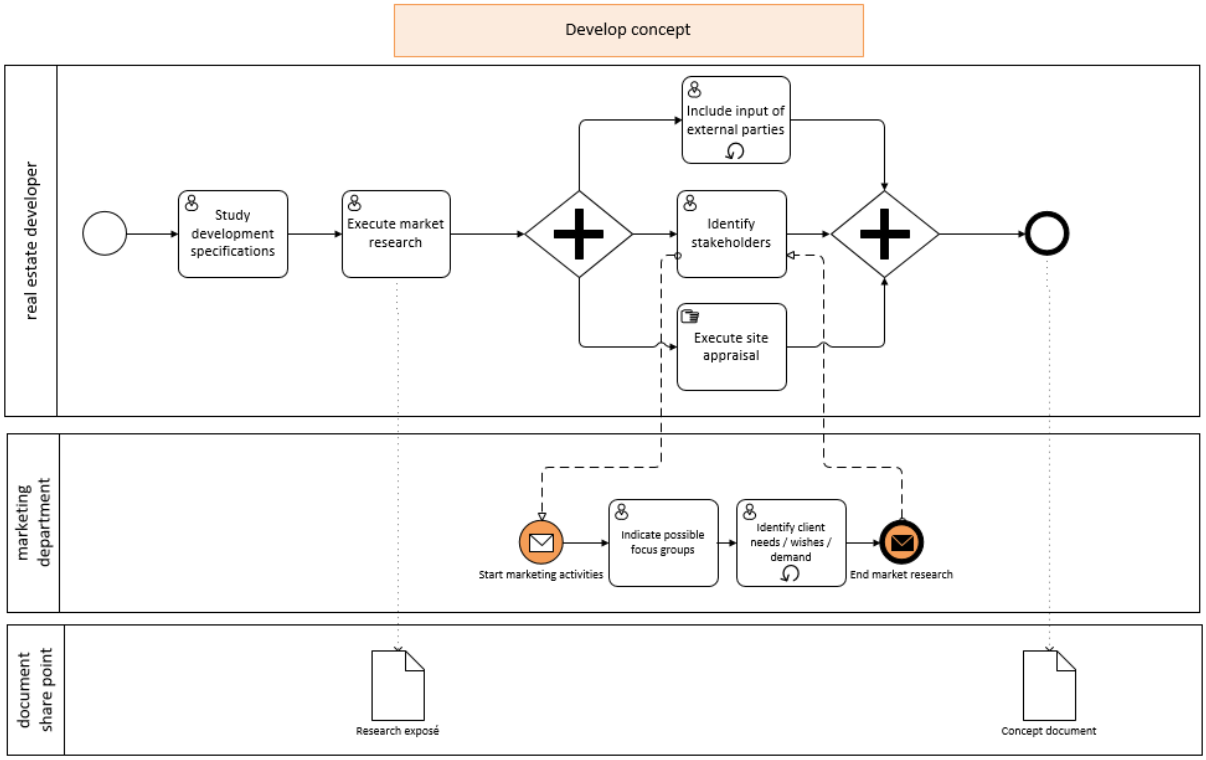


Figure 49: Traditional real estate development process - develop concept

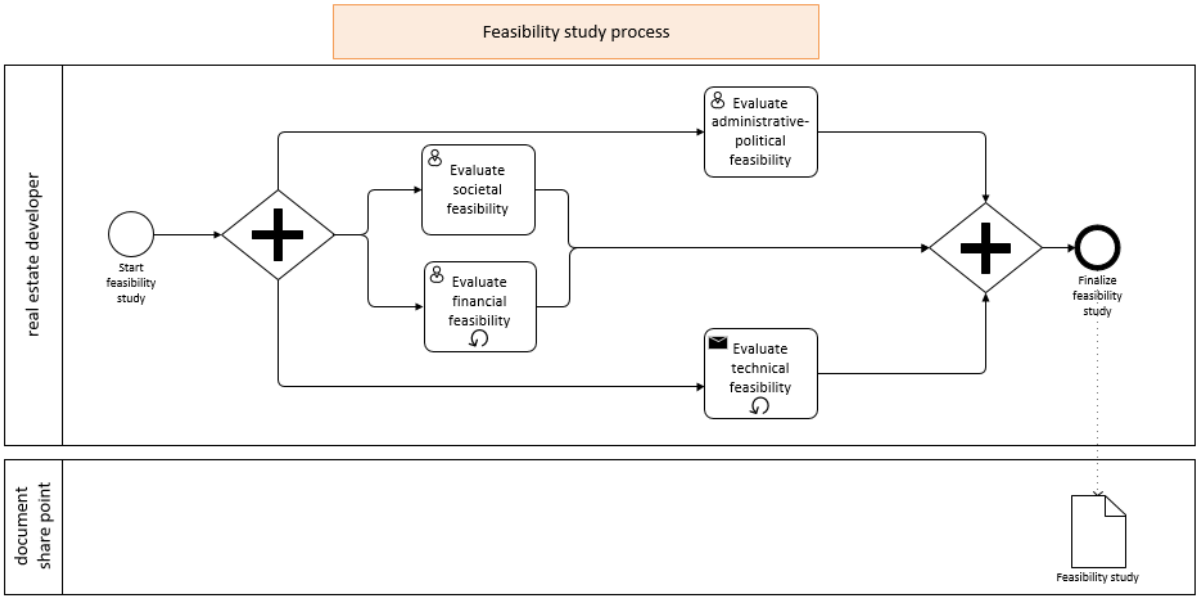


Figure 50: Traditional real estate development process - feasibility study process

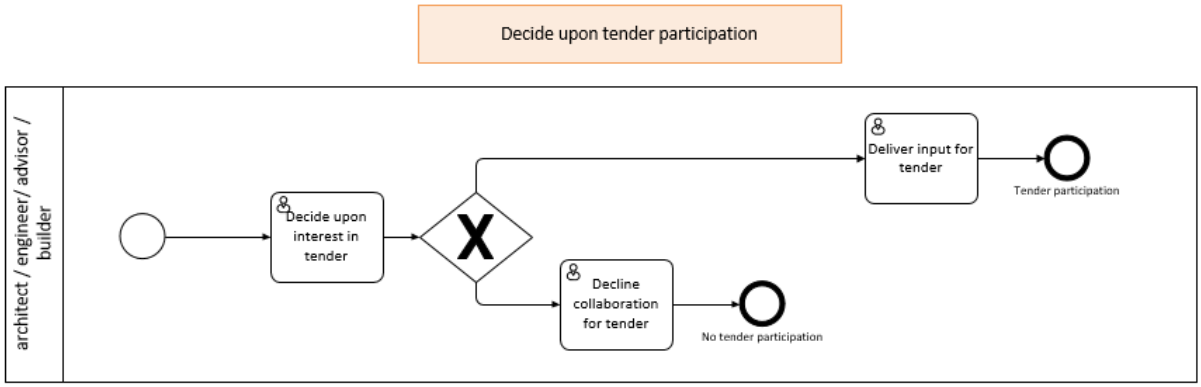


Figure 51: Traditional real estate development process - decide upon tender participation

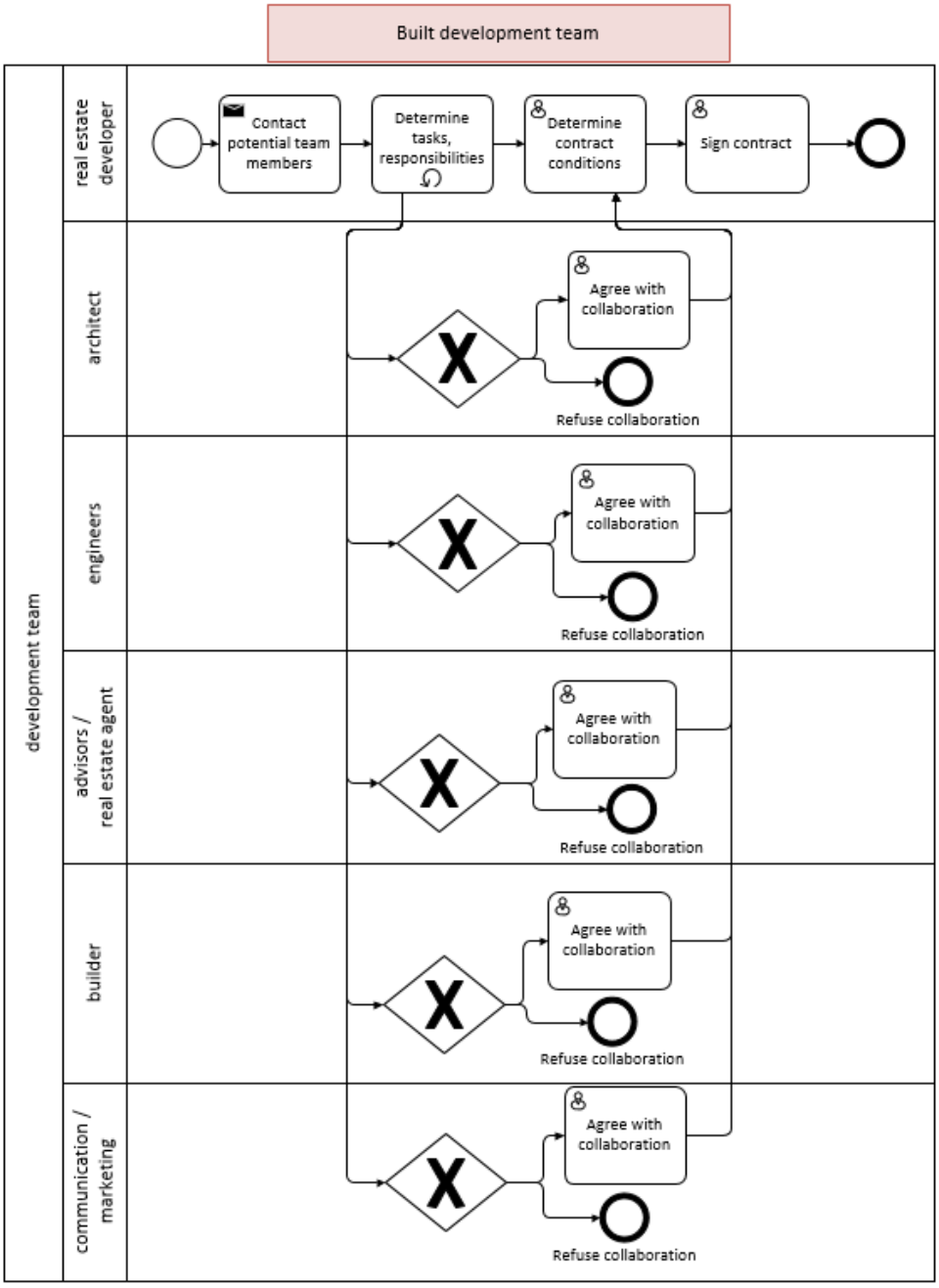


Figure 52: Traditional real estate development process – built development team

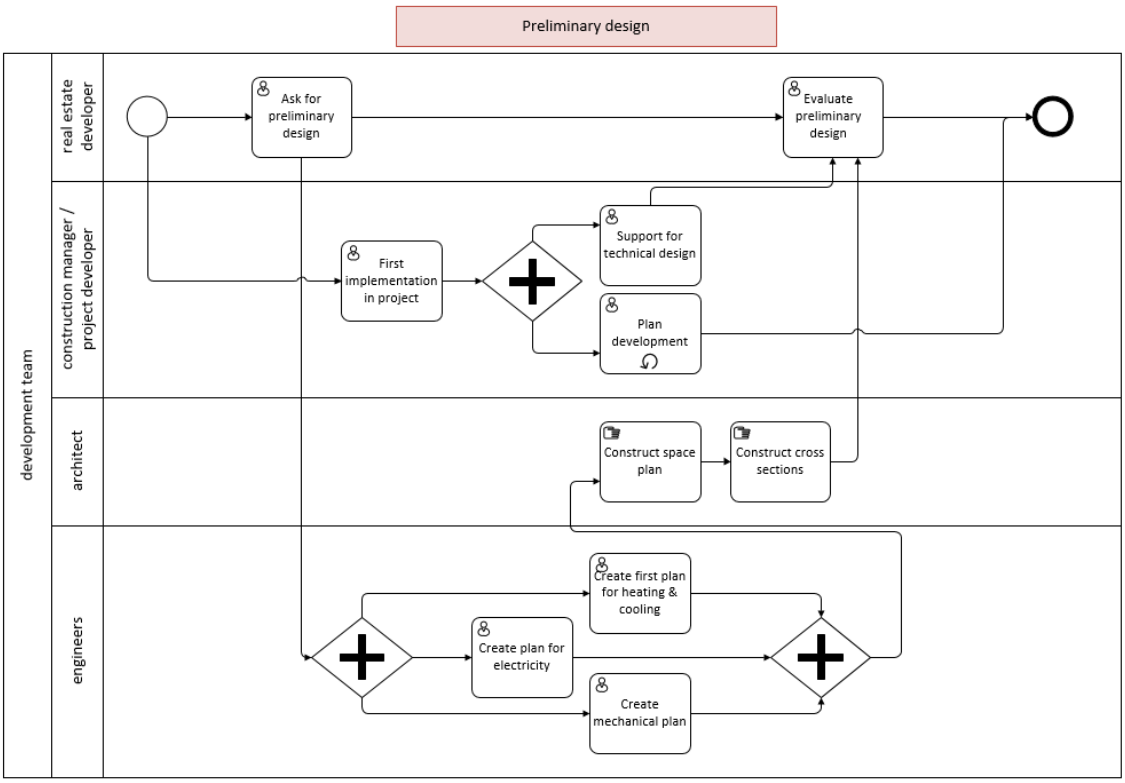


Figure 53: Traditional real estate development process - preliminary design

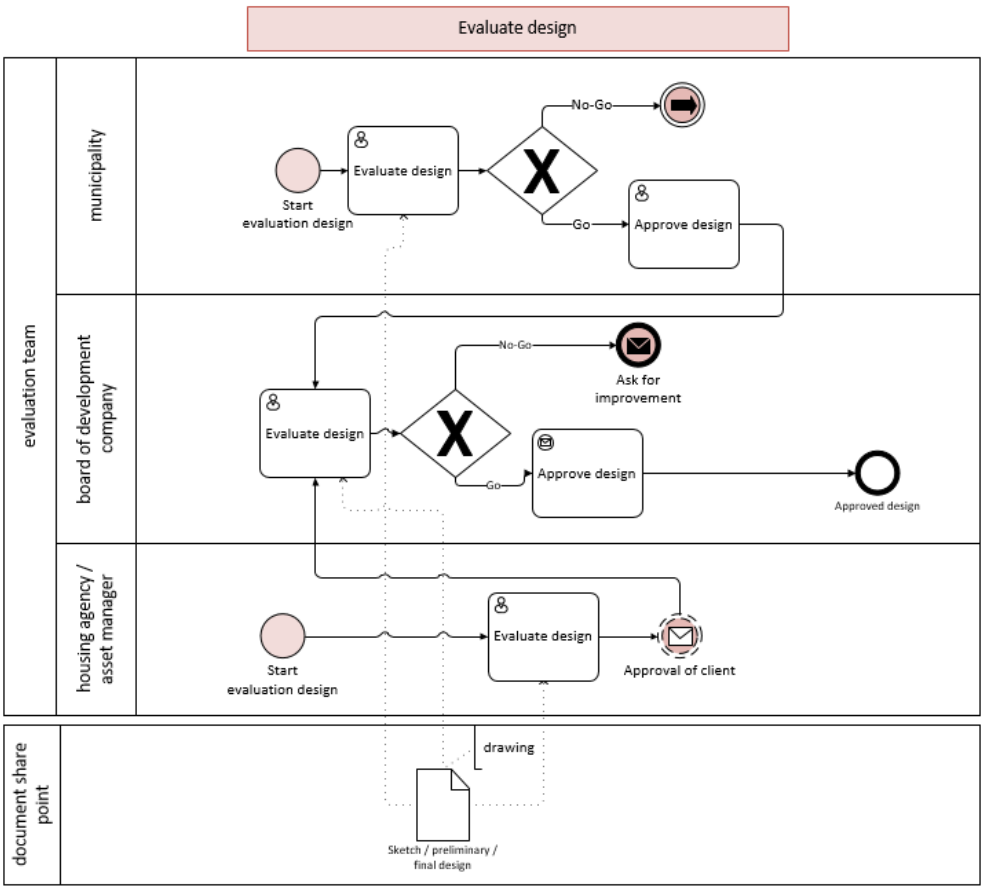


Figure 54: Traditional real estate development process - evaluate design

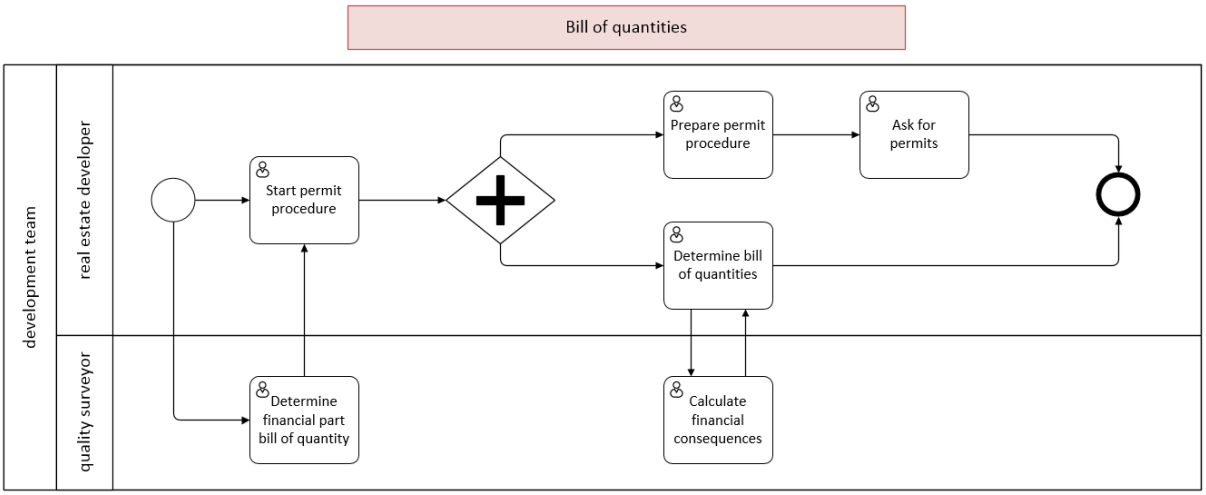


Figure 55: Traditional real estate development process - bill of quantities

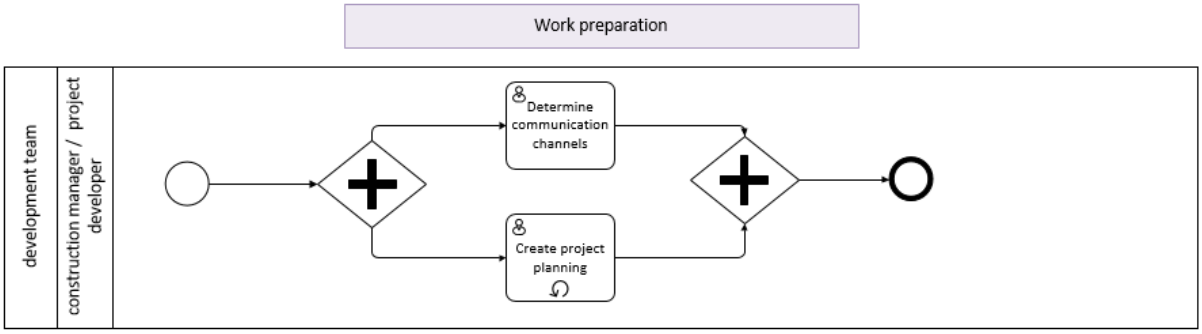


Figure 56: Traditional real estate development process - work preparation

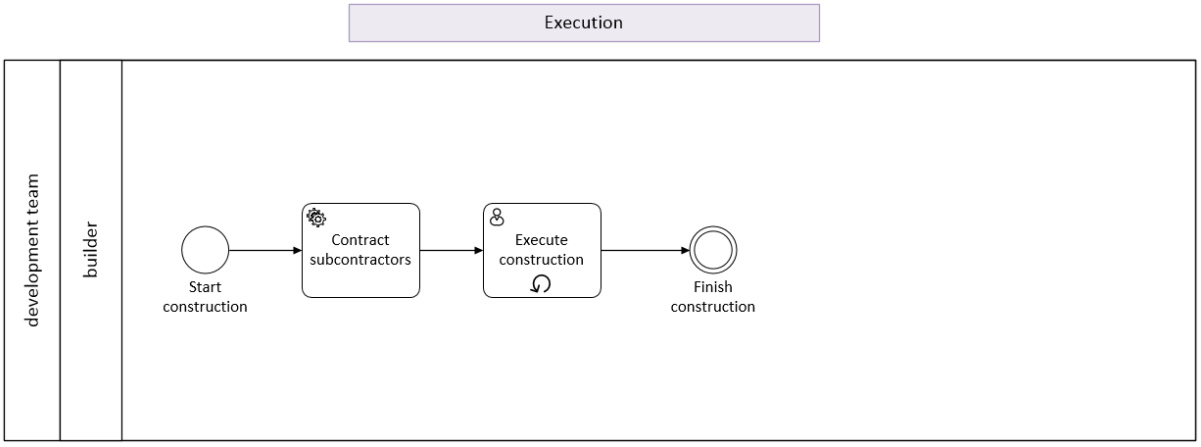


Figure 57: Traditional real estate development process - execution

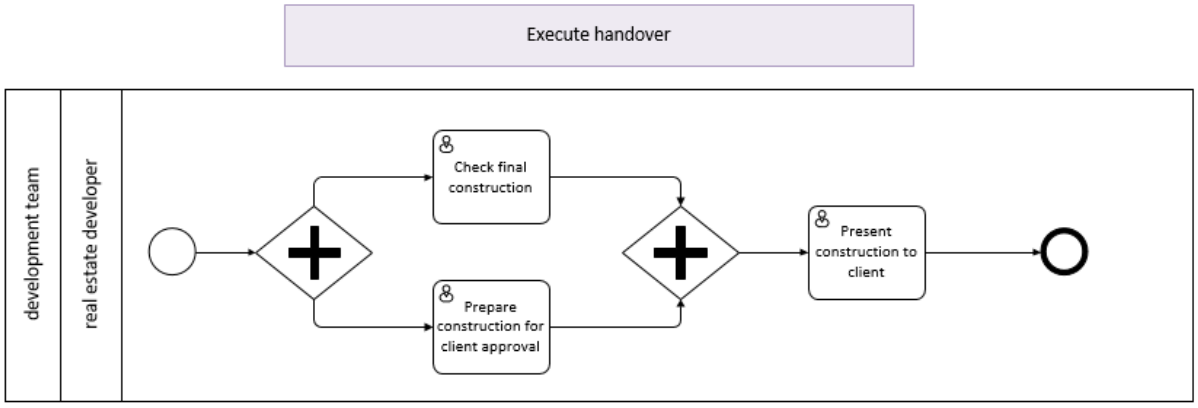


Figure 58: Traditional real estate development process - execute handover

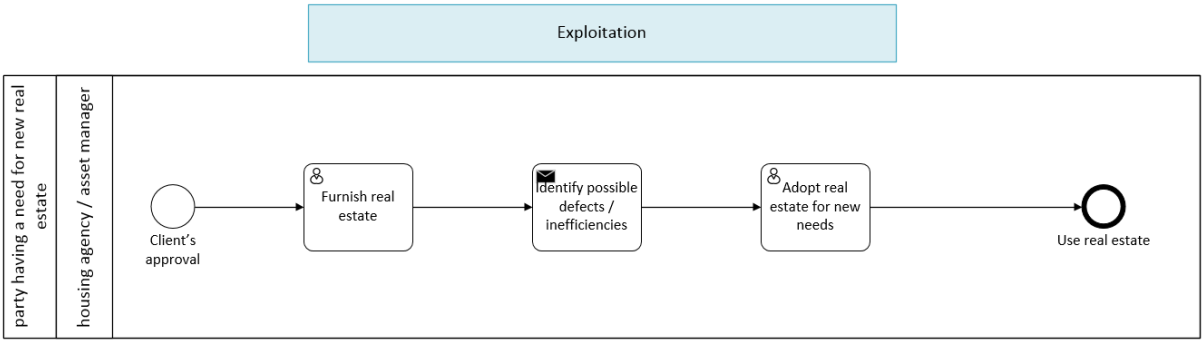


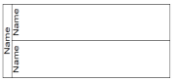
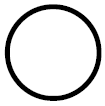
Figure 59: Traditional real estate development process - exploitation

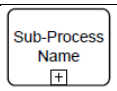
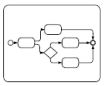
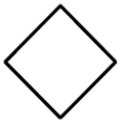
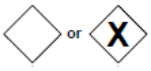
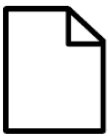
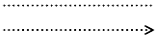
Appendix B - Methodology

This appendix includes additional information for the main chapter 4, which describes the method executed for this research. In the following, information can be found regarding the BPMN standard, the interviews executed for the first and second round of Delphi, as well as the codebook, a comparison of the interview outcomes and the BPMN models.

BPMN standard

Table 22: BPMN notation oriented on (OMG, 2013, pp. 26-39)

Notation category	Graphical element	Description	
Swimlane	Pools 	A Pool is the graphical representation of a *Participant* in a Collaboration. It also acts as a "swimlane" and a graphical container for partitioning a set of Activities from other Pools, usually in the context of B2B situations. A Pool MAY have internal details, in the form of the Process that will be executed. Or a Pool MAY have no internal details, i.e., it can be a "black box."	
	Lanes 	A Lane is a sub-partition within a Process, sometimes within a Pool, and will extend the entire length of the Process, either vertically or horizontally. Lanes are used to organize and categorize Activities.	
Flow object	Event 	An Event is something that "happens" during the course of a Process or a Choreography. These Events affect the flow of the model and usually have a cause (*trigger*) or an impact (*result*). Events are circles with open centers to allow internal markers to differentiate different *triggers* or *results*. There are three types of Events, based on when they affect the flow: Start, Intermediate, and End. Triggers identify the cause for an event, while results represent the consequence of a process. Triggers are shown by unfilled symbols, results by filled symbols.	
		Start 	indicates where a particular Process will start
		Intermediate 	• occur between a Start Event and an End Event • will affect the flow of the Process, but will not start or (directly) terminate the Process
		End 	Indicates where a Process will end
	Activity 	An Activity is a generic term for work that company performs in a Process. An Activity can be atomic or non-atomic (compound). The types of Activities that are a part of a Process Model are: Sub-Process and Task, which are rounded rectangles. Activities are used in both standard Processes and in Choreographies.	
		Collapsed sub-process	The details of the Sub-Process are not visible in the Diagram. A "plus" sign in the

			lower-center of the shape indicates that the Activity is a Sub-Process and has a lower level of detail.
		Expanded sub-process 	The boundary of the Sub-Process is expanded and the details (a Process) are visible within its boundary. Note that Sequence Flows cannot cross the boundary of a Sub-Process.
	Gateway 	A Gateway is used to control the divergence and convergence of Sequence Flows in a Process and in a Choreography. Thus, it will determine branching, forking, merging, and joining of paths. Internal markers will indicate the type of behavior control.	
		Exclusive 	Exclusive decision and merging. Both Exclusive and Event-Based perform exclusive decisions and merging Exclusive can be shown with or without the "X" marker.
		Parallel 	Parallel Gateway forking and joining.
Data	Data object 	Data Objects provide information about what Activities require to be performed and/or what they produce, Data Objects can represent a singular object or a collection of objects. Data Input and Data Output provide the same information for Processes.	
	Message 	A Message is used to depict the contents of a communication between two *Participants* (as defined by a business PartnerRole or a business PartnerEntity—see on page 91).	
Connecting object	Sequence flow	A Sequence Flow is used to show the order that Activities will be performed in a Process (see page 95) and in a Choreography.	
	Message flow	A Message Flow is used to show the flow of Messages between two *Participants* that are prepared to send and receive them. In BPMN, two separate Pools in a Collaboration Diagram will represent the two *Participants* (e.g., PartnerEntities and/or PartnerRoles).	
	Association 	An Association is used to link information and Artifacts with BPMN graphical elements. Text Annotations and other Artifacts can be Associated with the graphical elements. An arrowhead on the Association indicates a direction of flow (e.g., data), when appropriate.	
Artifact	Text annotation 	Text Annotations are a mechanism for a modeler to provide additional text information for the reader of a BPMN Diagram.	

Overview interviews

The first round of interviews following the Delphi method consisted of 21 interviews. The interview details are presented in Table 23.

Table 23: List of interviews (Delphi I)

Name	Organization	Function	Place	Form of contact
Olaf Blaauw	Delta Development Group / Delta Projectontwikkeling	senior strategic consultant / system executer	Hoofddorp	personal
Bouwe de Boer	Municipality Leeuwarden	Energy coordinator	by telephone	
Stefan Dannel	Studioninedots Architectenbureau	Project leader	Amsterdam	personal
Eberhard Dijkhuis	Dijkhuis Aannemersbedrijf bv	Direction / owner	by telephone	
Onno Dwars	VolkerWessels Vastgoed bv	Head of Acquisition & Innovation	by telephone	
Renate Heppener	Municipality Amsterdam	Project manager	Amsterdam	personal
Thijs Huijsmans	Royal Haskoning DHV	Project manager	Eindhoven	personal
Folkert Linnemans	Bouwgroep Dijkstra Draisma	Innovator	by telephone	
Jurgen Meijerink	Van Wijnen Gorredijk	Concept developer	by telephone	
Saman Mohammadi	Re-born bv , PhD TU Delft	direction re-born	Amsterdam	personal
Guus Mulder	TNO	Researcher / Consultant Building innovations	Den Haag	personal
Pim Peters	IMd Raadgevende Ingenieurs	Director, Advising Engineer	Written + discussed by telephone	
Mariëtte Pol	re-born BV	Project manager Duurzaam	Amsterdam	personal
Ricardo Poortvliet	BAM Bouw en Techniek B.V.	Tender manager	Apeldoorn	personal
Nena Rood	OVG Real Estate	Development Manager	Amsterdam	personal
Armand Schuurman	Amvest	Development manager	Amsterdam	personal
Joep Visschedijk	Amvest	Portfolio manager	Amsterdam	personal
Roy van Wechem	Delta Lloyd	portfolio manager	Amsterdam	personal
Bas van de Westerlo	C2C ExpoLAB	advisor circular construction and tendering	Venlo	personal
Rens Wijnakker	Delva Landscape Architecture& urbanism	Project leader & landscape architect	Amsterdam	personal
Freek Wullink	Arcadis	Consultant	Utrecht	personal

Introduction document interviews Delphi I

Introductie afstudeeronderzoek J. Scherer
In dit onderzoek ga ik in eerste instantie uit van het traditionele vastgoedontwikkelproces. Na het in kaart brengen van dit proces heb ik de meest belangrijke principes van circulaire economie op basis van een literatuurstudie geïdentificeerd. Deze principes zijn in het traditionele proces geïntegreerd, en op basis daarvan zijn er negen stellingen geformuleerd, die hierop betrekking hebben.
Voor de vragenlijst ben ik uitgegaan van enkele algemene uitgangspunten, uitgangspunten m.b.t. het traditionele vastgoedproces, en uitgangspunten m.b.t. circulaire principes. Een kort overzicht van de uitgangspunten komt nu aan de orde.

Algemene uitgangspunten
Voor dit onderzoek gelden de volgende algemene uitgangspunten:

- Het onderzoek is gericht op woningbouw in de vrije huur sector;
- Bouwrijpe grond wordt door de gemeente ter beschikking gesteld;
- De toekomstige eigenaar (belegger) is al bekend aan begin van het project;
- Het ontwikkelproces is gericht op samenwerking tussen partijen, exclusief financiële en wettelijke procesonderdelen (uitgaand van een traditionele samenwerking);
- Het ontwikkelproces gebeurt vanuit het perspectief van de professionele ontwikkelaar.

Traditioneel vastgoed ontwikkelproces
Het traditionele vastgoedontwikkelproces is in dit onderzoek beschreven aan de hand van vier fasen, namelijk: initiatieffase, ontwikkelfase, realisatiefase en exploitatiefase.

Initiatieffase: Tijdens deze fase wordt door de gemeente een tender uitbesteed, waarin zij partijen vragen een idee te ontwikkelen voor een woongebouw inclusief een aantal appartementen. Dit woongebouw zal gebouwd worden op bouwrijpe grond en na de bouw overgenomen worden door een belegger, die het gebouw in beheer neemt. Tijdens deze fase wordt de ontwikkeling van een idee aangestuurd door de projectontwikkelaar, die belangrijke partijen benadert en verzoekt of zij willen meewerken aan de tender. Mochten deze partijen dat willen, ontwikkelen zij samen op basis van een marktonderzoek, hun vakkennis, en de klantwensen een idee, die voor het tenderproces uitgewerkt wordt. Voordat de tender ingediend wordt, zal eerst een haalbaarheidsstudie gedaan worden, waarin de financiële, technische, politieke en sociale haalbaarheid onderzocht wordt. Als de uitkomst van de haalbaarheidsstudie positief is, wordt het concept voorgelegd aan de directie van het vastgoed ontwikkelbedrijf, en na hun toestemming ingediend bij het tenderproces. De gemeente zal dan beoordelen welk concept hun het beste lijkt voor dit project.

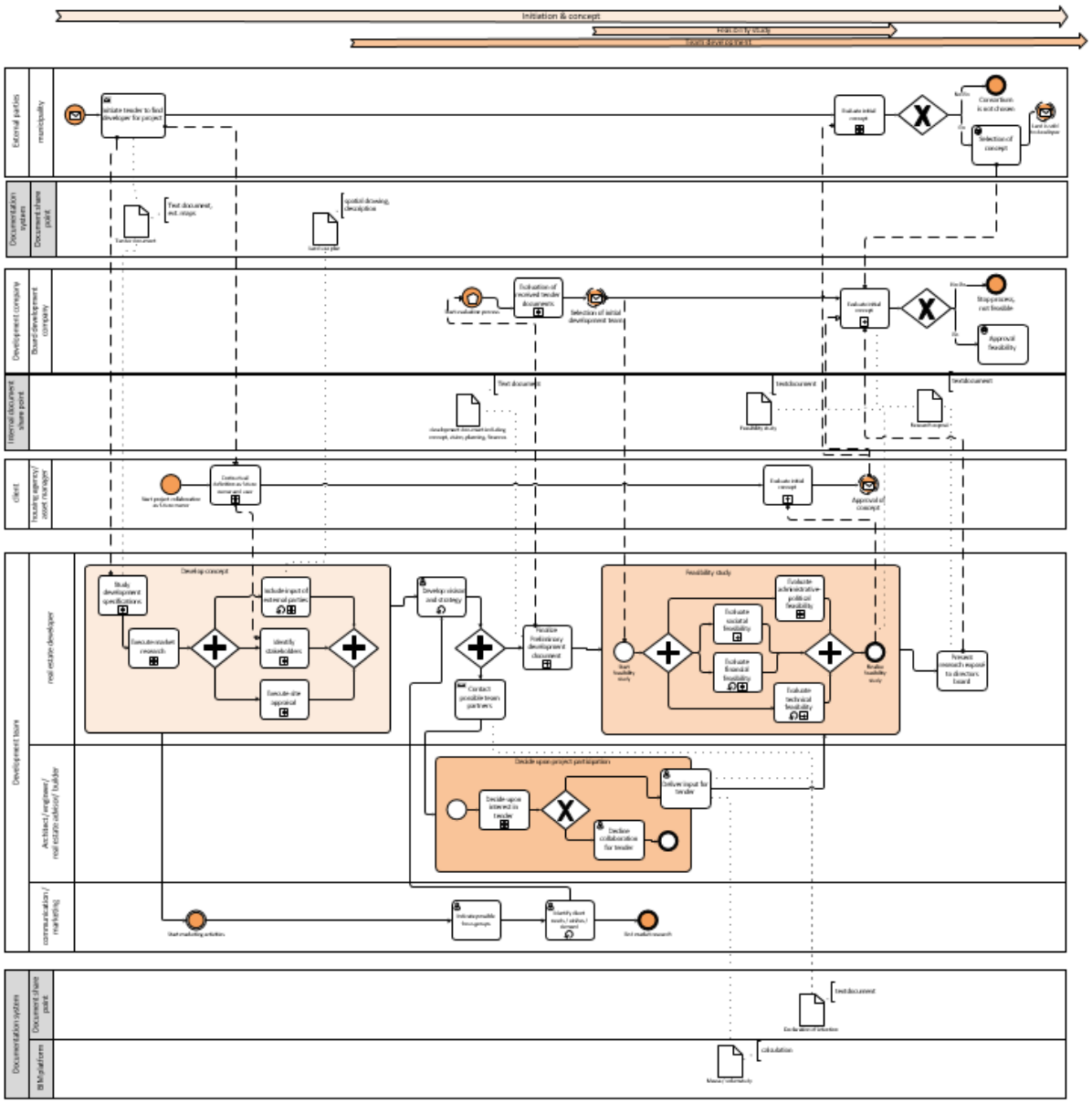


Figure 60: Deel van BPMN processchema voor initiatieffase (alleen als illustratie)

Ontwikkelfase: Deze fase begint nadat het concept van de ontwikkelaar is vastgesteld. Tijdens de ontwikkelfase wordt eerst een programma van eisen opgesteld, dat meestal functioneel en meetbaar beschrijft wat de opdrachtgever verwacht. Omdat in dit onderzoek ervan uitgegaan wordt dat een belegger het gebouw zal overnemen na de oplevering, zal zij een standard programma van eisen aan de ontwikkelaar overhandigen. Tegelijkertijd zal een ontwikkelaar een ontwikkelexposé opstellen, waarin beschreven is, wat de belangrijkste stappen tijdens de ontwikkeling zullen zijn, wanneer deze uitgevoerd worden, en vooral een indicatie van de geschatte kosten wordt gegeven. Dit exposé wordt ingediend bij de directie zodat deze financiële middelen beschikbaar kan maken voor de nieuwe fase in het ontwikkelproces. Tegelijkertijd met de uitwerking van het ontwikkelexposé, wordt het teambuildingproces afgerond. De partijen vanuit het tenderproces en eventuele nieuwe teamleden worden benaderd om met hen een samenwerkingscontract te sluiten. Tijdens dit proces is het belangrijk om verantwoordelijkheden, plichten en rechten duidelijk af te spreken zodat voor iedereen duidelijk is, wat van hen verwacht wordt. Als dit duidelijk is, kunnen de

teamleden beginnen met een schetsontwerp, op basis waarvan een voorontwerp en uiteindelijk een definitief ontwerp uitgewerkt kan worden. Tijdens iedere fase van de designontwikkeling neemt de mate van detail toe en daarmee neemt de flexibiliteit af om beslissingen te nemen. Iedere ontwerpstap wordt door de deelnemers van het ontwerpteam in samenwerking uitgewerkt en door de ontwikkelaar aan de belegger, zijn directie en de gemeente als toetsende instantie gepresenteerd. Mochten zij allemaal instemmen, wordt het design verder uitgewerkt. Als laatste onderdeel wordt op basis van het definitief ontwerp het bestek uitgewerkt, waarin de financiële consequenties van het ontwerp getoond worden samen met de definitieve tekeningen en calculaties. Parallel wordt ook de bouwvergunning aangevraagd bij de gemeente, die voor de uitvoering van de bouw voorhanden moet zijn.
In een traditioneel ontwikkeltraject heeft de ontwikkelaar de hoofdverantwoordelijkheid voor het project en is de aanspreekpartner voor de klant. Tijdens de ontwikkeling van het voorlopig ontwerp wordt de planontwikkelaar en projectmanager meer en meer betrokken om zijn ervaring van de traditionele uitvoering in te brengen en kennis op te bouwen voor de uitvoering.

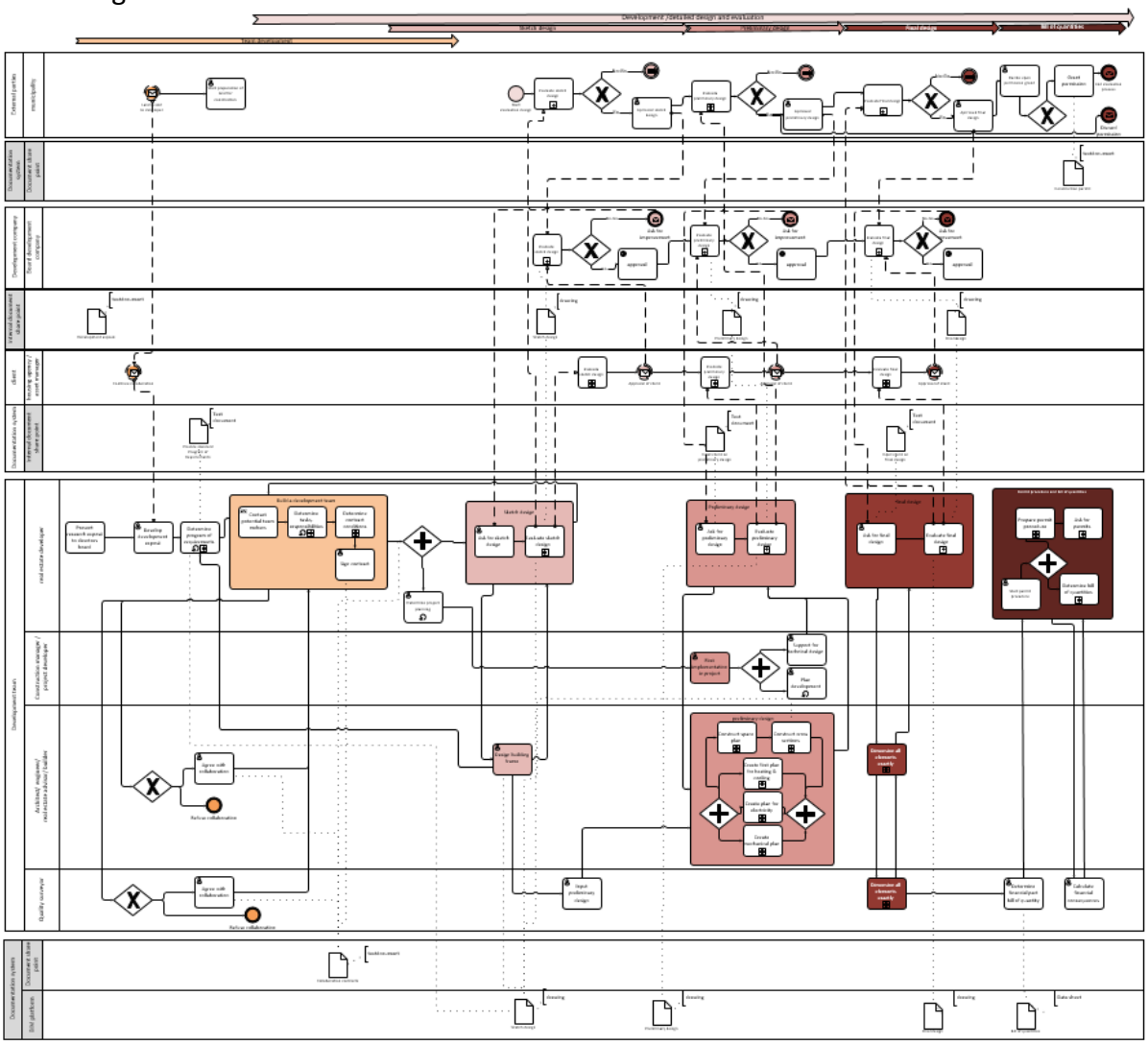


Figure 61: Deel van BPMN processchema voor ontwikkelfase (alleen als illustratie)

Realisatiefase: De realisatiefase begint evenals met de ontwikkelfase van een realisatie-exposé dat aan de directie van de ontwikkelaar wordt voorgelegd om financiële middelen beschikbaar te stellen. De taak van de projectontwikkelaar is nu meer gericht op controle,

communicatie en steun. Het aansturen van de bouwer en andere projectdeelnemers is nu de taak van de planontwikkelaar of projectmanager. Hij dient tijdens de werkvoorbereiding een planning op te stellen, waarin alle werkzaamheden met hun voorspelbare duur zijn aangegeven, inclusief uitvoerende partij of verantwoordelijke partij, en eveneens verantwoordelijkheden van taken. Maatregelen voor communicatie en samenwerking worden ingericht, evenals veiligheidsprotocollen. Een contract wordt gesloten met de bouwer en deze sluit weer contracten met zijn onderaannemers. Na de werkvoorbereiding wordt het werk daadwerkelijk uitgevoerd door de aannemers, gestuurd door de projectontwikkelaar. Het is zijn taak om kritische taken te identificeren en te waarborgen dat de KPI's te realiseren zijn. Hij moet erop reageren als iets niet volgens planning verloopt en oplossingen vinden. Aan het einde van de realisatiefase vindt de overdracht plaats, waarin het uiteindelijke product door de klant of zijn vertegenwoordiger, zoals een assetmanager, het product beoordeelt op kwalitatieve en functionele aspecten. De overdracht wordt uitgevoerd door de ontwikkelaar als eerste aanspreekspunt van de klant.

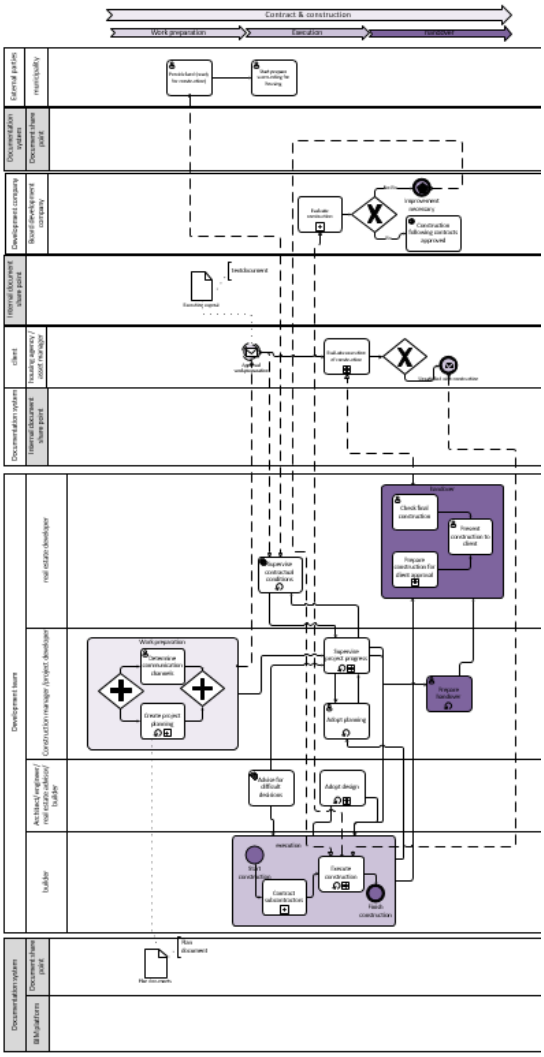


Figure 62: Deel van BPMN processchema voor constructiefase (alleen als illustratie)

Exploitatiefase: Aan het einde van het ontwikkelproces is er voor de ontwikkelaar nog de exploitatiefase. Dit is de fase, waarin de klant (hier de belegger) het gebouw in gebruik en in eigendoom neemt en de ontwikkelaar zijn ontwikkeltraject beoordeelt.

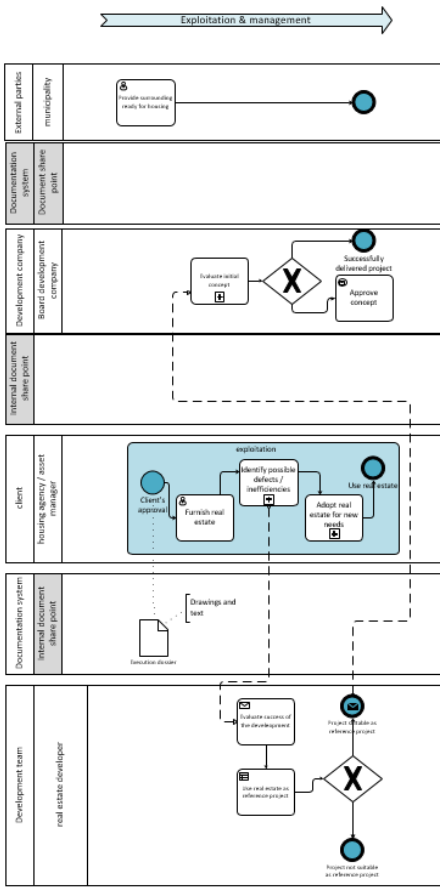


Figure 63: Deel van BPMN processchema voor exploitatiefase (alleen als illustratie)

Belangrijke stakeholders
Verder zijn als hoofdpersonen binnen het ontwikkelteam geïdentificeerd:

Ontwikkelteam
- Vastgoedontwikkelaar
- Planontwikkelaar / projectmanager
- Architect
- installatieadviseur, constructief, en/of bouwfysisch ingenieur
- Aannemer
- Kostendeskundige
- Partij vanuit de marketing

Externe partijen
- Directie vastgoed ontwikkelbedrijf
- Belegger als toekomstige eigenaar
- Gemeente

Circulaire principes

De circulaire principes zijn samengevat in de volgende drie tabellen als design principes, materiaalkeuze principes en samenwerkingsprincipes.

Design principes

Circulaire design principes	Beschrijving vanuit de literatuur
Ontwerp voor hergebruik (Design for reuse)	Elementen en hele onderdelen van gebouwen zullen voor een ander doel of als onderdeel van een ander gebouw hergebruikt kunnen worden zonder dat aanpassingen nodig zijn
Ontwerp voor demontage (Design for disassembly)	Elementen zijn zo ontworpen, dat ze gemakkelijk uit elkaar gehaald kunnen worden zodat materiaalcycli gemakkelijk te scheiden zijn
	Gebruikt om de levensduur van elementen te verlengen en sloop veilig in te richten
Voorkom vaste verbindingen	Voorkom vaste verbindingen zoals lijm, chemische of mechanische verbindingen; gebruik vooral geschroefde, gespijkerde of geklikte verbindingen
	Maak verbindingen bereikbaar voor werkzaamheden
Uitwisselbaarheid van componenten	Uitwisselbaarheid van componenten bereiken door modulaire, onafhankelijke en gestandaardiseerde materialen en systemen te gebruiken; dit kunnen geprefabriceerde onderdelen zijn
Aanpasbaar	Aanpasbare gebouwen, die simpel in structuur en vorm zijn en daardoor gemakkelijk geüpgraded kunnen worden zonder de gehele systeemperformance te beïnvloeden
	Gemakkelijk aanpasbaar voor veranderde toekomstige behoeften
Ontwerp om levenscycli te verlengen	Onderscheid elementen met verschillende levensduren, zoals structurele elementen, bekleding en installaties zodat functionaliteit en veiligheid op lange termijn gewaarborgd is
Ontwerp voor onderhoud en reparatie	Verbeteren van de presentatie van gebouwen door doelgericht ontwerp voor gemakkelijk onderhoud en reparatie
Verminder materiaal massa	Verminderen van materiaalmassa om materiaalverbruik te beperken en kosten te besparen voor materiaal, transport en mogelijke afval
Verminder afval	Optimaliseren van productieprocessen om afval te vermijden
	Ontwerp voor demontage om afval te vermijden
Verminder energie verbruik	Verminderen van energieverbruik door verschillende maatregelen, bijvoorbeeld: Gebruik van betere isolatie om energieverbruik tijdens de gebruiksfase te minimeren

Principes gerelateerd aan materiaalkeuze

Circulaire materiaalkeuze principes	Beschrijving vanuit de literatuur
Gebruik van biologisch afbreekbare materialen	Geen gebruik van toxische materialen
	Voorkeur voor biologisch afbreekbare materialen
	Sluit biologische cycli door biologische afbreking van materialen aan het einde van de levensduur
Verlenging van levenscycli van materialen	Verlenging van levenscycli van materialen door bescherming tegen externe invloeden, door design voor pure materiaalcycli en door te focussen op kwaliteitsbehoud
Voorkeur voor materialen die in de cyclus passen	Maximeren van waardenbehoud door gebruik van pure materialen en te focussen op het gehele hergebruik, daarna hergebruik van delen en tenslotte hergebruik van materialen
	Alleen gebruik van materialen, die binnen de technische of biologische cyclus passen
Gebruik materialen om performance te verbeteren	Gebruik materialen om gebouwperformance te verbeteren
	Focus op kwalitatief hoogwaardige producten om de waarde te verhogen
Gebruik van recyclede materialen	Gebruik van gerecyclede materialen in plaats van virgin materialen
Gebruik lokaal-verkrijgbare materialen	Gebruik lokaal verkrijgbare materialen om negatieve effecten van transport te beperken
Gebruik alleen hernieuwbare energie	Gebruik tijdens alle fasen van het ontwikkeltraject alleen hernieuwbare energie

Proces gerelateerde principes

Circulaire proces gerelateerde principes	Beschrijving vanuit de literatuur
Samenwerking met keten partners	Waardecreatie door cross-sectorale samenwerking van ketenpartners en corporaties om meervoudige waarde te creëren (economische waarde voor alle bedrijven van de keten, ecologische en sociale waarde)
	Creëer integratie en gedeelde waarden door nieuwe, langdurige relaties te ontwikkelen binnen de keten met langdurige business perspectieven en het durven nemen van verantwoordelijkheden
	Principes en ontwerp volgens duidelijk gedefinieerde doelen en geïntegreerde activiteiten
	Gebruiker stuurt de keten aan als onafhankelijke partijen
	Gebruik van nieuwe contractvorm zoals Product Service System
Aangepaste business cases	Aangepaste business cases volgens nieuwe verdienmodellen
Informatie uitwisseling	Verzamelen en uitwisselen van belangrijke informatie (ook materiaalbronnen), zoals BIM
Resource paspoort	Documentatie van materiaal gerelateerde informatie in de vorm van een database (welke materialen zijn waar gebruikt, op welke manier en hoe kunnen ze eruit gehaald worden)
Reversed logistics	Inrichten van reversed logistics om een systeem te creëren, dat materialen aan het einde van levenscycli terugneemt, verzamelt en voorbereidt voor nieuw gebruik in de markt
Aanpassen belastingsysteem	Belasting betalen voor materiaal in plaats van werk om arbeidsintensieve recycling te bevoordelen
Bedenk effecten later in het proces	Gebruik voorgefabriceerde componenten om materiaalafval te reduceren
Product als service	Gebruiker betaalt voor de performance van het product, maar wordt geen eigenaar in een functie georiënteerd business model
	Producent is verantwoordelijk voor productie, distributie, onderhoud en service maar blijft eigenaar van het product en de onderdelen ervan om optimaal gebruik voor gebruiker te kunnen garanderen of er is de optie voor terugkoop
Voorkom gevaarlijke emissies	Tijdens de productie en gebruik mogen geen gevaarlijke emissies vrij komen

Interview guide Delphi I

Toelichting interview circulaire vastgoedontwikkeling

Geachte heer/mevrouw,
Mijn naam is Johanna Scherer en ik volg de opleiding 'Construction Management and Engineering' aan de Technische Universiteit Eindhoven. Graag wil ik u uitnodigen om deel te nemen aan mijn afstudeeronderzoek.
Het onderwerp van circulaire economie is meer en meer van belang binnen de gebouwde omgeving, omdat grondstoffen schaars worden en daardoor duurder en uiteindelijk niet meer verkrijgbaar zullen zijn als wij vasthouden aan het huidige lineair economisch systeem. Om dit te veranderen is de Ellen MacArthur Foundation in 2013 begonnen met het concept van de circulaire economie te introduceren, wat van aanhoudende waardestromen voor grondstoffen uitgaat. In de afgelopen jaren wordt dit concept ook meer en meer geïntroduceerd binnen de bouwomgeving, die op basis van het enorme grondstoffengebruik heel erg getroffen zal worden bij grondstoffen schaarste. Als basis van de bouwindustrie wordt binnen dit onderzoek de vastgoedontwikkeling beschouwd, die voor het hergebruik of nieuwbouw van gebouwen zorgt. Dit onderzoek focust op de vraag hoe de principes van circulaire economie geïntroduceerd kunnen worden in vastgoedontwikkeling voor nieuwbouw in vrije sector huur in Nederland.
Om dit te doen is het traditionele vastgoedontwikkelproces in kaart gebracht in de vorm van een BPMN (Business Process Model and Notation) model. Eveneens zijn de meest belangrijke principes van de circulaire economie samengevat. Op basis hiervan zijn een aantal stellingen geformuleerd, hoe een circulair vastgoedontwikkelproces idealiter eruit kan zien en welke factoren bijzonder belangrijk zijn.
Ik wil u interviewen over de stellingen en in het bijzonder in hoeverre u het met de stelling eens bent en om welke redenen. Tevens vraag ik u, in dit interview, eerst een korte toelichting te geven op uw ervaring in vastgoedontwikkeling en circulaire economie, en om enige algemene informatie te geven.
Alle interviews met experts worden in juli gehouden, en worden begin augustus geëvalueerd. De uitkomsten van deze interviews worden eind augustus schriftelijk aan alle experts teruggekoppeld met de vraag om de stellingen opnieuw te beoordelen op basis van de feedback van alle antwoorden. Ik wil u vriendelijk vragen deel te nemen aan beide rondes om een goed en valide resultaat van het onderzoek te creëren.
Uw deelname helpt mij om dit afstudeeronderzoek tot een succes te maken. Ik wil u bij voorbaat bedanken voor uw medewerking.
Het interview zal ongeveer een uur duren. Ik wil graag het interview opnemen met een recorder voor mijn eigen documentatie. Uw informatie blijft geheel anoniem en wordt enkel voor dit onderzoek gebruikt.

Met vriendelijke groet,
Johanna Scherer

A. Algemene informatie

Datum: Click here to enter a date.
Tijd: Click here to enter text.

1. Wat is uw naam?
Click here to enter text.

2. Wat is uw geslacht?
☐ Vrouw
☐ Man

3. Wat is uw leeftijd?
☐ ≤ 30 jaar
☐ 31-40 jaar
☐ 41-50 jaar
☐ > 50 jaar

4. Voor welke organisatie bent u werkzaam?
_____

5. Welke functie hebt u op dit moment binnen deze organisatie?
Click here to enter text.

6. Hoeveel jaren hebt u ervaring met vastgoedontwikkeling?
☐ Minder dan 5 jaar
☐ 5-10 jaar
☐ 11-15 jaar
☐ 16-20 jaar
☐ Meer dan 20 jaar

7. Wat is uw ervaring met vastgoedontwikkeling? Vanuit welke functie heeft u deze ervaring?
_____
_____
_____
_____

8. Hebt u ervaring met circulaire economie binnen de bouwwereld?
☐ Nee
☐ Ja

9. Als u al ervaring hebt met circulaire economie, wat is dan uw ervaring? (graag een korte projectbeschrijving inclusieve betrokken stakeholders, tijdstip van ontwikkeling/ uitvoering, uw functie in het project, ontwikkelde kennis)

Korte beschrijving project:

_____
_____
_____
_____
_____
_____

Tijdstip van ontwikkeling / uitvoering:

_____

Uw functie:

_____

Welke ervaring en/of kennis heeft u met dit project opgedaan:

_____
_____
_____
_____

10. Heeft u opmerkingen m.b.t. de principes van circulaire economie in het vastgoed ontwikkelproces? Mist u nog belangrijke principes en voor welke stap(pen) binnen het vastgoed ontwikkelproces zouden deze belangrijk zijn?

Principe	Stap in het proces
Click here to enter text.	Click here to enter text.
Click here to enter text.	Click here to enter text.
Click here to enter text.	Click here to enter text.
Click here to enter text.	Click here to enter text.
Click here to enter text.	Click here to enter text.
Click here to enter text.	Click here to enter text.
Click here to enter text.	Click here to enter text.

B. Stellingen

Hierna treft u 9 stellingen aan rondom de toepassing van circulaire principes binnen het vastgoed ontwikkelingsproces.
Graag voor iedere stelling aangeven in welke mate u met de stelling (on)eens bent, en vergezeld met een korte motivatie en/of redenen.

1. De belangrijkste stakeholder om het vastgoedontwikkelingsproces circulair in te richten, is de vastgoedontwikkelaar. De vastgoedontwikkelaar heeft contact met alle andere stakeholders en dient daarom als eerste de circulaire principes toe te passen en van anderen te vragen dat ook te doen.

helemaal oneens	oneens	neutraal	eens	helemaal eens
☐	☐	☐	☐	☐

Motivering / redenen?

_____
_____
_____

2. Tijdens de initiatieffase, ontwikkeling en constructie is het meest belangrijk, dat het gebouw de design-principes 'design for disassembly' en 'adaptability' volgt, en materialen gebruikt worden, die binnen de cycli passen, en een sterke communicatie plaats vindt binnen het ontwikkelingsteam. Dan hoeft de klant of toekomstige eigenaar niet meer betrokken worden tijdens de ontwikkeling, omdat elke wens inpasbaar is in het ontwikkeld concept.

helemaal oneens	oneens	neutraal	eens	helemaal eens
☐	☐	☐	☐	☐

Motivering / redenen?

_____
_____
_____

3. Het is belangrijk om design principes al tijdens de initiatieffase in de conceptontwikkeling te introduceren, ook al bestaat er nog geen samenwerking met anderen stakeholders en ook al leidt dit tot hogere bouwkosten voor het ontwikkeld concept.

helemaal oneens	oneens	neutraal	eens	helemaal eens
☐	☐	☐	☐	☐

Motivering / redenen?

_____
_____
_____

4. Proces gerelateerde principes hebben vooral betrekking op het samenstellen van een ontwikkelingsteam en op de bouwuitvoering. In alle andere fasen, zoals design ontwikkeling, bestekfase, exploitatie en end-of-life zijn deze principes minder van belang.

helemaal oneens	oneens	neutraal	eens	helemaal eens
☐	☐	☐	☐	☐

Motivering / redenen?

_____
_____
_____

5. Het programma van eisen is één van de belangrijkste documenten in het vastgoed ontwikkelproces. Daarom is het essentieel, dat hier zowel design principes (zoals 'design for disassembly', adaptability, geen vaste materiaalverbindingen), maar ook materiaalkeuze principes in de vorm van prestatie-eisen in het programma van eisen verwerkt worden.

helemaal oneens	oneens	neutraal	eens	helemaal eens
☐	☐	☐	☐	☐

Motivering / redenen?

_____
_____
_____

6. Tijdens de design ontwikkeling zijn vooral de design-principes 'design for reuse' en 'design for disassembly' belangrijk, evenals de proces-principes van 'samenwerking met keten partners' en 'uitwisseling van informatie'. Andere design en proces principes zijn veel minder belangrijk, evenals de keuze voor bepaalde materialen.

helemaal oneens	oneens	neutraal	eens	helemaal eens
☐	☐	☐	☐	☐

Motivering / redenen?

_____
_____
_____

7. Tijdens de werkvoorbereiding en werkuitvoering moeten proces principes gebruikt worden om de communicatie te ondersteunen. Verder is het belangrijk, dat uitvoerders de design principes verstaan en tijdens de werkvoorbereiding de juisten materialen gekozen worden volgens de materiaal principes. Hun invloed tijdens de initiatieffase en ontwerp ontwikkeling moet vergroot worden.

helemaal oneens	oneens	neutraal	eens	helemaal eens
☐	☐	☐	☐	☐

Motivering / redenen?

_____
_____
_____

8. Het is belangrijk, dat gebruikers of eigenaren alle principes van circulaire gebouwen begrijpen om deze vanuit de ontwikkeling door te zetten tijdens de exploitatiefase. Dit betreft het vervangen van onderdelen, het bijhouden van een materiaal paspoort en de zuinige omgang met grondstoffen en afval.

helemaal oneens	oneens	neutraal	eens	helemaal eens
☐	☐	☐	☐	☐

Motivering / redenen?

_____
_____
_____

9. In vergelijking met het traditionele proces moet bij een circulair vastgoed ontwikkelproces nog een fase van end-of-life toegevoegd worden. Tijdens die fase zijn vooral ‘reverse logistics’ en ‘products as services’ van belang.

helemaal oneens	oneens	neutraal	eens	helemaal eens
☐	☐	☐	☐	☐

Motivering / redenen?

_____
_____
_____

Codebook

In order to be able to evaluate the given justification of the experts evaluation of the statements, a codebook is created, which represents the given reasons in form of codes. Further, Table 24 indicated how often the code was mentioned in total (#) and which percentage of all mentioned reasons this is (#/sum(#)).

Table 24: Codebook

	code	description	#	#/sum(#) [%]
Statement 1	reason1.1	the real estate developer is important, but he need to collaborate with other parties	10	21%
	reason1.2	the development is based on a chain development, where all chain partners have knowledge and willingness for circularity	3	6%
	reason1.3	the client is the most important stakeholder, as carrying the risks for the development	7	15%
	reason1.4	the client is the most important stakeholder of the process, who has knowledge about circularity and need to trigger the development	5	11%
	reason1.5	the real estate developer need to have knowledge and a preference for circularity principles	6	13%
	reason1.6	the real estate developer is central for the organization of the process as he keeps the overview over the finance and construction execution	7	15%
	reason1.7	if necessary, an circularity expert should provide advice and guidance	3	6%
	reason1.8	the government need to stimulate circularity by law supported by the investor	1	2%
	reason1.9	the investor need to trigger the ambition for circularity	3	6%
	reason1.10	it needs to fit within the legal regulations	2	4%
Statement 2	reason2.1	the client and his wishes need to be considered in any case	16	34%
	reason2.2	those principles are important to be considered	11	23%
	reason2.3	design for disassembly is not one of the most important principles	2	4%
	reason2.4	it is important to think about the modularity of the building early in the process	5	11%
	reason2.5	materials, that are coming free need to be considered	2	4%
	reason2.6	it's important to find circular materials	2	4%
	reason2.7	the principles depend on whether a long-term perspective or short-term use is considered for the building	2	4%
	reason2.8	the function, location and focus group of the building need to considered throughout the development	1	2%
	reason2.9	the client need to be considered at the beginning and his wishes need to be remembered throughout the development	6	13%

	code	description	#	#/sum(#) [%]
Statement 3	reason3.1	concept need to be introduced early on to take all chances	20	31%
	reason3.2	the ambition need to be defined at the beginning of the process together with the client and the fitting principles need to be defined	17	27%
	reason3.3	determine the business case for all parties throughout the lifecycle at the beginning	4	6%
	reason3.4	select your business partners based on ambition and knowledge	5	8%
	reason3.5	building circular can lead towards higher costs for construction, which can be earned back through lower costs during exploitation phase	8	13%
	reason3.6	higher construction costs need to be reimbursed by reduced exploitation costs	5	8%
	reason3.7	building circular is not necessarily more expensive	5	8%
Statement 4	reason4.1	those principles are of high importance for the exploitation phase	6	16%
	reason4.2	those principles are of high importance for the end-of-life phase	5	14%
	reason4.3	principles need to be considered mainly during the development and for bill of quantities	1	3%
	reason4.4	those principles are relevant for all phases	13	35%
	reason4.5	some process-related principles need to be considered for the selection of business partners, which takes place when formulating the bills of quantity	2	5%
	reason4.6	the selection of principles depends on the project conditions and need to be chosen at the beginning of the process	8	22%
	reason4.7	not everybody need to attend each of the phases	1	3%
	reason4.8	end-of-life is better called end-of-use	1	3%
Statement 5	reason5.1	performance-based procurement enables more innovations	7	13%
	reason5.2	the combination of programme of requirements and circular business case is most important	1	2%
	reason5.3	the programme of requirements need to be open for new innovations	12	22%
	reason5.4	the programme of requirements is an important document	16	30%
	reason5.5	the programme of requirements needs to ask for a solution of maximum quality paid with predefined budget	2	4%
	reason5.6	there are other important documents such as the vision, phase documents, ambition document and business case	4	7%
	reason5.7	the contract forms the basis for the PoR and need to be made as a performance contract	1	2%
	reason5.8	it need to be clear, what the wishes are and what the hard requirements are within the PoR	7	13%
	reason5.9	the PoR is better called programma of performances	3	6%
	reason5.10	the PoR need to be developed based on the exploitation phase	1	2%

	code	description	#	#/sum(#) [%]
Statement 6	reason6.1	those are not the only important principles	18	41%
	reason6.2	energy-related issues need to be considered as well	4	9%
	reason6.3	process-related principles are important as well	5	11%
	reason6.4	material choice is important as well	11	25%
	reason6.5	the design need to follow the needs of future users	4	9%
	reason6.6	all other principles are only relevant later on in the process	1	2%
	reason6.7	the most important principle is to create a healthy environment	1	2%
Statement 7	reason7.1	the executor need to be actively included in the team early on	12	39%
	reason7.2	the executor need to be passively included in the team early on	1	3%
	reason7.3	not the work executor, but the project manager from the construction company	5	16%
	reason7.4	the executor need to take over the task of market evaluation regarding possibilities for materialization and purchase	1	3%
	reason7.5	not only the builder, but also the producer and supplier with an intention towards CE need to be included earlier in the process	3	10%
	reason7.6	standardized concepts need to be developed. Here the executors should attend to support the concept development.	6	19%
	reason7.7	the executor should not attend earlier since this can diminish the innovations	3	10%
Statement 8	reason8.1	tenants do not need to be confronted with too technical details, but mainly with principles, which are relevant for their living environment so that it stays nice to live there	17	32%
	reason8.2	the user can be asked to maintain the circularity measures of a building	4	8%
	reason8.3	the owner of the building is responsible to communicate the most important principles towards the tenants and need to actively supervise changes in the building and assist the tenant in executing changes	11	21%
	reason8.4	all parties need to sign official commitment to maintaining the circularity principles	2	4%
	reason8.5	a professional party, such as a facility manager / asset manager need to maintain the circularity of the building	11	21%
	reason8.6	the design need to be so, that the tenant follows automatically the circularity principles	1	2%
	reason8.7	the tenant and owner need to maintain the principles based on their personal interest for it, not due to an obligation	6	11%
	reason8.8	totally agree with statement as described	1	2%
Statement 9	reason9.1	this final phase of the cycle is important, but future developments are difficult to predict (existence of project partners, responsibility for last phase)	17	44%
	reason9.2	end-of-life is not a separate phase, but part of the circle	10	26%
	reason9.3	it needs to be renamed: end-of-use	5	13%
	reason9.4	it is important if the building shows a remaining value	2	5%
	reason9.5	adoptability and flexibility are important	5	13%
	reason9.6	it's important to ensure, that elements and materials can be separated at the end of use	16	41%

Interview evaluation

The tables underneath present the coding of the 21 interviews executed personally in July and beginning of August. The whole table can be found on the CD with the title 'Data evaluation Delphi I' in order to have access to the data set.

Table 25: Written evaluation proposition1

participant	1 vastgoedontwikkelaar als belangrijkste stakeholder		likert value	reason1.1	reason1.2	reason1.3	reason1.4	reason1.5	reason1.6	reason1.7	reason1.8	reason1.9	reason1.10	uitleg
participant1	eens	agree	1	1	0	0	0	1	1	0	0	0	0	*eens, dat
participant2	oneens	disagree	-1	0	0	1	0	1	0	0	0	0	0	*de opdra
participant3	eens	agree	1	1	0	0	0	1	0	1	0	0	0	*vastgoed
participant4	eens	agree	1	0	0	0	0	0	1	0	0	0	0	de vastgoe
participant5	oneens	disagree	-1	0	0	0	0	0	0	0	1	1	0	de overhei
participant6	helemaal eens	totally agree	2	0	0	1	0	0	0	0	0	0	1	helemaal e
participant7	oneens	disagree	-1	1	0	0	0	1	0	1	0	0	0	vastgoedo
participant8	oneens	disagree	-1	0	0	1	1	0	0	0	0	0	1	in de huidi
participant9	eens	agree	1	1	0	0	0	0	1	0	0	0	0	na zijn ide
participant10	eens	agree	1	1	0	0	0	0	1	0	0	0	0	de vastgoe
participant11	helemaal oneens	totally disagree	-2	0	1	0	0	0	0	0	0	0	0	Hierbij wo
participant12	eens	agree	1	0	0	0	0	1	1	0	0	0	0	in het trad
participant13	eens	agree	1	1	0	0	0	1	1	1	0	0	0	De vastgo
participant14	eens	agree	1	1	0	1	1	0	1	0	0	0	0	eens, vast
participant15	oneens	disagree	-1	0	1	0	0	0	0	0	0	0	0	in een circ
participant16	oneens	disagree	-1	0	0	1	1	0	0	0	0	1	0	Bij het eer
participant17	helemaal eens	totally agree	2	0	0	1	1	0	0	0	0	0	0	Dit is volge
participant18	neutraal / eens	neutral / agree	0.5	1	0	0	0	0	0	0	0	0	0	Op zich en
participant19	eens	agree	1	1	0	0	0	0	0	0	0	1	0	de vastgoe
participant20	eens	agree	1	0	0	1	1	0	0	0	0	0	0	in het alge
participant21	eens	agree	1	1	1	0	0	0	0	0	0	0	0	MAAR het
				10	3	7	5	6	7	3	1	3	2	
				21%	6%	15%	11%	13%	15%	6%	2%	6%	4%	

Table 26: Written evaluation proposition2

2 perfect aanpasbar, klant niet meer belangrijk		likert value	reason2.1	reason2.2	reason2.3	reason2.4	reason2.5	reason2.6	reason2.7	reason2.8	reason2.9	uitleg
oneens	disagree	-1	0	1	0	0	0	0	0	1	0	*uiteindeli
helemaal oneens	totally disagree	-2	1	1	0	0	0	0	0	0	0	*eerste ge
oneens	disagree	-1	1	1	0	1	0	1	0	0	0	*design fo
oneens	disagree	-1	1	0	0	0	0	0	0	0	0	oneens wa
oneens	disagree	-1	1	0	0	0	0	0	0	0	0	de investe
oneens	disagree	-1	0	0	0	0	0	0	0	0	1	*want de s
oneens	disagree	-1	0	0	0	0	0	0	0	0	1	de klant is
helemaal oneens	totally disagree	-2	1	1	0	1	0	0	0	0	0	design for
oneens	disagree	-1	1	0	0	0	0	0	0	0	0	natuurlijk r
oneens	disagree	-1	1	1	0	0	0	0	0	0	0	heel ideali
eens	agree	1	1	1	0	0	0	0	0	0	0	En dat er n
oneens	disagree	-1	1	0	1	0	1	0	1	0	0	als een kla
oneens	disagree	-1	0	0	1	0	0	0	0	0	0	In dit rijtje
neutraal	neutral	0	1	1	0	0	0	0	0	0	0	deel mee e
oneens	disagree	-1	1	0	0	0	0	0	1	0	0	klant = bel
oneens	disagree	-1	1	1	0	1	0	1	0	0	0	de mate va
eens	agree	1	0	1	0	1	1	0	0	0	0	Echter is h
eens	agree	1	1	1	0	0	0	0	0	0	1	Disessemb
oneens	disagree	-1	1	0	0	0	0	0	0	0	1	De klant m
oneens	disagree	-1	1	1	0	1	0	0	0	0	1	Het is altijd
oneens	disagree	-1	1	0	0	0	0	0	0	0	1	De klant m
			16	11	2	5	2	2	2	1	6	
			34%	23%	4%	11%	4%	4%	4%	2%	13%	

Table 27: Written evaluation proposition3

participant	3 initiaffase		likert value	reason3.1	reason3.2	reason3.3	reason3.4	reason3.5	reason3.6	reason3.7	uitleg
participant1	eens	agree	1	1	1	1	0	0	0	0	*de princi
participant2	helemaal eens	totally agree	2	1	1	0	1	0	0	0	*heel bela
participant3	helemaal eens	totally agree	2	1	0	1	0	0	0	0	*desto ee
participant4	helemaal eens	totally agree	2	1	1	0	0	0	1	0	hogere bo
participant5	helemaal eens	totally agree	2	1	0	0	0	0	0	0	*thema's l
participant6	oneens	disagree	-1	0	0	0	0	1	1	0	want hoge
participant7	eens	agree	1	1	0	0	0	1	1	1	grotendee
participant8	oneens	disagree	-1	1	1	0	0	0	0	0	circulaire
participant9	eens	agree	1	1	1	0	0	0	0	0	dat is bela
participant10	oneens	disagree	-1	1	1	0	0	1	0	1	Als de prin
participant11	helemaal eens	totally agree	2	1	1	1	0	1	0	1	Waarom z
participant12	helemaal eens	totally agree	2	1	1	1	1	0	0	0	Hogere bo
participant13	eens	agree	1	1	1	0	0	1	1	0	Door tijde
participant14	eens	agree	1	1	1	0	1	0	0	1	als je het r
participant15	eens	agree	1	1	1	0	0	0	0	0	Het is juist
participant16	eens	agree	1	1	1	0	0	0	0	0	circulaire
participant17	helemaal eens	totally agree	2	1	1	0	1	1	0	0	Wanneer
participant18	eens	agree	1	1	1	0	0	1	1	0	Eens, de ir
participant19	eens	agree	1	1	1	0	0	0	0	0	als het lat
participant20	neutraal	neutral	0	1	1	0	1	0	0	1	De princip
participant21	helemaal eens	totally agree	2	1	1	0	0	1	0	0	in het begi
				20	17	4	5	8	5	5	
				31%	27%	6%	8%	13%	8%	8%	

Table 28: Written evaluation proposition4

4 proces-relateerde principes		likert value	reason4.1	reason4.2	reason4.3	reason4.4	reason4.5	reason4.6	reason4.7	reason4.8	uitleg
oneens	disagree	-1	1	1	0	0	0	1	0	0	*proces re
helemaal oneens	totally disagree	-2	0	0	0	1	0	0	0	0	*deze prin
helemaal oneens	totally disagree	-2	0	0	0	1	0	0	0	0	*proces-re
helemaal oneens	totally disagree	-2	0	0	0	1	0	0	0	1	end of life
oneens	disagree	-1	0	0	0	1	0	0	0	0	principes z
helemaal oneens	totally disagree	-2	0	0	0	1	0	0	0	0	want de ke
helemaal oneens	totally disagree	-2	0	0	0	1	0	0	0	0	*klopt niet
oneens	disagree	-1	1	0	0	0	0	1	0	0	nee, zijn o
oneens	disagree	-1	1	1	0	0	0	1	0	0	tijdens de
helemaal oneens	totally disagree	-2	1	1	0	0	0	0	0	0	Voor de ex
helemaal oneens	totally disagree	-2	0	0	0	1	0	1	0	0	iedereen n
oneens	disagree	-1	0	0	0	0	1	1	1	0	*er moet r
oneens	disagree	-1	0	0	0	0	1	0	0	0	Voor het s
oneens	disagree	-1	0	0	0	1	0	0	0	0	het moet v
oneens	disagree	-1	0	0	0	1	0	1	0	0	het is EEN
oneens	disagree	-1	0	0	0	1	0	0	0	0	de hele ke
helemaal oneens	totally disagree	-2	1	1	0	0	0	1	0	0	Benaderd
oneens	disagree	-1	0	0	0	1	0	1	0	0	Oneens. Bi
helemaal oneens	totally disagree	-2	0	0	0	1	0	0	0	0	dit gaat jui
oneens	disagree	-1	1	1	0	1	0	0	0	0	proces-rel
oneens	disagree	-1	0	0	1	0	0	0	0	0	tijdens de
			6	5	1	13	2	8	1	1	
			16%	14%	3%	35%	5%	22%	3%	3%	

Table 29: Written evaluation proposition5

participant	5 PvE		likert value	reason5.1	reason5.2	reason5.3	reason5.4	reason5.5	reason5.6	reason5.7	reason5.8	reason5.9	reason5.10	uitleg
participant1	eens	agree	1	0	0	0	1	0	0	0	1	0	0	*principes
participant2	helemaal eens	totally agree	2	0	0	1	1	0	0	0	0	0	0	*het is afh
participant3	eens	agree	1	0	0	1	1	1	1	0	0	0	0	*PvE is nie
participant4	eens	agree	1	0	0	0	0	1	0	0	0	0	0	*eens, MA
participant5	eens	agree	1	0	0	1	1	0	0	0	0	0	0	gebeurd al
participant6	oneens	disagree	-1	0	1	0	1	0	1	0	0	1	0	want het F
participant7	eens	agree	1	1	0	0	1	0	0	0	0	1	0	prestatie-(
participant8	oneens	disagree	-1	0	0	0	0	0	1	1	0	0	0	PvE is een
participant9	eens	agree	1	0	0	1	0	0	0	0	1	0	0	neem wel
participant10	eens	agree	1	0	0	1	1	0	0	0	0	0	0	PvE komt v
participant11	eens	agree	1	0	0	1	1	0	0	0	0	0	1	PvE moet
participant12	eens	agree	1	1	0	0	0	0	0	0	0	0	0	prestatieg
participant13	oneens	disagree	-1	0	0	1	1	0	0	0	1	0	0	De materia
participant14	helemaal eens	totally agree	2	0	0	1	1	0	0	0	1	0	0	dit is in pri
participant15	eens	agree	1	0	0	1	1	0	0	0	0	0	0	Het is een
participant16	helemaal eens	totally agree	2	1	0	1	1	0	0	0	1	1	0	eens, dat h
participant17	helemaal eens	totally agree	2	1	0	0	1	0	0	0	0	0	0	Dit klopt v
participant18	eens	agree	1	0	0	1	1	0	0	0	1	0	0	Eens, een
participant19	eens	agree	1	1	0	0	0	0	0	0	0	0	0	het zou he
participant20	helemaal eens	totally agree	2	1	0	0	1	0	0	0	1	0	0	Voor dat h
participant21	eens	agree	1	1	0	1	1	0	1	0	0	0	0	Binnen ee
				7	1	12	16	2	4	1	7	3	1	
				13%	2%	22%	30%	4%	7%	2%	13%	6%	2%	

Table 30: Written evaluation proposition6

6 design ontwikkeling		likert value	reason6.1	reason6.2	reason6.3	reason6.4	reason6.5	reason6.6	reason6.7	uitleg
oneens	disagree	-1	1	1	0	0	0	0	0	*er zit een
helemaal oneens	totally disagree	-2	1	0	1	0	0	0	0	ook ander
helemaal oneens	totally disagree	-2	1	0	0	0	1	0	0	deze uitleg
oneens	disagree	-1	1	0	0	1	0	0	0	materiaalk
oneens	disagree	-1	1	0	1	1	0	0	0	keuze van
helemaal eens	totally agree	2	0	0	0	0	0	1	0	de design p
neutraal	neutral	0	1	0	1	0	0	0	0	dit zijn bel
helemaal oneens	totally disagree	-2	0	0	0	1	0	0	0	geen geloo
helemaal oneens	totally disagree	-2	1	1	0	0	0	0	0	deze vier p
helemaal oneens	totally disagree	-2	1	1	1	1	0	0	0	dat is te ko
neutraal	neutral	0	1	1	0	0	1	0	0	je moet be
oneens	disagree	-1	1	0	0	1	0	0	0	*het mate
oneens	disagree	-1	1	0	0	1	0	0	0	De design
oneens	disagree	-1	1	0	0	1	0	0	0	dit is ook e
neutraal	neutral	0	1	0	0	0	0	0	0	deze zijn b
eens	agree	1	1	0	0	1	1	0	0	dat zijn de
neutraal	neutral	0	1	0	0	1	0	0	0	Ik ben het
eens	agree	1	0	0	1	0	0	0	0	zie punt 5g
oneens	disagree	-1	1	0	0	1	0	0	0	in plaats va
oneens	disagree	-1	1	0	0	0	1	0	0	Tijdens de
neutraal	neutral	0	1	0	0	1	0	0	1	het moet v
			18	4	5	11	4	1	1	
			41%	9%	11%	25%	9%	2%	2%	

Table 31: Written evaluation proposition7

participant	7 werkvoorbereiding/-uitvoering, betrekking van werkvoorbereider		likert value	reason7.1	reason7.2	reason7.3	reason7.4	reason7.5	reason7.6	reason7.7	uitleg
participant1	helemaal eens	totally agree	2	1	0	0	0	0	0	0	*heel bela
participant2	helemaal eens	totally agree	2	1	0	0	0	0	0	0	wat verzor
participant3	eens	agree	1	1	0	0	0	0	0	0	aanemer n
participant4	eens	agree	1	1	0	0	0	0	0	0	de betrekk
participant5	helemaal eens	totally agree	2	1	0	0	0	0	0	0	ja, zij moet
participant6	helemaal eens	totally agree	2	0	1	0	0	0	0	0	tijdens de i
participant7	eens	agree	1	1	0	0	0	1	0	0	MAAR de l
participant8	oneens	disagree	-1	0	0	0	0	0	1	1	zij moten n
participant9	helemaal eens	totally agree	2	1	0	0	0	0	0	0	uitvoerder
participant10	oneens	disagree	-1	0	0	1	0	0	1	0	*Werkvoo
participant11	eens	agree	1	1	0	0	0	0	1	0	Met name
participant12	eens	agree	1	1	0	1	0	1	0	0	*de juiste
participant13	oneens	disagree	-1	0	0	0	0	0	0	1	De bijdrage
participant14	oneens	disagree	-1	0	0	1	0	0	1	0	naar mijn n
participant15	eens	agree	1	1	0	0	1	0	1	0	werkvoorb
participant16	neutraal	neutral	0	0	0	0	0	0	1	0	Werkvoorb
participant17	helemaal oneens	totally disagree	-2	0	0	1	0	0	0	0	De praktijk
participant18	neutraal	neutral	0	1	0	0	0	1	0	0	Niet alleer
participant19	eens	agree	1	1	0	0	0	0	0	0	om de ont
participant20	oneens	disagree	-1	0	0	0	0	0	0	1	Dit is afhar
participant21	helemaal eens	totally agree	2	0	0	1	0	0	0	0	hier is het
				12	1	5	1	3	6	3	
				39%	3%	16%	3%	10%	19%	10%	

Table 32: Written evaluation proposition8

8 exploitatiefase, betrekking van eigenaren / gebruikers		likert value	reason8.1	reason8.2	reason8.3	reason8.4	reason8.5	reason8.6	reason8.7	reason8.8	uitleg
eens	agree	1	1	0	1	0	1	0	0	0	*de belegg
neutraal	neutral	0	1	0	0	0	0	0	0	0	*alle princ
eens	agree	1	1	1	0	0	0	0	1	0	de gebruik
helemaal eens	totally agree	2	0	0	0	0	0	0	0	1	zoals het s
eens	agree	1	1	0	1	0	0	0	1	0	*op dit mo
oneens	disagree	-1	1	0	1	0	0	0	1	0	*eigenarer
eens	agree	1	1	0	0	0	1	0	0	0	*in het alg
oneens	disagree	-1	1	0	0	0	1	0	0	0	*circulair g
eens	agree	1	1	0	0	0	0	1	0	0	de klant m
eens	agree	1	0	1	1	1	0	0	0	0	is me eens
helemaal eens	totally agree	2	1	1	1	0	1	0	0	0	Mensen m
oneens	disagree	-1	1	0	1	0	0	0	0	0	*weinig ge
eens	agree	1	0	1	1	1	0	0	0	0	Met name
eens	agree	1	1	0	0	0	1	0	1	0	ze moeten
helemaal eens	totally agree	2	1	0	0	0	1	0	0	0	MAAR wel
oneens	disagree	-1	1	0	0	0	1	0	0	0	Wil een kla
eens	agree	1	1	0	0	0	1	0	1	0	Ook van be
eens	agree	1	1	0	1	0	1	0	0	0	zie punt 4*
eens	agree	1	1	0	1	0	1	0	0	0	het is bela
eens	agree	1	1	0	1	0	1	0	0	0	vooral de l
eens	agree	1	0	0	1	0	0	0	1	0	-een mate
			17	4	11	2	11	1	6	1	
			32%	8%	21%	4%	21%	2%	11%	2%	

Table 33: Written evaluation proposition9

participant	9 end-of-life: reverse logistics, products as service		likert value	reason9.1	reason9.2	reason9.3	reason9.4	reason9.5	reason9.6	uitleg
participant1	helemaal eens	totally agree	2	1	0	0	0	0	1	*ontwikkel
participant2	eens	agree	1	1	0	0	0	0	0	*het is bel
participant3	helemaal eens	totally agree	2	1	1	0	0	0	1	deze fase r
participant4	neutraal	neutral	0	0	1	1	1	0	1	*het moet
participant5	eens	agree	1	1	0	0	1	1	1	*houdt oo
participant6	oneens	disagree	-1	0	1	1	0	0	0	end-of-life
participant7	oneens	disagree	-1	0	1	1	0	0	1	*end-of-lif
participant8	eens	agree	1	1	0	0	0	0	1	*te idealist
participant9	helemaal eens	totally agree	2	1	0	0	0	1	0	end-of-life
participant10	oneens	disagree	-1	1	1	1	0	0	0	eens, dat e
participant11	oneens	disagree	-1	1	1	0	0	1	1	*end-of-lif
participant12	oneens	disagree	-1	1	0	0	0	0	1	*reversed
participant13	helemaal eens	totally agree	2	1	0	0	0	1	1	Ook de mo
participant14	oneens	disagree	-1	0	1	0	0	0	1	Dit is onde
participant15	eens	agree	1	1	1	0	0	0	1	end-of-life
participant16	eens	agree	1	1	1	0	0	0	0	end-of-life
participant17	helemaal eens	totally agree	2	1	0	0	0	1	1	Ook te ber
participant18	neutraal/ eens	neutral / agree	0.5	1	0	0	0	0	1	Dat zou he
participant19	oneens	disagree	-1	1	1	0	0	0	1	bij woningl
participant20	oneens	disagree	-1	1	0	1	0	0	1	end-of-life
participant21	helemaal eens	totally agree	2	1	0	0	0	0	1	het is belar
				17	10	5	2	5	16	
				44%	26%	13%	5%	13%	41%	

Comparison professional background – proposition evaluation

Based on the evaluation of the propositions included in the first questionnaire cross tables are created by SPSS23 in order to find relations between the professional background of the expert and the evaluation of the proposition. The detailed results are presented per proposition hereafter. A summary of the results can be found in 4.3.4.4 General feedback on page 95.

Proposition1

Based on the main function of the respondents a very widespread opinion can be found as shown in Table 34. Whereas the architects mainly agreed with the proposition, all other function-groups showed propositions of agreement and disagreement likewise.

Table 34: Cross table: function-expert opinion (proposition1)

		proposition1_EN					
		totally disagree	disagree	neutral / agree	agree	totally agree	Total
function_cluster	architect	0	0	1	1	0	2
	construction company	1	1	0	1	0	3
	consultant	0	1	0	3	1	5
	developer	0	1	0	3	0	4
	engineer	0	1	0	1	1	3
	investor	0	1	0	1	0	2
	municipality	0	1	0	1	0	2
Total		1	6	1	11	2	21

Proposition2

All consultants disagreed with this proposition, as well as the developers, investors and employees of municipalities interviewed, as shown in Table 35. Architects, employees of construction companies and engineers showed more variation in their answers.

Table 35: Cross table: function-expert opinion (proposition2)

		proposition2_EN				
		totally disagree	disagree	neutral	agree	Total
function_cluster	architect	0	1	0	1	2
	construction company	0	2	0	1	3
	consultant	0	5	0	0	5
	developer	1	2	1	0	4
	engineer	0	2	0	1	3
	investor	0	2	0	0	2
	municipality	1	1	0	0	2
Total		2	15	1	3	21

Proposition3

Overall, it can be said, that architects, employers of construction companies, engineers, investors and employers of municipalities showed a clear tendency towards agreement, whereas consultants and developers draw a picture of more variation (see Table 36).

Table 36: Cross table: function-expert opinion (proposition3)

		proposition3_EN				
		disagree	neutral	agree	totally agree	Total
function_cluster	architect	0	0	2	0	2
	construction company	0	0	1	2	3
	consultant	1	1	1	2	5
	developer	2	0	1	1	4
	engineer	0	0	2	1	3
	investor	0	0	1	1	2
	municipality	0	0	1	1	2
Total		3	1	9	8	21

Proposition4

This proposition showed the most alignment in expert opinions. All experts indicated disagreement (57%) or even total disagreement (43%) throughout all functional backgrounds (see Table 37). With a mean value of -1.43 and a very small standard deviation of 0.507 and variance of 0.257 a high degree of alignment is measured between all expert opinions.

Table 37: Cross table: function-expert opinion (proposition4)

		proposition4_EN		
		totally disagree	disagree	Total
function_cluster	architect	0	2	2
	construction company	1	2	3
	consultant	3	2	5
	developer	2	2	4
	engineer	1	2	3
	investor	1	1	2
	municipality	1	1	2
Total		9	12	21

Proposition5

Architects, employers of construction companies and municipalities, as well as investors indicated agreement, whereas consultants, developers and engineers indicated a more variated picture (see Table 38).

Table 38: Cross table: function-expert opinion (proposition5)

		proposition5_EN			
		disagree	agree	totally agree	Total
function_cluster	architect	0	2	0	2
	construction company	0	2	1	3
	consultant	1	3	1	5
	developer	1	2	1	4
	engineer	1	1	1	3
	investor	0	2	0	2
	municipality	0	1	1	2
Total		3	13	5	21

Proposition6

As shown in Table 39, developers, engineers and employees of municipalities indicated a clear tendency towards disagreement, whereas all experts of other professional backgrounds did not show clear tendencies (see Table 39).

Table 39: Cross table: function-expert opinion (proposition6)

		proposition6_EN					
		totally disagree	disagree	neutral	agree	totally agree	Total
function_cluster	architect	1	0	0	1	0	2
	construction company	0	0	2	1	0	3
	consultant	1	2	1	0	1	5
	developer	2	2	0	0	0	4
	engineer	0	1	2	0	0	3
	investor	0	2	0	0	0	2
	municipality	1	1	0	0	0	2
Total		5	8	5	2	1	21

Proposition7

Whereas architects, employees of a construction company and municipality and investors indicate a positive reaction towards this proposition, consultants, developers and engineers show a less clear picture regarding agreement or disagreement as shown in Table 40.

Table 40: Cross table: function-expert opinion (proposition7)

		proposition7_EN					
		totally disagree	disagree	neutral	agree	totally agree	Total
function_cluster	architect	0	0	1	0	1	2
	construction company	0	0	1	1	1	3
	consultant	0	1	0	3	1	5
	developer	0	3	0	1	0	4
	engineer	1	1	0	1	0	3
	investor	0	0	0	1	1	2
	municipality	0	0	0	0	2	2
Total		1	5	2	7	6	21

Proposition8

Architects, engineers, investors and employees of municipalities show a tendency towards agreement, whereas consultants, developers and employees of construction companies show a less clear picture (see Table 41).

Table 41: Cross table: function-expert opinion (proposition8)

		proposition8_EN				
		disagree	neutral	agree	totally agree	Total
function_cluster	architect	0	0	2	0	2
	construction company	1	0	1	1	3
	consultant	2	0	3	0	5
	developer	1	0	2	1	4
	engineer	0	0	2	1	3
	investor	0	0	2	0	2
	municipality	0	1	1	0	2
Total		4	1	13	3	21

Proposition9

As shown in Table 42, architects, engineers and employees of municipalities showed clear tendency towards agreement with the proposition. All other function groups did not draw a clear picture.

Table 42: Cross table: function-expert opinion (proposition9)

		proposition9_EN					
		disagree	neutral	neutral / agree	agree	totally agree	Total
function_cluster	architect	0	0	1	0	1	2
	construction company	1	0	0	1	1	3
	consultant	4	0	0	0	1	5
	developer	2	1	0	1	0	4
	engineer	0	0	0	1	2	3
	investor	1	0	0	1	0	2
	municipality	0	0	0	1	1	2
Total		8	1	1	5	6	21

General evaluation Delphi I

The personal interviews executed as round one of the Delphi method, did not only lead towards an evaluation of the presented propositions, but also provided some general feedback regarding a circular real estate development process. All comments are summarized and clustered in general definition, development focus, building circular, collaboration / information exchange, contracting, finances and development process hereafter.

General definition

Circularity is a holistic approach, which is filled in differently by every expert. As such the concept of circular economy can be describes as a process optimization on project level, which can be defined as a financially driven environment incentive. It is stated, that to reach circularity, every chain partner should aim for a better solution instead of just reducing bad effects following the slogan “less bad is not good enough”. Circular economy need to be seen on system level, in which materials do not change in quantity, but in quality and position within the system. To meet this approach, circular economy asks for a new mind-set. Due to that, a process schema for a circular real estate development should not be based on a traditional one, but should start from scratch. In order to reach circularity, it is important to think through the concept and invest much time in the preparation. However, finally the concept need to be implemented to learn whether the concepts works in practice.

Development focus (purpose)

The purpose of a circular development can follow different purposes, which include value creation, solving the waste issue, prevent toxicity, develop human-centric under the use of biobased materials, develop based on a circular city concept or purely as circular real estate. Finally it need to be decided, how circularity and sustainability are approached. Overall, it need to be said, that broad variation of interpretations of circularity focusses exist. Therefore, it is important to choose the focus for the project and its conditions early in the process.

In order to create value, the development should aim on this instead of earning money. Furthermore, developing new real estate can focus on solving the problem of emerging free materials and preventing to destroy valuable materials. In line with this, it need to be decided upfront, whether toxicity is a reason not to reuse old materials and in how far it is relevant for new materials in the context of maintenance and residual value.

The development of real estate should start with the needs of future users (“human-centric”), not with the possibilities of the participating chain partners. To reach this, some experts plead for the use of biobased materials to create healthy and comfortable living environments. Some others however do not consider those materials. They argue that those materials might be less reusable and stable.

Likewise, a decision need to be made, whether the focus of the development goes purely towards the building to be developed or towards the building as part of its environment (“circular building versus circular city”). No building can be developed totally separated from its environment, but the measure of inclusion of environment-factors need to be decided upon. Based on this, the meaning of a building within the environmental context need to be determined including the possible functional scale, as well as the available infrastructure. This

comes along with the decision for or against the inclusion of social responsibility within the ambition of circularity.
Just as different options are possible for spatial level, the focus regarding lifespan need to be determined between durability and flexibility. It needs to be decided upon the expected use-duration of the building. As such, the building can be developed rather modular to enable deconstruction and reuse after a short period of time, whereas a flexible and durable approach focusses on the realization of an building for a long lifespan, which can easily be redesigned for different functions.

Building circular
Building circularly does not only influence the material choice, design principles and forms of collaboration between chain partners, but also influences legally and financial aspects largely. Besides that, building circular can be described as building without negative effects on the environment, energy and materials. Some experts indicated that the building should be seen as consisting of different layers with different use-durations following the concept of Brand (1994). Likewise, a building can be split up following the concept of Durmisevic and Brouwer (2002). Depending on the layer within the building, different parties are relevant to continue circularity. As such the inner layers are more important for users, whereas the outside layers are more important for the owner of the building. The future of building circular lays in building in a standardized and modular manner to enable simplified reuse of elements, which is a scalable concept suitable for a perfect future situation.

Collaboration / information exchange
It is important to form a development team early on in the process, based on the ambition of the client, the willingness of every single party to be open for innovative solutions and the trust in their partners to share also sensible information. Likewise, a good process structure need to be realized to work still efficient while everybody is fully informed and feels committed to decisions. Regular feedback sessions are part of the process to create long-term cooperation's with knowledgeable and experienced partners. Here, it is important to include the client as well. Through this close cooperation and use of synergy effects multiple values can be created (economically, ecologically and social). However, in such a collaboration it is important to award partners with the possibilities to earn conform their input.

In order to exchange building-related information, a BIM model can be useful, especially for new constructions. For redevelopment projects, BIM models are more difficult to use currently. Furthermore, the BIM model need to be dynamically updated on a real-time basis. To realize the full potential of a BIM model for maintenance, redevelopment, reuse and recycling, the model need to be kept up-to-date throughout the whole lifespan of the building. To reach that, a professional party should take over this task. Besides material-related information, the BIM model should include information regarding the engineering process.

Contracting
Contracting is an important aspect to implement circularity principles since it indicates, which parties take responsibilities for certain risks. Furthermore, maintenance specialists or tenants can be committed to continue the circularity principles through contracts. Just as changing the programme of requirements towards a more performance-oriented approach, performance contracts need to be used to reach circularity. Besides this, producers and suppliers may keep

the ownership of parts of the building and provide lease contracts for the use of those elements. However, up till now, this concept is especially relevant for elements of the inner layers with short lifespans, for long lifespan elements it is more difficult to adopt the concept. In any case a good documentation and document management need to be executed. Depending on the form of contract, the collaboration of chain partners will be distinguished.

Finances

Some experts mentioned, that circularity will only be executed if it is financially attractive. Therefore, new revenue models need to be introduced, such as product-as-service and lease contracts for building elements. Likewise, investors will start to invest in elements instead of whole buildings. However, products-as-service need to be attractive, financially and qualitatively. Likewise, redemption guarantees give the security, that elements will be taken back by the supplier or producer. However, it need to be guaranteed, that the elements are in the same status as during delivery. This can make it difficult to guarantee the redemption.

Besides these specific cases, the overall costs need to be diminished based on the concept of total cost of ownership, which reviews the total costs for all elements of the building over the whole lifespan. In addition, the shadow costs of materials might be considered as well. Due to these cost models, it is important, that a residual value is reached at the end of the use-duration of the building. If this is reached, lower investment costs are necessary. However, even for a circular development, the available budget of the client need to be kept in mind. To reach this, the tender should ask for the highest quality reachable with a certain budget instead of asking for a certain quality and trying afterwards to minimize the costs.

The financial aspect should be included in a circular business case, which is relevant for the whole cycle and can guarantee circularity. Through showing the added value clients can get convinced of the concept. In line with this, several sources ask for a change of the tax system, wherein taxes should be paid for material instead of labor. Many experts indicate, that this would be a very helpful measure to support circularity within the built environment with many labor-intensive tasks. However, little faith is shown, that this will change on short term.

Development process

During the initiative phase it is indicated to be important, that the ambition is formulated early on by the client and his development team to indicate the most important principles. To do so, the topics mentioned as “development purpose” should be considered. Furthermore, it is important to take the necessary time to make well-thought-through decisions. During the tender execution, the correct questions need to be asked. This means asking based on a predefined budget, performance-oriented and open for innovative solutions. During the development phase, the ambition formulated during the initiative phase need to become concrete. Predefined principles need to be used. Likewise, an open mind for new solutions and alternatives should be maintained. During the construction phase, the planning made during the development phase need to be executed based on the circularity principles agreed upon within the development team. During the exploitation phase, steps of maintenance, reuse, remanufacture and recycling appear due to the different life- and use-spans per element. Therefore, clear responsibilities need to be defined per element for maintaining the circular character. This includes a professional maintenance party, the tenant, the owner of the building, but also suppliers, producers and construction companies.

Questionnaire Delphi II – informative document

Evaluatie interviews circulair vastgoedontwikkeling

Beste expert,

Nogmaals bedankt voor jouw/uw tijd en inspanningen om mij te ondersteunen bij mijn afstudeerproject betreffende het circulair inrichten van een vastgoedontwikkelproces.
Zoals in de interviewguide voor het eerste interview was aangegeven, wil ik je/u bij deze informeren over de uitkomsten van de eerste interviews. Tegelijkertijd vindt je/u een link voor een online survey, waarin ik je/u vraag opnieuw negen stellingen te beoordelen. Deze zijn gebaseerd op de oorspronkelijke stellingen en mijn evaluatie van de eerste interviews.
Het invullen van de online vragenlijst zal maximaal 5 tot 10 minuten duren omdat ik alleen jouw/uw beoordeling zonder toelichting vraag. Het is belangrijk voor mijn onderzoek, dat je/u ook aan deze vragenronde deelneemt om voor mij een goed en valide resultaat te bereiken.
Ik wil je/u bij voorbaat danken voor uw medewerking.
Mocht je/u vragen of opmerkingen hebben, hoor ik het graag.

Met vriendelijke groet,
Johanna Scherer

Stelling 1:
Oorspronkelijke stelling
De belangrijkste stakeholder om het vastgoedontwikkelingsproces circulair in te richten, is de vastgoedontwikkelaar. De vastgoedontwikkelaar heeft contact met alle andere stakeholders en dient daarom als eerste de circulaire principes toe te passen en van anderen te vragen dat ook te doen.
Redenen voor eens / oneens (in Engels):

1. the real estate developer is important, but he need to collaborate with other parties
2. the client is the most important stakeholder, as carrying the risks for the development
3. the real estate developer is central for the organization of the process as he keeps the overview over the finance and construction execution
4. the real estate developer need to have knowledge and a preference for circularity principles

Aangepaste stelling:
De belangrijkste stakeholder in iedere ontwikkelingsproces is de opdrachtgever als risicodragende partij. Voor een vastgoedontwikkelproject kan dit de vastgoedontwikkelaar zijn, die het proces samen met andere partijen aanstuurt. De opdrachtgever dient daarom kennis en een voorkeur voor circulariteit te hebben en als eerste de circulaire principes toe te passen en van anderen te vragen dat ook te doen.

Stelling 2

Oorspronkelijke stelling

Tijdens de initiatieffase, ontwikkeling en constructie is het meest belangrijk, dat het gebouw de design-principes 'design for disassembly' en 'adaptability' volgt, en materialen gebruikt worden, die binnen de cycli passen, en een sterke communicatie plaatsvindt binnen het ontwikkelingsteam. Dan hoeft de klant of toekomstige eigenaar niet meer betrokken te worden tijdens de ontwikkeling, omdat elke wens inpasbaar is in het ontwikkeld concept.

Redenen voor eens / oneens (in Engels):

1. the client and his wishes need to be considered in any case
2. those principles are important to be considered
3. the client need to be considered at the beginning and his wishes need to be remembered throughout the development
4. it is important to think about the modularity of the building early in the process

Aangepaste stelling:

Tijdens de initiatieffase, ontwikkeling en constructie is het belangrijk, dat het gebouw de design-principes 'design for disassembly', 'adaptability' en 'modularity' volgt, en materialen gebruikt worden, die binnen de biologische of technische cycli passen. Verder is een sterke communicatie nodig binnen het ontwikkelingsteam. De wensen van de klant en zijn prioriteiten moeten al in begin van het proces, tijdens de initiatieffase, goed in kaart gebracht worden. Hij moet gedurende het gehele proces betrokken blijven, maar tijdens de ontwikkeling, realisatie en exploitatie vooral vanuit een toetsende rol.

Stelling 3

Oorspronkelijke stelling:

Het is belangrijk om design principes al tijdens de initiatieffase in de conceptontwikkeling te introduceren, ook al bestaat er nog geen samenwerking met anderen stakeholders en ook al leidt dit tot hogere bouwkosten voor het ontwikkeld concept.

Redenen voor eens / oneens (in Engels):

1. concept need to be introduced early on to take all chances
2. the ambition need to be defined at the beginning of the process together with the client and the fitting principles need to be defined
3. building circular can lead towards higher costs for construction, which can be earned back through lower costs during the exploitation phase

Aangepaste stelling:

Het is belangrijk om design principes al tijdens de initiatieffase in de conceptontwikkeling te introduceren, ook al bestaat er nog geen samenwerking met anderen stakeholders. Hiervoor dienen de meest belangrijke principes samen met de klant gedefinieerd te worden. Om op een circulaire manier te bouwen kan, afhankelijk van de projectgegevens, leiden tot hogere bouwkosten. Daar moeten lagere kosten vooral tijdens de exploitatiefase tegenover staan, zodat in totaal de investeringskosten gelijk of zelfs lager zijn dan bij een traditioneel gebouw.

Stelling 4

Oorspronkelijke stelling

Proces gerelateerde principes hebben vooral betrekking op het samenstellen van een ontwikkelingsteam en op de bouwuitvoering. In alle andere fasen, zoals design ontwikkeling, bestekfase, exploitatie en end-of-life zijn deze principes minder van belang.

Redenen voor eens / oneens (in Engels):

1. those principles are relevant for all phases
2. the selection of principles depends on the project conditions and need to be chosen at the beginning of the process
3. those principles are also of high importance for the exploitation and end-of-life phase

Aangepaste stelling:

Proces relateerde principes hebben betrekking op het gehele proces en alle fases van het proces moeten als een eenheid begrepen worden. De selectie van principes is wel afhankelijk van de project condities en dient aan het begin van het proces duidelijk afgesproken te worden.

Stelling 5

Oorspronkelijke stelling

Het programma van eisen is één van de belangrijkste documenten in het vastgoed ontwikkelproces. Daarom is het essentieel, dat hier zowel design principes (zoals 'design for disassembly', adaptability, geen vaste materiaalverbindingen), maar ook materiaalkeuze principes in de vorm van prestatie-eisen in het programma van eisen verwerkt worden.

Belangrijkste redenen voor eens / oneens (in Engels):

1. the programme of requirements is an important document
2. the programme of requirements need to be open for new innovations
3. performance-based procurement enables more innovations
4. it need to be clear, what the wishes are and what the hard requirements are within the programme of requirements

Aangepaste stelling:

Het programma van eisen is een belangrijk document voor het vastgoed ontwikkelproces. Hierin moeten wensen en eisen prestatiegericht verwoord worden om open te staan voor toekomstige innovaties. Andere belangrijke documenten zijn een circulaire business case, een visie of ambitie document, en het contract.

Stelling 6

Oorspronkelijke stelling

Tijdens de design ontwikkeling zijn vooral de design-principes ‘design for reuse’ and ‘design for disassembly’ belangrijk, evenals de proces-principes van ‘samenwerking met keten partners’ en ‘uitwisseling van informatie’. Andere design en proces principes zijn veel minder belangrijk, evenals de keuze voor bepaalde materialen.

Redenen voor eens / oneens (in Engels):

1. those are not the only important principles
2. material choice is important as well
3. process-related principles are important as well

Aangepaste stelling:

Voor de ontwikkeling en initiatieffase moeten alle circulariteitsprincipes in gedachten gehouden worden. Afhankelijk van de projectcondities en gericht op de toekomstige gebruiker zullen de meest belangrijke principes gekozen en toegepast worden om de behoeftes van toekomstige gebruikers te kunnen voldoen.

Stelling7

Oorspronkelijke stelling

Tijdens de werkvoorbereiding en werkuitvoering moeten proces principes gebruikt worden om de communicatie te ondersteunen. Verder is het belangrijk, dat uitvoerders de design principes begrijpen en tijdens de werkvoorbereiding de juisten materialen gekozen worden volgens de materiaal principes. Hun invloed tijdens de initiatieffase en ontwerp ontwikkeling moet vergroot worden.

Redenen voor eens / oneens (in Engels):

1. the executor need to be actively included in the team early on
2. standardized concepts need to be developed. Here the executors should attend to support the concept development.
3. not the work executor, but the project manager from the construction company

Aangepaste stelling:

Medewerkers van de aannemer hebben veel kennis van de bouwuitvoering. Om te waarborgen, dat alle mogelijkheden voor innovaties meegenomen worden en het ontwikkeld concept tijdens de uitvoering niet tegengewerkt wordt, moeten zij al tijdens de ontwikkeling betrokken worden. Als een standardconcept ontwikkeld wordt, moet een medewerker van de aannemer bij de ontwikkeling aansluiten. Dat kan afhankelijk van zijn kennis, de uitvoerder or project manager zijn.

Stelling 8

Oorspronkelijke stelling

Het is belangrijk, dat gebruikers of eigenaren alle principes van circulaire gebouwen begrijpen om deze vanuit de ontwikkelingsfase door te zetten tijdens de exploitatiefase. Dit betreft het vervangen van onderdelen, het bijhouden van een materiaalpaspoort en de zuinige omgang met grondstoffen en afval.

Redenen voor eens / oneens (in Engels):

1. tenants do not need to be confronted with too technical details, but mainly with principles, which are relevant for their living environment so that it stays nice to live there
2. the owner of the building is responsible to communicate the most important principles towards the tenants and need to actively supervise changes in the building and assist the tenant in executing changes
3. a professional party, such as a facility manager / asset manager need to maintain the circularity of the building
4. the tenant and owner need to maintain the principles based on their personal interest for it, not due to an obligation

Aangepaste stelling:

Het is belangrijk, dat zowel gebruikers als eigenaren de principes van circulaire gebouwen begrijpen, die voor hun belangrijk zijn. Een gebruiker moet dus vooral principes kennen, die zijn directe leefomgeving betreffen, terwijl een eigenaar vooral de waardebehoud van het gebouw moet garanderen. Afhankelijk van de kennis van de eigenaar over circulatietijd zal hij een professionele partij voor onderhoud en reparatie inhuren, die de circulaire karakteristiek van het gebouw waarborgt.

Stelling 9

Oorspronkelijke stelling

In vergelijking met het traditionele ontwikkelproces moet bij een circulair vastgoed ontwikkelproces nog een fase van end-of-life toegevoegd worden. Tijdens die fase zijn vooral ‘reverse logistics’ en ‘products as services’ van belang.

Redenen voor eens / oneens (in Engels):

1. this final phase of the cycle is important, but future developments are difficult to predict (existence of project partners, responsibility for last phase)
2. it's important to ensure, that elements and materials can be separated at the end of use
3. end-of-life is not a separate phase, but part of the circle

Aangepaste stelling:

Om de levenscyclus van het gebouw te kunnen voltooien is het belangrijk, dat ook het einde van de gebruiksduur van gebouwelementen in gedachten gehouden worden. Ontwikkelingen zijn echter moeilijk te bepalen, die doorlopen tot het einde van de gebruiksduur van gebouwelementen met een lange levensduur. Wat er gebeurt bij het end-of-use van gebouwelementen of het gehele gebouw moet al tijdens de ontwikkelingsfase in het ontwerp beschouwd worden. Daarbij is het belangrijk, dat onderhoudspartijen en eigenaren van elementen vroegtijdig betrokken worden.

Questionnaire Delphi II

This questionnaire was executed as an online-questionnaire in order to simplify respondents to react on the second set of statements. The pictures hereunder represent the slides of this survey.


Technische Universiteit Eindhoven University of Technology

vragenlijst 2 voor afstudeerproject 'circulair vastgoedontwikkelproces'

17 %

Stelling 1:
De belangrijkste stakeholder in iedere ontwikkelingsproces is de opdrachtgever als risicodragende partij. Voor een vastgoedontwikkelproject kan dit de vastgoedontwikkelaar zijn, die het proces samen met andere partijen aanstuurt. De opdrachtgever dient daarom kennis en een voorkeur voor circulariteit te hebben en als eerste de circulaire principes toe te passen en van anderen te vragen dat ook te doen. *

helemaal oneens | oneens | neutraal | eens | helemaal eens

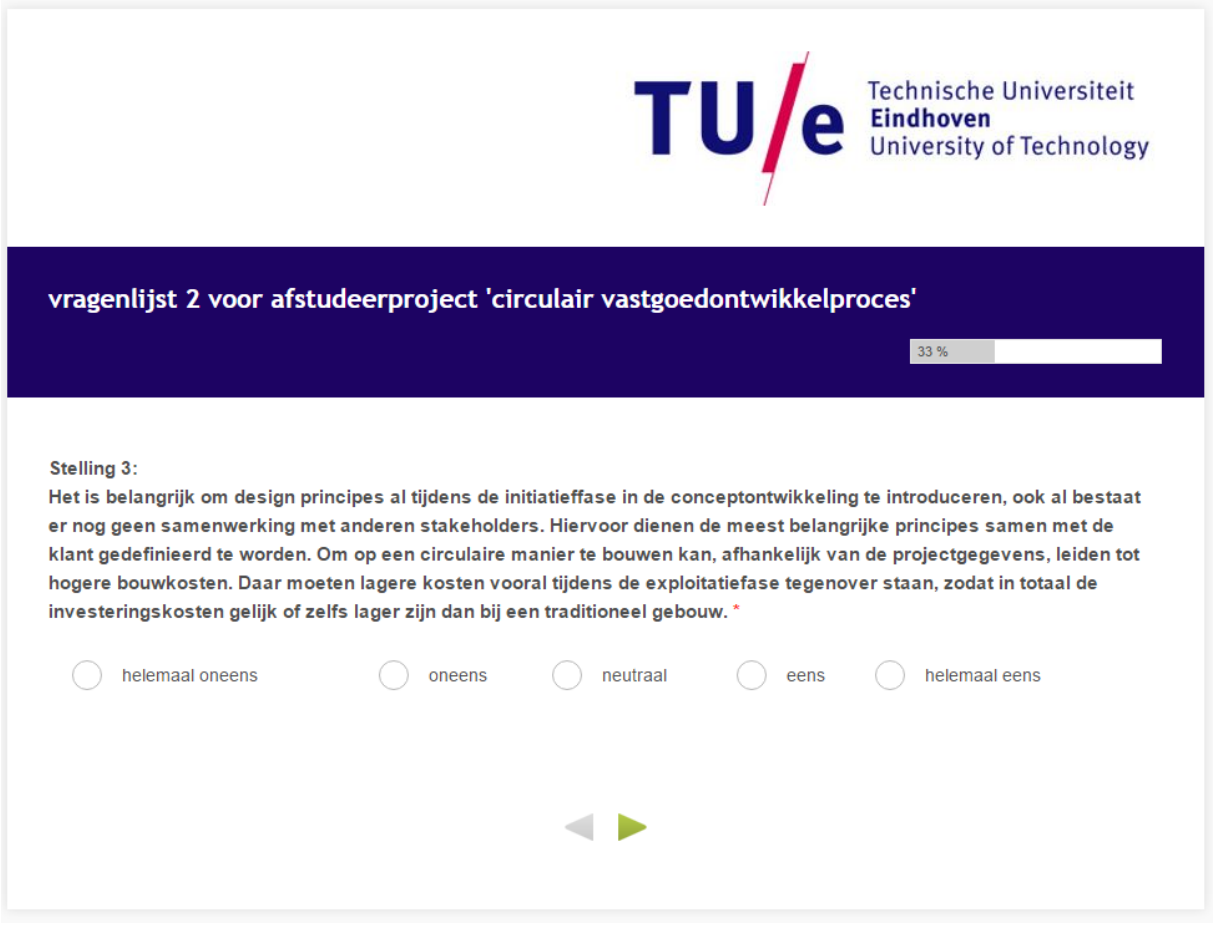

Technische Universiteit Eindhoven University of Technology

vragenlijst 2 voor afstudeerproject 'circulair vastgoedontwikkelproces'

25 %

Stelling 2:
Tijdens de initiatieffase, ontwikkeling en constructie is het belangrijk, dat het gebouw de design-principes 'design for disassembly', 'adaptability' en 'modularity' volgt, en materialen gebruikt worden, die binnen de biologische of technische cycli passen. Verder is een sterke communicatie nodig binnen het ontwikkelingsteam. De wensen van de klant en zijn prioriteiten moeten al in begin van het proces, tijdens de initiatieffase, goed in kaart gebracht worden. Hij moet gedurende het gehele proces betrokken blijven, maar tijdens de ontwikkeling, realisatie en exploitatie vooral vanuit een toetsende rol. *

helemaal oneens | oneens | neutraal | eens | helemaal eens


Technische Universiteit
Eindhoven
University of Technology
vragenlijst 2 voor afstudeerproject 'circulair vastgoedontwikkelproces'
33 %
Stelling 3:
Het is belangrijk om design principes al tijdens de initiatieffase in de conceptontwikkeling te introduceren, ook al bestaat er nog geen samenwerking met anderen stakeholders. Hiervoor dienen de meest belangrijke principes samen met de klant gedefinieerd te worden. Om op een circulaire manier te bouwen kan, afhankelijk van de projectgegevens, leiden tot hogere bouwkosten. Daar moeten lagere kosten vooral tijdens de exploitatiefase tegenover staan, zodat in totaal de investeringskosten gelijk of zelfs lager zijn dan bij een traditioneel gebouw. *
helemaal oneens
oneens
neutraal
eens
helemaal eens


Technische Universiteit
Eindhoven
University of Technology
vragenlijst 2 voor afstudeerproject 'circulair vastgoedontwikkelproces'
42 %
Stelling 4:
Proces relateerde principes hebben betrekking op het gehele proces en alle fases van het proces moeten als een eenheid begrepen worden. De selectie van principes is wel afhankelijk van de project condities en dient aan het begin van het proces duidelijk afgesproken te worden. *
helemaal oneens
oneens
neutraal
eens
helemaal eens

Technische Universiteit Eindhoven University of Technology

vragenlijst 2 voor afstudeerproject 'circulair vastgoedontwikkelproces'

50 %

Stelling 5:
Het programma van eisen is een belangrijk document voor het vastgoed ontwikkelproces. Hierin moeten wensen en eisen prestatiegericht verwoord worden om open te staan voor toekomstige innovaties. Andere belangrijke documenten zijn een circulaire business case, een visie of ambitie document, en het contract. *

helemaal oneens | oneens | neutraal | eens | helemaal eens

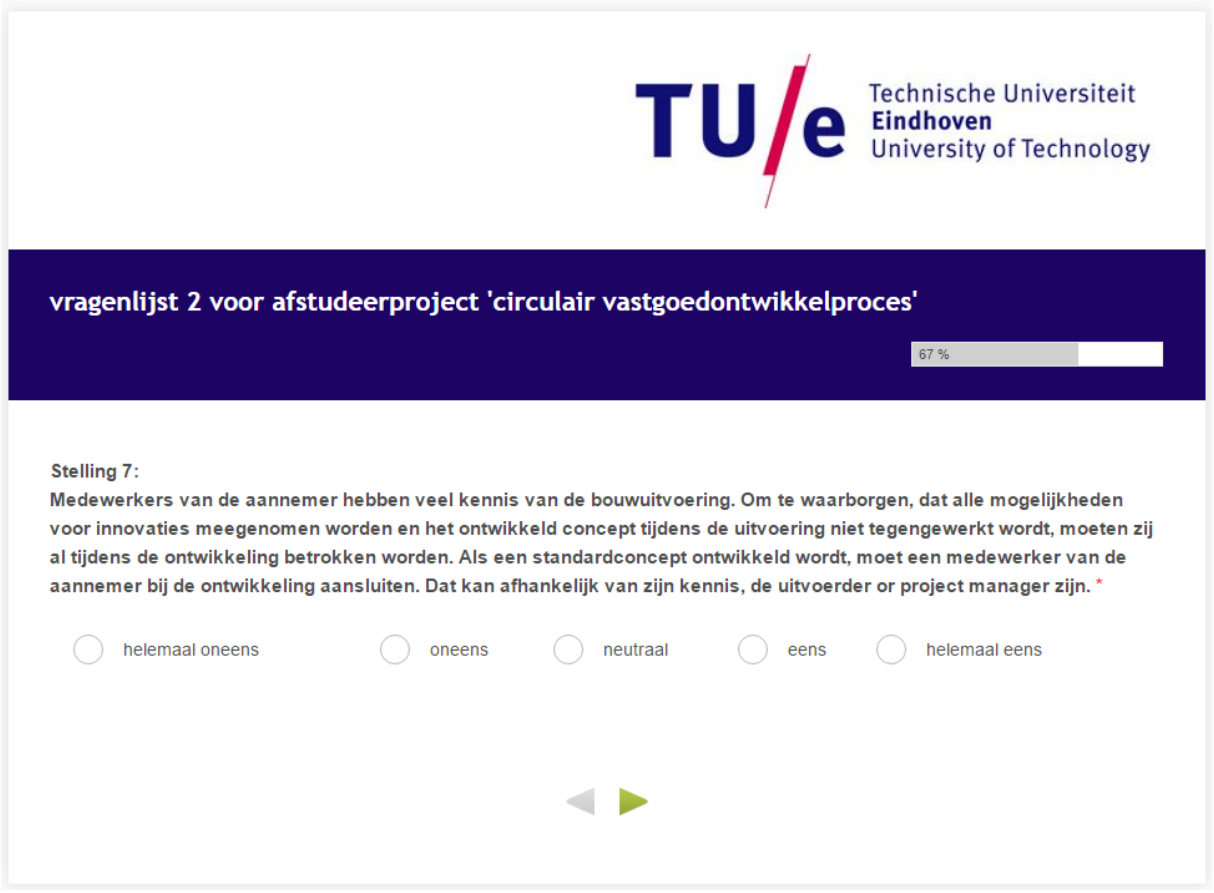
Technische Universiteit Eindhoven University of Technology

vragenlijst 2 voor afstudeerproject 'circulair vastgoedontwikkelproces'

58 %

Stelling 6:
Voor de ontwikkeling en initiatieffase moeten alle circulariteitsprincipes in gedachten gehouden worden. Afhankelijk van de projectcondities en gericht op de toekomstige gebruiker zullen de meest belangrijke principes gekozen en toegepast worden om de behoeftes van toekomstige gebruikers te kunnen voldoen. *

helemaal oneens | oneens | neutraal | eens | helemaal eens


Technische Universiteit
Eindhoven
University of Technology
vragenlijst 2 voor afstudeerproject 'circulair vastgoedontwikkelproces'
67 %
Stelling 7:
Medewerkers van de aannemer hebben veel kennis van de bouwuitvoering. Om te waarborgen, dat alle mogelijkheden voor innovaties meegenomen worden en het ontwikkeld concept tijdens de uitvoering niet tegengewerkt wordt, moeten zij al tijdens de ontwikkeling betrokken worden. Als een standardconcept ontwikkeld wordt, moet een medewerker van de aannemer bij de ontwikkeling aansluiten. Dat kan afhankelijk van zijn kennis, de uitvoerder or project manager zijn. *
helemaal oneens
oneens
neutraal
eens
helemaal eens


Technische Universiteit
Eindhoven
University of Technology
vragenlijst 2 voor afstudeerproject 'circulair vastgoedontwikkelproces'
75 %
Stelling 8:
Het is belangrijk, dat zowel gebruikers als eigenaren de principes van circulaire gebouwen begrijpen, die voor hun belangrijk zijn. Een gebruiker moet dus vooral principes kennen, die zijn directe leefomgeving betreffen, terwijl een eigenaar vooral de waardebehoud van het gebouw moet garanderen. Afhankelijk van de kennis van de eigenaar over circulatietijd zal hij een professionele partij voor onderhoud en reparatie inhuren, die de circulaire karakteristiek van het gebouw waarborgt. *
helemaal oneens
oneens
neutraal
eens
helemaal eens

Technische Universiteit Eindhoven University of Technology

vragenlijst 2 voor afstudeerproject 'circulair vastgoedontwikkelproces'

83 %

Stelling 9:
Om de levenscyclus van het gebouw te kunnen voltooien is het belangrijk, dat ook het einde van de gebruiksduur van gebouwelementen in gedachten gehouden worden. Ontwikkelingen zijn echter moeilijk te bepalen, die doorlopen tot het einde van de gebruiksduur van gebouwelementen met een lange levensduur. Wat er gebeurt bij het end-of-use van gebouwelementen of het gehele gebouw moet al tijdens de ontwikkelingsfase in het ontwerp beschouwd worden. Daarbij is het belangrijk, dat onderhoudspartijen en eigenaren van elementen vroegtijdig betrokken worden. *

helemaal oneens | oneens | neutraal | eens | helemaal eens

Technische Universiteit Eindhoven University of Technology

vragenlijst 2 voor afstudeerproject 'circulair vastgoedontwikkelproces'

92 %

Beste expert,

hartelijk dank voor uw deelname aan deze enquête! Uw antwoorden zijn heel waardevol voor mijn onderzoek en ik wil u daarom van harte danken voor uw tijd en inspanningen om mij te ondersteunen.

Met hartelijke groet,

Johanna Scherer

Bent u geïnteresseerd om over de resultaten van mijn onderzoek geïnformeerd te worden?

Als u hier aangeeft, dat u interesse heeft, zult u later een samenvatting van mijn resultaten via e-mail ontvangen.

- ja
- nee

Hebt u nog aanmerkingen of commentaren? Ik verneem deze graag hieronder.

Circular BPMN model

The original schemas can be found on the attached CD as 'circular BPMN'.

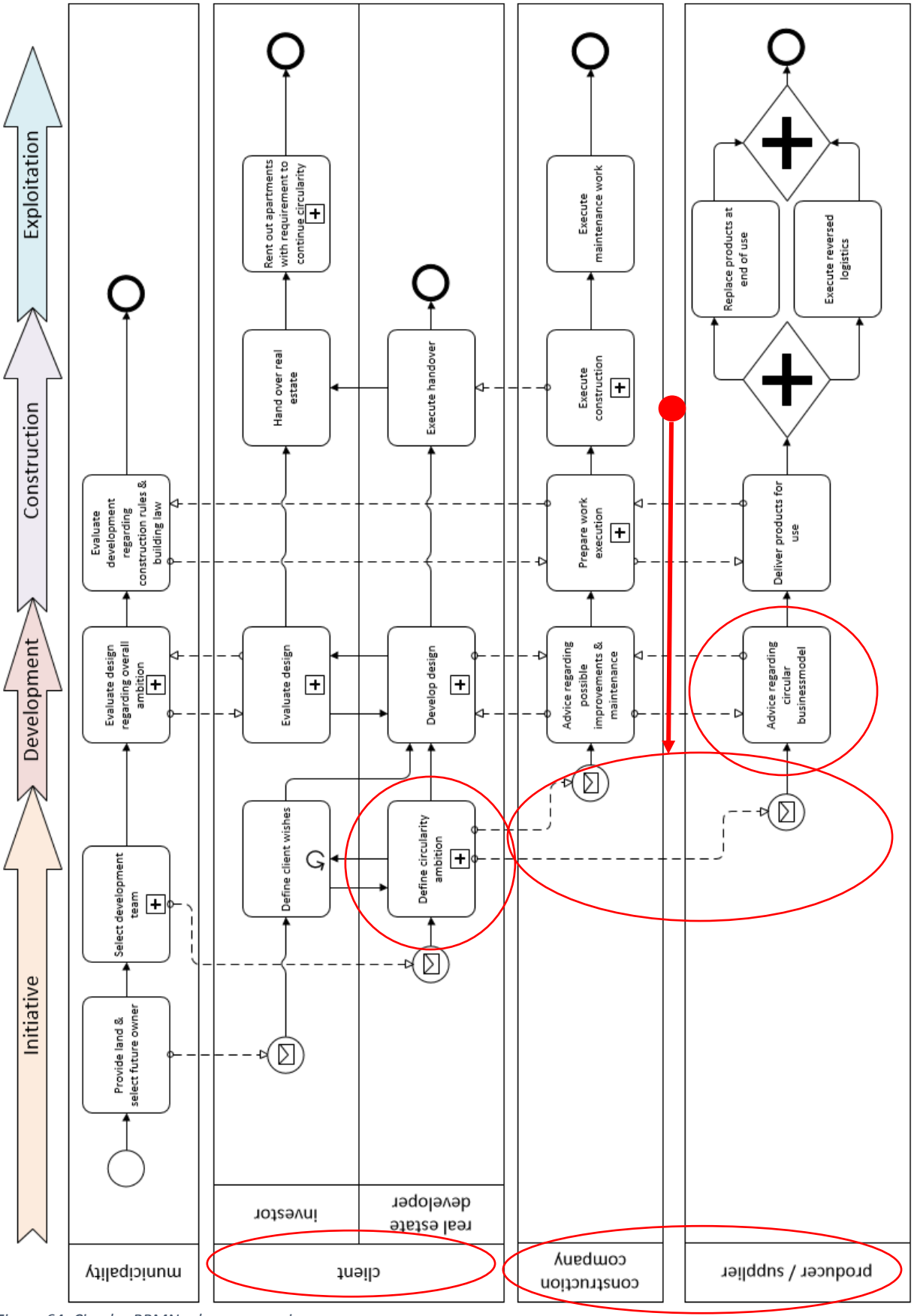


Figure 64: Circular BPMN schema: overview page

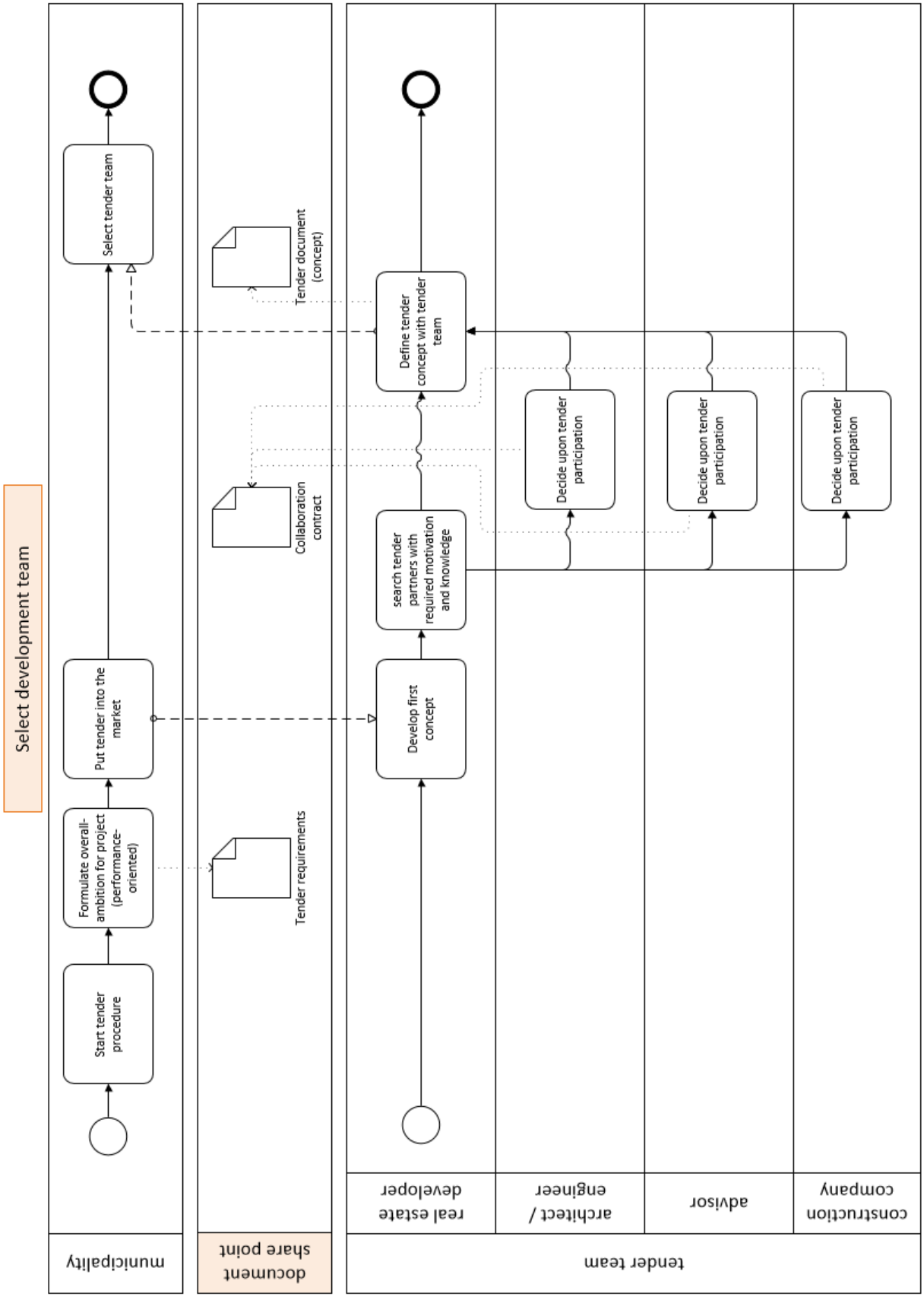


Figure 65: Circular BPMN schema: select development team

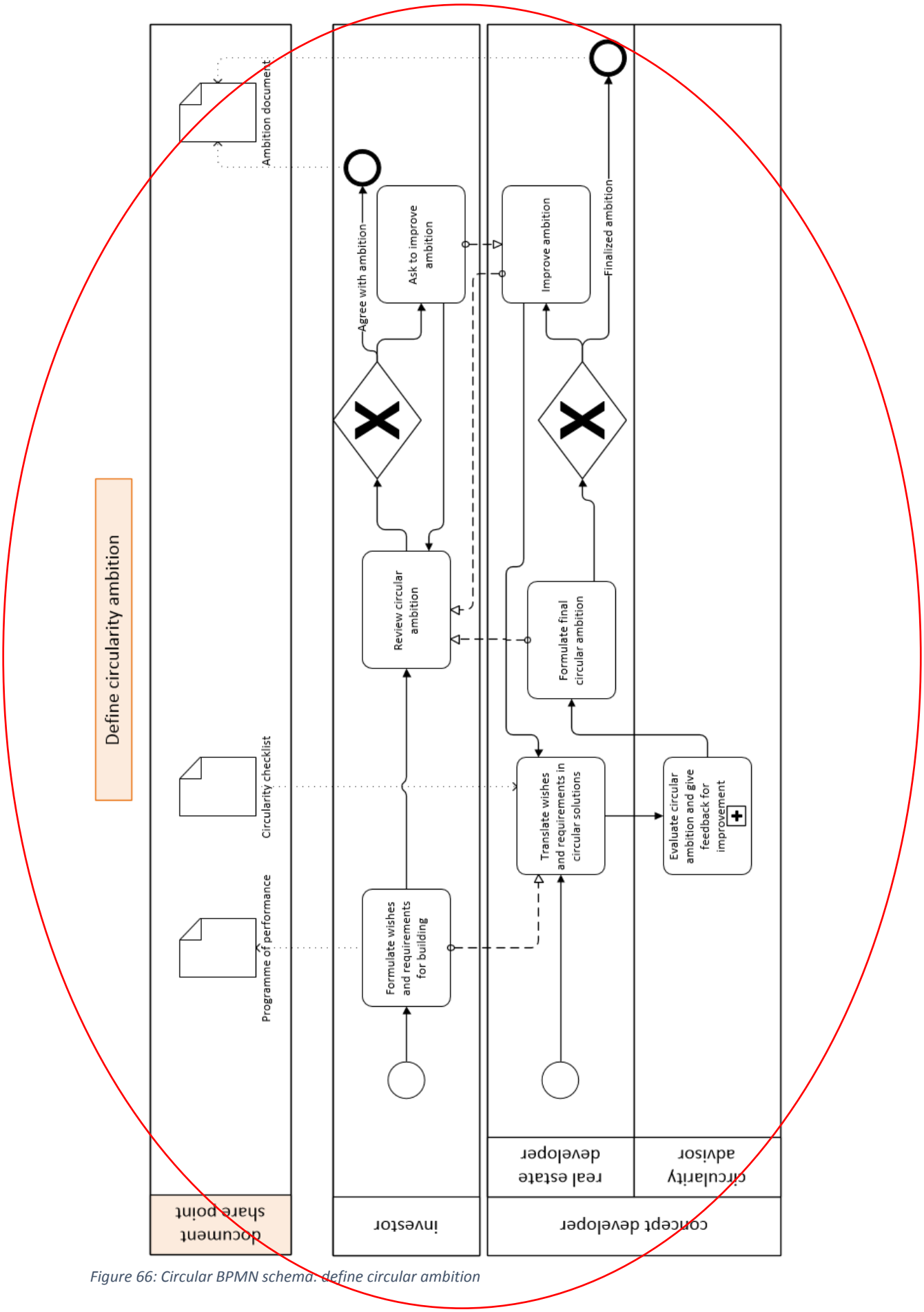


Figure 66: Circular BPMN schema: define circular ambition

Circularity checklist

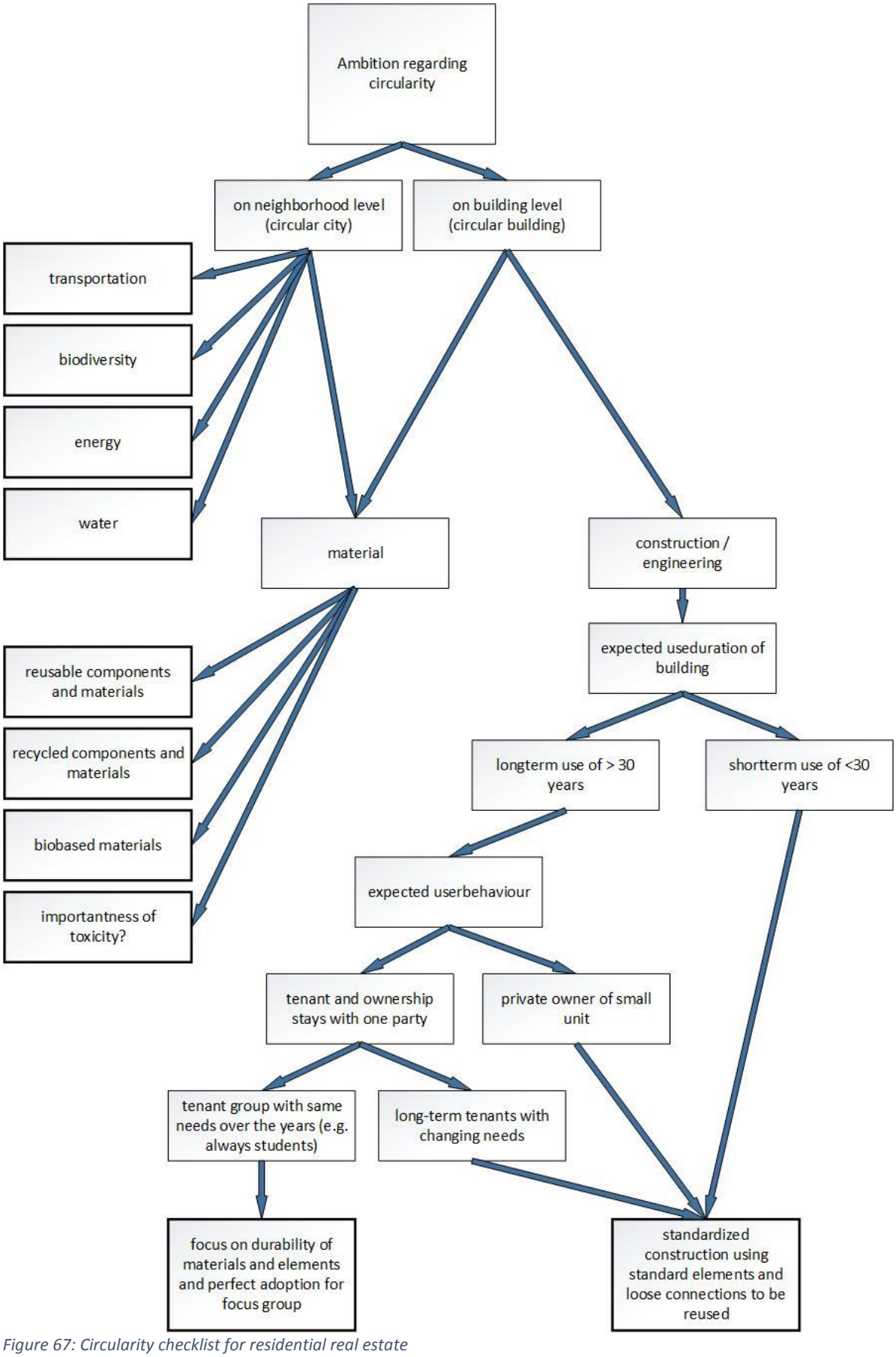


Figure 67: Circularity checklist for residential real estate

Using the tables underneath, the ambition can be connected with first principles. A '●' in the last column (II) indicates the suitability of the principle for a durability ambition. A '●' in the second-last column (I) indicates the suitability of the principle for the standardization ambition.

Table 43: Building-related circularity principles for checklist

	Building-related circularity principle	**I**	**II**
Maintenance	Design for maintenance and repair	●	●
	Design to lengthen lifecycle		●
	Minimize energy use	●	●
	Use of materials of high quality		●
	Use of biologically degradable materials	●	
Reuse / redistribution	Design for reuse		
	Prevent fixed connections	●	
	Use of standardized, modular elements	●	
	Design to enable top-up		●
Refurbish / remanufacture	Design for disassembly	●	
	Reduce used material mass	●	
Recycle	Reduce energy use		●
	Use of recycled materials	●	
	Reverse logistics	●	●

Table 44: Process-related circularity principles for checklist

	Process-related principle	**I**	**II**
Framework conditions	Human-centric development	●	●
	Use only renewable energy	●	●
	Use of locally available materials	●	●
	Prevent harmful emissions	●	●
	Change of tax-system towards work instead of material	●	●
Collaboration	Long-term collaboration with chain partners	●	●
	Information exchange and maintenance via BIM model & material passport incl. engineering knowledge	●	●
	Circular business case based on TCO concepts	●	●
	Product as service	●	●

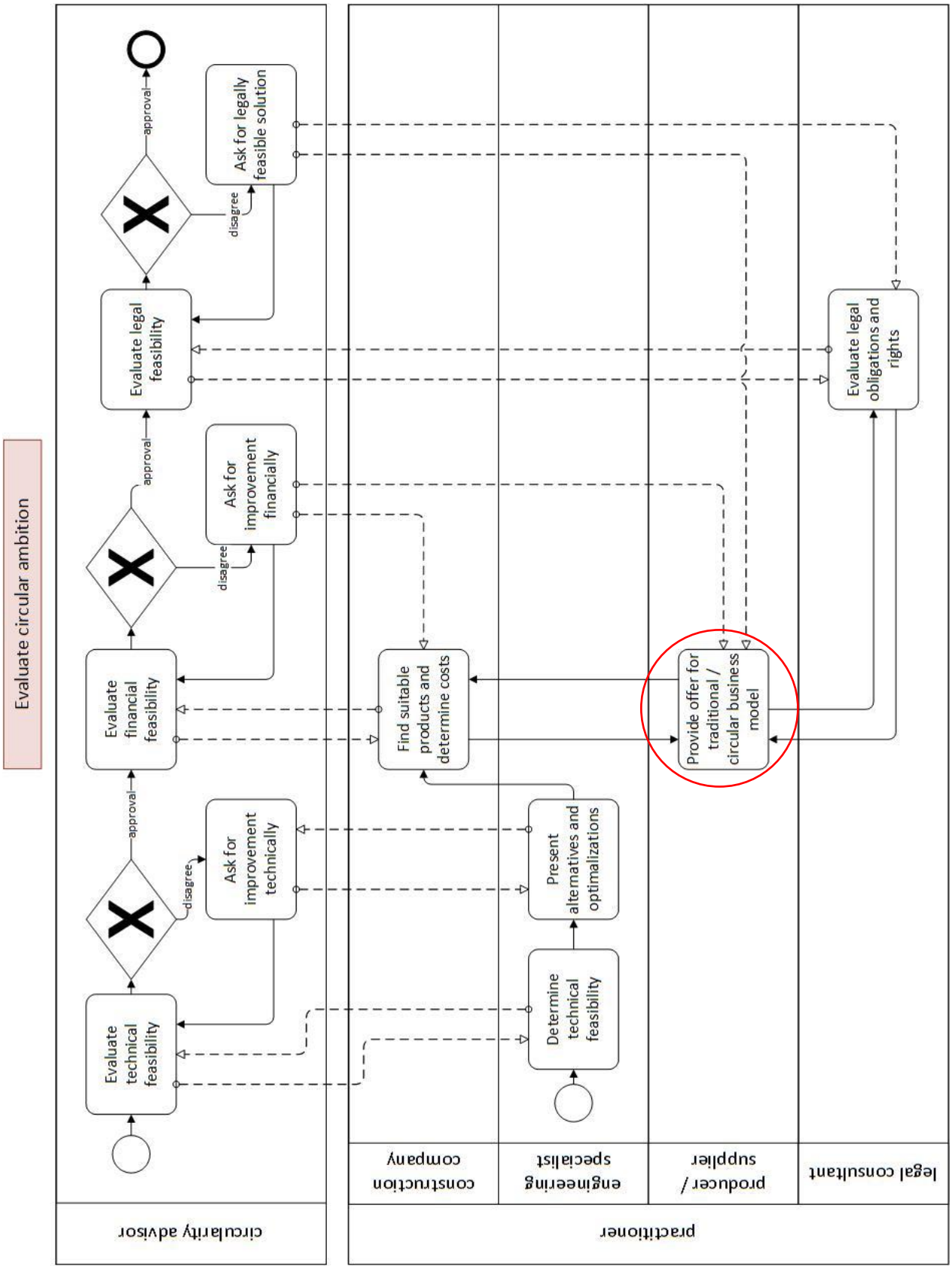


Figure 68: Circular BPMN schema: evaluate circular ambition

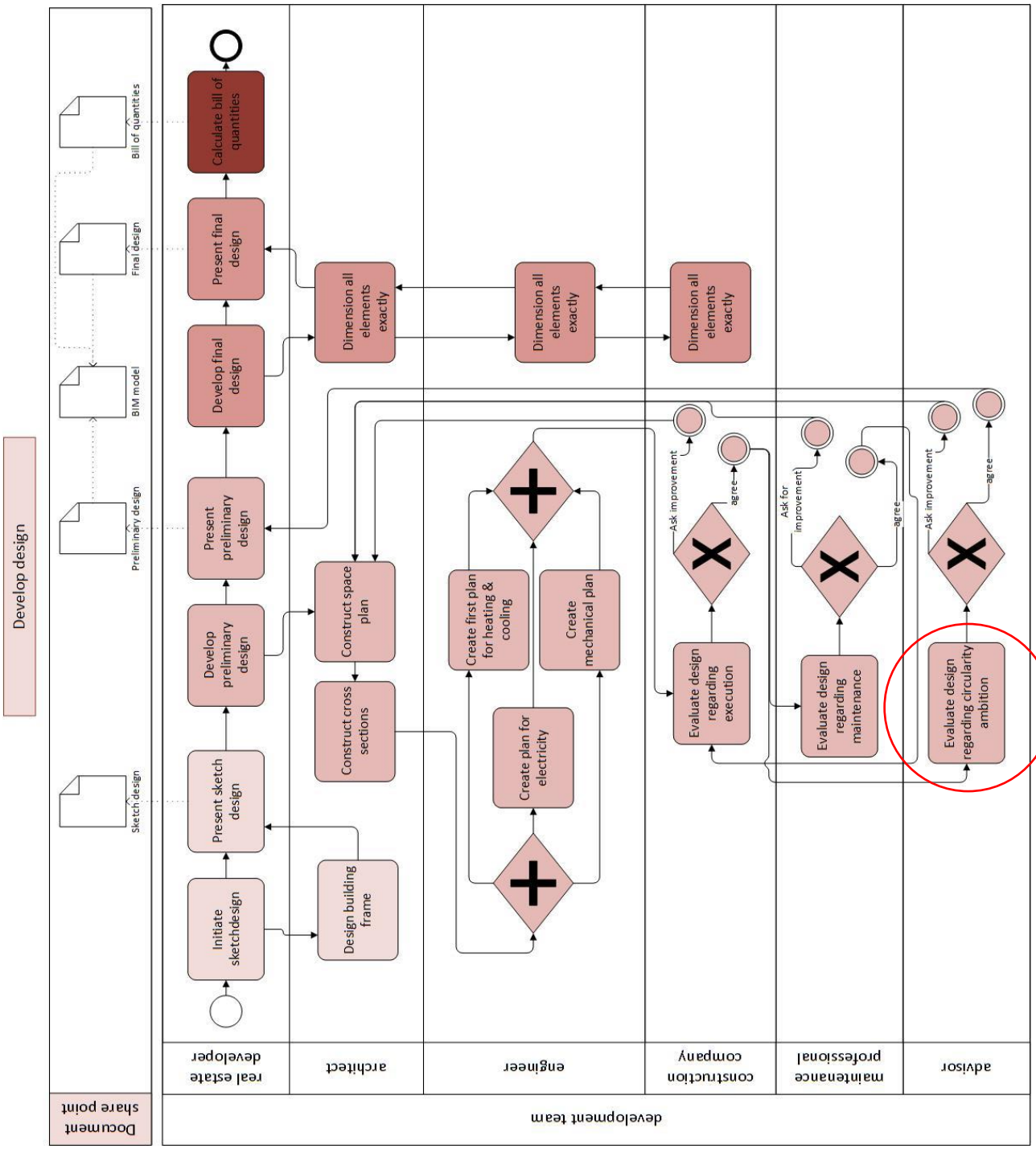


Figure 69: Circular BPMN schema: develop design

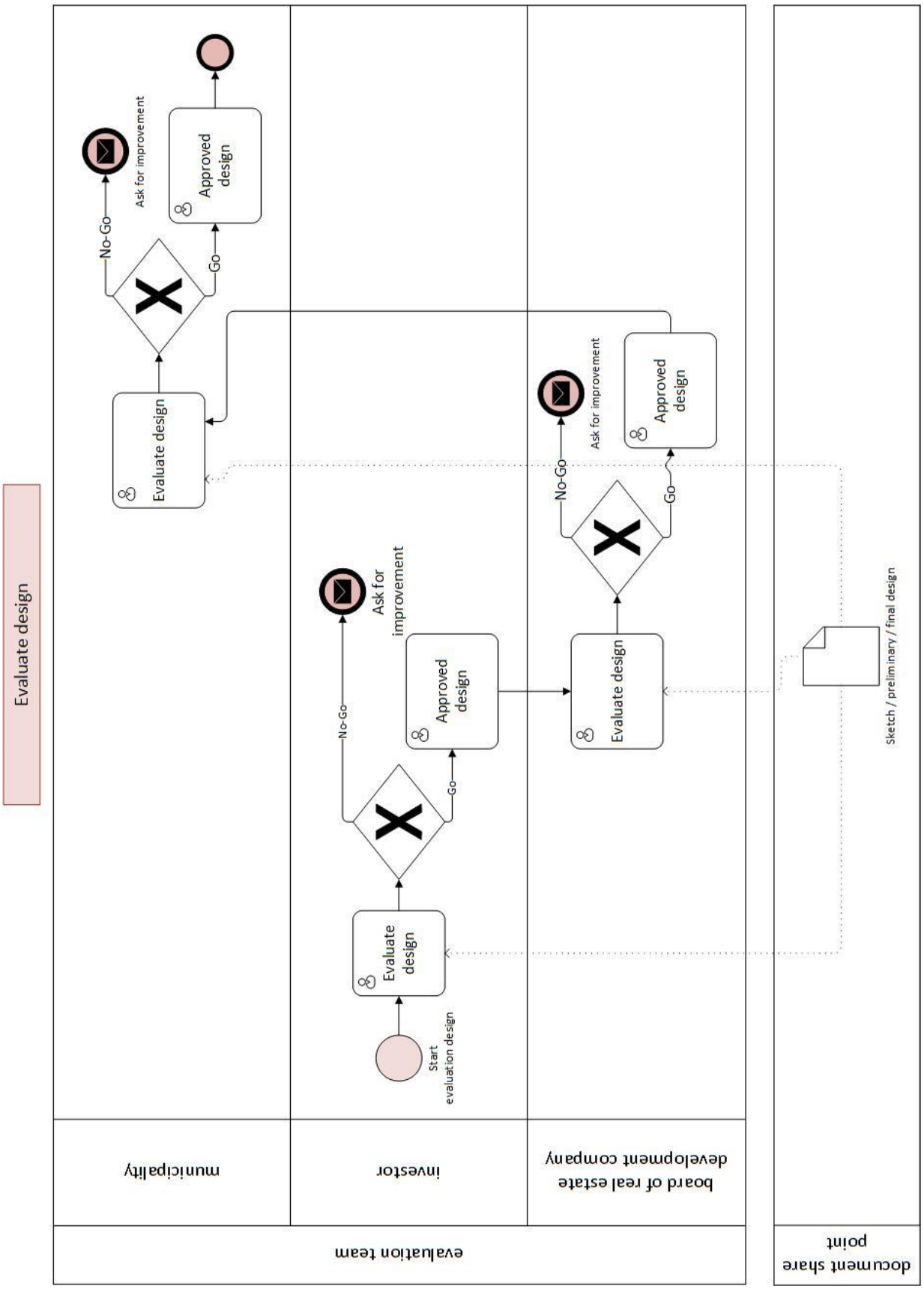


Figure 70:Circular BPMN schema: evaluate design

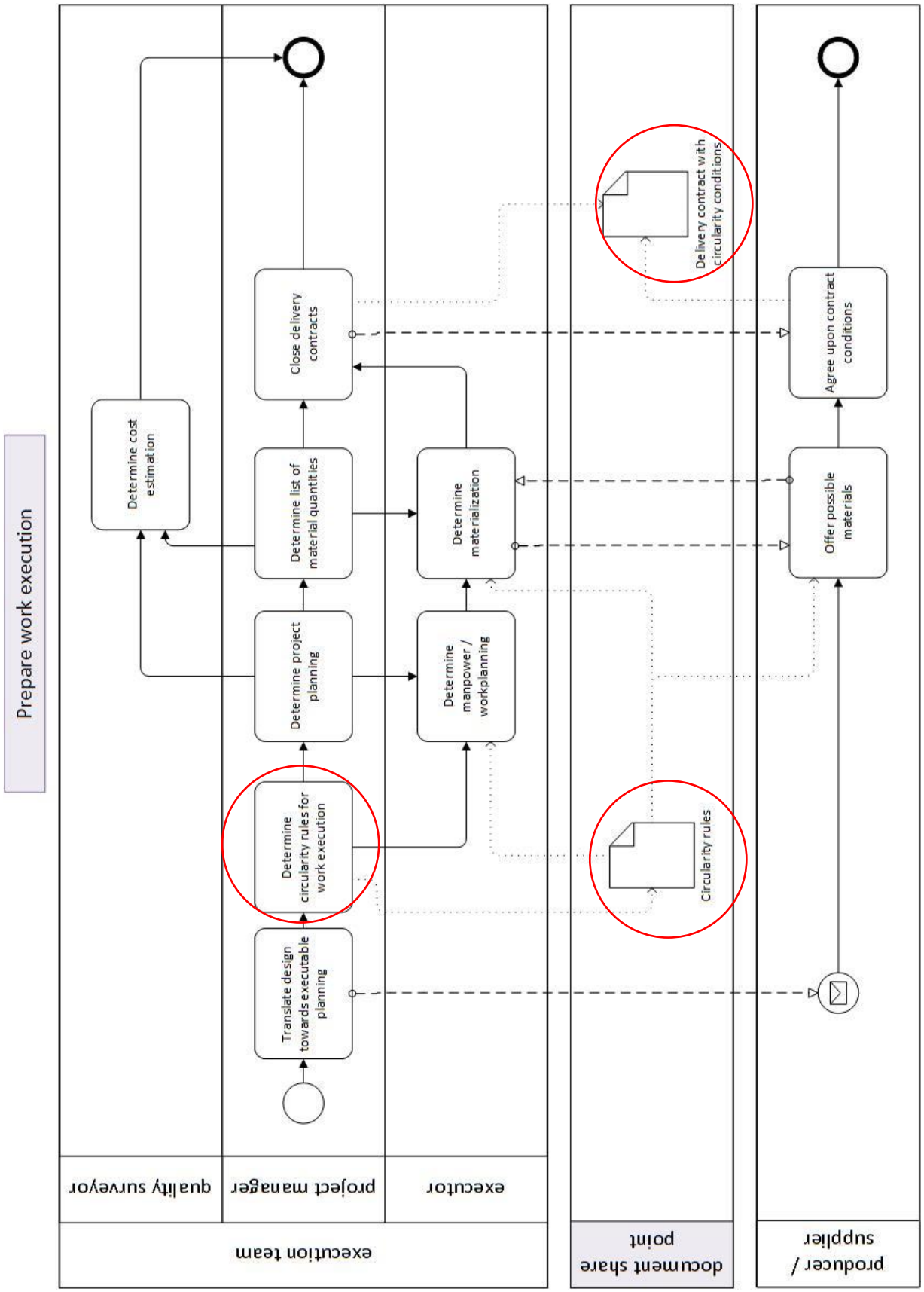


Figure 71: Circular BPMN : prepare work execution

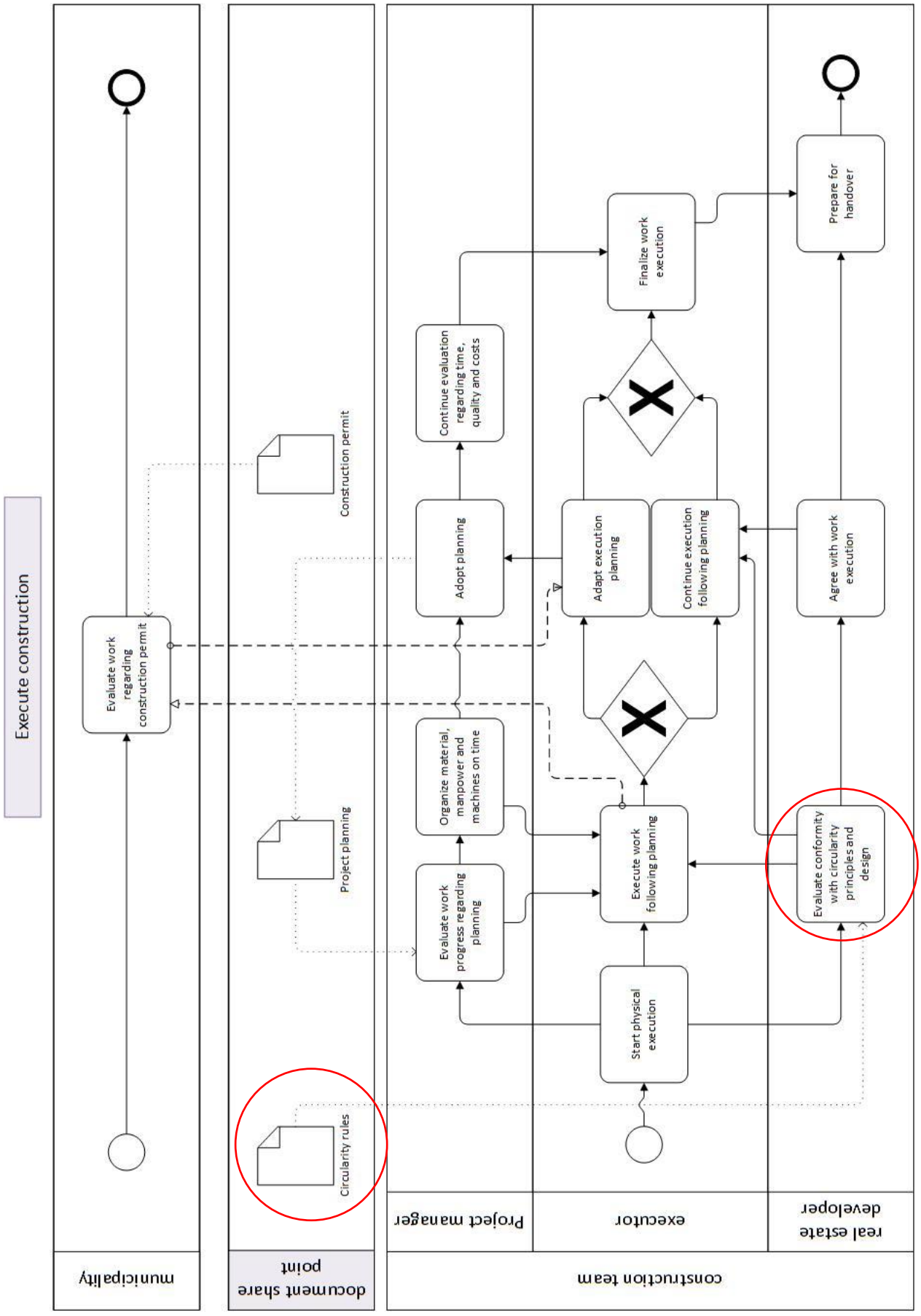


Figure 72: Circular BPMN: execute construction

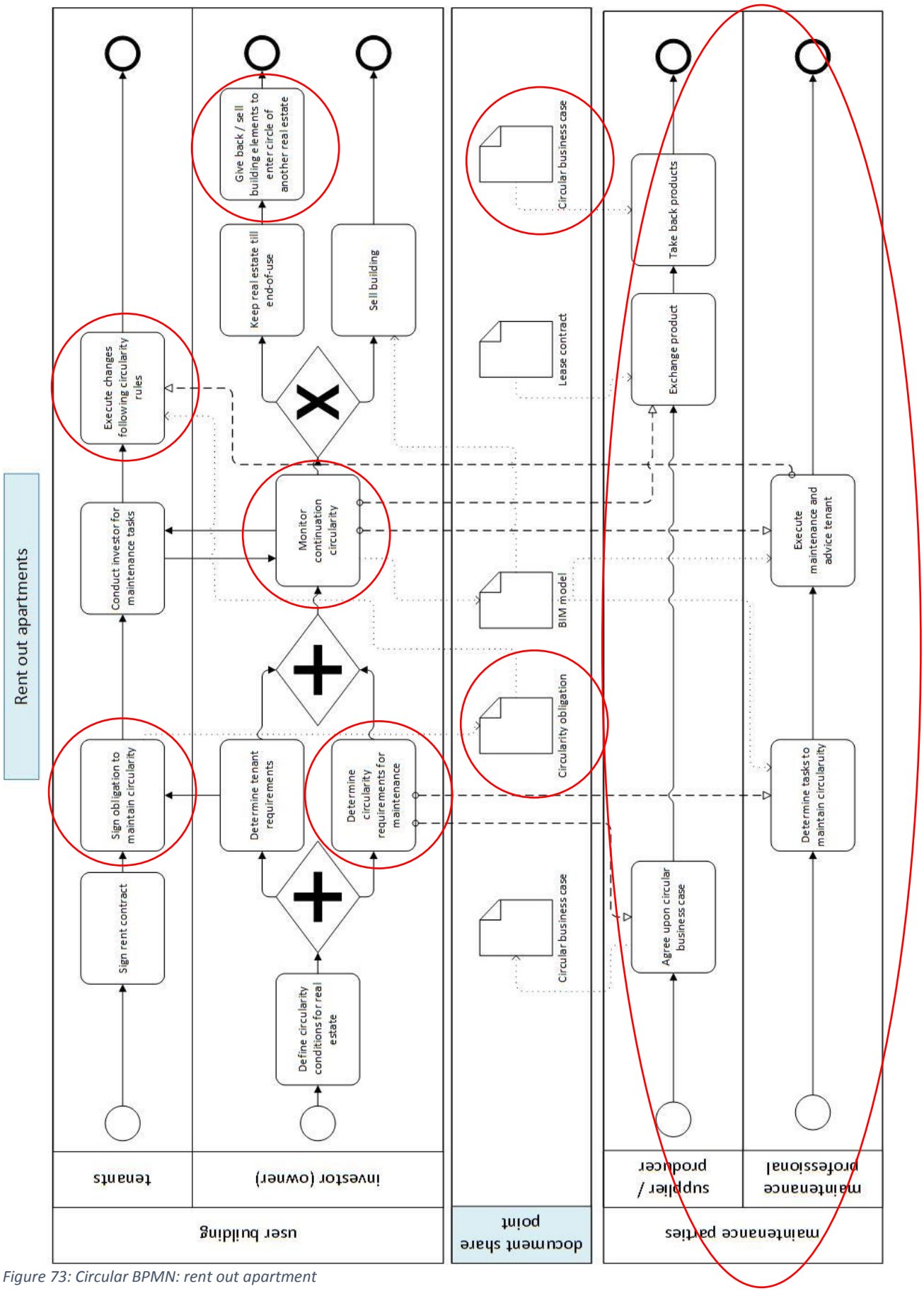


Figure 73: Circular BPMN: rent out apartment